

Personalized cancer diagnosis

Assignment 1-

Apply All the models with tf-idf features (Replace CountVectorizer with tfidfVectorizer and run the same cells)

1. Business Problem

1.1. Description

Source: <https://www.kaggle.com/c/msk-redefining-cancer-treatment/>

Data: Memorial Sloan Kettering Cancer Center (MSKCC)

Download training_variants.zip and training_text.zip from Kaggle.

Context:

Source: <https://www.kaggle.com/c/msk-redefining-cancer-treatment/discussion/35336#198462>

Problem statement :

Classify the given genetic variations/mutations based on evidence from text-based clinical literature.

1.2. Source/Useful Links

Some articles and reference blogs about the problem statement

1. <https://www.forbes.com/sites/matthewherper/2017/06/03/a-new-cancer-drug-helped-almost-everyone-who-took-it-almost-heres-what-it-teaches-us/#2a44ee2f6b25>
2. <https://www.youtube.com/watch?v=UwbuW7oK8rk>
3. <https://www.youtube.com/watch?v=qxXRKVompl8>

1.3. Real-world/Business objectives and constraints.

- No low-latency requirement.
- Interpretability is important.
- Errors can be very costly.
- Probability of a data-point belonging to each class is needed.

2. Machine Learning Problem Formulation

2.1. Data

2.1.1. Data Overview

- Source: <https://www.kaggle.com/c/msk-redefining-cancer-treatment/data>
- We have two data files: one contains the information about the genetic mutations and the other contains the clinical evidence (text) that human experts/pathologists use to classify the genetic mutations.
- Both these data files have a common column called ID

- Both these data files have a common column called ID

- Data file's information:
 - training_variants (ID , Gene, Variations, Class)
 - training_text (ID, Text)

2.1.2. Example Data Point

training_variants

ID,Gene,Variation,Class
 0,FAM58A,Truncating Mutations,1
 1,CBL,W802*,2
 2,CBL,Q249E,2
 ...

training_text

ID,Text
 0||Cyclin-dependent kinases (CDKs) regulate a variety of fundamental cellular processes. CDK10 stands out as one of the last orphan CDKs for which no activating cyclin has been identified and no kinase activity revealed. Previous work has shown that CDK10 silencing increases ETS2 (v-ets erythroblastosis virus E26 oncogene homolog 2)-driven activation of the MAPK pathway, which confers tamoxifen resistance to breast cancer cells. The precise mechanisms by which CDK10 modulates ETS2 activity, and more generally the functions of CDK10, remain elusive. Here we demonstrate that CDK10 is a cyclin-dependent kinase by identifying cyclin M as an activating cyclin. Cyclin M, an orphan cyclin, is the product of FAM58A, whose mutations cause STAR syndrome, a human developmental anomaly whose features include toe syndactyly, telecanthus, and anogenital and renal malformations. We show that STAR syndrome-associated cyclin M mutants are unable to interact with CDK10. Cyclin M silencing phenocopies CDK10 silencing in increasing c-Raf and in conferring tamoxifen resistance to breast cancer cells. CDK10/cyclin M phosphorylates ETS2 in vitro, and in cells it positively controls ETS2 degradation by the proteasome. ETS2 protein levels are increased in cells derived from a STAR patient, and this increase is attributable to decreased cyclin M levels. Altogether, our results reveal an additional regulatory mechanism for ETS2, which plays key roles in cancer and development. They also shed light on the molecular mechanisms underlying STAR syndrome.Cyclin-dependent kinases (CDKs) play a pivotal role in the control of a number of fundamental cellular processes (1). The human genome contains 21 genes encoding proteins that can be considered as members of the CDK family owing to their sequence similarity with bona fide CDKs, those known to be activated by cyclins (2). Although discovered almost 20 y ago (3, 4), CDK10 remains one of the two CDKs without an identified cyclin partner. This knowledge gap has largely impeded the exploration of its biological functions. CDK10 can act as a positive cell cycle regulator in some cells (5, 6) or as a tumor suppressor in others (7, 8). CDK10 interacts with the ETS2 (v-ets erythroblastosis virus E26 oncogene homolog 2) transcription factor and inhibits its transcriptional activity through an unknown mechanism (9). CDK10 knockdown derepresses ETS2, which increases the expression of the c-Raf protein kinase, activates the MAPK pathway, and induces resistance of MCF7 cells to tamoxifen (6). ...

2.2. Mapping the real-world problem to an ML problem

2.2.1. Type of Machine Learning Problem

There are nine different classes a genetic mutation can be classified into => Multi class classification problem

2.2.2. Performance Metric

Source: <https://www.kaggle.com/c/msk-redefining-cancer-treatment#evaluation>

Metric(s):

- Multi class log-loss
- Confusion matrix

2.2.3. Machine Learning Objectives and Constraints

Objective: Predict the probability of each data-point belonging to each of the nine classes.

Constraints:

- Interpretability
- Class probabilities are needed.
- Penalize the errors in class probabilities => Metric is Log-loss.
- No Latency constraints.

2.3. Train, CV and Test Datasets

Split the dataset randomly into three parts train, cross validation and test with 64%, 16%, 20% of data respectively

3. Exploratory Data Analysis

In [1]:

```
import pandas as pd
import matplotlib.pyplot as plt
import re
import time
import warnings
import numpy as np
from nltk.corpus import stopwords
from sklearn.decomposition import TruncatedSVD
from sklearn.preprocessing import normalize
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.manifold import TSNE
import seaborn as sns
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import confusion_matrix
from sklearn.metrics.classification import accuracy_score, log_loss
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import SGDClassifier
from imblearn.over_sampling import SMOTE
from collections import Counter
from scipy.sparse import hstack
from sklearn.multiclass import OneVsRestClassifier
from sklearn.svm import SVC
from sklearn.model_selection import StratifiedKFold
from collections import Counter, defaultdict
from sklearn.calibration import CalibratedClassifierCV
from sklearn.naive_bayes import MultinomialNB
from sklearn.naive_bayes import GaussianNB
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV
import math
from sklearn.metrics import normalized_mutual_info_score
from sklearn.ensemble import RandomForestClassifier
warnings.filterwarnings("ignore")

from mlxtend.classifier import StackingClassifier

from sklearn import model_selection
from sklearn.linear_model import LogisticRegression
```

3.1. Reading Data

3.1.1. Reading Gene and Variation Data

In [2]:

```
data = pd.read_csv('E:\\Machine Learning\\Assignments\\Personalized_Cancer_Diagnosis\\Data\\training_variants')
print('Number of data points : ', data.shape[0])
print('Number of features : ', data.shape[1])
print('Features : ', data.columns.values)
```

```

In [2]:
data.head()

Number of data points : 3321
Number of features : 4
Features : ['ID' 'Gene' 'Variation' 'Class']

```

Out[2]:

ID	Gene	Variation	Class
0	0	FAM58A Truncating Mutations	1
1	1	CBL W802*	2
2	2	CBL Q249E	2
3	3	CBL N454D	3
4	4	CBL L399V	4

training/training_variants is a comma separated file containing the description of the genetic mutations used for training.

Fields are

- **ID** : the id of the row used to link the mutation to the clinical evidence
- **Gene** : the gene where this genetic mutation is located
- **Variation** : the aminoacid change for this mutations
- **Class** : 1-9 the class this genetic mutation has been classified on

3.1.2. Reading Text Data

In [3]:

```

# note the separator in this file
data_text = pd.read_csv("E:\\Machine Learning\\Assignments\\Personalized_Cancer_Diagnosis\\Data\\training_text",sep="\\|\\|",engine="python",names=["ID","TEXT"],skiprows=1)
print('Number of data points : ', data_text.shape[0])
print('Number of features : ', data_text.shape[1])
print('Features : ', data_text.columns.values)
data_text.head()

```

Number of data points : 3321
Number of features : 2
Features : ['ID' 'TEXT']

Out[3]:

ID	TEXT
0	0 Cyclin-dependent kinases (CDKs) regulate a var...
1	1 Abstract Background Non-small cell lung canc...
2	2 Abstract Background Non-small cell lung canc...
3	3 Recent evidence has demonstrated that acquired...
4	4 Oncogenic mutations in the monomeric Casitas B...

3.1.3. Preprocessing of text

In [4]:

```

# loading stop words from nltk library
stop_words = set(stopwords.words('english'))

def nlp_preprocessing(total_text, index, column):
    if type(total_text) is not int:

```

```

string = ""
# replace every special char with space
total_text = re.sub('[^a-zA-Z0-9\n]', ' ', total_text)
# replace multiple spaces with single space
total_text = re.sub('\s+', ' ', total_text)
# converting all the chars into lower-case.
total_text = total_text.lower()

for word in total_text.split():
    # if the word is a not a stop word then retain that word from the data
    if not word in stop_words:
        string += word + " "

data_text[column][index] = string

```

In [8]:

```

#text processing stage.
start_time = time.clock()
for index, row in data_text.iterrows():
    if type(row['TEXT']) is str:
        nlp_preprocessing(row['TEXT'], index, 'TEXT')
    else:
        print("there is no text description for id:",index)
print('Time took for preprocessing the text :',time.clock() - start_time, "seconds")

```

```

there is no text description for id: 1109
there is no text description for id: 1277
there is no text description for id: 1407
there is no text description for id: 1639
there is no text description for id: 2755
Time took for preprocessing the text : 190.432737707 seconds

```

In [9]:

```

#merging both gene_variations and text data based on ID
result = pd.merge(data, data_text, on='ID', how='left')
result.head()

```

Out[9]:

ID	Gene	Variation	Class	TEXT
0	FAM58A	Truncating Mutations	1	cyclin dependent kinases cdks regulate variety...
1	CBL	W802*	2	abstract background non small cell lung cancer...
2	CBL	Q249E	2	abstract background non small cell lung cancer...
3	CBL	N454D	3	recent evidence demonstrated acquired uniparen...
4	CBL	L399V	4	oncogenic mutations monomeric casitas b lineage...

In [10]:

```
result[result.isnull().any(axis=1)]
```

Out[10]:

ID	Gene	Variation	Class	TEXT
1109	1109	FANCA	S1088F	1 NaN
1277	1277	ARID5B	Truncating Mutations	1 NaN
1407	1407	FGFR3	K508M	6 NaN
1639	1639	FLT1	Amplification	6 NaN
2755	2755	BRAF	G596C	7 NaN

In [11]:

```
result.loc[result['TEXT'].isnull(), 'TEXT'] = result['Gene'] + ' ' + result['Variation']
```

In [12]:

```
result[result['ID']==1109]
```

Out[12]:

ID	Gene	Variation	Class	TEXT
1109	1109	FANCA	S1088F	1 FANCA S1088F

3.1.4. Test, Train and Cross Validation Split

3.1.4.1. Splitting data into train, test and cross validation (64:20:16)

In [13]:

```
from sklearn.model_selection import train_test_split
y_true = result['Class'].values
result.Gene      = result.Gene.str.replace('\s+', '_')
result.Variation = result.Variation.str.replace('\s+', '_')

# split the data into test and train by maintaining same distribution of output variable 'y_true'
[X_train, test_df, y_train, y_test] = train_test_split(result, y_true, stratify=y_true, test_size=0.2)
# split the train data into train and cross validation by maintaining same distribution of output variable 'y_train' [stratify=y_train]
[train_df, cv_df, y_train, y_cv] = train_test_split(X_train, y_train, stratify=y_train, test_size=0.2)
```

We split the data into train, test and cross validation data sets, preserving the ratio of class distribution in the original data set

In [14]:

```
print('Number of data points in train data:', train_df.shape[0])
print('Number of data points in test data:', test_df.shape[0])
print('Number of data points in cross validation data:', cv_df.shape[0])
```

```
Number of data points in train data: 2124
Number of data points in test data: 665
Number of data points in cross validation data: 532
```

3.1.4.2. Distribution of y_i's in Train, Test and Cross Validation datasets

In [15]:

```
# it returns a dict, keys as class labels and values as the number of data points in that class
train_class_distribution = train_df['Class'].value_counts().sortlevel()
test_class_distribution = test_df['Class'].value_counts().sortlevel()
cv_class_distribution = cv_df['Class'].value_counts().sortlevel()

my_colors = 'rgbkymc'
train_class_distribution.plot(kind='bar')
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/train_df.shape[0]*100), 3), '%')')
```

```

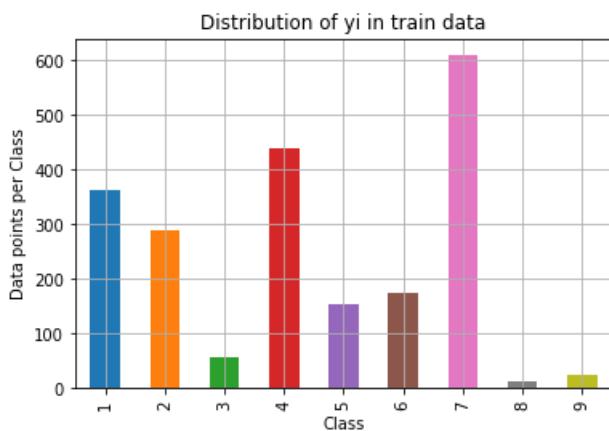
print('*'*80)
my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar')
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-test_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', test_class_distribution.values[i], '(', np.round((test_class_distribution.values[i]/test_df.shape[0]*100), 3), '%)')

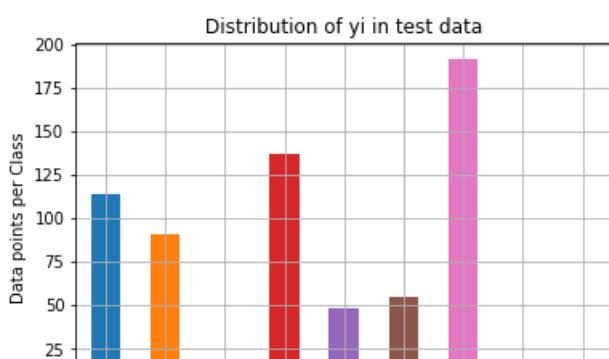
print('*'*80)
my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar')
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

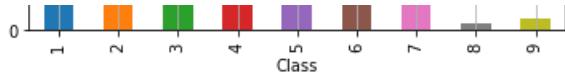
# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/cv_df.shape[0]*100), 3), '%)')

```



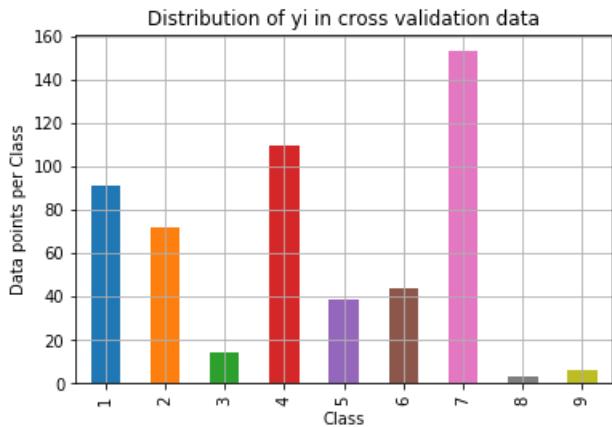
Number of data points in class 7 : 609 (28.672 %)
 Number of data points in class 4 : 439 (20.669 %)
 Number of data points in class 1 : 363 (17.09 %)
 Number of data points in class 2 : 289 (13.606 %)
 Number of data points in class 6 : 176 (8.286 %)
 Number of data points in class 5 : 155 (7.298 %)
 Number of data points in class 3 : 57 (2.684 %)
 Number of data points in class 9 : 24 (1.13 %)
 Number of data points in class 8 : 12 (0.565 %)





```

Number of data points in class 7 : 191 ( 28.722 %)
Number of data points in class 4 : 137 ( 20.602 %)
Number of data points in class 1 : 114 ( 17.143 %)
Number of data points in class 2 : 91 ( 13.684 %)
Number of data points in class 6 : 55 ( 8.271 %)
Number of data points in class 5 : 48 ( 7.218 %)
Number of data points in class 3 : 18 ( 2.707 %)
Number of data points in class 9 : 7 ( 1.053 %)
Number of data points in class 8 : 4 ( 0.602 %)
-----
```



```

Number of data points in class 7 : 153 ( 28.759 %)
Number of data points in class 4 : 110 ( 20.677 %)
Number of data points in class 1 : 91 ( 17.105 %)
Number of data points in class 2 : 72 ( 13.534 %)
Number of data points in class 6 : 44 ( 8.271 %)
Number of data points in class 5 : 39 ( 7.331 %)
Number of data points in class 3 : 14 ( 2.632 %)
Number of data points in class 9 : 6 ( 1.128 %)
Number of data points in class 8 : 3 ( 0.564 %)
```

3.2 Prediction using a 'Random' Model

In a 'Random' Model, we generate the NINE class probabilities randomly such that they sum to 1.

In [16]:

```

# 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 corresponds to columns and axis=1 corresponds to rows in two
    # dimensional array
    # C.sum(axis =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 corresponds to columns and axis=1 corresponds to rows in two
# dimensional array
# C.sum(axis =0) = [[4, 6]]
# (C/C.sum(axis=0)) = [[1/4, 2/6],
#                      [3/4, 4/6]]

labels = [1,2,3,4,5,6,7,8,9]
# representing A in heatmap format
print("-"*20, "Confusion matrix", "-"*20)
plt.figure(figsize=(20,7))
sns.heatmap(C, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
plt.xlabel('Predicted Class')
plt.ylabel('Original Class')
plt.show()

print("-"*20, "Precision matrix (Column Sum=1)", "-"*20)
plt.figure(figsize=(20,7))
sns.heatmap(B, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
plt.xlabel('Predicted Class')
plt.ylabel('Original Class')
plt.show()

# representing B in heatmap format
print("-"*20, "Recall matrix (Row sum=1)", "-"*20)
plt.figure(figsize=(20,7))
sns.heatmap(A, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
plt.xlabel('Predicted Class')
plt.ylabel('Original Class')
plt.show()

```

In [17]:

```

# we need to generate 9 numbers and the sum of numbers should be 1
# one solution is to generate 9 numbers and divide each of the numbers by their sum
# ref: https://stackoverflow.com/a/18662466/4084039
test_data_len = test_df.shape[0]
cv_data_len = cv_df.shape[0]

# we create a output array that has exactly same size as the CV data
cv_predicted_y = np.zeros((cv_data_len,9))
for i in range(cv_data_len):
    rand_probs = np.random.rand(1,9)
    cv_predicted_y[i] = ((rand_probs/sum(sum(rand_probs))))[0])
print("Log loss on Cross Validation Data using Random Model",log_loss(y_cv,cv_predicted_y, eps=le-15))

# Test-Set error.
#we create a output array that has exactly same as the test data
test_predicted_y = np.zeros((test_data_len,9))
for i in range(test_data_len):
    rand_probs = np.random.rand(1,9)
    test_predicted_y[i] = ((rand_probs/sum(sum(rand_probs))))[0])
print("Log loss on Test Data using Random Model",log_loss(y_test,test_predicted_y, eps=le-15))

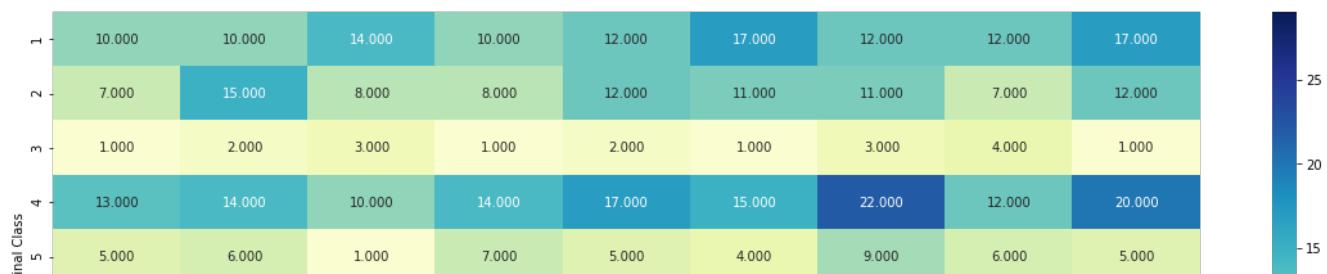
predicted_y = np.argmax(test_predicted_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)

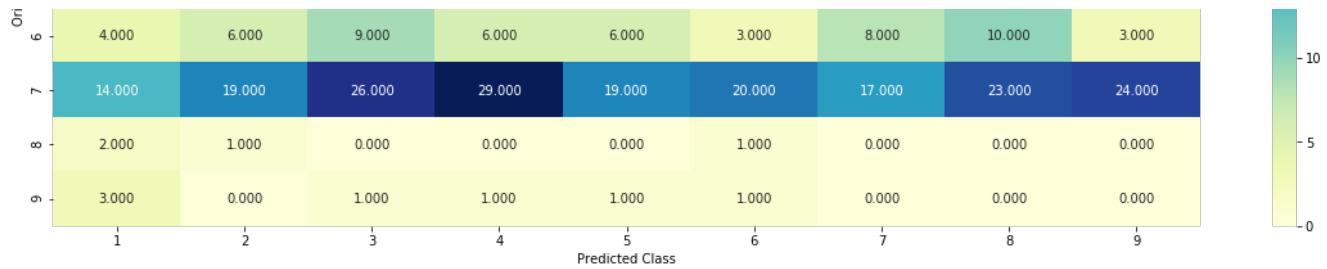
```

Log loss on Cross Validation Data using Random Model 2.486222020944124

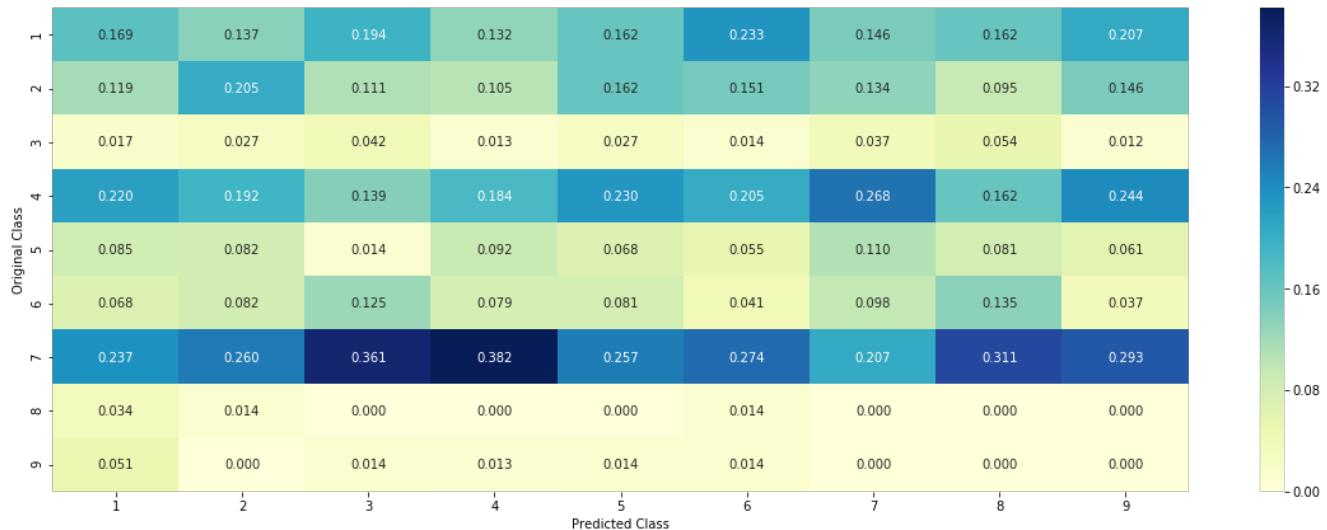
Log loss on Test Data using Random Model 2.465420582861255

----- Confusion matrix -----

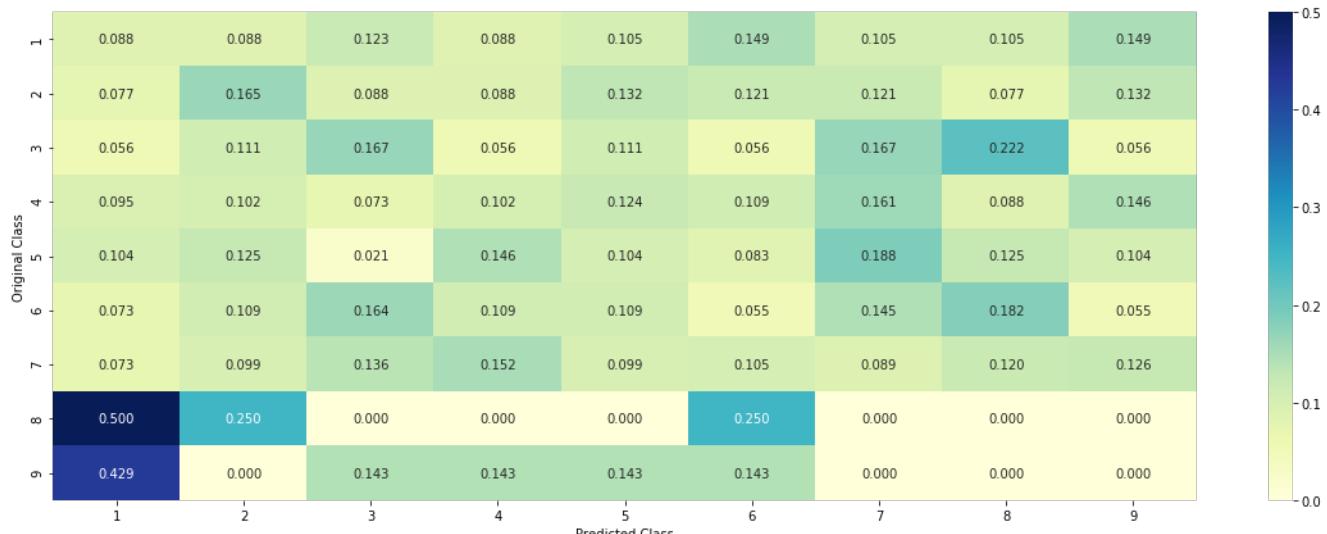




Precision matrix (Column Sum=1)



Recall matrix (Row sum=1)



3.3 Univariate Analysis

In [18]:

```
# code for response coding with Laplace smoothing.
# alpha : used for laplace smoothing
# feature: ['gene', 'variation']
# df: ['train_df', 'test_df', 'cv_df']
# algorithm
#
# Consider all unique values and the number of occurrences of given feature in train data dataframe
# build a vector (1*9) , the first element = (number of times it occurred in class1 + 10*alpha / number of time it occurred in total data+90*alpha)
# gv_dict is like a look up table, for every gene it store a (1*9) representation of it
# for a value of feature in df:
```

```

# if it is in train data:
# we add the vector that was stored in 'gv_dict' look up table to 'gv_fea'
# if it is not there is train:
# we add [1/9, 1/9, 1/9, 1/9, 1/9, 1/9, 1/9] to 'gv_fea'
# return 'gv_fea'
# ----

# get_gv_fea_dict: Get Gene variation Feature Dict
def get_gv_fea_dict(alpha, feature, df):
    # value_count: it contains a dict like
    # print(train_df['Gene'].value_counts())
    # output:
    #
    {BRCA1      174
     TP53       106
     EGFR        86
     BRCA2       75
     PTEN        69
     KIT         61
     BRAF        60
     ERBB2       47
     PDGFRA     46
     ...
    }
    # print(train_df['Variation'].value_counts())
    # output:
    #
    {Truncating_Mutations      63
     Deletion                 43
     Amplification            43
     Fusions                  22
     Overexpression            3
     E17K                     3
     Q61L                     3
     S222D                   2
     P130S                   2
     ...
    }
    value_count = train_df[feature].value_counts()

    # gv_dict : Gene Variation Dict, which contains the probability array for each gene/variation
    gv_dict = dict()

    # denominator will contain the number of time that particular feature occurred in whole data
    for i, denominator in value_count.items():
        # vec will contain ( $p(y_i == 1/G_i)$ ) probability of gene/variation belongs to particular class
        # vec is 9 dimensional vector
        vec = []
        for k in range(1,10):
            # print(train_df.loc[(train_df['Class']==1) & (train_df['Gene']=='BRCA1')])
            #
            ID      Gene          Variation   Class
            # 2470  2470  BRCA1           S1715C    1
            # 2486  2486  BRCA1           S1841R    1
            # 2614  2614  BRCA1           M1R       1
            # 2432  2432  BRCA1           L1657P    1
            # 2567  2567  BRCA1           T1685A    1
            # 2583  2583  BRCA1           E1660G    1
            # 2634  2634  BRCA1           W1718L    1
            # cls_cnt.shape[0] will return the number of rows

            cls_cnt = train_df.loc[(train_df['Class']==k) & (train_df[feature]==i)]

            # cls_cnt.shape[0] (numerator) will contain the number of time that particular feature occurred in whole data
            vec.append((cls_cnt.shape[0] + alpha*10)/ (denominator + 90*alpha))

            # we are adding the gene/variation to the dict as key and vec as value
            gv_dict[i]=vec
    return gv_dict

# Get Gene variation feature
def get_gv_feature(alpha, feature, df):
    # print(gv_dict)
    #
    {'BRCA1': [0.2007575757575757, 0.03787878787878788, 0.0681818181818177,
    0.13636363636363635, 0.25, 0.1931818181818181, 0.03787878787878788, 0.03787878787878788,
    0.03787878787878788],
     'TP53': [0.32142857142857145, 0.061224489795918366, 0.061224489795918366,
    0.27040816326530615, 0.061224489795918366, 0.066326530612244902, 0.051020408163265307, 0.051020408
    163265307, 0.056122448979591837],
```

```

#     'EGFR': [0.0568181818181816, 0.21590909090909091, 0.0625, 0.0681818181818177,
0.0681818181818177, 0.0625, 0.34659090909090912, 0.0625, 0.05681818181816],
#     'BRCA2': [0.1333333333333333, 0.0606060606060608, 0.060606060606060608,
0.0787878787878782, 0.1393939393939394, 0.34545454545454546, 0.060606060606060608,
0.060606060606060608, 0.060606060606060608],
#     'PTEN': [0.069182389937106917, 0.062893081761006289, 0.069182389937106917,
0.46540880503144655, 0.07547169813207544, 0.062893081761006289, 0.069182389937106917, 0.062893081
761006289, 0.062893081761006289],
#     'KIT': [0.066225165562913912, 0.25165562913907286, 0.072847682119205295,
0.072847682119205295, 0.066225165562913912, 0.066225165562913912, 0.27152317880794702,
0.066225165562913912, 0.066225165562913912],
#     'BRAF': [0.06666666666666666, 0.17999999999999999, 0.07333333333333334,
0.07333333333333334, 0.09333333333333338, 0.080000000000000002, 0.29999999999999999,
0.06666666666666666, 0.06666666666666666],
#     ...
# }
gv_dict = get_gv_fea_dict(alpha, feature, df)
# value_count is similar in get_gv_fea_dict
value_count = train_df[feature].value_counts()

# gv_fea: Gene_variation feature, it will contain the feature for each feature value in the data
gv_fea = []
# for every feature values in the given data frame we will check if it is there in the train data then we will add the feature to gv_fea
# if not we will add [1/9,1/9,1/9,1/9,1/9,1/9,1/9,1/9] to gv_fea
for index, row in df.iterrows():
    if row[feature] in dict(value_count).keys():
        gv_fea.append(gv_dict[row[feature]])
    else:
        gv_fea.append([1/9,1/9,1/9,1/9,1/9,1/9,1/9,1/9])
#         gv_fea.append([-1,-1,-1,-1,-1,-1,-1,-1])
return gv_fea

```

when we calculate the probability of a feature belongs to any particular class, we apply laplace smoothing

- $(\text{numerator} + 10^{\alpha}) / (\text{denominator} + 90^{\alpha})$

3.2.1 Univariate Analysis on Gene Feature

Q1. Gene, What type of feature it is ?

Ans. Gene is a categorical variable

Q2. How many categories are there and How they are distributed?

In [19]:

```

unique_genes = train_df['Gene'].value_counts()
print('Number of Unique Genes :', unique_genes.shape[0])
# the top 10 genes that occurred most
print(unique_genes.head(10))

```

```

Number of Unique Genes : 234
BRCA1      170
TP53       108
EGFR        88
BRCA2        85
PTEN        77
KIT          63
BRAF          63
ERBB2        51
ALK           47
PIK3CA        40
Name: Gene, dtype: int64

```

In [20]:

```

print("Ans: There are", unique_genes.shape[0], "different categories of genes in the train data, and they are distributed as follows")

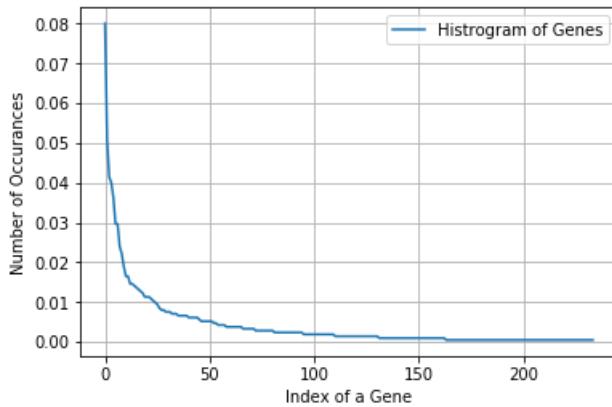
```

Ans: There are 234 different categories of genes in the train data and they are distributed as follows

Ans: there are 254 different categories or genes in the train data, and they are distributed as follows

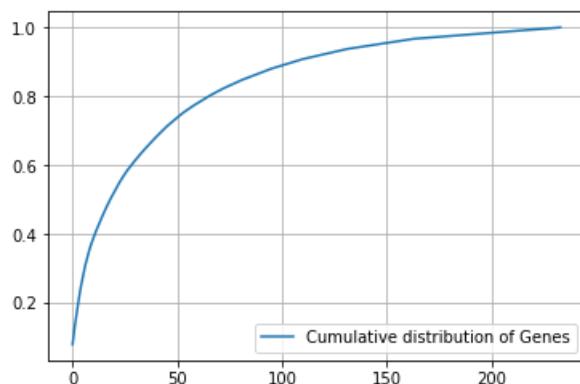
In [21]:

```
s = sum(unique_genes.values);
h = unique_genes.values/s;
plt.plot(h, label="Histogram of Genes")
plt.xlabel('Index of a Gene')
plt.ylabel('Number of Occurrences')
plt.legend()
plt.grid()
plt.show()
```



In [22]:

```
c = np.cumsum(h)
plt.plot(c,label='Cumulative distribution of Genes')
plt.grid()
plt.legend()
plt.show()
```



Q3. How to featurize this Gene feature ?

Ans.there are two ways we can featurize this variable check out this video:

<https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/handling-categorical-and-numerical-features/>

1. One hot Encoding
2. Response coding

We will choose the appropriate featurization based on the ML model we use. For this problem of multi-class classification with categorical features, one-hot encoding is better for Logistic regression while response coding is better for Random Forests.

In [23]:

```
#response-coding of the Gene feature
# alpha is used for laplace smoothing
alpha = 1
```

```
# train gene feature
train_gene_feature_responseCoding = np.array(get_gv_feature(alpha, "Gene", train_df))
# test gene feature
test_gene_feature_responseCoding = np.array(get_gv_feature(alpha, "Gene", test_df))
# cross validation gene feature
cv_gene_feature_responseCoding = np.array(get_gv_feature(alpha, "Gene", cv_df))
```

In [24]:

```
print("train_gene_feature_responseCoding is converted feature using response coding method. The shape of gene feature:", train_gene_feature_responseCoding.shape)
```

```
train_gene_feature_responseCoding is converted feature using response coding method. The shape of gene feature: (2124, 9)
```

In []:

```
# one-hot encoding of Gene feature.
gene_vectorizer = TfidfVectorizer()
train_gene_feature_onehotCoding = gene_vectorizer.fit_transform(train_df['Gene'])
test_gene_feature_onehotCoding = gene_vectorizer.transform(test_df['Gene'])
cv_gene_feature_onehotCoding = gene_vectorizer.transform(cv_df['Gene'])
```

In []:

```
train_df['Gene'].head()
```

In [60]:

```
gene_vectorizer.get_feature_names()
```

Out[60]:

```
['abl1',
'acvr1',
'ago2',
'akt1',
'akt2',
'akt3',
'alk',
'apc',
'ar',
'araf',
'arid1b',
'arid2',
'asxl2',
'atm',
'atrx',
'aurka',
'axin1',
'axl',
'b2m',
'bap1',
'bard1',
'bcl10',
'bcl2111',
'bcor',
'braf',
'brca1',
'brca2',
'brip1',
'btk',
'card11',
'carm1',
'casp8',
'cbl',
'ccnd1',
'ccnd3',
'ccne1',
'cdh1',
'cdk12',
'cdk4',
'cgf1'
```

'cakb',
'cdkn1a',
'cdkn1b',
'cdkn2a',
'cdkn2b',
'cebpA',
'chek2',
'cic',
'crebbp',
'ctcf',
'ctla4',
'ctnnb1',
'ddr2',
'dicer1',
'dnmt3a',
'dnmt3b',
'egfr',
'eiflax',
'elf3',
'ep300',
'epas1',
'epcam',
'erbb2',
'erbb3',
'erbb4',
'ercc2',
'ercc3',
'ercc4',
'erg',
'esr1',
'etv1',
'etv6',
'ewsr1',
'ezh2',
'fanca',
'fancc',
'fat1',
'fbxw7',
'fqlf19',
'fgf3',
'fgf4',
'fgfr1',
'fgfr2',
'fgfr3',
'fgfr4',
'flt1',
'flt3',
'foxal1',
'foxl2',
'foxo1',
'foxp1',
'fubp1',
'gata3',
'gli1',
'gna11',
'gnaq',
'gnas',
'h3f3a',
'hla',
'hnf1a',
'hras',
'idh1',
'idh2',
'igf1r',
'ikbke',
'ikzf1',
'il7r',
'jak1',
'jak2',
'jun',
'kdm5c',
'kdm6a',
'kdr',
'keap1',
'kit',
'kmt2a',
'kmt2b',
.....

'kmtzc',
'kmt2d',
'knstrn',
'kras',
'lats1',
'lats2',
'map2k1',
'map2k2',
'map2k4',
'map3k1',
'mdm4',
'med12',
'mef2b',
'men1',
'met',
'mga',
'mlh1',
'mpl',
'msh2',
'msh6',
'mtoi',
'myc',
'mycn',
'myd88',
'myod1',
'ncor1',
'nf1',
'nf2',
'nfe2l2',
'nkbia',
'nkx2',
'notch1',
'notch2',
'npm1',
'nras',
'nsd1',
'ntrk1',
'ntrk2',
'ntrk3',
'nup93',
'pak1',
'pax8',
'pbprm1',
'pdgfra',
'pdgfrb',
'pik3ca',
'pik3cb',
'pik3cd',
'pik3r1',
'pik3r2',
'pik3r3',
'pim1',
'pms1',
'pms2',
'pole',
'ppmld',
'ppp2rla',
'ppp6c',
'prdm1',
'ptch1',
'pten',
'ptpn11',
'ptprd',
'ptprt',
'rab35',
'rac1',
'rad50',
'rad51b',
'rad51c',
'rad541',
'raf1',
'rara',
'rasa1',
'rb1',
'rbm10',
'ret',
'rheb',
.....

```
'rhoa',
'rit1',
'rnf43',
'ros1',
'runx1',
'rxra',
'rybp',
'sdhb',
'setd2',
'sf3b1',
'shoc2',
'smad2',
'smad3',
'smad4',
'smarca4',
'smarcb1',
'smo',
'sos1',
'sox9',
'spop',
'src',
'srsf2',
'stat3',
'stk11',
'tcf3',
'tcf712',
'tert',
'tet1',
'tet2',
'tgfb1',
'tgfb2',
'tmprss2',
'tp53',
'tsc1',
'tsc2',
'u2af1',
'vegfa',
'vhl',
'whsc111',
'xpol',
'yap1']
```

In [61]:

```
print("train_gene_feature_onehotCoding is converted feature using tfidf encoding method. The shape of gene feature:", train_gene_feature_onehotCoding.shape)
```

```
train_gene_feature_onehotCoding is converted feature using tfidf encoding method. The shape of gene feature: (2124, 234)
```

Q4. How good is this gene feature in predicting y_i?

There are many ways to estimate how good a feature is, in predicting y_i. One of the good methods is to build a proper ML model using just this feature. In this case, we will build a logistic regression model using only Gene feature (one hot encoded) to predict y_i.

In [62]:

```
alpha = [10 ** x for x in range(-5, 1)] # hyperparam for SGD classifier.

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

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

```

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


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

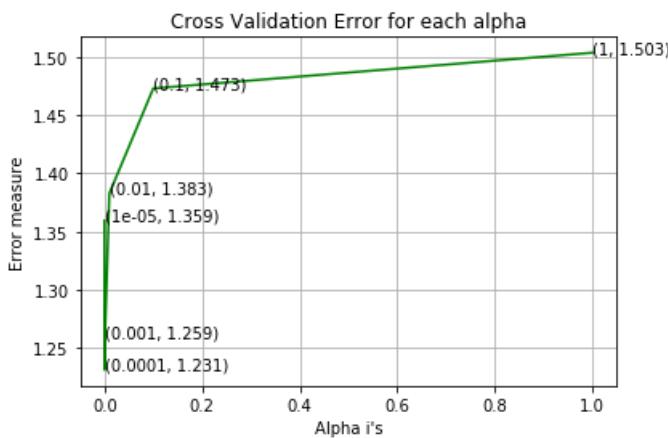
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

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

predict_y = sig_clf.predict_proba(train_gene_feature_onehotCoding)
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(cv_gene_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_lo
ss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_gene_feature_onehotCoding)
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))

```

For values of alpha = 1e-05 The log loss is: 1.3594255909585153
 For values of alpha = 0.0001 The log loss is: 1.2312771219759846
 For values of alpha = 0.001 The log loss is: 1.258845433442175
 For values of alpha = 0.01 The log loss is: 1.3826827277253506
 For values of alpha = 0.1 The log loss is: 1.4728081434047233
 For values of alpha = 1 The log loss is: 1.5034410713085773



For values of best alpha = 0.0001 The train log loss is: 1.0435396389708098
 For values of best alpha = 0.0001 The cross validation log loss is: 1.2312771219759846
 For values of best alpha = 0.0001 The test log loss is: 1.185225807369909

Q5. Is the Gene feature stable across all the data sets (Test, Train, Cross validation)?

Ans. Yes, it is. Otherwise, the CV and Test errors would be significantly more than train error.

In [63]:

```
print("Q6. How many data points in Test and CV datasets are covered by the ", unique_genes.shape[0], " genes in train dataset?")  
  
test_coverage=test_df[test_df['Gene'].isin(list(set(train_df['Gene'])))].shape[0]  
cv_coverage=cv_df[cv_df['Gene'].isin(list(set(train_df['Gene'])))].shape[0]  
  
print('Ans\n1. In test data',test_coverage, 'out of',test_df.shape[0], ":" ,(test_coverage/test_df.shape[0])*100)  
print('2. In cross validation data',cv_coverage, 'out of ',cv_df.shape[0], ":" ,(cv_coverage/cv_df.shape[0])*100)
```

Q6. How many data points in Test and CV datasets are covered by the 234 genes in train dataset?

Ans

1. In test data 643 out of 665 : 96.69172932330827
2. In cross validation data 518 out of 532 : 97.36842105263158

3.2.2 Univariate Analysis on Variation Feature

Q7. Variation, What type of feature is it ?

Ans. Variation is a categorical variable

Q8. How many categories are there?

In [64]:

```
unique_variations = train_df['Variation'].value_counts()  
print('Number of Unique Variations :', unique_variations.shape[0])  
# the top 10 variations that occurred most  
print(unique_variations.head(10))
```

```
Number of Unique Variations : 1937  
Truncating_Mutations      56  
Amplification            45  
Deletion                 43  
Fusions                  23  
E17K                     2  
Y64A                     2  
M1R                      2  
G35R                     2  
E542K                   2  
P34R                     2  
Name: Variation, dtype: int64
```

In [65]:

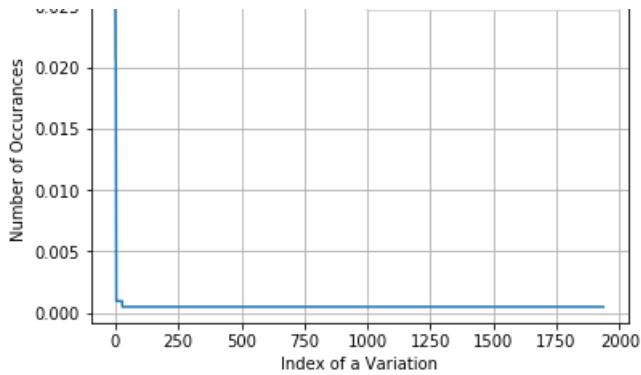
```
print("Ans: There are", unique_variations.shape[0] , "different categories of variations in the  
train data, and they are distributed as follows")
```

Ans: There are 1937 different categories of variations in the train data, and they are distributed as follows

In [66]:

```
s = sum(unique_variations.values);  
h = unique_variations.values/s;  
plt.plot(h, label="Histogram of Variations")  
plt.xlabel('Index of a Variation')  
plt.ylabel('Number of Occurrences')  
plt.legend()  
plt.grid()  
plt.show()
```

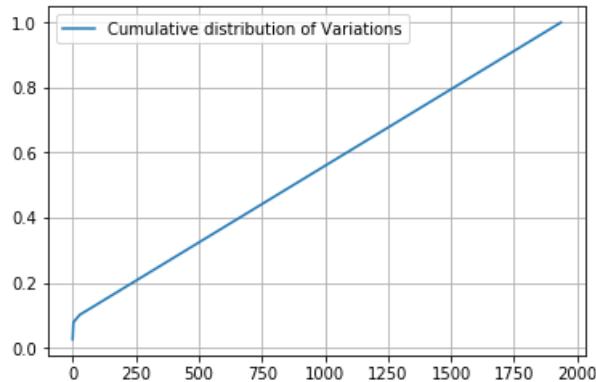




In [67]:

```
c = np.cumsum(h)
print(c)
plt.plot(c,label='Cumulative distribution of Variations')
plt.grid()
plt.legend()
plt.show()
```

[0.02636535 0.04755179 0.06779661 ... 0.99905838 0.99952919 1.]



Q9. How to featurize this Variation feature ?

Ans. There are two ways we can featurize this variable check out this video:

<https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/handling-categorical-and-numerical-features/>

1. One hot Encoding
2. Response coding

We will be using both these methods to featurize the Variation Feature

In [68]:

```
# alpha is used for laplace smoothing
alpha = 1
# train gene feature
train_variation_feature_responseCoding = np.array(get_gv_feature(alpha, "Variation", train_df))
# test gene feature
test_variation_feature_responseCoding = np.array(get_gv_feature(alpha, "Variation", test_df))
# cross validation gene feature
cv_variation_feature_responseCoding = np.array(get_gv_feature(alpha, "Variation", cv_df))
```

In [69]:

```
print("train_variation_feature_responseCoding is a converted feature using the response coding method. The shape of Variation feature:", train_variation_feature_responseCoding.shape)
```

train_variation_feature_responseCoding is a converted feature using the response coding method. The shape of Variation feature: (2124, 9)

In [70]:

```
# one-hot encoding of variation feature.
variation_vectorizer = TfidfVectorizer()
train_variation_feature_onehotCoding = variation_vectorizer.fit_transform(train_df['Variation'])
test_variation_feature_onehotCoding = variation_vectorizer.transform(test_df['Variation'])
cv_variation_feature_onehotCoding = variation_vectorizer.transform(cv_df['Variation'])
```

In [71]:

```
print("train_variation_feature_onehotEncoded is converted feature using the Tfifd encoding method.
The shape of Variation feature:", train_variation_feature_onehotCoding.shape)
```

train_variation_feature_onehotEncoded is converted feature using the Tfifd encoding method. The shape of Variation feature: (2124, 1972)

Q10. How good is this Variation feature in predicting y_i?

Let's build a model just like the earlier!

In [72]:

```
alpha = [10 ** x for x in range(-5, 1)]  
  
# read more about SGDClassifier() at http://scikit-  
learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html  
# -----  
# default parameters  
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_  
iter=None, tol=None,  
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0  
=0.0, power_t=0.5,  
# class_weight=None, warm_start=False, average=False, n_iter=None)  
  
# some of methods  
# fit(X, y[, coef_init, intercept_init, ...]) Fit linear model with Stochastic Gradient Descent.  
# predict(X) Predict class labels for samples in X.  
  
#-----  
# video link:  
#-----  
  
cv_log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(train_variation_feature_onehotCoding, y_train)

    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_variation_feature_onehotCoding, y_train)
    predict_y = sig_clf.predict_proba(cv_variation_feature_onehotCoding)

    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:", log_loss(y_cv, predict_y, labels=clf.clas
ses_, eps=1e-15))

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_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(cv_log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(train_variation_feature_onehotCoding, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
```

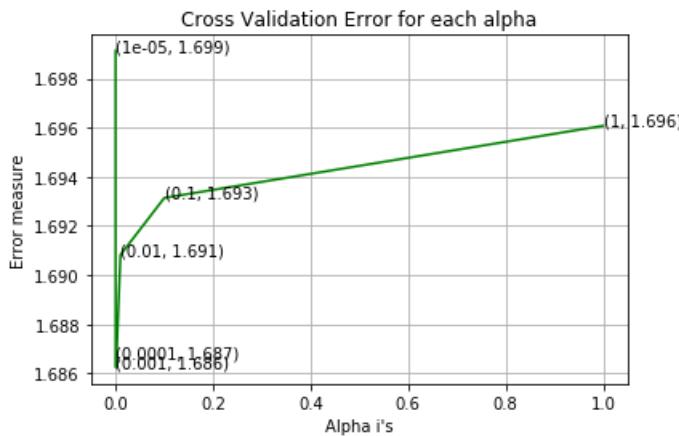
```

sig_clf.fit(train_variation_feature_onehotCoding, y_train)

predict_y = sig_clf.predict_proba(train_variation_feature_onehotCoding)
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(cv_variation_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_lo
ss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_variation_feature_onehotCoding)
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))

```

For values of alpha = 1e-05 The log loss is: 1.6991281731112573
 For values of alpha = 0.0001 The log loss is: 1.6866548190069321
 For values of alpha = 0.001 The log loss is: 1.686227756846665
 For values of alpha = 0.01 The log loss is: 1.6908232328700088
 For values of alpha = 0.1 The log loss is: 1.6931429506102331
 For values of alpha = 1 The log loss is: 1.6960744859856016



For values of best alpha = 0.001 The train log loss is: 1.13295554404374
 For values of best alpha = 0.001 The cross validation log loss is: 1.686227756846665
 For values of best alpha = 0.001 The test log loss is: 1.71802541596272

Q11. Is the Variation feature stable across all the data sets (Test, Train, Cross validation)?

Ans. Not sure! But lets be very sure using the below analysis.

In [73]:

```

print("Q12. How many data points are covered by total ", unique_variations.shape[0], " genes in te
st and cross validation data sets?")
test_coverage=test_df[test_df['Variation'].isin(list(set(train_df['Variation'])))].shape[0]
cv_coverage=cv_df[cv_df['Variation'].isin(list(set(train_df['Variation'])))].shape[0]
print('Ans\n1. In test data',test_coverage, 'out of',test_df.shape[0],":", (test_coverage/test_df.
shape[0])*100)
print('2. In cross validation data',cv_coverage, 'out of ',cv_df.shape[0],":", (cv_coverage/cv_df.s
hape[0])*100)

```

Q12. How many data points are covered by total 1937 genes in test and cross validation data sets?

Ans

1. In test data 69 out of 665 : 10.37593984962406
2. In cross validation data 62 out of 532 : 11.654135338345863

3.2.3 Univariate Analysis on Text Feature

1. How many unique words are present in train data?
2. How are word frequencies distributed?
3. How to featurize text field?
4. Is the text feature useful in predicting y_i?
5. Is the text feature stable across train, test and CV datasets?

In [74]:

```
# cls_text is a data frame
# for every row in data fram consider the 'TEXT'
# split the words by space
# make a dict with those words
# increment its count whenever we see that word

def extract_dictionary_paddle(cls_text):
    dictionary = defaultdict(int)
    for index, row in cls_text.iterrows():
        for word in row['TEXT'].split():
            dictionary[word] +=1
    return dictionary
```

In [75]:

```
import math
#https://stackoverflow.com/a/1602964
def get_text_responsecoding(df):
    text_feature_responseCoding = np.zeros((df.shape[0],9))
    for i in range(0,9):
        row_index = 0
        for index, row in df.iterrows():
            sum_prob = 0
            for word in row['TEXT'].split():
                sum_prob += math.log((dict_list[i].get(word,0)+10)/(total_dict.get(word,0)+90)))
            text_feature_responseCoding[row_index][i] = math.exp(sum_prob/len(row['TEXT'].split()))
            row_index += 1
    return text_feature_responseCoding
```

In [76]:

```
#from sklearn.feature_extraction.text import TfidfVectorizer
# building a CountVectorizer with all the words that occurred minimum 3 times in train data
text_vectorizer = TfidfVectorizer(min_df=3)
train_text_feature_onehotCoding = text_vectorizer.fit_transform(train_df['TEXT'])
# getting all the feature names (words)
train_text_features= text_vectorizer.get_feature_names()

# train_text_feature_onehotCoding.sum(axis=0).A1 will sum every row and returns (1*number of features) vector
train_textfea_counts = train_text_feature_onehotCoding.sum(axis=0).A1

# zip(list(text_features),text_fea_counts) will zip a word with its number of times it occurred
text_fea_dict = dict(zip(list(train_text_features),train_textfea_counts))

print("Total number of unique words in train data :", len(train_text_features))
```

Total number of unique words in train data : 52820

In [77]:

```
dict_list = []
# dict_list [] contains 9 dictionaries each corresponds to a class
for i in range(1,10):
    cls_text = train_df[train_df['Class']==i]
    # build a word dict based on the words in that class
    dict_list.append(extract_dictionary_paddle(cls_text))
    # append it to dict_list

# dict_list[i] is build on i'th class text data
# total_dict is build on whole training text data
total_dict = extract_dictionary_paddle(train_df)

confuse_array = []
for i in train_text_features:
    ratios = []
    max_val = -1
    for j in range(0,9):
        ratios.append(total_dict.get(i,0)+10)/(dict_list[j].get(i,0)+10)
        if ratios[-1] > max_val:
            max_val = ratios[-1]
```

```
ratios.append((true_positives / (total_positives + false_positives)))
confuse_array.append(ratios)
confuse_array = np.array(confuse_array)
```

In [78]:

```
#response coding of text features
train_text_feature_responseCoding = get_text_responseCoding(train_df)
test_text_feature_responseCoding = get_text_responseCoding(test_df)
cv_text_feature_responseCoding = get_text_responseCoding(cv_df)
```

In [79]:

```
# https://stackoverflow.com/a/16202486
# we convert each row values such that they sum to 1
train_text_feature_responseCoding =
(train_text_feature_responseCoding.T/train_text_feature_responseCoding.sum(axis=1)).T
test_text_feature_responseCoding =
(test_text_feature_responseCoding.T/test_text_feature_responseCoding.sum(axis=1)).T
cv_text_feature_responseCoding = (cv_text_feature_responseCoding.T/cv_text_feature_responseCoding.
sum(axis=1)).T
```

In [80]:

```
# don't forget to normalize every feature
train_text_feature_onehotCoding = normalize(train_text_feature_onehotCoding, axis=0)

# we use the same vectorizer that was trained on train data
test_text_feature_onehotCoding = text_vectorizer.transform(test_df['TEXT'])
# don't forget to normalize every feature
test_text_feature_onehotCoding = normalize(test_text_feature_onehotCoding, axis=0)

# we use the same vectorizer that was trained on train data
cv_text_feature_onehotCoding = text_vectorizer.transform(cv_df['TEXT'])
# don't forget to normalize every feature
cv_text_feature_onehotCoding = normalize(cv_text_feature_onehotCoding, axis=0)
```

In [81]:

```
#https://stackoverflow.com/a/2258273/4084039
sorted_text_fea_dict = dict(sorted(text_fea_dict.items(), key=lambda x: x[1], reverse=True))
sorted_text_occur = np.array(list(sorted_text_fea_dict.values()))
```

In [82]:

```
# Number of words for a given frequency.
print(Counter(sorted_text_occur))
```

```
Counter({0.00637778945673886: 326, 0.01584286039959725: 322, 0.022404064542368346: 232,
0.06504627523750255: 198, 0.3337720535092029: 149, 0.0261851742840414: 144, 0.05777968322208005: 1
25, 0.24064917366850103: 124, 0.028340246688005388: 115, 0.05171680671180984: 114,
0.07622738122429003: 109, 0.010361555867866764: 109, 0.043363793855899314: 106,
0.09185691688496543: 103, 0.050965205434039165: 101, 0.04761064086327321: 94,
0.027106682817830574: 94, 0.028347784396570815: 92, 0.11230743483678986: 86, 0.031062656944201655:
86, 0.021451644731008603: 85, 0.026357984142053228: 83, 0.014876169384919907: 81,
0.03677283433527112: 76, 0.016242048321505227: 76, 0.039906616459153305: 72, 0.03590934028485084:
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0.06094445091337256: 63, 0.025875770812543743: 63, 0.015115468192289677: 63, 0.014410559030510419:
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```

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In [83]:

```
# Train a Logistic regression+Calibration model using text features which are on-hot encoded
alpha = [10 ** x for x in range(-5, 1)]

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

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

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


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

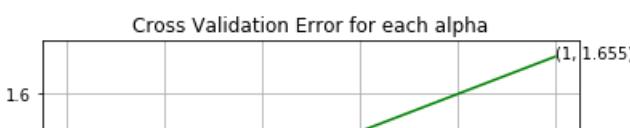
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_text_feature_onehotCoding, y_train)
    predict_y = sig_clf.predict_proba(cv_text_feature_onehotCoding)
    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha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

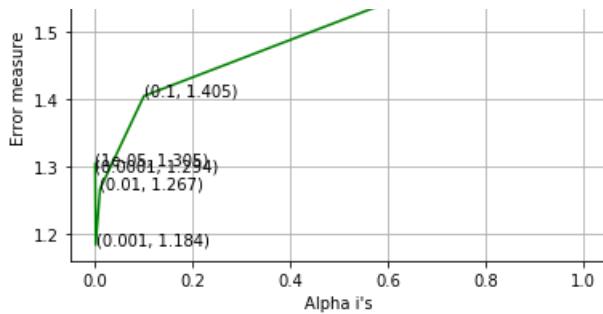
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

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

predict_y = sig_clf.predict_proba(train_text_feature_onehotCoding)
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(cv_text_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_text_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:", log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
```

For values of alpha = 1e-05 The log loss is: 1.304848029754782
For values of alpha = 0.0001 The log loss is: 1.2938659833712511
For values of alpha = 0.001 The log loss is: 1.1842926649384575
For values of alpha = 0.01 The log loss is: 1.2673366802561363
For values of alpha = 0.1 The log loss is: 1.4052575526976758
For values of alpha = 1 The log loss is: 1.6549160150083748





For values of best alpha = 0.001 The train log loss is: 0.6869387292972173
 For values of best alpha = 0.001 The cross validation log loss is: 1.1842926649384575
 For values of best alpha = 0.001 The test log loss is: 1.088529294096822

Q. Is the Text feature stable across all the data sets (Test, Train, Cross validation)?

Ans. Yes, it seems like!

In [86]:

```
def get_intersec_text(df):
    df_text_vec = TfidfVectorizer(min_df=3)
    df_textfea = df_text_vec.fit_transform(df['TEXT'])
    df_text_features = df_text_vec.get_feature_names()

    df_textfea_counts = df_textfea.sum(axis=0).A1
    df_textfea_dict = dict(zip(list(df_text_features), df_textfea_counts))
    len1 = len(set(df_text_features))
    len2 = len(set(train_text_features) & set(df_text_features))
    return len1, len2
```

In [87]:

```
len1, len2 = get_intersec_text(test_df)
print(np.round((len2/len1)*100, 3), "% of word of test data appeared in train data")
len1, len2 = get_intersec_text(cv_df)
print(np.round((len2/len1)*100, 3), "% of word of Cross Validation appeared in train data")
```

96.509 % of word of test data appeared in train data
 97.398 % of word of Cross Validation appeared in train data

4. Machine Learning Models

In [88]:

```
#Data preparation for ML models.

#Misc. functionns for ML models

def predict_and_plot_confusion_matrix(train_x, train_y, test_x, test_y, clf):
    clf.fit(train_x, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x, train_y)
    pred_y = sig_clf.predict(test_x)

    # for calculating log_loss we will provide the array of probabilities belongs to each class
    print("Log loss :", log_loss(test_y, sig_clf.predict_proba(test_x)))
    # calculating the number of data points that are misclassified
    print("Number of mis-classified points :", np.count_nonzero((pred_y - test_y))/test_y.shape[0])
    plot_confusion_matrix(test_y, pred_y)
```

In [89]:

```
def report_log_loss(train_x, train_y, test_x, test_y, clf):
    clf.fit(train_x, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
```

```

sig_clf = CalibratedClassifierCV(clf, method="sigmoid",
sig_clf.fit(train_x, train_y)
sig_clf_probs = sig_clf.predict_proba(test_x)
return log_loss(test_y, sig_clf_probs, eps=1e-15)

```

In [90]:

```

# this function will be used just for naive bayes
# for the given indices, we will print the name of the features
# and we will check whether the feature present in the test point text or not
def get_imptfeature_names(indices, text, gene, var, no_features):
    gene_count_vec = CountVectorizer()
    var_count_vec = CountVectorizer()
    text_count_vec = CountVectorizer(min_df=3)

    gene_vec = gene_count_vec.fit(train_df['Gene'])
    var_vec = var_count_vec.fit(train_df['Variation'])
    text_vec = text_count_vec.fit(train_df['TEXT'])

    feal_len = len(gene_vec.get_feature_names())
    fea2_len = len(var_count_vec.get_feature_names())

    word_present = 0
    for i,v in enumerate(indices):
        if (v < feal_len):
            word = gene_vec.get_feature_names()[v]
            yes_no = True if word == gene else False
            if yes_no:
                word_present += 1
                print(i, "Gene feature [{}] present in test data point [{}].format(word,yes_no)")
        elif (v < feal_len+fea2_len):
            word = var_vec.get_feature_names()[v-(feal_len)]
            yes_no = True if word == var else False
            if yes_no:
                word_present += 1
                print(i, "variation feature [{}] present in test data point [{}].format(word,yes_no))
        else:
            word = text_vec.get_feature_names()[v-(feal_len+fea2_len)]
            yes_no = True if word in text.split() else False
            if yes_no:
                word_present += 1
                print(i, "Text feature [{}] present in test data point [{}].format(word,yes_no))

    print("Out of the top ",no_features," features ", word_present, "are present in query point")

```

Stacking the three types of features

In [91]:

```

# merging gene, variance and text features

# building train, test and cross validation data sets
# a = [[1, 2],
#       [3, 4]]
# b = [[4, 5],
#       [6, 7]]
# hstack(a, b) = [[1, 2, 4, 5],
#                  [3, 4, 6, 7]]

train_gene_var_onehotCoding =
hstack((train_gene_feature_onehotCoding,train_variation_feature_onehotCoding))
test_gene_var_onehotCoding =
hstack((test_gene_feature_onehotCoding,test_variation_feature_onehotCoding))
cv_gene_var_onehotCoding = hstack((cv_gene_feature_onehotCoding, cv_variation_feature_onehotCoding))

train_x_onehotCoding = hstack((train_gene_var_onehotCoding, train_text_feature_onehotCoding)).tocsr()
train_y = np.array(list(train_df['Class']))

test_x_onehotCoding = hstack((test_gene_var_onehotCoding, test_text_feature_onehotCoding)).tocsr()
test_y = np.array(list(test_df['Class']))

```

```

cv_x = np.concatenate((cv_gene_var_onehotCoding, cv_text_feature_onehotCoding), axis=1)

cv_x_onehotCoding = hstack((cv_gene_var_onehotCoding, cv_text_feature_onehotCoding)).tocsr()
cv_y = np.array(list(cv_df['Class']))

train_gene_var_responseCoding =
np.hstack((train_gene_feature_responseCoding, train_variation_feature_responseCoding))
test_gene_var_responseCoding =
np.hstack((test_gene_feature_responseCoding, test_variation_feature_responseCoding))
cv_gene_var_responseCoding =
np.hstack((cv_gene_feature_responseCoding, cv_variation_feature_responseCoding))

train_x_responseCoding = np.hstack((train_gene_var_responseCoding,
train_text_feature_responseCoding))
test_x_responseCoding = np.hstack((test_gene_var_responseCoding, test_text_feature_responseCoding))
)
cv_x_responseCoding = np.hstack((cv_gene_var_responseCoding, cv_text_feature_responseCoding))

```

In [92]:

```

print("One hot encoding features :")
print("(number of data points * number of features) in train data = ", train_x_onehotCoding.shape)
print("(number of data points * number of features) in test data = ", test_x_onehotCoding.shape)
print("(number of data points * number of features) in cross validation data =", cv_x_onehotCoding.shape)

```

One hot encoding features :
(number of data points * number of features) in train data = (2124, 55026)
(number of data points * number of features) in test data = (665, 55026)
(number of data points * number of features) in cross validation data = (532, 55026)

In [93]:

```

print(" Response encoding features :")
print("(number of data points * number of features) in train data = ", train_x_responseCoding.shape)
print("(number of data points * number of features) in test data = ", test_x_responseCoding.shape)
print("(number of data points * number of features) in cross validation data =", cv_x_responseCoding.shape)

```

Response encoding features :
(number of data points * number of features) in train data = (2124, 27)
(number of data points * number of features) in test data = (665, 27)
(number of data points * number of features) in cross validation data = (532, 27)

4.1. Base Line Model

4.1.1. Naive Bayes

4.1.1.1. Hyper parameter tuning

In [94]:

```

# find more about Multinomial Naive base function here http://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html
# -----
# default parameters
# sklearn.naive_bayes.MultinomialNB(alpha=1.0, fit_prior=True, class_prior=None)

# some of methods of MultinomialNB()
# fit(X, y[, sample_weight]) Fit Naive Bayes classifier according to X, y
# predict(X) Perform classification on an array of test vectors X.
# predict_log_proba(X) Return log-probability estimates for the test vector X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/naive-bayes-algorithm-1/
# -----

```

```

# find more about CalibratedClassifierCV here at http://scikit-
learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/naive-bayes-
# algorithm-1/
# -----


alpha = [0.00001, 0.0001, 0.001, 0.1, 1, 10, 100, 1000]
cv_log_error_array = []
for i in alpha:
    print("for alpha =", i)
    clf = MultinomialNB(alpha=i)
    clf.fit(train_x_onehotCoding, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x_onehotCoding, train_y)
    sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
    cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilitis we use log-probability estimates
    print("Log Loss :", log_loss(cv_y, sig_clf_probs))

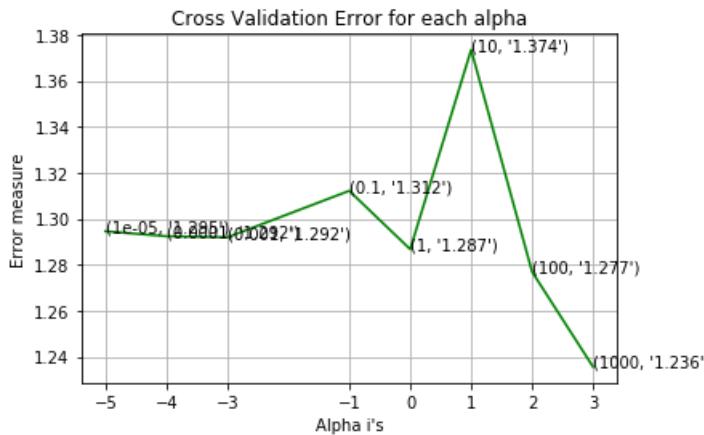
fig, ax = plt.subplots()
ax.plot(np.log10(alpha), cv_log_error_array, c='g')
for i, txt in enumerate(np.round(cv_log_error_array, 3)):
    ax.annotate((alpha[i], str(txt)), (np.log10(alpha[i]), cv_log_error_array[i]))
plt.grid()
plt.xticks(np.log10(alpha))
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

best_alpha = np.argmin(cv_log_error_array)
clf = MultinomialNB(alpha=alpha[best_alpha])
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_onehotCoding)
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(cv_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_lo
ss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_onehotCoding)
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))

for alpha = 1e-05
Log Loss : 1.294535772817202
for alpha = 0.0001
Log Loss : 1.2923722240789692
for alpha = 0.001
Log Loss : 1.291898445074156
for alpha = 0.1
Log Loss : 1.312133744964861
for alpha = 1
Log Loss : 1.2867103849921884
for alpha = 10
Log Loss : 1.373537400054389
for alpha = 100
Log Loss : 1.276859453660011
for alpha = 1000
Log Loss : 1.2355273243348592

```



For values of best alpha = 1000 The train log loss is: 0.9347578867638857
 For values of best alpha = 1000 The cross validation log loss is: 1.2355273243348592
 For values of best alpha = 1000 The test log loss is: 1.1758794553912877

4.1.1.2. Testing the model with best hyper parameters

In [95]:

```
# find more about Multinomial Naive base function here http://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html
# -----
# default paramters
# sklearn.naive_bayes.MultinomialNB(alpha=1.0, fit_prior=True, class_prior=None)

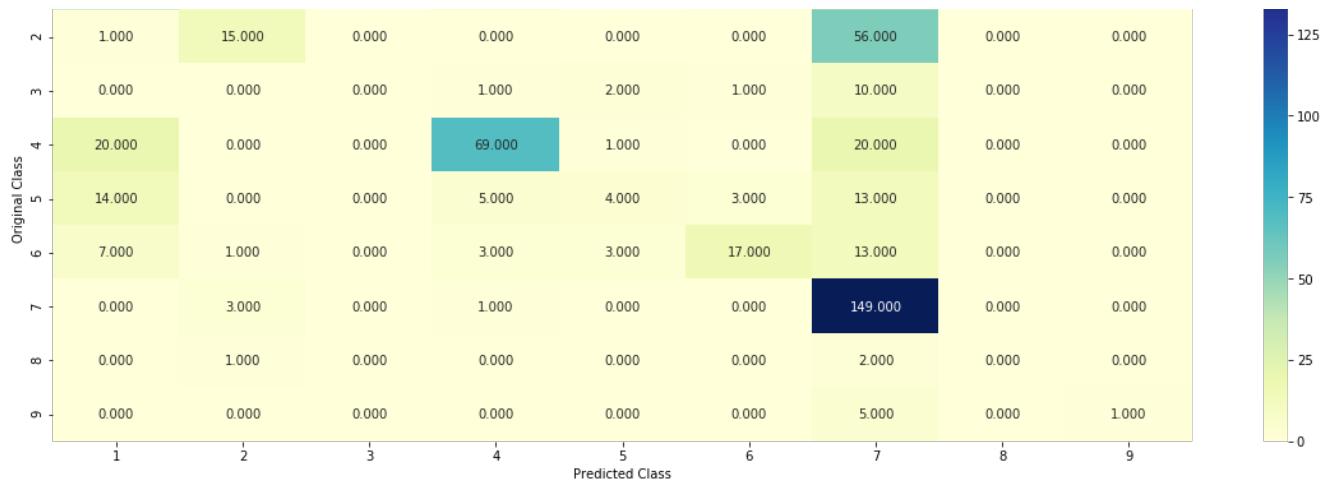
# some of methods of MultinomialNB()
# fit(X, y[, sample_weight]) Fit Naive Bayes classifier according to X, y
# predict(X) Perform classification on an array of test vectors X.
# predict_log_proba(X) Return log-probability estimates for the test vector X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/naive-bayes-algorithm-1/
# -----


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default paramters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
# -----

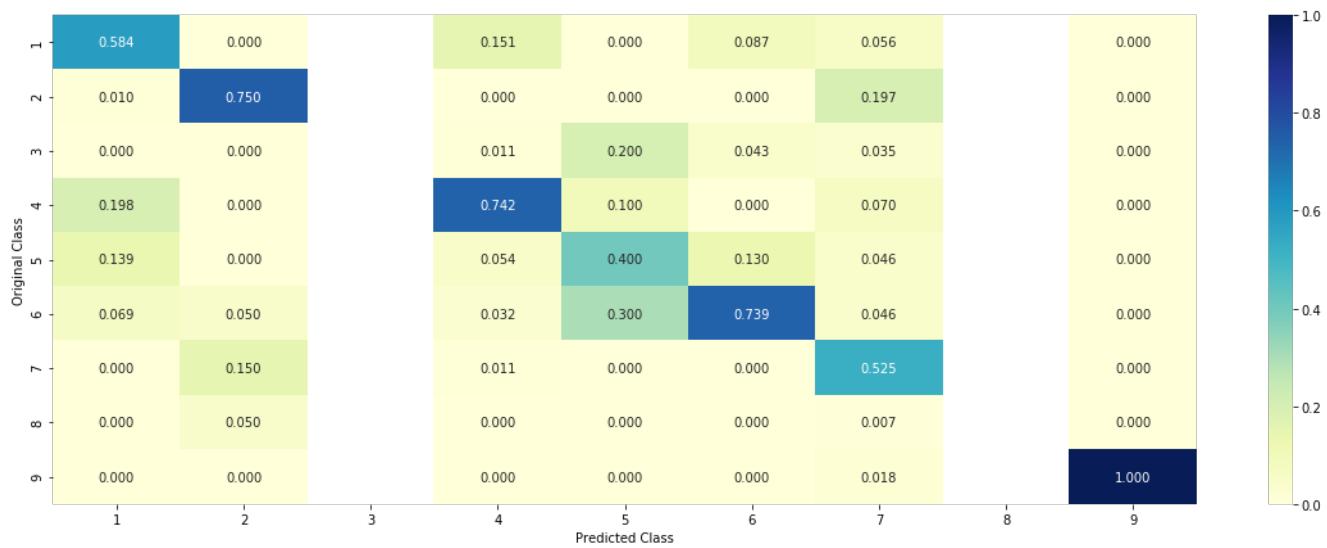

clf = MultinomialNB(alpha=alpha[best_alpha])
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)
sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
# to avoid rounding error while multiplying probabilitites we use log-probability estimates
print("Log Loss :",log_loss(cv_y, sig_clf_probs))
print("Number of missclassified point :", np.count_nonzero((sig_clf.predict(cv_x_onehotCoding)- cv_y)/cv_y.shape[0]))
plot_confusion_matrix(cv_y, sig_clf.predict(cv_x_onehotCoding.toarray()))
```

Log Loss : 1.2355273243348592
 Number of missclassified point : 0.40977443609022557
 ----- Confusion matrix -----

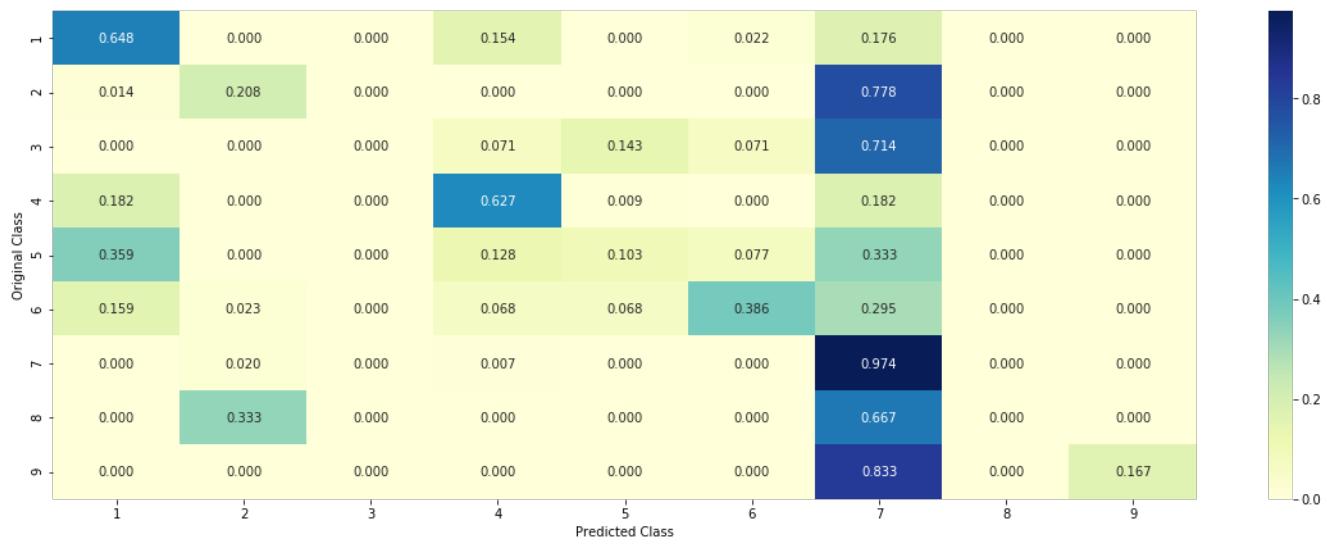
59.000	0.000	0.000	14.000	0.000	2.000	16.000	0.000	0.000
--------	-------	-------	--------	-------	-------	--------	-------	-------



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.1.1.3. Feature Importance, Correctly classified point

In [96]:

```
test_point_index = 1
no_feature = 100
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class : ", predicted_cls[0])
```

```

print('Predicted Class : ', predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imptfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)

```

```

Predicted Class : 7
Predicted Class Probabilities: [[1.028e-01 8.810e-02 2.500e-03 1.465e-01 3.220e-02 2.560e-02 6.012
e-01
 8.000e-04 2.000e-04]]
Actual Class : 2
-----
16 Text feature [kinase] present in test data point [True]
18 Text feature [activation] present in test data point [True]
22 Text feature [cell] present in test data point [True]
24 Text feature [phosphorylation] present in test data point [True]
25 Text feature [downstream] present in test data point [True]
26 Text feature [contrast] present in test data point [True]
27 Text feature [factor] present in test data point [True]
29 Text feature [growth] present in test data point [True]
30 Text feature [signaling] present in test data point [True]
31 Text feature [shown] present in test data point [True]
32 Text feature [also] present in test data point [True]
33 Text feature [suggest] present in test data point [True]
34 Text feature [inhibitor] present in test data point [True]
35 Text feature [10] present in test data point [True]
36 Text feature [however] present in test data point [True]
37 Text feature [addition] present in test data point [True]
38 Text feature [recently] present in test data point [True]
39 Text feature [compared] present in test data point [True]
40 Text feature [similar] present in test data point [True]
41 Text feature [previously] present in test data point [True]
42 Text feature [tyrosine] present in test data point [True]
43 Text feature [found] present in test data point [True]
44 Text feature [independent] present in test data point [True]
45 Text feature [mechanism] present in test data point [True]
46 Text feature [well] present in test data point [True]
47 Text feature [increased] present in test data point [True]
48 Text feature [mutations] present in test data point [True]
49 Text feature [enhanced] present in test data point [True]
50 Text feature [higher] present in test data point [True]
51 Text feature [treated] present in test data point [True]
52 Text feature [figure] present in test data point [True]
53 Text feature [mutant] present in test data point [True]
54 Text feature [consistent] present in test data point [True]
55 Text feature [fig] present in test data point [True]
59 Text feature [potential] present in test data point [True]
61 Text feature [using] present in test data point [True]
63 Text feature [obtained] present in test data point [True]
64 Text feature [constitutively] present in test data point [True]
65 Text feature [demonstrated] present in test data point [True]
67 Text feature [interestingly] present in test data point [True]
68 Text feature [followed] present in test data point [True]
69 Text feature [without] present in test data point [True]
70 Text feature [various] present in test data point [True]
72 Text feature [may] present in test data point [True]
73 Text feature [mutation] present in test data point [True]
74 Text feature [inhibition] present in test data point [True]
75 Text feature [including] present in test data point [True]
76 Text feature [reported] present in test data point [True]
77 Text feature [total] present in test data point [True]
79 Text feature [increase] present in test data point [True]
82 Text feature [respectively] present in test data point [True]
84 Text feature [activating] present in test data point [True]
86 Text feature [observed] present in test data point [True]
87 Text feature [furthermore] present in test data point [True]
88 Text feature [identified] present in test data point [True]
89 Text feature [sensitive] present in test data point [True]
90 Text feature [absence] present in test data point [True]
91 Text feature [two] present in test data point [True]
92 Text feature [molecular] present in test data point [True]
95 Text feature [performed] present in test data point [True]
96 Text feature [either] present in test data point [True]

```

```
98 Text feature [inhibitors] present in test data point [True]
Out of the top 100 features 62 are present in query point
```

4.1.1.4. Feature Importance, Incorrectly classified point

In [97]:

```
test_point_index = 100
no_feature = 100
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imptfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)
```

```
Predicted Class : 4
Predicted Class Probabilities: [[1.863e-01 1.130e-02 2.000e-03 5.059e-01 1.972e-01 5.630e-02 4.020
e-02
 5.000e-04 1.000e-04]]
Actual Class : 6
-----
10 Text feature [protein] present in test data point [True]
11 Text feature [activity] present in test data point [True]
16 Text feature [indicated] present in test data point [True]
17 Text feature [acid] present in test data point [True]
18 Text feature [shown] present in test data point [True]
19 Text feature [function] present in test data point [True]
20 Text feature [whereas] present in test data point [True]
21 Text feature [determined] present in test data point [True]
24 Text feature [amino] present in test data point [True]
25 Text feature [described] present in test data point [True]
26 Text feature [results] present in test data point [True]
27 Text feature [loss] present in test data point [True]
28 Text feature [mammalian] present in test data point [True]
32 Text feature [whether] present in test data point [True]
33 Text feature [also] present in test data point [True]
37 Text feature [important] present in test data point [True]
38 Text feature [two] present in test data point [True]
39 Text feature [abrogate] present in test data point [True]
40 Text feature [related] present in test data point [True]
41 Text feature [type] present in test data point [True]
43 Text feature [expression] present in test data point [True]
46 Text feature [reduced] present in test data point [True]
47 Text feature [levels] present in test data point [True]
48 Text feature [indicate] present in test data point [True]
51 Text feature [mutations] present in test data point [True]
52 Text feature [lower] present in test data point [True]
54 Text feature [either] present in test data point [True]
56 Text feature [analyzed] present in test data point [True]
58 Text feature [determine] present in test data point [True]
59 Text feature [bind] present in test data point [True]
61 Text feature [thus] present in test data point [True]
62 Text feature [containing] present in test data point [True]
65 Text feature [contribute] present in test data point [True]
66 Text feature [wild] present in test data point [True]
67 Text feature [lack] present in test data point [True]
68 Text feature [missense] present in test data point [True]
69 Text feature [incubated] present in test data point [True]
70 Text feature [may] present in test data point [True]
72 Text feature [three] present in test data point [True]
73 Text feature [using] present in test data point [True]
74 Text feature [30] present in test data point [True]
80 Text feature [generated] present in test data point [True]
83 Text feature [although] present in test data point [True]
84 Text feature [vivo] present in test data point [True]
86 Text feature [vector] present in test data point [True]
87 Text feature [cells] present in test data point [True]
91 Text feature [indicates] present in test data point [True]
93 Text feature [suggest] present in test data point [True]
```

```

96 Text feature [affected] present in test data point [True]
98 Text feature [critical] present in test data point [True]
99 Text feature [functional] present in test data point [True]
Out of the top 100 features 51 are present in query point

```

4.2. K Nearest Neighbour Classification

4.2.1. Hyper parameter tuning

In [98]:

```

# find more about KNeighborsClassifier() here http://scikit-
learn.org/stable/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

# methods of
# fit(X, y) : Fit the model using X as training data and y as target values
# predict(X):Predict the class labels for the provided data
# predict_proba(X):Return probability estimates for the test data X.
#-----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/k-nearest-ne
ighbors-geometric-intuition-with-a-toy-example-1/
#-----


# find more about CalibratedClassifierCV here at http://scikit-
learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
#-----
# video link:
#-----


alpha = [5, 11, 15, 21, 31, 41, 51, 99]
cv_log_error_array = []
for i in alpha:
    print("for alpha =", i)
    clf = KNeighborsClassifier(n_neighbors=i)
    clf.fit(train_x_responseCoding, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x_responseCoding, train_y)
    sig_clf_probs = sig_clf.predict_proba(cv_x_responseCoding)
    cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probalites we use log-probability estimates
    print("Log Loss :",log_loss(cv_y, sig_clf_probs))

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],str(txt)), (alpha[i],cv_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(cv_log_error_array)
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
clf.fit(train_x_responseCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_responseCoding, train_y)

```

```

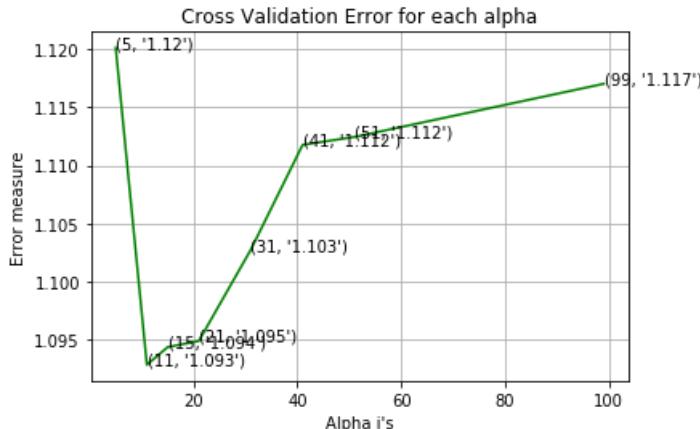
predict_y = sig_clf.predict_proba(train_x_responseCoding)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(cv_x_responseCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_lo
ss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_responseCoding)
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))

```

```

for alpha = 5
Log Loss : 1.1201163517520127
for alpha = 11
Log Loss : 1.0928486251943774
for alpha = 15
Log Loss : 1.0943753023963068
for alpha = 21
Log Loss : 1.094898514700979
for alpha = 31
Log Loss : 1.1027350989936242
for alpha = 41
Log Loss : 1.1117675291681817
for alpha = 51
Log Loss : 1.1124444570732646
for alpha = 99
Log Loss : 1.1170152458552367

```



```

For values of best alpha = 11 The train log loss is: 0.6383337154898796
For values of best alpha = 11 The cross validation log loss is: 1.0928486251943774
For values of best alpha = 11 The test log loss is: 1.0117192577162553

```

4.2.2. Testing the model with best hyper parameters

In [99]:

```

# find more about KNeighborsClassifier() here http://scikit-
learn.org/stable/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

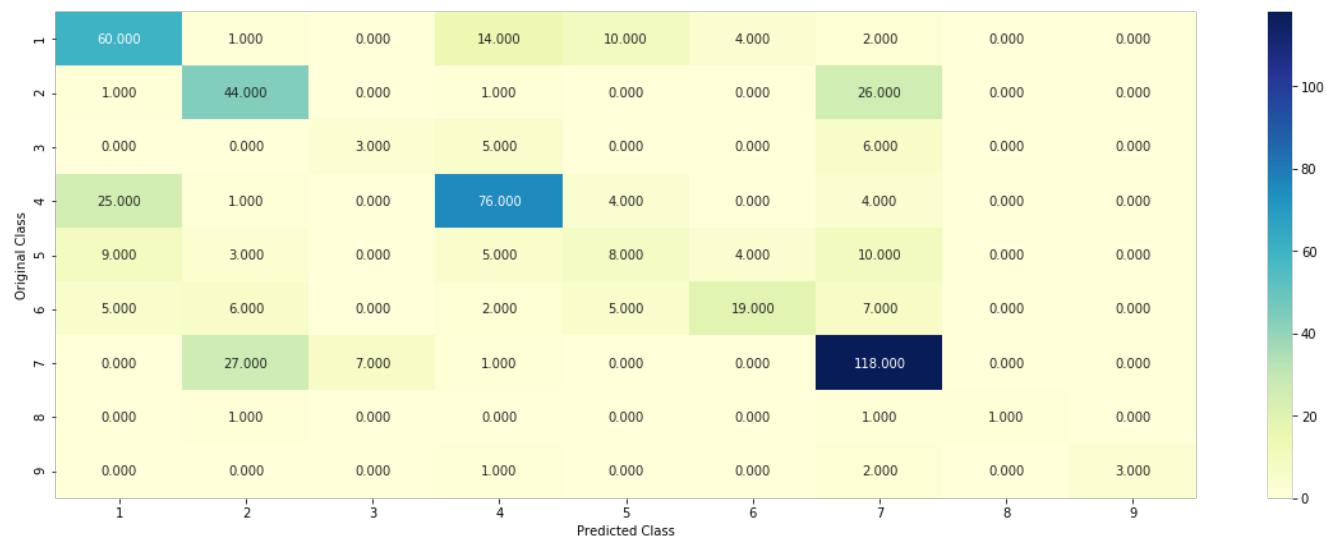
# methods of
# fit(X, y) : Fit the model using X as training data and y as target values
# predict(X) : Predict the class labels for the provided data
# predict_proba(X) : Return probability estimates for the test data X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/k-nearest-ne
ighbors-geometric-intuition-with-a-toy-example-1/
# -----
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
predict_and_plot_confusion_matrix(train_x_responseCoding, train_y, cv_x_responseCoding, cv_y, clf)

```

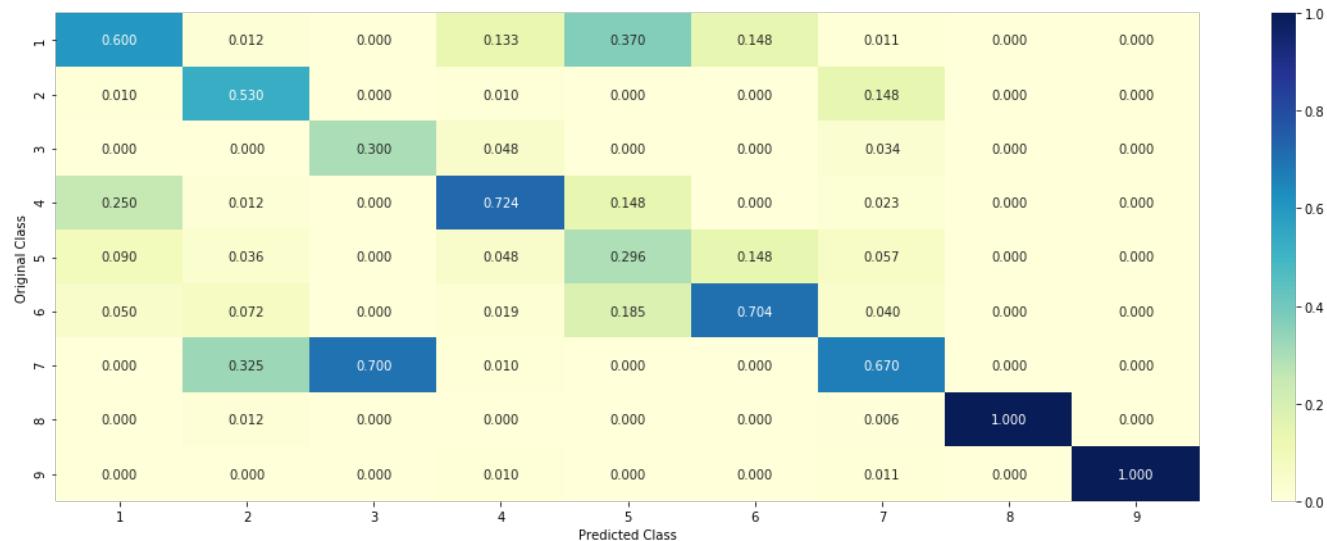
Log loss : 1.0928486251943774

Number of mis-classified points : 0.37593984962406013

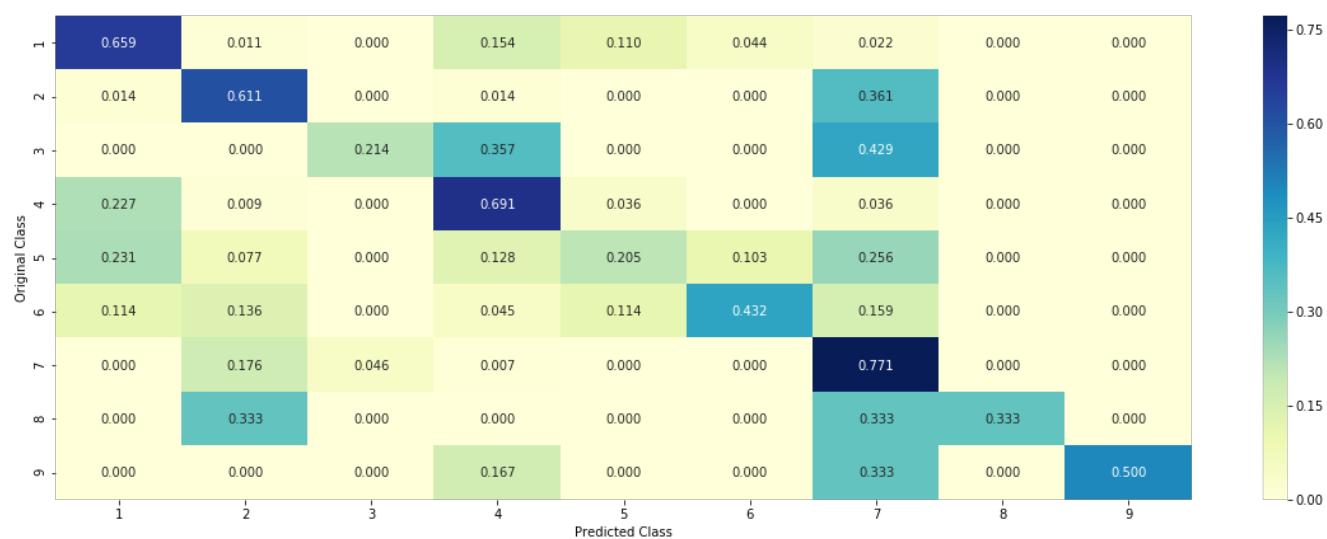
----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.2.3.Sample Query point -1

In [100]:

```
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
clf.fit(train_x_responseCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_responseCoding, train_y)

test_point_index = 1
predicted_cls = sig_clf.predict(test_x_responseCoding[0].reshape(1,-1))
print("Predicted Class :", predicted_cls[0])
print("Actual Class :", test_y[test_point_index])
neighbors = clf.kneighbors(test_x_responseCoding[test_point_index].reshape(1, -1), alpha[best_alpha])
print("The ",alpha[best_alpha]," nearest neighbours of the test points belongs to classes",train_y[neighbors[1][0]])
print("Frequency of nearest points :",Counter(train_y[neighbors[1][0]]))
```

```
Predicted Class : 7
Actual Class : 2
The 11 nearest neighbours of the test points belongs to classes [7 7 2 2 5 5 7 5 7 1 2]
Frequency of nearest points : Counter({7: 4, 2: 3, 5: 3, 1: 1})
```

4.2.4. Sample Query Point-2

In [101]:

```
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
clf.fit(train_x_responseCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_responseCoding, train_y)

test_point_index = 100

predicted_cls = sig_clf.predict(test_x_responseCoding[test_point_index].reshape(1,-1))
print("Predicted Class :", predicted_cls[0])
print("Actual Class :", test_y[test_point_index])
neighbors = clf.kneighbors(test_x_responseCoding[test_point_index].reshape(1, -1), alpha[best_alpha])
print("the k value for knn is",alpha[best_alpha],"and the nearest neighbours of the test points be longs to classes",train_y[neighbors[1][0]])
print("Frequency of nearest points :",Counter(train_y[neighbors[1][0]]))
```

```
Predicted Class : 4
Actual Class : 6
the k value for knn is 11 and the nearest neighbours of the test points belongs to classes [5 3 4 4 4 5 4 4 5 4]
Frequency of nearest points : Counter({4: 7, 5: 3, 3: 1})
```

4.3. Logistic Regression

4.3.1. With Class balancing

4.3.1.1. Hyper parameter tuning

In [102]:

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

# some of methods
```

```

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

#-----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/geometric-intuition-1/
#-----


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
#-----
# video link:
#-----


alpha = [10 ** x for x in range(-6, 3)]
cv_log_error_array = []
for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(class_weight='balanced', alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(train_x_onehotCoding, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x_onehotCoding, train_y)
    sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
    cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilitites we use log-probability estimates
    print("Log Loss :", log_loss(cv_y, sig_clf_probs))

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array, c='g')
for i, txt in enumerate(np.round(cv_log_error_array, 3)):
    ax.annotate((alpha[i], str(txt)), (alpha[i], cv_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(cv_log_error_array)
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_onehotCoding)
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(cv_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:", log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))

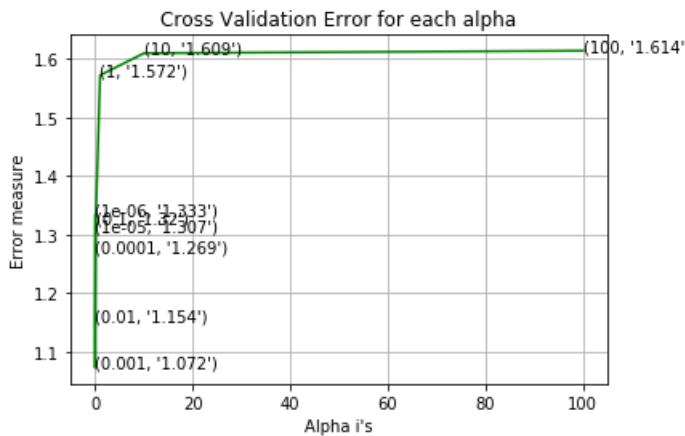
for alpha = 1e-06
Log Loss : 1.3331820804813532
for alpha = 1e-05
Log Loss : 1.307167733628865
for alpha = 0.0001
Log Loss : 1.2693128184453906
for alpha = 0.001
Log Loss : 1.0723517916085625
for alpha = 0.01
Log Loss : 1.153602498704637
for alpha = 0.1

```

```

for alpha = 0.1
Log Loss : 1.3201452675515333
for alpha = 1
Log Loss : 1.5717710162032033
for alpha = 10
Log Loss : 1.6094349006240591
for alpha = 100
Log Loss : 1.6136814266388104

```



For values of best alpha = 0.001 The train log loss is: 0.5927290995688326
 For values of best alpha = 0.001 The cross validation log loss is: 1.0723517916085625
 For values of best alpha = 0.001 The test log loss is: 1.00675388375175

4.3.1.2. Testing the model with best hyper parameters

In [103]:

```

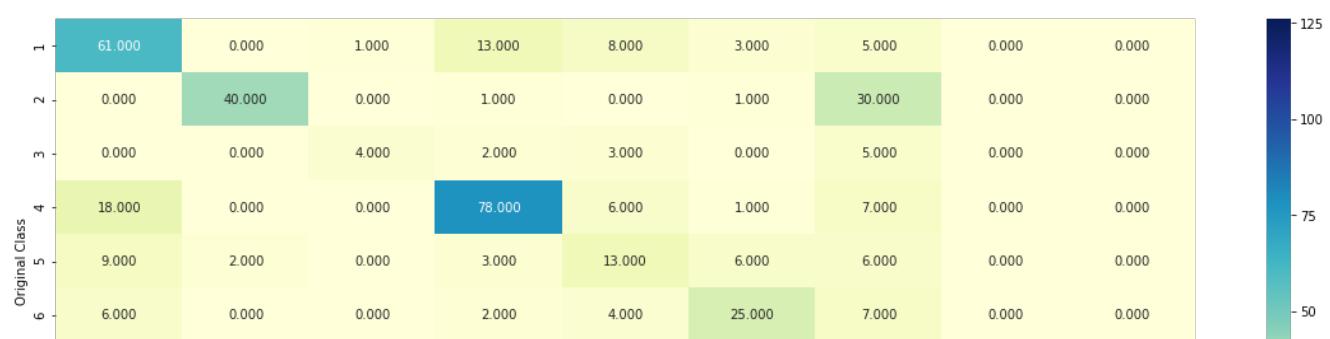
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# -----
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_iter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1,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

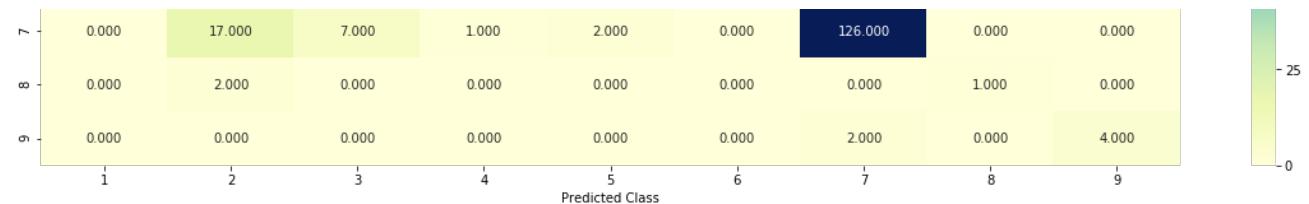
# some of methods
# fit(X, y[, coef_init, intercept_init, ...]) Fit linear model with Stochastic Gradient Descent.
# predict(X) Predict class labels for samples in X.

#-----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/geometric-intuition-1/
#-----
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusion_matrix(train_x_onehotCoding, train_y, cv_x_onehotCoding, cv_y, clf)

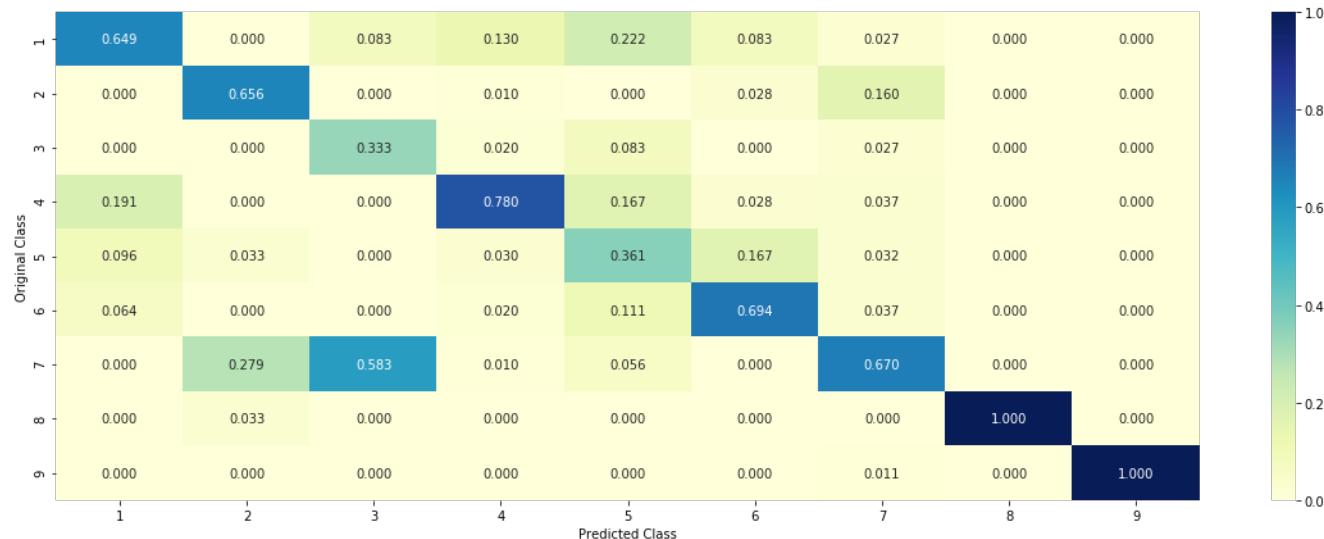
```

Log loss : 1.0723517916085625
 Number of mis-classified points : 0.3383458646616541
 ----- Confusion matrix -----

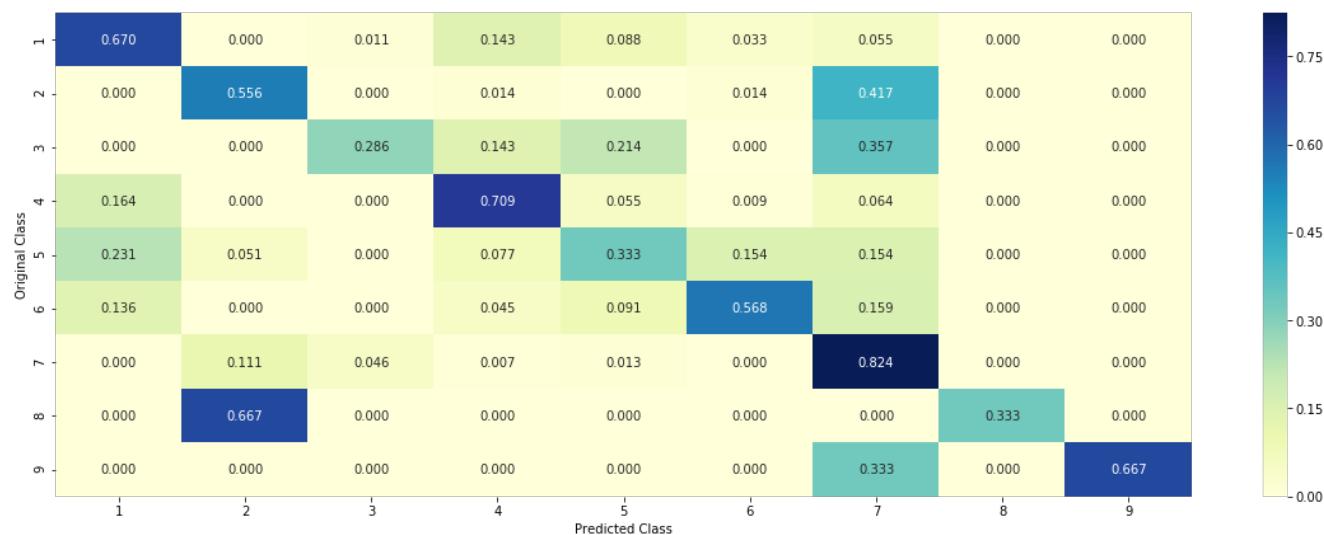




----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.3.1.3. Feature Importance

In [104]:

```
def get_imp_feature_names(text, indices, removed_ind = []):
    word_present = 0
    tabulte_list = []
    incresingorder_ind = 0
    for i in indices:
        if i < train_gene_feature_onehotCoding.shape[1]:
            tabulte_list.append([incresingorder_ind, "Gene", "Yes"])
        elif i< 18:
            tabulte_list.append([incresingorder_ind,"Variation", "Yes"])
        if ((i > 17) & (i not in removed_ind)) :
            word = train_text_features[i]
            yes_no = True if word in text.split() else False
            if yes_no:
                word present += 1
```

```

tabulte_list.append([incresingorder_ind,train_text_features[i], yes_no])
incresingorder_ind += 1
print(word_present, "most important features are present in our query point")
print("-"*50)
print("The features that are most important of the ",predicted_cls[0]," class:")
print(tabulate(tabulte_list, headers=["Index",'Feature name', 'Present or Not']))

```

4.3.1.3.1. Correctly Classified point

In [105]:

```

# from tabulate import tabulate
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(train_x_onehotCoding,train_y)
test_point_index = 1
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:", np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation'].iloc[test_point_index], no_feature)

```

```

Predicted Class : 7
Predicted Class Probabilities: [[0.0945 0.2624 0.0081 0.0833 0.1      0.0219 0.405   0.0184 0.0064]]
Actual Class : 2
-----
34 Text feature [constitutively] present in test data point [True]
49 Text feature [activation] present in test data point [True]
80 Text feature [ligand] present in test data point [True]
86 Text feature [thyroid] present in test data point [True]
93 Text feature [receptors] present in test data point [True]
129 Text feature [oncogene] present in test data point [True]
169 Text feature [transformation] present in test data point [True]
199 Text feature [oncogenes] present in test data point [True]
267 Text feature [dramatic] present in test data point [True]
275 Text feature [downstream] present in test data point [True]
283 Text feature [phosphorylation] present in test data point [True]
311 Text feature [divergence] present in test data point [True]
346 Text feature [kinase] present in test data point [True]
352 Text feature [improvement] present in test data point [True]
394 Text feature [843] present in test data point [True]
466 Text feature [braf] present in test data point [True]
Out of the top 500 features 16 are present in query point

```

4.3.1.3.2. Incorrectly Classified point

In [106]:

```

test_point_index = 100
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:", np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation'].iloc[test_point_index], no_feature)

```

```

Predicted Class : 5
Predicted Class Probabilities: [[0.018  0.0349 0.0045 0.4235 0.4915 0.0055 0.0146 0.0048 0.0027]]
Actual Class : 6
-----

```

```
Out of the top 500 features 0 are present in query point
```

4.3.2. Without Class balancing

4.3.2.1. Hyper parameter tuning

In [107]:

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

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

#-----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/geometric-intuition-1/
#-----

# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
#-----
# video link:
#-----


alpha = [10 ** x for x in range(-6, 1)]
cv_log_error_array = []
for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(train_x_onehotCoding, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x_onehotCoding, train_y)
    sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
    cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :", log_loss(cv_y, sig_clf_probs))

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array, c='g')
for i, txt in enumerate(np.round(cv_log_error_array, 3)):
    ax.annotate((alpha[i], str(txt)), (alpha[i], cv_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(cv_log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_onehotCoding)
```

```

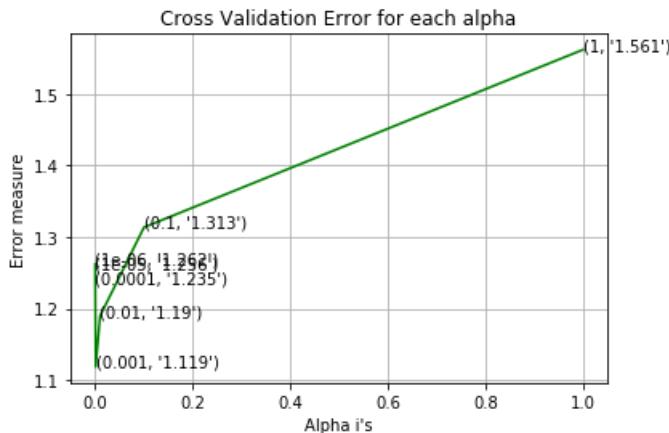
predict_y = sig_clf.predict_proba(train_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:", log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(cv_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_lo
ss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_onehotCoding)
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))

```

```

for alpha = 1e-06
Log Loss : 1.262054138659966
for alpha = 1e-05
Log Loss : 1.2560840138959912
for alpha = 0.0001
Log Loss : 1.2351839611944868
for alpha = 0.001
Log Loss : 1.1186589861374228
for alpha = 0.01
Log Loss : 1.1897318009620887
for alpha = 0.1
Log Loss : 1.3134700821021015
for alpha = 1
Log Loss : 1.561458747548685

```



```

For values of best alpha =  0.001 The train log loss is: 0.5911460086410115
For values of best alpha =  0.001 The cross validation log loss is: 1.1186589861374228
For values of best alpha =  0.001 The test log loss is: 1.0475544142997646

```

4.3.2.2. Testing model with best hyper parameters

In [108]:

```

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

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

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

clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusion_matrix(train_x_onehotCoding, train_y, cv_x_onehotCoding, cv_y, clf)

```

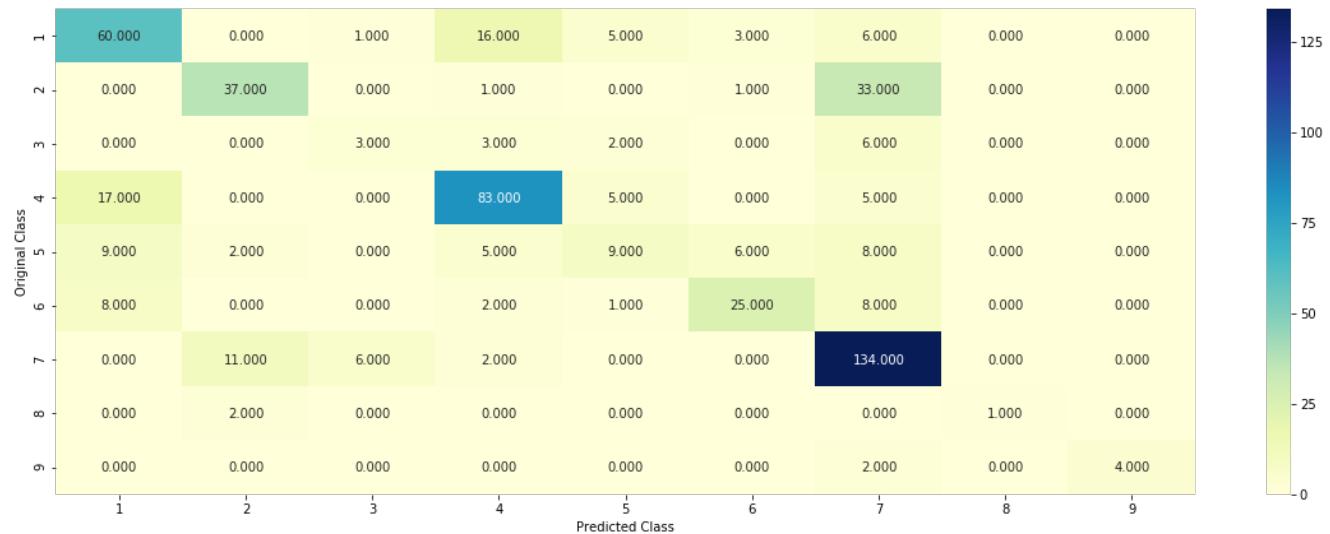
```

Log loss : 1.1186589861374228
Number of misclassified points : 0 2200270676601720

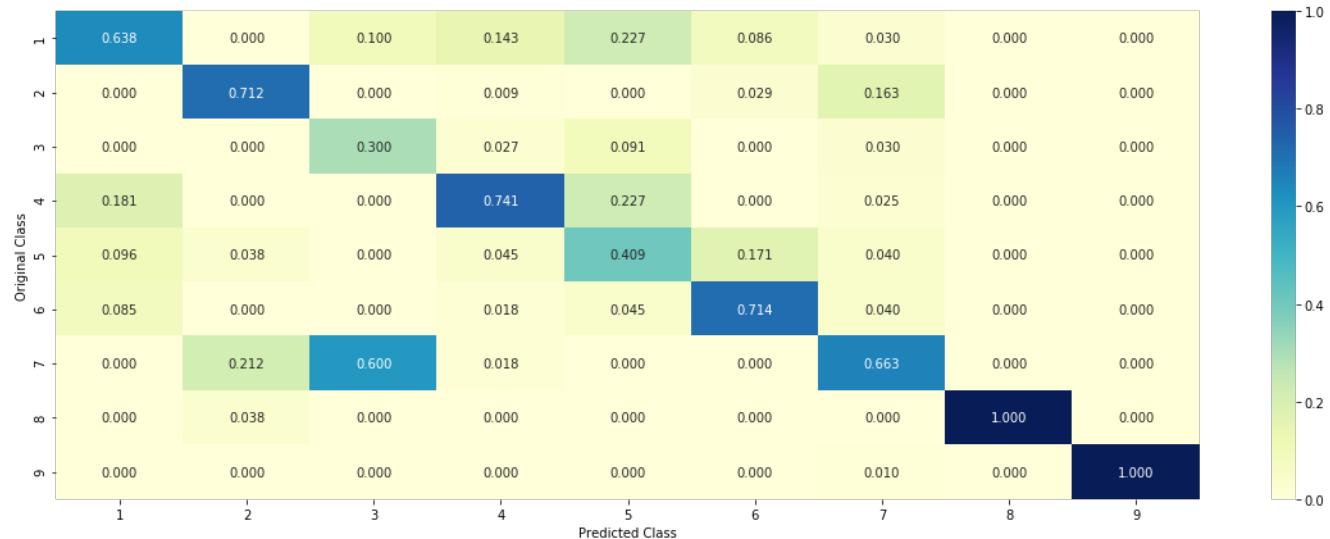
```

NUMBER OF MIS-CLASSIFIED POINTS : 0.0000 / 00 / 0000 / 00

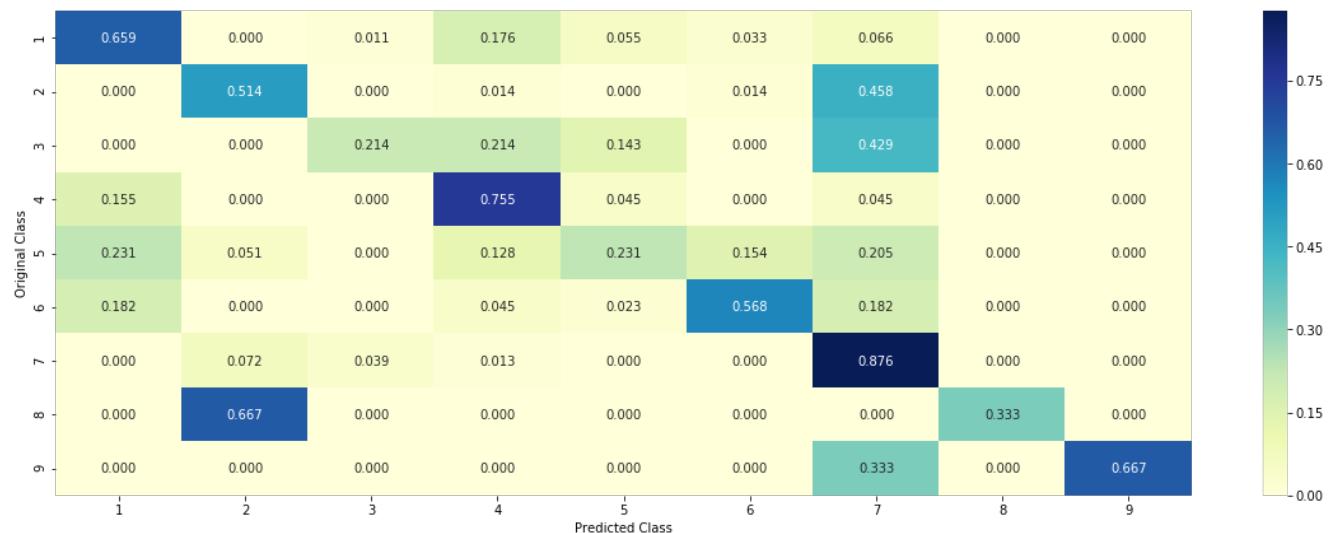
----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.3.2.3. Feature Importance, Correctly Classified point

In [109]:

```
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(train_x_onehotCoding, train_y)
test_point_index = 1
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)
```

```
Predicted Class : 7
Predicted Class Probabilities: [[1.015e-01 2.221e-01 2.800e-03 8.820e-02 6.020e-02 1.370e-02 5.107
e-01
   6.000e-04 2.000e-04]]
Actual Class : 2
-----
88 Text feature [constitutively] present in test data point [True]
99 Text feature [activation] present in test data point [True]
146 Text feature [thyroid] present in test data point [True]
154 Text feature [receptors] present in test data point [True]
156 Text feature [ligand] present in test data point [True]
157 Text feature [transformation] present in test data point [True]
238 Text feature [phosphorylation] present in test data point [True]
264 Text feature [oncogene] present in test data point [True]
268 Text feature [downstream] present in test data point [True]
288 Text feature [kinase] present in test data point [True]
312 Text feature [divergence] present in test data point [True]
327 Text feature [oncogenes] present in test data point [True]
328 Text feature [braf] present in test data point [True]
346 Text feature [dramatic] present in test data point [True]
444 Text feature [activating] present in test data point [True]
489 Text feature [transforming] present in test data point [True]
Out of the top 500 features 16 are present in query point
```

4.3.2.4. Feature Importance, Incorrectly Classified point

In [110]:

```
test_point_index = 100
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)
```

```
Predicted Class : 4
Predicted Class Probabilities: [[9.300e-03 3.940e-02 2.300e-03 5.546e-01 3.633e-01 4.100e-03 2.680
e-02
   3.000e-04 1.000e-04]]
Actual Class : 6
-----
249 Text feature [instability] present in test data point [True]
393 Text feature [kindreds] present in test data point [True]
419 Text feature [1008] present in test data point [True]
476 Text feature [come] present in test data point [True]
Out of the top 500 features 4 are present in query point
```

4.4. Linear Support Vector Machines

4.4.1. Hyper parameter tuning

In [111]:

```
# read more about support vector machines with linear kernels here http://scikit-learn.org/stable/modules/generated/sklearn.svm.SVC.html

# -----
# default parameters
# SVC(C=1.0, kernel='rbf', degree=3, gamma='auto', coef0=0.0, shrinking=True, probability=False, tol=0.001,
# cache_size=200, class_weight=None, verbose=False, max_iter=-1, decision_function_shape='ovr', random_state=None)

# Some of methods of SVM()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/mathematical-derivation-copy-8/
# -----


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
# -----
# video link:
# -----


alpha = [10 ** x for x in range(-5, 3)]
cv_log_error_array = []
for i in alpha:
    print("for C =", i)
    # clf = SVC(C=i,kernel='linear',probability=True, class_weight='balanced')
    clf = SGDClassifier(class_weight='balanced', alpha=i, penalty='l2', loss='hinge', random_state=42)
    clf.fit(train_x_onehotCoding, train_y)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_x_onehotCoding, train_y)
    sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
    cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :", log_loss(cv_y, sig_clf_probs))

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array, c='g')
for i, txt in enumerate(np.round(cv_log_error_array, 3)):
    ax.annotate((alpha[i], str(txt)), (alpha[i], cv_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(cv_log_error_array)
# clf = SVC(C=i,kernel='linear',probability=True, class_weight='balanced')
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='hinge', random_state=42)
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_onehotCoding)
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))
```

```

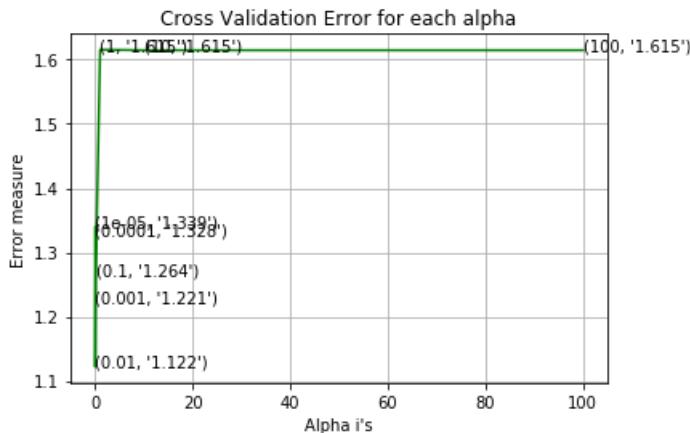
predict_y, labels=clf.classes_, eps=1e-15)
predict_y = sig_clf.predict_proba(cv_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:", log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:", log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))

```

```

for C = 1e-05
Log Loss : 1.338767401881729
for C = 0.0001
Log Loss : 1.3279716794213035
for C = 0.001
Log Loss : 1.2212431599492883
for C = 0.01
Log Loss : 1.1218224067588416
for C = 0.1
Log Loss : 1.264347501792574
for C = 1
Log Loss : 1.615408420094792
for C = 10
Log Loss : 1.6146722231188197
for C = 100
Log Loss : 1.6146721770613965

```



```

For values of best alpha =  0.01 The train log loss is: 0.7175398258948259
For values of best alpha =  0.01 The cross validation log loss is: 1.1218224067588416
For values of best alpha =  0.01 The test log loss is: 1.0683753052905078

```

4.4.2. Testing model with best hyper parameters

In [112]:

```

# read more about support vector machines with linear kernels here http://scikit-
learn.org/stable/modules/generated/sklearn.svm.SVC.html

# -----
# default parameters
# SVC(C=1.0, kernel='rbf', degree=3, gamma='auto', coef0=0.0, shrinking=True, probability=False, t
o1=0.001,
# cache_size=200, class_weight=None, verbose=False, max_iter=-1, decision_function_shape='ovr', ra
ndom_state=None)

# Some of methods of SVM()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-
online/lessons/mathematical-derivation-copy-8/
# -----

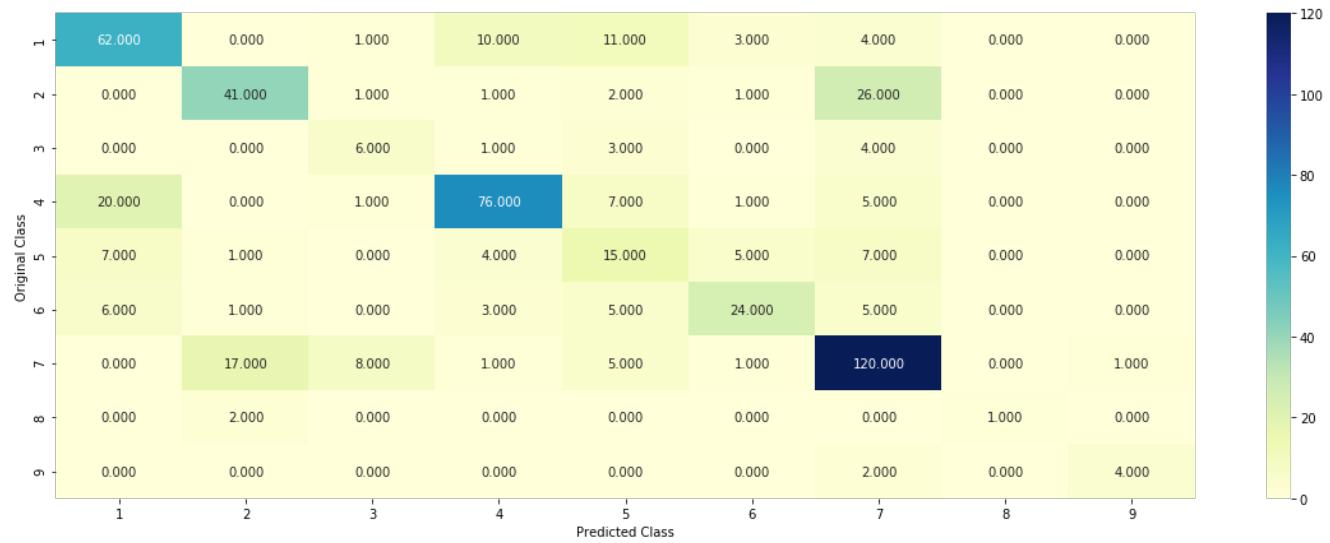

# clf = SVC(C=alpha[best_alpha],kernel='linear',probability=True, class_weight='balanced')
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='hinge',
random_state=42, class_weight='balanced')
predict_and_plot_confusion_matrix(train_x_onehotCoding, train_y, cv_x_onehotCoding, cv_y, clf)

```

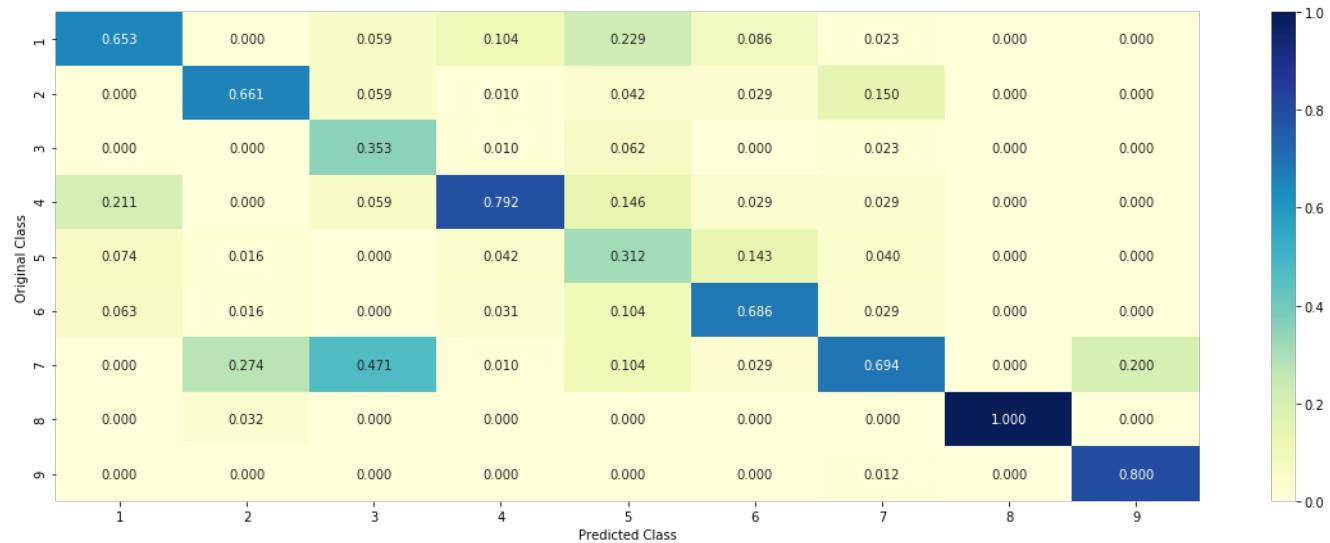
Log loss : 1.1218224067588416

Number of mis-classified points : 0.34398496240601506

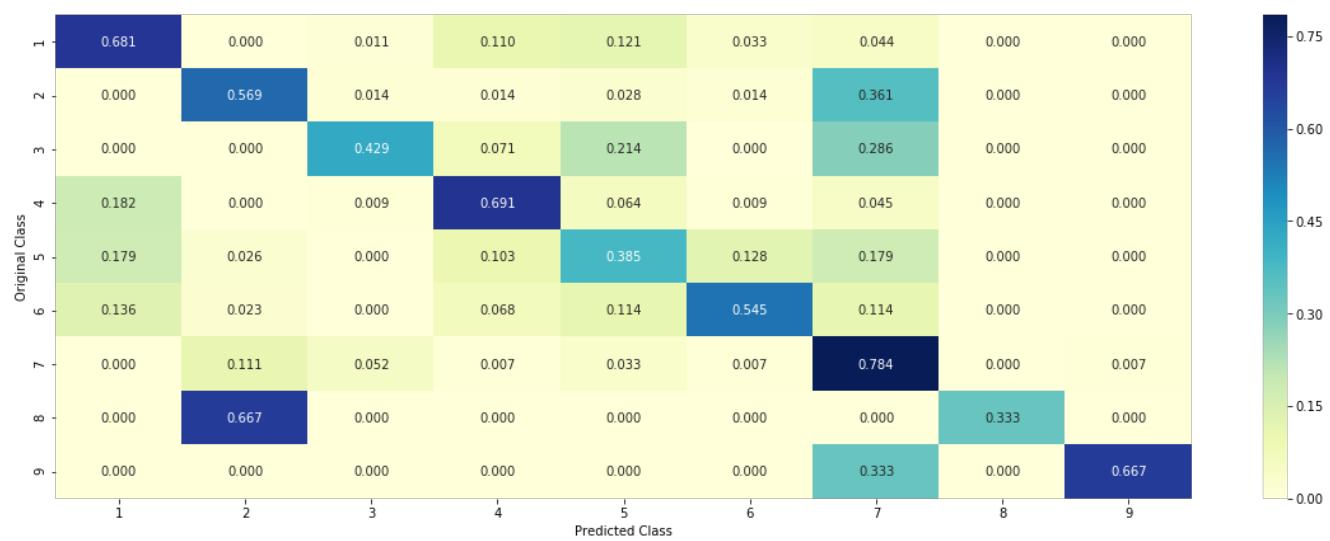
----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.3.3. Feature Importance

4.3.3.1. For Correctly classified point

In [113]:

```
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='hinge', random_state=42)
clf.fit(train_x_onehotCoding,train_y)
test_point_index = 1
# test_point_index = 100
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)
```

```
Predicted Class : 7
Predicted Class Probabilities: [[0.1015 0.2152 0.0084 0.1207 0.0919 0.0404 0.4122 0.0069 0.003 ]]
Actual Class : 2
-----
32 Text feature [constitutively] present in test data point [True]
35 Text feature [activation] present in test data point [True]
42 Text feature [transformation] present in test data point [True]
52 Text feature [thyroid] present in test data point [True]
67 Text feature [ligand] present in test data point [True]
78 Text feature [receptors] present in test data point [True]
90 Text feature [oncogene] present in test data point [True]
92 Text feature [phosphorylation] present in test data point [True]
98 Text feature [oncogenes] present in test data point [True]
163 Text feature [activating] present in test data point [True]
199 Text feature [843] present in test data point [True]
202 Text feature [dramatic] present in test data point [True]
222 Text feature [kinase] present in test data point [True]
271 Text feature [transforming] present in test data point [True]
378 Text feature [oncogenic] present in test data point [True]
388 Text feature [snapshots] present in test data point [True]
414 Text feature [tyrosine] present in test data point [True]
444 Text feature [downstream] present in test data point [True]
457 Text feature [divergence] present in test data point [True]
Out of the top 500 features 19 are present in query point
```

4.3.3.2. For Incorrectly classified point

In [114]:

```
test_point_index = 100
no_feature = 500
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.coef_)[predicted_cls-1][:,:no_feature]
print("-"*50)
get_imfeature_names(indices[0],
test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation']
.iloc[test_point_index], no_feature)
```

```
Predicted Class : 5
Predicted Class Probabilities: [[0.023 0.0678 0.0085 0.3293 0.4588 0.0105 0.0953 0.0038 0.003 ]]
Actual Class : 6
-----
Out of the top 500 features 0 are present in query point
```

4.5 Random Forest Classifier

4.5.1. Hyper parameter tuning (With Tfifd Encoding)

In [115]:

```
# -----
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None,
# verbose=0, warm_start=False,
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/random-forest-and-their-construction-2/
# -----


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
# -----
# default paramters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
#-----
# video link:
#-----


alpha = [100,200,500,1000,2000]
max_depth = [5, 10]
cv_log_error_array = []
for i in alpha:
    for j in max_depth:
        print("for n_estimators =", i,"and max depth = ", j)
        clf = RandomForestClassifier(n_estimators=i, criterion='gini', max_depth=j, random_state=42
, n_jobs=-1)
        clf.fit(train_x_onehotCoding, train_y)
        sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
        sig_clf.fit(train_x_onehotCoding, train_y)
        sig_clf_probs = sig_clf.predict_proba(cv_x_onehotCoding)
        cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
        print("Log Loss :",log_loss(cv_y, sig_clf_probs))

'''fig, ax = plt.subplots()
features = np.dot(np.array(alpha)[:,None],np.array(max_depth)[None]).ravel()
ax.plot(features, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[int(i/2)],max_depth[int(i%2)],str(txt)),
    (features[i],cv_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(cv_log_error_array)
clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/2)], criterion='gini', max_depth=max_depth[int(best_alpha*2)], random_state=42, n_jobs=-1)
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_onehotCoding)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The train log loss is:", log_loss(y_train, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(cv_x_onehotCoding)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The cross validation log loss is:", log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_onehotCoding)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The test log loss is:", log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))

```

```

for n_estimators = 100 and max depth = 5
Log Loss : 1.2860004735030424
for n_estimators = 100 and max depth = 10
Log Loss : 1.220140881809432
for n_estimators = 200 and max depth = 5
Log Loss : 1.264616247891615
for n_estimators = 200 and max depth = 10
Log Loss : 1.208311705472191
for n_estimators = 500 and max depth = 5
Log Loss : 1.2630369085703328
for n_estimators = 500 and max depth = 10
Log Loss : 1.1974180532353467
for n_estimators = 1000 and max depth = 5
Log Loss : 1.262528994368401
for n_estimators = 1000 and max depth = 10
Log Loss : 1.1946897752256904
for n_estimators = 2000 and max depth = 5
Log Loss : 1.2614203865162297
for n_estimators = 2000 and max depth = 10
Log Loss : 1.1970171615683205
For values of best estimator = 1000 The train log loss is: 0.6774289722940123
For values of best estimator = 1000 The cross validation log loss is: 1.1946897752256904
For values of best estimator = 1000 The test log loss is: 1.1253886303902965

```

4.5.2. Testing model with best hyper parameters (Tfidf Encoding)

In [116]:

```

# -----
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None,
# verbose=0, warm_start=False,
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/random-forest-and-their-construction-2/
# -----

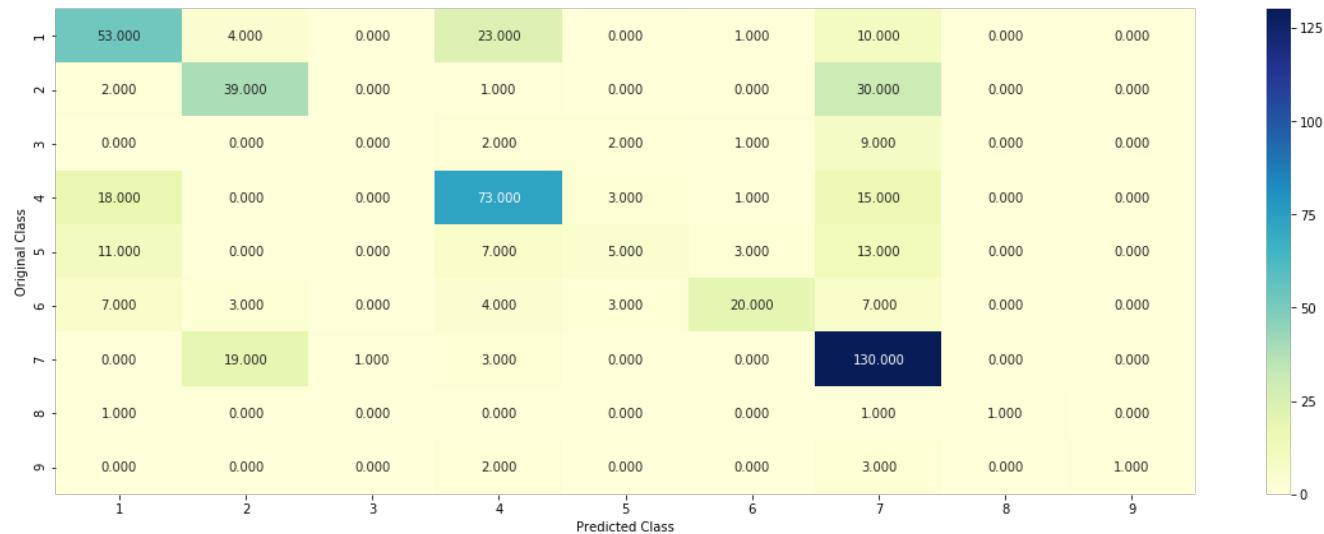

clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/2)], criterion='gini', max_depth=max_depth[int(best_alpha*2)], random_state=42, n_jobs=-1)
predict_and_plot_confusion_matrix(train_x_onehotCoding, train_y, cv_x_onehotCoding, cv_y, clf)

```

LOG LOSS : 1.194689 / 52256904

Number of mis-classified points : 0.39473684210526316

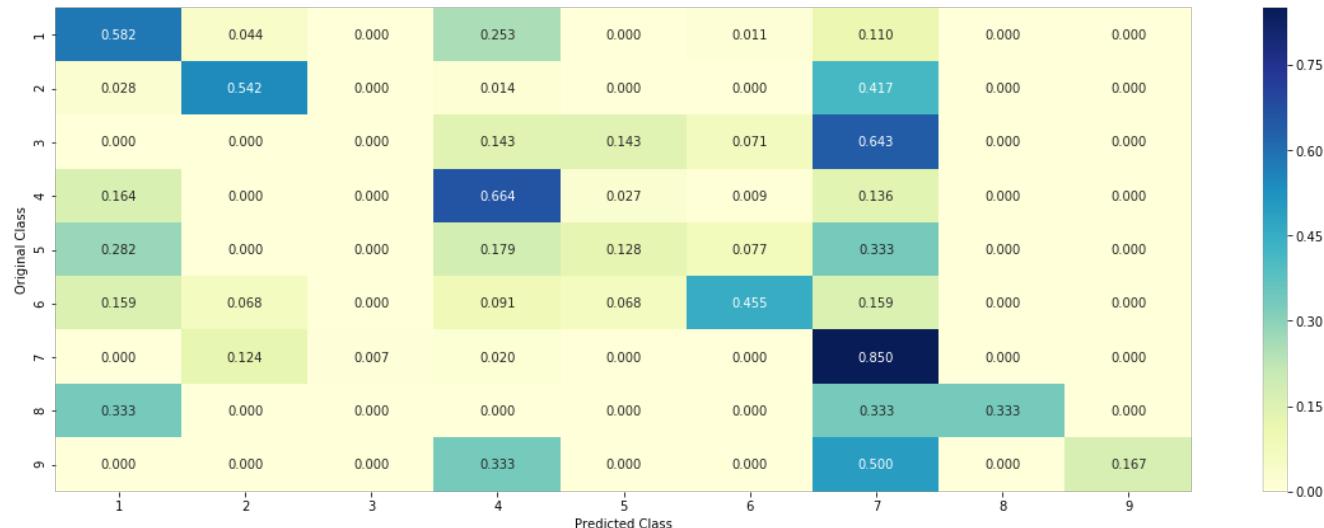
----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.5.3. Feature Importance

4.5.3.1. Correctly Classified point

In [117]:

```
# test_point_index = 10
clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/2)], criterion='gini', max_depth=max_depth[int(best_alpha*2)], random_state=42, n_jobs=-1)
clf.fit(train_x_onehotCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_onehotCoding, train_y)

test_point_index = 1
no_feature = 100
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.feature_importances_)
print("-"*50)
get_imptfeature_names(indices[:no_feature], test_df['TEXT'].iloc[test_point_index],test_df['Gene'].iloc[test_point_index],test_df['Variation'].iloc[test_point_index], no_feature)
```

```
Predicted Class : 7
Predicted Class Probabilities: [[0.1581 0.2206 0.0292 0.1462 0.078 0.0952 0.2585 0.0051 0.0091]]
Actual Class : 2
-----
0 Text feature [kinase] present in test data point [True]
1 Text feature [activating] present in test data point [True]
2 Text feature [phosphorylation] present in test data point [True]
4 Text feature [activation] present in test data point [True]
5 Text feature [tyrosine] present in test data point [True]
6 Text feature [function] present in test data point [True]
8 Text feature [loss] present in test data point [True]
9 Text feature [inhibitors] present in test data point [True]
10 Text feature [oncogenic] present in test data point [True]
14 Text feature [inhibitor] present in test data point [True]
16 Text feature [transforming] present in test data point [True]
18 Text feature [missense] present in test data point [True]
19 Text feature [downstream] present in test data point [True]
20 Text feature [growth] present in test data point [True]
22 Text feature [protein] present in test data point [True]
23 Text feature [drug] present in test data point [True]
24 Text feature [stability] present in test data point [True]
25 Text feature [constitutively] present in test data point [True]
28 Text feature [signaling] present in test data point [True]
33 Text feature [receptor] present in test data point [True]
39 Text feature [inhibition] present in test data point [True]
42 Text feature [cell] present in test data point [True]
47 Text feature [autophosphorylation] present in test data point [True]
48 Text feature [predicted] present in test data point [True]
50 Text feature [proliferation] present in test data point [True]
54 Text feature [proteins] present in test data point [True]
56 Text feature [treated] present in test data point [True]
58 Text feature [functional] present in test data point [True]
60 Text feature [egfr] present in test data point [True]
61 Text feature [phosphorylated] present in test data point [True]
63 Text feature [kinases] present in test data point [True]
66 Text feature [potential] present in test data point [True]
68 Text feature [resistance] present in test data point [True]
69 Text feature [oncogene] present in test data point [True]
72 Text feature [ic50] present in test data point [True]
73 Text feature [functions] present in test data point [True]
76 Text feature [receptors] present in test data point [True]
82 Text feature [active] present in test data point [True]
84 Text feature [tumors] present in test data point [True]
89 Text feature [response] present in test data point [True]
91 Text feature [deleterious] present in test data point [True]
92 Text feature [resistant] present in test data point [True]
94 Text feature [families] present in test data point [True]
95 Text feature [ligand] present in test data point [True]
Out of the top 100 features 44 are present in query point
```

4.5.3.2. Incorrectly Classified point

In [118]:

```
test_point_index = 100
no_feature = 100
predicted_cls = sig_clf.predict(test_x_onehotCoding[test_point_index])
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_onehotCoding[test_point_index]),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.feature_importances_)
print("-"*50)
get_imfeature_names(indices[:no_feature], test_df['TEXT'].iloc[test_point_index], test_df['Gene'].iloc[test_point_index], test_df['Variation'].iloc[test_point_index], no_feature)

Predicted Class : 5
Predicted Class Probabilities: [[0.2041 0.048 0.0265 0.2506 0.3292 0.0925 0.0367 0.0045 0.0079]]
Actual Class : 6
-----
4 Text feature [activation] present in test data point [True]
6 Text feature [function] present in test data point [True]
8 Text feature [loss] present in test data point [True]
13 Text feature [constitutive] present in test data point [True]
18 Text feature [missense] present in test data point [True]
22 Text feature [protein] present in test data point [True]
27 Text feature [variants] present in test data point [True]
29 Text feature [cells] present in test data point [True]
35 Text feature [yeast] present in test data point [True]
37 Text feature [brcal] present in test data point [True]
48 Text feature [predicted] present in test data point [True]
58 Text feature [functional] present in test data point [True]
61 Text feature [phosphorylated] present in test data point [True]
62 Text feature [clinical] present in test data point [True]
65 Text feature [variant] present in test data point [True]
84 Text feature [tumors] present in test data point [True]
85 Text feature [brca2] present in test data point [True]
90 Text feature [likelihood] present in test data point [True]
91 Text feature [deleterious] present in test data point [True]
94 Text feature [families] present in test data point [True]
Out of the top 100 features 20 are present in query point
```

4.5.3. Hyper parameter tuning (With Response Coding)

In [93]:

```
# -----
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None,
# verbose=0, warm_start=False,
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/random-forests-and-their-construction-2/
# -----


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/generated/sklearn.calibration.CalibratedClassifierCV.html
```

```

# -----
# default parameters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight]) Fit the calibrated model
# get_params([deep]) Get parameters for this estimator.
# predict(X) Predict the target of new samples.
# predict_proba(X) Posterior probabilities of classification
#-----
# video link:
#-----

alpha = [10,50,100,200,500,1000]
max_depth = [2,3,5,10]
cv_log_error_array = []
for i in alpha:
    for j in max_depth:
        print("for n_estimators =", i,"and max depth = ", j)
        clf = RandomForestClassifier(n_estimators=i, criterion='gini', max_depth=j, random_state=42
, n_jobs=-1)
        clf.fit(train_x_responseCoding, train_y)
        sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
        sig_clf.fit(train_x_responseCoding, train_y)
        sig_clf_probs = sig_clf.predict_proba(cv_x_responseCoding)
        cv_log_error_array.append(log_loss(cv_y, sig_clf_probs, labels=clf.classes_, eps=1e-15))
        print("Log Loss :",log_loss(cv_y, sig_clf_probs))
    ...
fig, ax = plt.subplots()
features = np.dot(np.array(alpha)[:,None],np.array(max_depth)[None]).ravel()
ax.plot(features, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[int(i/4)],max_depth[int(i%4)],str(txt)),(features[i],cv_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(cv_log_error_array)
clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/4)], criterion='gini', max_depth=max
_depth[int(best_alpha*4)], random_state=42, n_jobs=-1)
clf.fit(train_x_responseCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_responseCoding, train_y)

predict_y = sig_clf.predict_proba(train_x_responseCoding)
print('For values of best alpha = ', alpha[int(best_alpha/4)], "The train log loss is:",log_loss(y_
_train, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(cv_x_responseCoding)
print('For values of best alpha = ', alpha[int(best_alpha/4)], "The cross validation log loss is:"
,log_loss(y_cv, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(test_x_responseCoding)
print('For values of best alpha = ', alpha[int(best_alpha/4)], "The test log loss is:",log_loss(y_
test, predict_y, labels=clf.classes_, eps=1e-15))

for n_estimators = 10 and max depth = 2
Log Loss : 2.2657048897349608
for n_estimators = 10 and max depth = 3
Log Loss : 1.7459205010556096
for n_estimators = 10 and max depth = 5
Log Loss : 1.4368353925512503
for n_estimators = 10 and max depth = 10
Log Loss : 1.904597809032912
for n_estimators = 50 and max depth = 2
Log Loss : 1.7221951095007484
for n_estimators = 50 and max depth = 3
Log Loss : 1.4984825877845531
for n_estimators = 50 and max depth = 5
Log Loss : 1.4593628982873716
for n_estimators = 50 and max depth = 10
Log Loss : 1.8434939703555409
for n_estimators = 100 and max depth = 2
Log Loss : 1.6182209245331227

```

```

for n_estimators = 100 and max depth =  3
Log Loss : 1.5199297988828253
for n_estimators = 100 and max depth =  5
Log Loss : 1.4177501184246677
for n_estimators = 100 and max depth =  10
Log Loss : 1.8227504417195126
for n_estimators = 200 and max depth =  2
Log Loss : 1.6622571648074496
for n_estimators = 200 and max depth =  3
Log Loss : 1.4800771339141767
for n_estimators = 200 and max depth =  5
Log Loss : 1.4412060242341358
for n_estimators = 200 and max depth =  10
Log Loss : 1.7892406351442258
for n_estimators = 500 and max depth =  2
Log Loss : 1.715950314170445
for n_estimators = 500 and max depth =  3
Log Loss : 1.5658682738699774
for n_estimators = 500 and max depth =  5
Log Loss : 1.4445360301518217
for n_estimators = 500 and max depth =  10
Log Loss : 1.8421097596928397
for n_estimators = 1000 and max depth =  2
Log Loss : 1.6834927870864949
for n_estimators = 1000 and max depth =  3
Log Loss : 1.5631973035931377
for n_estimators = 1000 and max depth =  5
Log Loss : 1.4449980792724129
for n_estimators = 1000 and max depth =  10
Log Loss : 1.85233132619749
For values of best alpha =  100 The train log loss is: 0.060702709444608406
For values of best alpha =  100 The cross validation log loss is: 1.417750118424668
For values of best alpha =  100 The test log loss is: 1.3806278998341923

```

4.5.4. Testing model with best hyper parameters (Response Coding)

In [94]:

```

# -----
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None,
# verbose=0, warm_start=False,
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

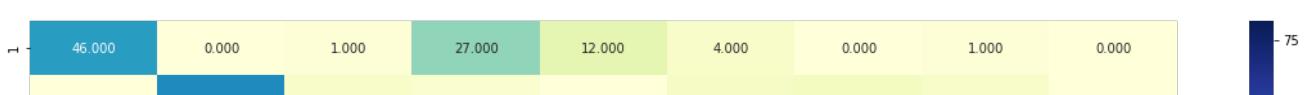
# some of attributes of RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/random-forest-and-their-construction-2/
# -----

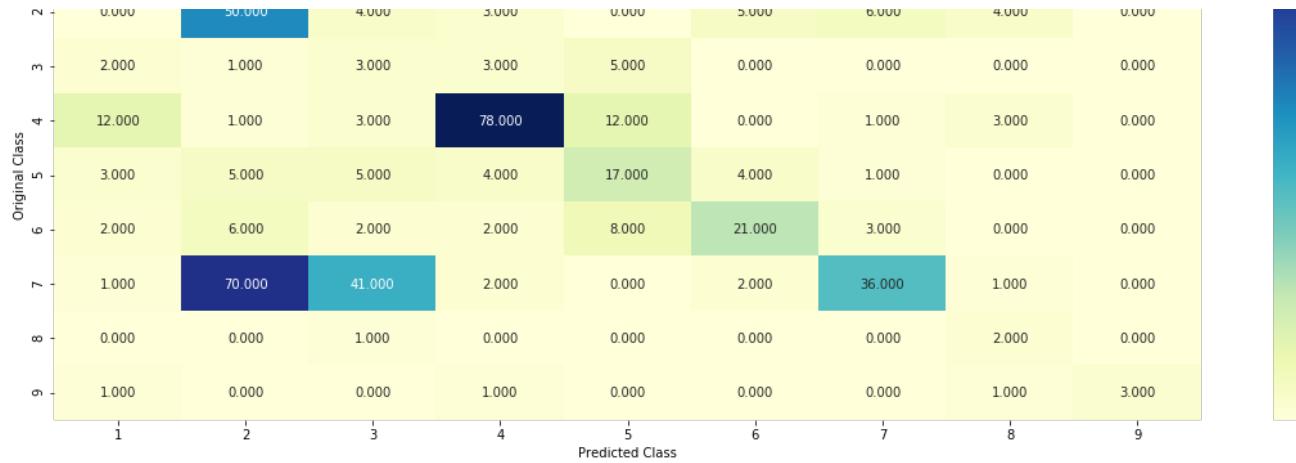

clf = RandomForestClassifier(max_depth=max_depth[int(best_alpha%4)],
n_estimators=alpha[int(best_alpha/4)], criterion='gini', max_features='auto', random_state=42)
predict_and_plot_confusion_matrix(train_x_responseCoding, train_y, cv_x_responseCoding, cv_y, clf)

```

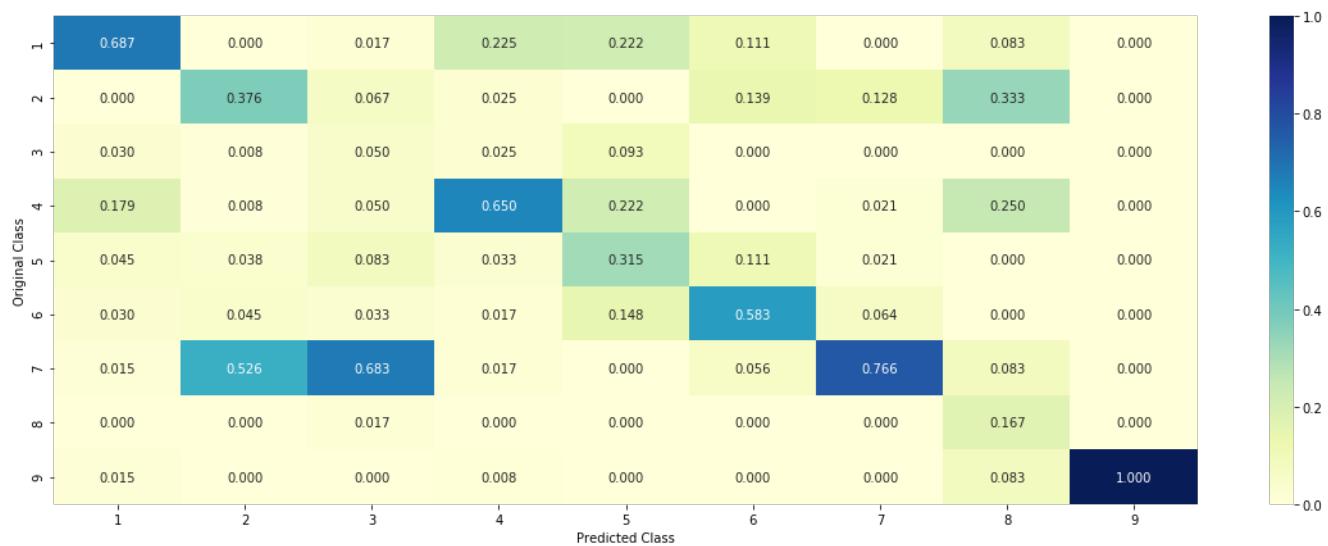
Log loss : 1.4177501184246677
Number of mis-classified points : 0.518796992481203
----- Confusion matrix -----



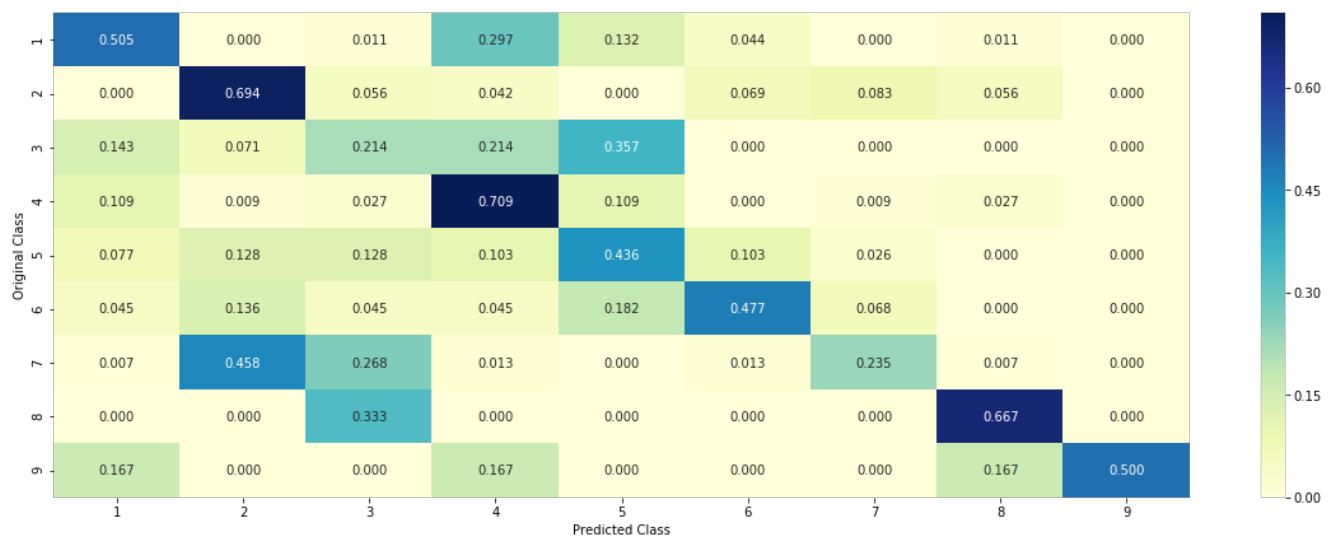
- 75



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



4.5.5. Feature Importance

4.5.5.1. Correctly Classified point

In [95]:

```
clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/4)], criterion='gini', max_depth=max
```

```

_depth[int(best_alpha%4)], random_state=42, n_jobs=-1)
clf.fit(train_x_responseCoding, train_y)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_x_responseCoding, train_y)

test_point_index = 1
no_feature = 27
predicted_cls = sig_clf.predict(test_x_responseCoding[test_point_index].reshape(1,-1))
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_responseCoding[test_point_index].reshape(1,-1)),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.feature_importances_)
print("-"*50)
for i in indices:
    if i<9:
        print("Gene is important feature")
    elif i<18:
        print("Variation is important feature")
    else:
        print("Text is important feature")

Predicted Class : 2
Predicted Class Probabilities: [[0.0143 0.5044 0.1471 0.0191 0.0245 0.065 0.1724 0.039 0.0142]]
Actual Class : 7
-----
Variation is important feature
Variation is important feature
Variation is important feature
Variation is important feature
Text is important feature
Variation is important feature
Gene is important feature
Variation is important feature
Text is important feature
Text is important feature
Text is important feature
Text is important feature
Gene is important feature
Text is important feature
Gene is important feature
Variation is important feature
Text is important feature
Gene is important feature
Gene is important feature
Gene is important feature
Variation is important feature
Variation is important feature
Text is important feature
Text is important feature
Gene is important feature
Text is important feature
Gene is important feature
Gene is important feature

```

4.5.5.2. Incorrectly Classified point

In [96]:

```

test_point_index = 100
predicted_cls = sig_clf.predict(test_x_responseCoding[test_point_index].reshape(1,-1))
print("Predicted Class :", predicted_cls[0])
print("Predicted Class Probabilities:",
np.round(sig_clf.predict_proba(test_x_responseCoding[test_point_index].reshape(1,-1)),4))
print("Actual Class :", test_y[test_point_index])
indices = np.argsort(-clf.feature_importances_)
print("-"*50)
for i in indices:
    if i<9:
        print("Gene is important feature")
    elif i<18:
        print("Variation is important feature")
    else:
        print("Text is important feature")

```

```

Predicted Class : 7
Predicted Class Probabilities: [[0.0281 0.2006 0.203  0.0857 0.0626 0.0906 0.2249 0.0676 0.0369]]
Actual Class : 7
-----
Variation is important feature
Variation is important feature
Variation is important feature
Variation is important feature
Text is important feature
Variation is important feature
Gene is important feature
Variation is important feature
Text is important feature
Text is important feature
Text is important feature
Gene is important feature
Text is important feature
Gene is important feature
Variation is important feature
Text is important feature
Gene is important feature
Gene is important feature
Gene is important feature
Variation is important feature
Variation is important feature
Text is important feature
Text is important feature
Gene is important feature
Text is important feature
Gene is important feature
Gene is important feature

```

4.7 Stack the models

4.7.1 testing with hyper parameter tuning

In [119]:

```

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

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

#-----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/geometric-in-
tuition-1/
#-----


# read more about support vector machines with linear kernels here http://scikit-
learn.org/stable/modules/generated/sklearn.svm.SVC.html
# -----
# default parameters
# SVC(C=1.0, kernel='rbf', degree=3, gamma='auto', coef0=0.0, shrinking=True, probability=False, t
ol=0.001,
# cache_size=200, class_weight=None, verbose=False, max_iter=-1, decision_function_shape='ovr', ra
ndom_state=None)

# Some of methods of SVM()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-

```

```

# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/mathematical-derivation-copy-8/
# ----

# read more about support vector machines with linear kernels here http://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html
# ----
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None,
# verbose=0, warm_start=False,
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight]) Fit the SVM model according to the given training data.
# predict(X) Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -----
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/random-forests-and-their-construction-2/
# -----

```

```

clf1 = SGDClassifier(alpha=0.001, penalty='l2', loss='log', class_weight='balanced', random_state=0)
clf1.fit(train_x_onehotCoding, train_y)
sig_clf1 = CalibratedClassifierCV(clf1, method="sigmoid")

clf2 = SGDClassifier(alpha=1, penalty='l2', loss='hinge', class_weight='balanced', random_state=0)
clf2.fit(train_x_onehotCoding, train_y)
sig_clf2 = CalibratedClassifierCV(clf2, method="sigmoid")

clf3 = MultinomialNB(alpha=0.001)
clf3.fit(train_x_onehotCoding, train_y)
sig_clf3 = CalibratedClassifierCV(clf3, method="sigmoid")

sig_clf1.fit(train_x_onehotCoding, train_y)
print("Logistic Regression : Log Loss: %0.2f" % (log_loss(cv_y, sig_clf1.predict_proba(cv_x_onehotCoding))))
sig_clf2.fit(train_x_onehotCoding, train_y)
print("Support vector machines : Log Loss: %0.2f" % (log_loss(cv_y, sig_clf2.predict_proba(cv_x_onehotCoding))))
sig_clf3.fit(train_x_onehotCoding, train_y)
print("Naive Bayes : Log Loss: %0.2f" % (log_loss(cv_y, sig_clf3.predict_proba(cv_x_onehotCoding))))
)
print("-" * 50)
alpha = [0.0001, 0.001, 0.01, 0.1, 1, 10]
best_alpha = 999
for i in alpha:
    lr = LogisticRegression(C=i)
    sclf = StackingClassifier(classifiers=[sig_clf1, sig_clf2, sig_clf3], meta_classifier=lr, use_probas=True)
    sclf.fit(train_x_onehotCoding, train_y)
    print("Stacking Classifier : for the value of alpha: %f Log Loss: %0.3f" % (i, log_loss(cv_y, sclf.predict_proba(cv_x_onehotCoding))))
    log_error = log_loss(cv_y, sclf.predict_proba(cv_x_onehotCoding))
    if best_alpha > log_error:
        best_alpha = log_error

```

```

Logistic Regression : Log Loss: 1.09
Support vector machines : Log Loss: 1.62
Naive Bayes : Log Loss: 1.29
-----
Stacking Classifier : for the value of alpha: 0.000100 Log Loss: 2.178
Stacking Classifier : for the value of alpha: 0.001000 Log Loss: 2.035
Stacking Classifier : for the value of alpha: 0.010000 Log Loss: 1.496
Stacking Classifier : for the value of alpha: 0.100000 Log Loss: 1.097

```

Stacking Classifier : for the value of alpha: 1.000000 Log Loss: 1.167
 Stacking Classifier : for the value of alpha: 10.000000 Log Loss: 1.367

4.7.2 testing the model with the best hyper parameters

In [120]:

```
lr = LogisticRegression(C=0.1)
sclf = StackingClassifier(classifiers=[sig_clf1, sig_clf2, sig_clf3], meta_classifier=lr, use_proba=True)
sclf.fit(train_x_onehotCoding, train_y)

log_error = log_loss(train_y, sclf.predict_proba(train_x_onehotCoding))
print("Log loss (train) on the stacking classifier :", log_error)

log_error = log_loss(cv_y, sclf.predict_proba(cv_x_onehotCoding))
print("Log loss (CV) on the stacking classifier :", log_error)

log_error = log_loss(test_y, sclf.predict_proba(test_x_onehotCoding))
print("Log loss (test) on the stacking classifier :", log_error)

print("Number of missclassified point :", np.count_nonzero((sclf.predict(test_x_onehotCoding) - test_y)/test_y.shape[0]))
plot_confusion_matrix(test_y=test_y, predict_y=sclf.predict(test_x_onehotCoding))
```

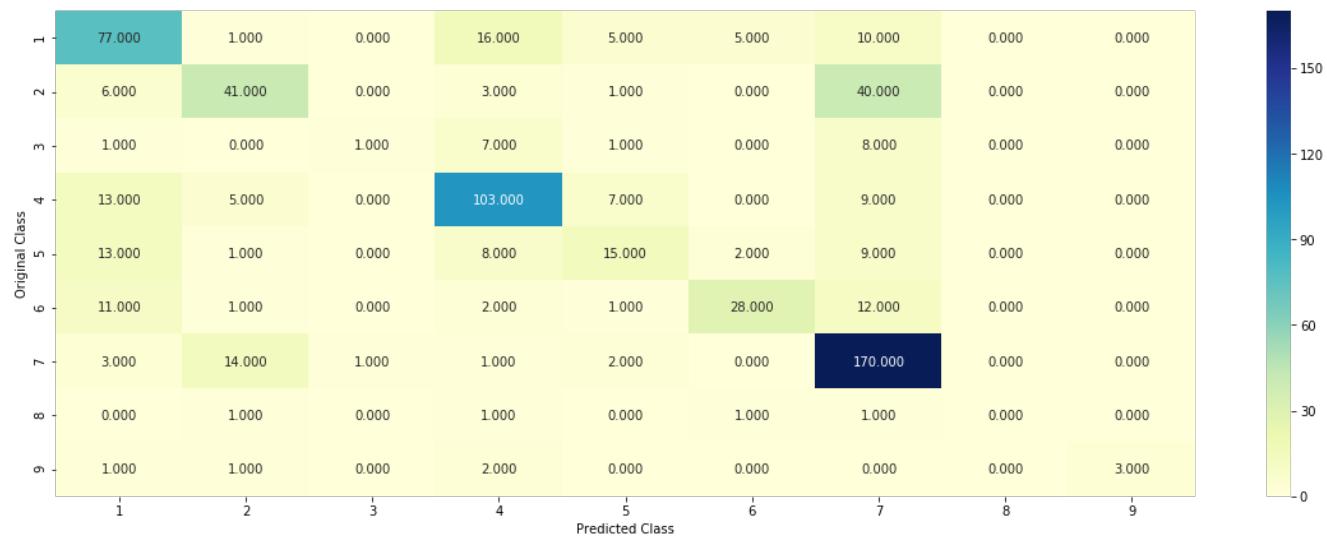
Log loss (train) on the stacking classifier : 0.6523737033018553

Log loss (CV) on the stacking classifier : 1.0965335469251474

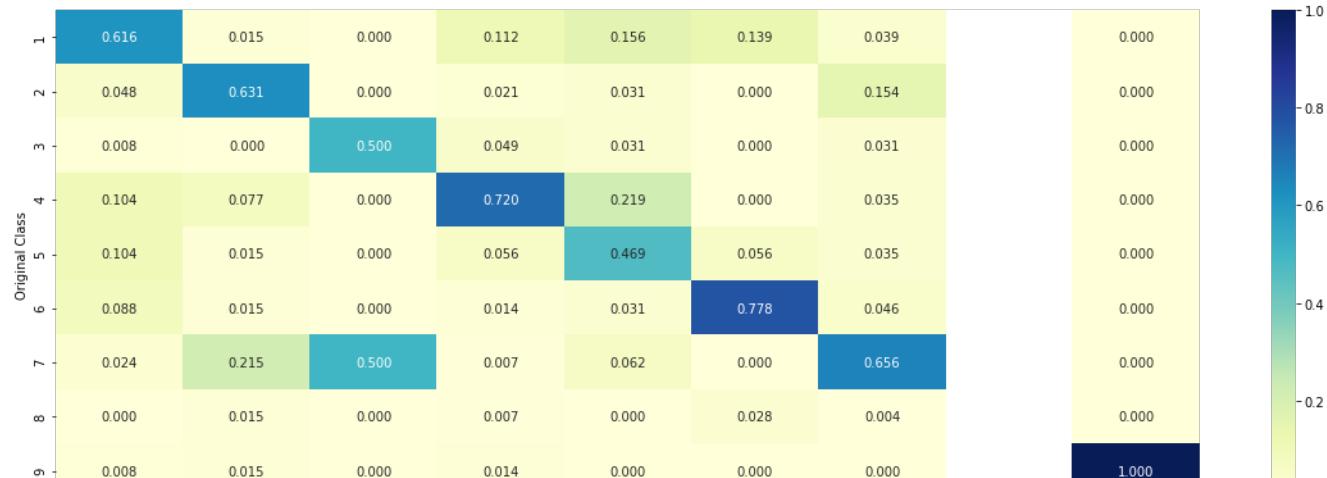
Log loss (test) on the stacking classifier : 1.068557908116401

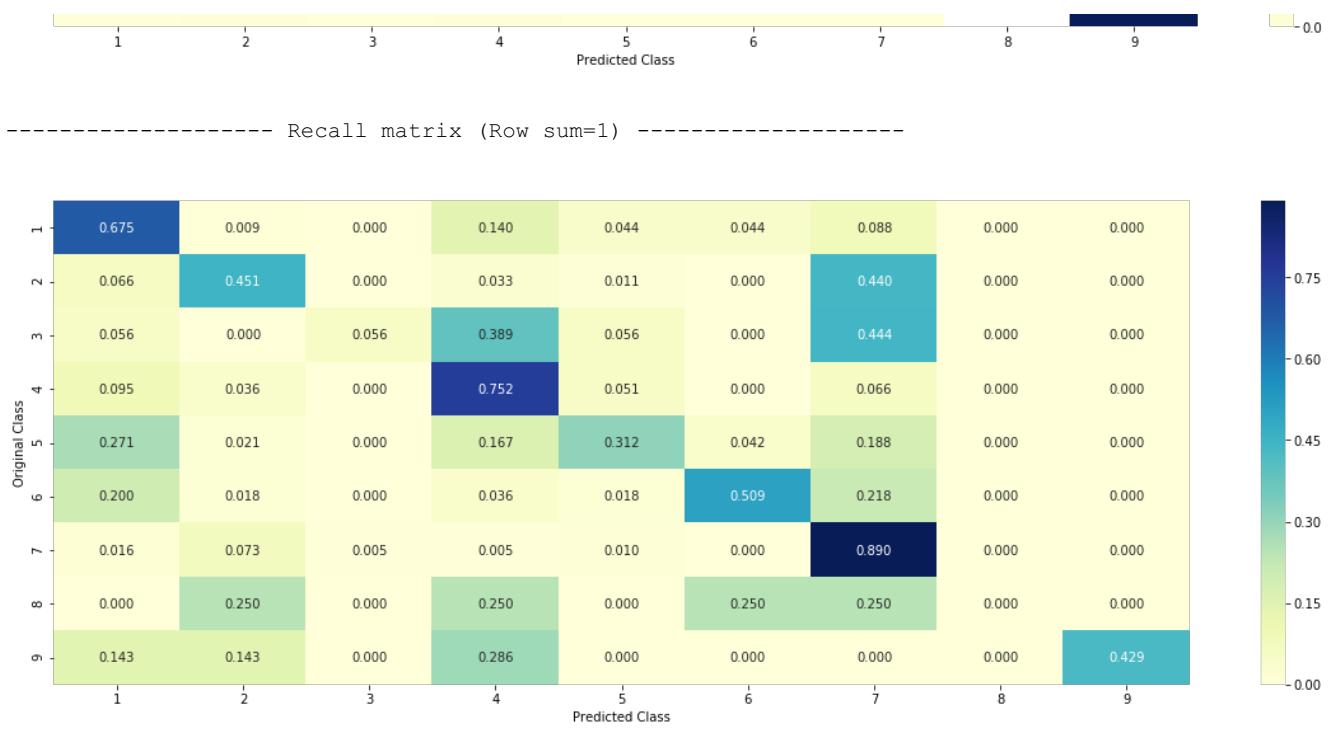
Number of missclassified point : 0.34135338345864663

----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----





4.7.3 Maximum Voting classifier

In [121]:

```
#Refer:http://scikit-learn.org/stable/modules/generated/sklearn.ensemble.VotingClassifier.html
from sklearn.ensemble import VotingClassifier
vclf = VotingClassifier(estimators=[('lr', sig_clf1), ('svc', sig_clf2), ('rf', sig_clf3)], voting='soft')
vclf.fit(train_x_onehotCoding, train_y)
print("Log loss (train) on the VotingClassifier :", log_loss(train_y, vclf.predict_proba(train_x_onehotCoding)))
print("Log loss (CV) on the VotingClassifier :", log_loss(cv_y, vclf.predict_proba(cv_x_onehotCoding)))
print("Log loss (test) on the VotingClassifier :", log_loss(test_y, vclf.predict_proba(test_x_onehotCoding)))
print("Number of missclassified point :", np.count_nonzero((vclf.predict(test_x_onehotCoding) - test_y)/test_y.shape[0]))
plot_confusion_matrix(test_y=test_y, predict_y=vclf.predict(test_x_onehotCoding))
```

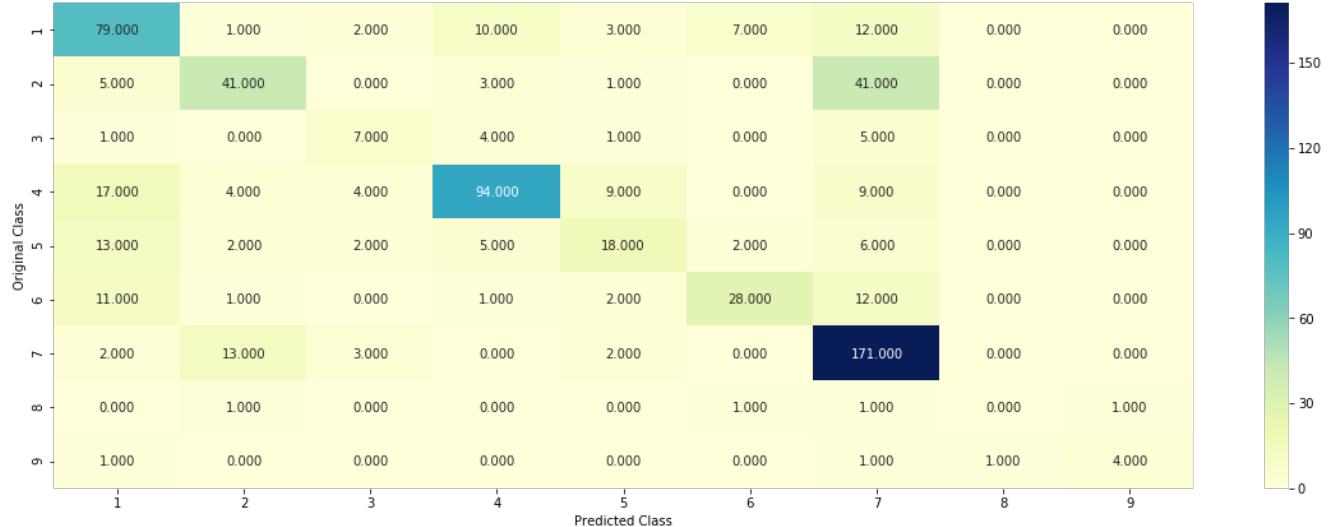
Log loss (train) on the VotingClassifier : 0.8652939848551144

Log loss (CV) on the VotingClassifier : 1.1784851621622894

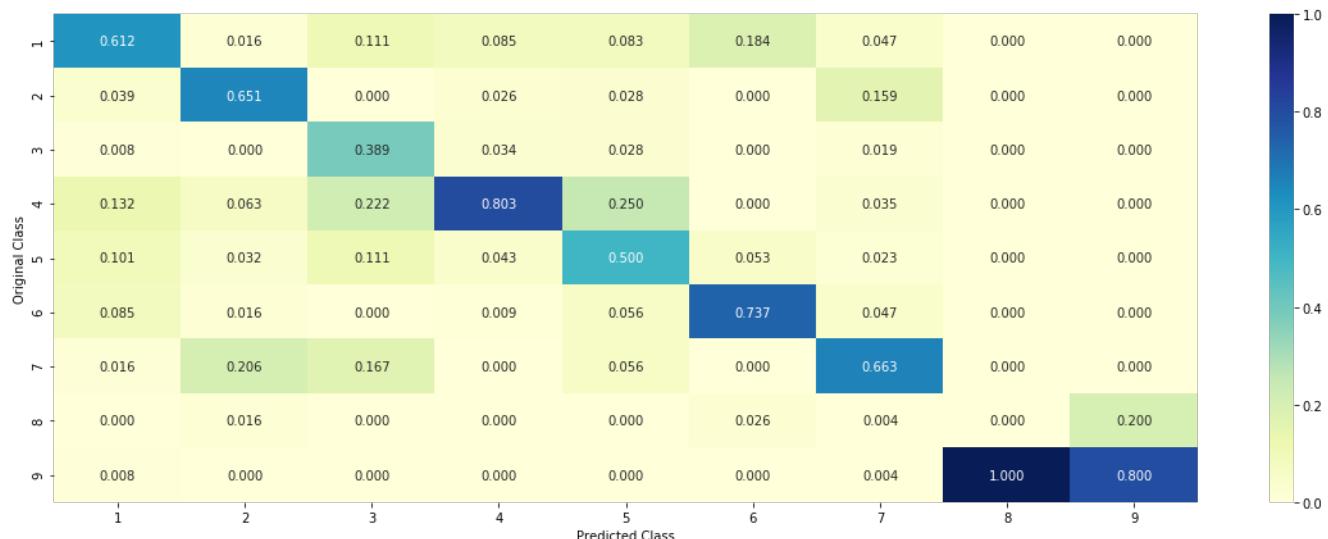
Log loss (test) on the VotingClassifier : 1.1356340908983944

Number of missclassified point : 0.33533834586466166

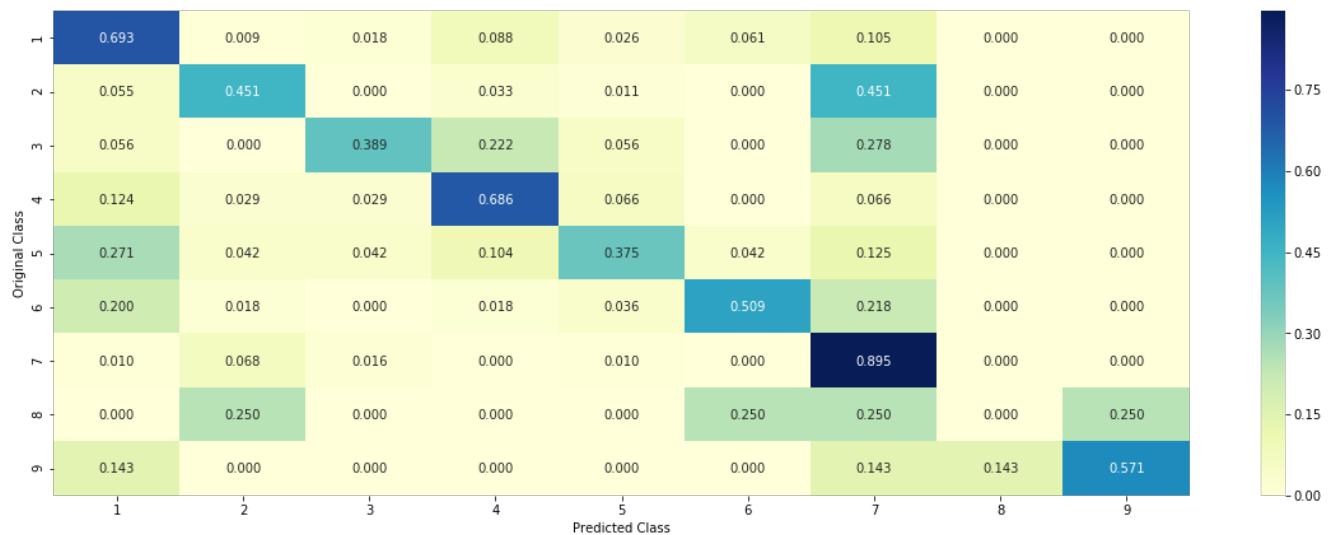
----- Confusion matrix -----



----- Precision matrix (Column Sum=1) -----



----- Recall matrix (Row sum=1) -----



5. Conclusion

5.1 Step Taken

Instead of using all the words in the dataset, use only the top 1000 words based of tf-idf values

5.2 Model Comparision

In [11]:

```
#https://www.kaggle.com/premvardhan/amazon-fine-food-reviews-analysis-using-knn
models = pd.DataFrame({'Model': ['Naive Bayes', 'K-NN', "Logistic Regression with Class Balancing", 'Logistic Regression without Class Balancing', 'Linear SVM', 'Random forest', 'Random forest(response encoding)', 'Stacking classifier', 'Maximum voting classifier'], 'Log-Loss': [1.235, 1.092, 1.072, 1.118, 1.121, 1.194, 1.417, 1.224, 1.283], 'Percent of Misclassified points': [.405, .375, 0.338, .330, .343, .394, .518, .372, .381], 'Hyperparameter': [.1, .15, .001, .001, .01, 1000, 100, .1, 0]}, columns = ["Model", "Log-Loss", "Percent of Misclassified points", "Hyperparameter"])
models
```

Out[11]:

	Model	Log-Loss	Percent of Misclassified points	Hyperparameter
0	Naive Bayes	1.235	0.405	0.100
1	K-NN	1.092	0.375	15.000
2	Logistic Regression with Class Balancing	1.072	0.338	0.001
3	Logistic Regression without Class Balancing	1.118	0.330	0.001
4	Linear SVM	1.121	0.343	0.010
5	Random forest	1.194	0.394	1000.000
6	Random forest(response encoding)	1.417	0.518	100.000
7	Stacking classifier	1.224	0.372	0.100
8	Maximum voting classifier	1.283	0.381	0.000