PERSONALIZED CANCER DIAGNOSIS

Problem Statement :

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

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 probabilites => Metric is Log-loss.

No Latency constraints.

```
import pandas as pd
import matplotlib.pyplot as plt
import time
import warnings
import numpy as np
warnings.filterwarnings("ignore")
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc
from nltk.stem.porter import PorterStemmer
import re
import string
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from nltk.stem.wordnet import WordNetLemmatizer
from gensim.models import Word2Vec
from gensim.models import KeyedVectors
import pickle
from tqdm import tqdm
import os
```

```
from google.colab import drive

drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk8qdgf4n4g3pf

Enter your authorization code:
··········
Mounted at /content/drive
```

READ THE TRAINING VARIANTS DATA

```
data = pd.read_csv('/content/drive/My Drive/Colab Notebooks/Personalized_Cancer_Diagnosis/training_variants')
```

```
data = pd.read_csv('/content/drive/My Drive/Colab Notebooks/Personalized Cancer Diagnosis/training_variants')
print('Number of data points : ', data.shape[0])
print('Number of features : ', data.shape[1])
print('Features : ', data.columns.values)
data.head()
```

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

	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

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

READ THE TEXT DATA

```
data_text =pd.read_csv("/content/drive/My Drive/Colab Notebooks/Personalized Cancer Diagnosis/training_text",sep='
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']
```

	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...

```
import nltk
nltk.download('stopwords')
```

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

```
stop_words = set(stopwords.words('english'))
```

APPLY NLP PREPROCESSING TASK

```
def nlp_preprocessing(total_text,index,column):
  if type(total_text) is not int:
    string = ""

    # REPLACE EVERY SPECIAL CHARACTER WITH THE 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)

    # CONVERT ALL THE CHARACTER TO LOWER CASE
    total_text=total_text.lower()

    for word in total_text.split() :
      if not word in stop_words:    # IF THE WORD IS NOT STOP WORD THEN RETAIN THAT WORD AND ASSINGN IN STRING VAR
        string+=word + " "
    data_text[column][index] = string
```

```
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 : ',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 :  29.239386999999997 seconds
```

```
# MERGE THE DATA (GENE AND VARIATIONS) & TEXT DATA BASED ON THE ID
final_data = pd.merge(data,data_text,on='ID',how='left')

final_data.head()
```

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

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

	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

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

```
from sklearn.model_selection import train_test_split
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score
from sklearn.model_selection import cross_val_score
from collections import Counter
from sklearn.metrics import confusion_matrix
from sklearn.metrics import classification_report


Y_Class=final_data['Class'].values
final_data.Gene=final_data.Gene.str.replace('\s+','_')
final_data.Variation=final_data.Variation.str.replace('\s+','_')

# SPLIT THE DATA INTO TEST,TRAIN AND CV
X_1,X_Test,Y_1,Y_Test=train_test_split(final_data,Y_Class,stratify=Y_Class,test_size=0.2)
X_Train,X_CV,Y_Train,Y_CV=train_test_split(X_1,Y_1,test_size=0.2)
```

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

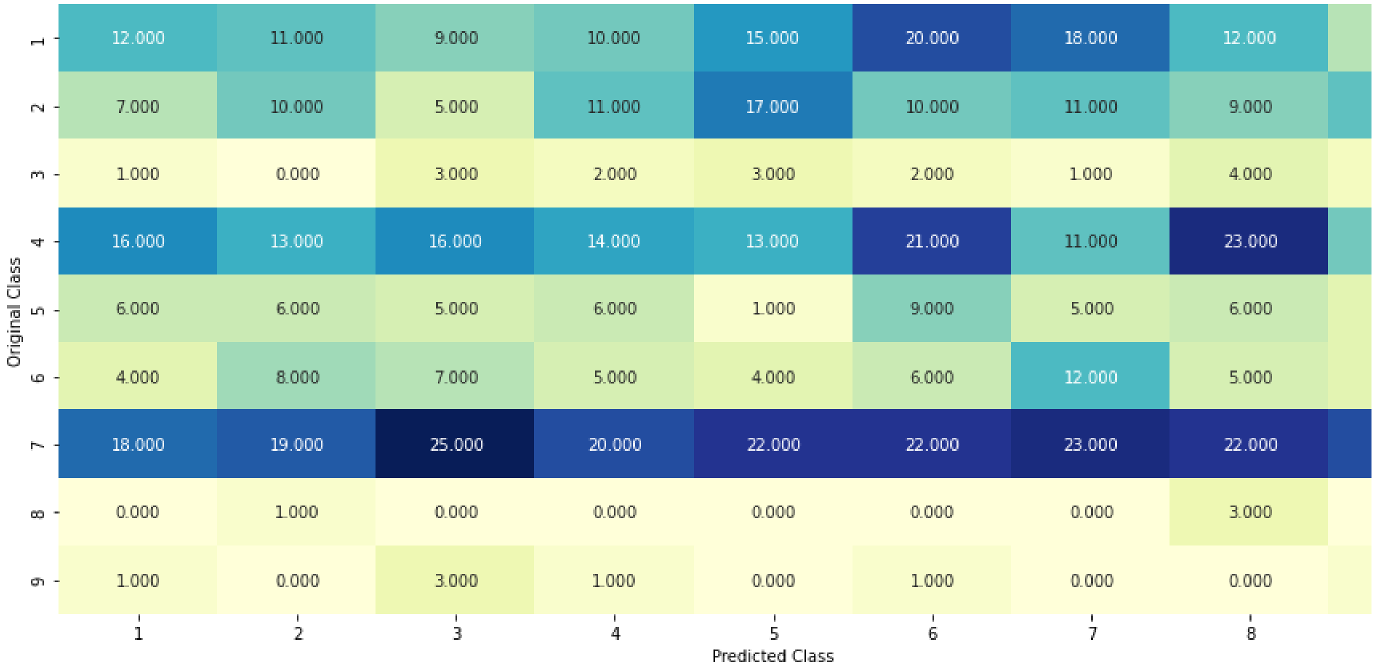
```
Number of data points in train data: 2124
Number of data points in test data: 2124
Number of data points in cross validation data: 532
```

```
def plot_confusion_matrix(test_y,predict_y):
  C = confusion_matrix(test_y,predict_y)

  A=(((C.T)/(C.sum(axis=1))).T)

  B = (C/C.sum(axis=0))

  labels = [1,2,3,4,5,6,7,8,9]

  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 (Columm 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()

  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()
```

```
from sklearn.metrics import log_loss
import seaborn as sns
X_Test_len = X_Test.shape[0]
```

```
X_CV_len = X_CV.shape[0]

Y_CV_Predicted = np.zeros((X_CV_len,9))

for i in range(X_CV_len):
  rand_probs=np.random.rand(1,9)
  Y_CV_Predicted[i] =((rand_probs/sum(sum(rand_probs)))[0])
print("Log Loss on CV using Random Model",log_loss(Y_CV, Y_CV_Predicted,eps=1e-15))


Y_Test_Predicted = np.zeros((X_Test_len,9))

for i in range(X_Test_len ):
  rand_probs=np.random.rand(1,9)
  Y_Test_Predicted[i] =((rand_probs/sum(sum(rand_probs)))[0])
print("Log Loss on CV using Random Model",log_loss(Y_Test, Y_Test_Predicted,eps=1e-15))

predicted_y =np.argmax(Y_Test_Predicted, axis=1)
plot_confusion_matrix(Y_Test, predicted_y+1)
```

```
Log Loss on CV using Random Model 2.4338510975006904
Log Loss on CV using Random Model 2.4719389345050624
-------------------- Confusion Matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```

UNIVARIATE ANALYSIS

```python
def get_gene_variation_feature_dic(alpha,feature,df):

  value_count=df[feature].value_counts()
  print("Value Count :", value_count)
  gene_var = dict()

  for i,denominator in value_count.items():
    vec=[]

    for k in range(1,10):
      class_count=df.loc[(df['Class'] == k) & (df[feature] == i)]
      vec.append((class_count.shape[0] + alpha*10)/ (denominator + 90*alpha))   #Laplace Smoothing
    gene_var[i]=vec
  return gene_var
```

```python
def get_gene_variation_features(alpha,feature,df):

  gv_dict=get_gene_variation_feature_dic(alpha,feature,df)

  value_count=df[feature].value_counts()

  gv_fea=[]
  print("DF Iteration_rows", df.iterrows())
  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([1/9,1/9,1/9,1/9,1/9,1/9,1/9,1/9,1/9])
  return gv_fea
```

Univariate Analysis on Gene Features

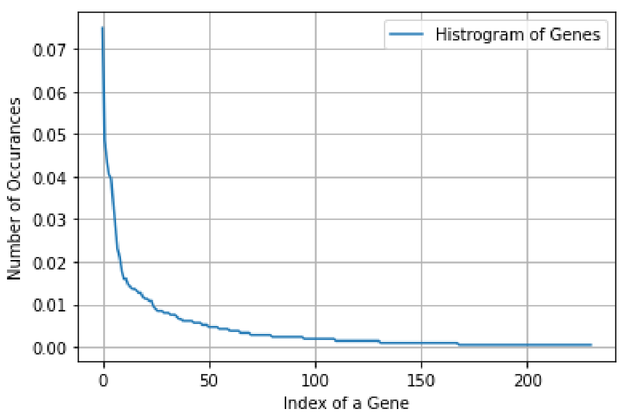
```
unique_genes=X_Train['Gene'].value_counts()

print("Number of Unique Genes :",unique_genes.shape[0])

print(unique_genes.head(10))
```

```
Number of Unique Genes : 231
BRCA1     159
TP53      103
EGFR       93
BRCA2      86
PTEN       84
KIT        72
BRAF       61
ERBB2      49
ALK        45
PDGFRA     38
Name: Gene, dtype: int64
```

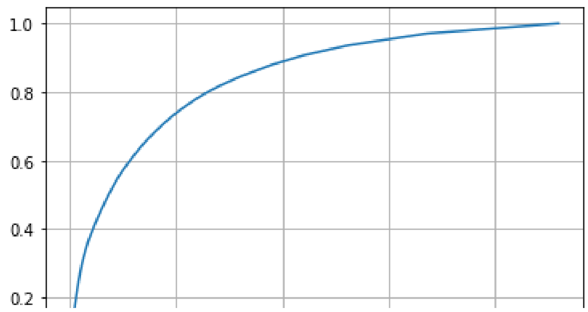
Looking at the count , looks like there are 236 different categories of Gene thats are in Training Data

Distribution are as follows

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




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



There are 2 ways we can featurize this variable.

1. One Hot Encoding
2. Response Coding

We will choose the appropriate featurization based on the ML model we use.

BAG OF WORDS VECTORIZATION TECHNIQUE

Response Coding Method on Gene Feature

```
alpha = 1

X_Train_gene_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Gene",X_Train))
print("Train Gene Feature :",X_Train_gene_Feature_responsecoding.shape)

print("="*100)

X_Test_gen_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Gene",X_Test))
print("Test Gene Feature :",X_Test_gen_Feature_responsecoding.shape)

print("="*100)

X_CV_gene_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Gene",X_CV))
print("CV Gene Feature :",X_CV_gene_Feature_responsecoding.shape)

print("="*100)
```

```
Value Count : BRCA1     159
TP53      103
EGFR       93
BRCA2      86
PTEN       84
         ...
ARID1B      1
WHSC1       1
ATRX        1
CDK8        1
CCND2       1
Name: Gene, Length: 231, dtype: int64
DF Iteration_rows <generator object DataFrame.iterrows at 0x7fd82baa7308>
Train Gene Feature : (2124, 9)
====================================================================================================
Value Count : BRCA1     56
TP53      34
EGFR      31
PTEN      25
BRAF      19
          ..
MPL        1
CDK12      1
FAM58A     1
ETV6       1
PMS1       1
Name: Gene, Length: 162, dtype: int64
```

One Hot Encoding Method on Gene feature

```
Value Count : BRCA1     49
```

```python
from sklearn.feature_extraction.text import CountVectorizer
gene_vectorizer=CountVectorizer()

X_Train_gene_Feature_onehotEncoding=gene_vectorizer.fit_transform(X_Train["Gene"])
print(" Train Gene Feature :" ,X_Train_gene_Feature_onehotEncoding.shape)

print("="*100)

X_Test_gene_Feature_onehotencoding=gene_vectorizer.transform(X_Test["Gene"])
print(" Test Gene Feature :" ,X_Test_gene_Feature_onehotencoding.shape)

print("="*100)


X_CV_gene_Feature_onehotencoding=gene_vectorizer.transform(X_CV["Gene"])
print(" CV Gene Feature :" ,X_CV_gene_Feature_onehotencoding.shape)

print("="*100)
```

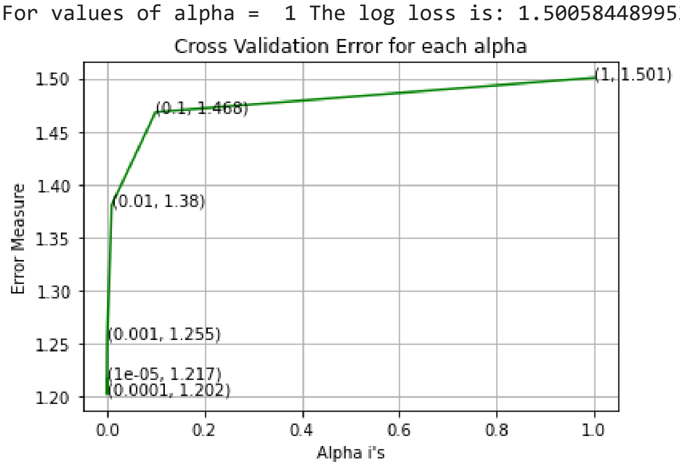
```
 Train Gene Feature : (2124, 231)
====================================================================================================
 Test Gene Feature : (665, 231)
====================================================================================================
 CV Gene Feature : (532, 231)
====================================================================================================
```

APPLY SVM --> SGD CLASSIFIER TO FIND THE BEST HYPERPARAMETER

```python
from sklearn.linear_model import SGDClassifier
from sklearn.calibration import CalibratedClassifierCV
alpha = [10 ** x for x in range(-5, 1)]

cv_log_error=[]

```

```
for i in alpha :
  clf=SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
  clf.fit(X_Train_gene_Feature_onehotEncoding,Y_Train)
  sig_clf=CalibratedClassifierCV(clf,method="sigmoid")
  sig_clf.fit(X_Train_gene_Feature_onehotEncoding,Y_Train)
  Predicted_Y=sig_clf.predict_proba(X_CV_gene_Feature_onehotencoding)
  cv_log_error.append(log_loss(Y_CV,Predicted_Y,labels=clf.classes_,eps=1e-15))
  print('For values of alpha = ', i, "The log loss is:",log_loss(Y_CV, Predicted_Y, labels=clf.classes_, eps=1e-15

fig,ax = plt.subplots()
ax.plot(alpha,cv_log_error,c='g')

for i , txt in enumerate(np.round(cv_log_error,3)):
  ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error[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)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_Train_gene_Feature_onehotEncoding, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_gene_Feature_onehotEncoding, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_gene_Feature_onehotEncoding)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_gene_Feature_onehotencoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_gene_Feature_onehotencoding)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
For values of alpha =  1e-05 The log loss is: 1.2166022018727414
For values of alpha =  0.0001 The log loss is: 1.2015674070771591
For values of alpha =  0.001 The log loss is: 1.2551213383409736
For values of alpha =  0.01 The log loss is: 1.3804867072117146
For values of alpha =  0.1 The log loss is: 1.468121389285184
For values of alpha =  1 The log loss is: 1.500584489952845
```




```
For values of best alpha =  0.0001 The train log loss is: 0.9882420694256845
For values of best alpha =  0.0001 The cross validation log loss is: 1.2015674070771591
For values of best alpha =  0.0001 The test log loss is: 1.1981102682844584
```

```
print("Q6. How many data points in Test and CV datasets are covered by the ", unique_genes.shape[0], " genes in tr

test_coverage=X_Test[X_Test['Gene'].isin(list(set(X_Train['Gene'])))].shape[0]
cv_coverage=X_CV[X_CV['Gene'].isin(list(set(X_Train['Gene'])))].shape[0]

print('Ans\n1. In test data',test_coverage, 'out of',X_Test.shape[0], ":",(test_coverage/X_Test.shape[0])*100)
print('2. In cross validation data',cv_coverage, 'out of ',X_CV.shape[0],":" ,(cv_coverage/X_CV.shape[0])*100)
```

```
print(' 2. In cross validation data',cv_coverage, 'out of ',X_CV.shape[0], ":" ,(cv_coverage/X_CV.shape[0])*100)
```

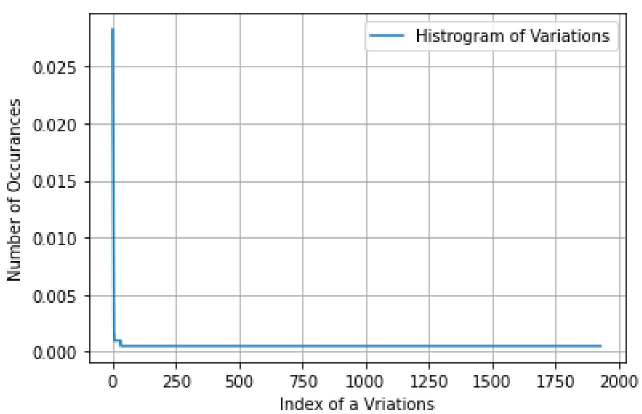
```
Q6. How many data points in Test and CV datasets are covered by the  231  genes in train dataset?
Ans
1. In test data 645 out of 665 : 96.99248120300751
2. In cross validation data 514 out of  532 : 96.61654135338345
```

Univariate Analysis on Variation Features

```
unique_variations=X_Train['Variation'].value_counts()

print("Number of Unique Genes :",unique_variations.shape[0])

print(unique_variations.head(10))
```

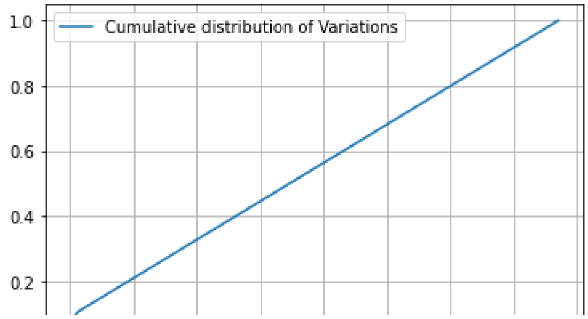
```
Number of Unique Genes : 1929
Truncating_Mutations         60
Deletion                     48
Amplification                41
Fusions                      18
Overexpression                4
Q61L                          3
G12V                          3
R170W                         2
Q61H                          2
Promoter_Hypermethylation     2
Name: Variation, dtype: int64
```

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




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

```
[0.02824859 0.05084746 0.07015066 ... 0.99905838 0.99952919 1.        ]
```



There are 2 ways we can featurize this variable.

1. One Hot Encoding
2. Response Coding

We will choose the appropriate featurization based on the ML model we use.

Response Coding Method on Variation Features

```
alpha = 1

X_Train_variation_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Variation",X_Train))
print("Train Variation Feature :",X_Train_variation_Feature_responsecoding.shape)

print("="*100)

X_Test_variation_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Variation",X_Test))
print("Test Variation Feature :",X_Test_variation_Feature_responsecoding.shape)

print("="*100)

X_CV_variation_Feature_responsecoding = np.array(get_gene_variation_features(alpha,"Variation",X_CV))
print("CV Variation Feature :",X_CV_variation_Feature_responsecoding.shape)

print("="*100)
```

```
Value Count : Truncating_Mutations    60
Deletion                48
Amplification           41
Fusions                 18
Overexpression           4
                        ..
L122R                    1
T34_A289del              1
EWSR1-FLI1_Fusion        1
C2060G                   1
P287A                    1
Name: Variation, Length: 1929, dtype: int64
DF Iteration_rows <generator object DataFrame.iterrows at 0x7fd826c7e7d8>
Train Variation Feature : (2124, 9)
====================================================================================================
Value Count : Deletion               16
Truncating_Mutations    16
Amplification           14
Fusions                 11
Q61R                     2
                        ..
A1131T                   1
K590R                    1
```

One Hot Encoding on Variation Feature

```
Name: Variation, Length: 611, dtype: int64
```

```
from sklearn.feature_extraction.text import CountVectorizer
variation_vectorizer=CountVectorizer()

X_Train_variation_Feature_onehotEncoding=variation_vectorizer.fit_transform(X_Train["Variation"])
print(" Train Variation Feature :" ,X_Train_variation_Feature_onehotEncoding.shape)

print("="*100)

X_Test_variation_Feature_onehotencoding=variation_vectorizer.transform(X_Test["Variation"])
print(" Test Variation Feature :" ,X_Test_variation_Feature_onehotencoding.shape)

print("="*100)


X_CV_variation_Feature_onehotencoding=variation_vectorizer.transform(X_CV["Variation"])
print(" CV Variation Feature :" ,X_CV_variation_Feature_onehotencoding.shape)

print("="*100)
```

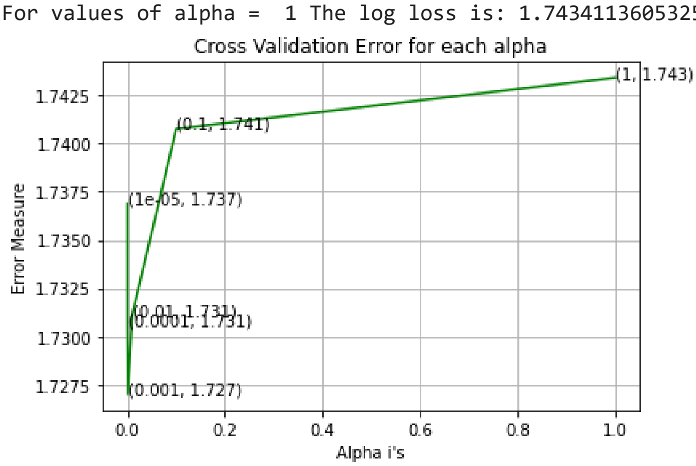
```
 Train Variation Feature : (2124, 1956)
====================================================================================================
 Test Variation Feature : (665, 1956)
====================================================================================================
 CV Variation Feature : (532, 1956)
====================================================================================================
```

APPLY SVM --> SGD CLASSIFIER TO FIND THE BEST HYPERPARAMETER

```
from sklearn.linear_model import SGDClassifier
from sklearn.calibration import CalibratedClassifierCV
alpha = [10 ** x for x in range(-5, 1)]

cv_log_error=[]

for i in alpha :
  clf=SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
  clf.fit(X_Train_variation_Feature_onehotEncoding,Y_Train)
  sig_clf=CalibratedClassifierCV(clf,method="sigmoid")
```

```
  sig_clf.fit(X_Train_variation_Feature_onehotEncoding,Y_Train)
  Predicted_Y=sig_clf.predict_proba(X_CV_variation_Feature_onehotencoding)
  cv_log_error.append(log_loss(Y_CV,Predicted_Y,labels=clf.classes_,eps=1e-15))
  print('For values of alpha = ', i, "The log loss is:",log_loss(Y_CV, Predicted_Y, labels=clf.classes_, eps=1e-15

fig,ax = plt.subplots()
ax.plot(alpha,cv_log_error,c='g')

for i , txt in enumerate(np.round(cv_log_error,3)):
  ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error[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)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_Train_variation_Feature_onehotEncoding, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_variation_Feature_onehotEncoding, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_variation_Feature_onehotEncoding)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_variation_Feature_onehotencoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_variation_Feature_onehotencoding)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
For values of alpha =  1e-05 The log loss is: 1.7368916556958085
For values of alpha =  0.0001 The log loss is: 1.7305804509088687
For values of alpha =  0.001 The log loss is: 1.7269911213724305
For values of alpha =  0.01 The log loss is: 1.731115111931615
For values of alpha =  0.1 The log loss is: 1.7407613800259418
For values of alpha =  1 The log loss is: 1.7434113605325594
```




```
For values of best alpha =  0.001 The train log loss is: 1.0374898189029886
For values of best alpha =  0.001 The cross validation log loss is: 1.7269911213724305
For values of best alpha =  0.001 The test log loss is: 1.704806332912111
```

```
test_coverage=X_Test[X_Test['Variation'].isin(list(set(X_Train['Variation'])))].shape[0]
cv_coverage=X_CV[X_CV['Variation'].isin(list(set(X_Train['Variation'])))].shape[0]

print('1. In test data',test_coverage, 'out of',X_Test.shape[0], ":",(test_coverage/X_Test.shape[0])*100)
print('2. In cross validation data',cv_coverage, 'out of ',X_CV.shape[0],":" ,(cv_coverage/X_CV.shape[0])*100)
```

```
1. In test data 66 out of 665 : 9.924812030075188
2. In cross validation data 59 out of  532 : 11.090225563909774
```

```
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()))
```

APPLY SVM --> SGD CLASSIFIER TO FIND THE BEST HYPERPARAMETER

```
from sklearn.linear_model import SGDClassifier
from sklearn.calibration import CalibratedClassifierCV
alpha = [10 ** x for x in range(-5, 1)]

cv_log_error=[]

for i in alpha :
  clf=SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
  clf.fit(X_Train_feature_onehotCoding,Y_Train)
  sig_clf=CalibratedClassifierCV(clf,method="sigmoid")
  sig_clf.fit(X_Train_feature_onehotCoding,Y_Train)
  Predicted_Y=sig_clf.predict_proba(X_CV_text_feature_onehotCoding)
  cv_log_error.append(log_loss(Y_CV,Predicted_Y,labels=clf.classes_,eps=1e-15))
  print('For values of alpha = ', i, "The log loss is:",log_loss(Y_CV, Predicted_Y, labels=clf.classes_, eps=1e-15

fig,ax = plt.subplots()
ax.plot(alpha,cv_log_error,c='g')

for i , txt in enumerate(np.round(cv_log_error,3)):
  ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error[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)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_Train_feature_onehotCoding, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_feature_onehotCoding, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_text_feature_onehotCoding)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_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
```

Univariate Analysis on Text Features

```
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
```

```
import math

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
```

One Hot Encoding on Text Feature

```
text_vectorizer = CountVectorizer(min_df=3)
X_Train_feature_onehotCoding = text_vectorizer.fit_transform(X_Train['TEXT'])
# getting all the feature names (words)
X_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_text_fea_counts = X_Train_feature_onehotCoding.sum(axis=0).A1

# zip(list(text_features),text_fea_counts) will zip a word with its number of times it occured
text_fea_dict = dict(zip(list(X_Train_text_features),train_text_fea_counts))


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

```
Total number of unique words in train data : 52882
```

```
from collections import defaultdict
dict_list = []
# dict_list =[] contains 9 dictoinaries each corresponds to a class
for i in range(1,10):
    cls_text = X_Train[X_Train['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


total_dict = extract_dictionary_paddle(X_Train)


confuse_array = []
for i in X_Train_text_features:
    ratios = []
    max_val = -1
    for j in range(0,9):
        ratios.append((dict_list[j][i]+10 )/(total_dict[i]+90))
```

```
    confuse_array.append(ratios)
confuse_array = np.array(confuse_array)
```

Response Coding on Text Feature

```
X_Train_text_feature_responseCoding  = get_text_responsecoding(X_Train)
print("Train Text Feature :", X_Train_text_feature_responseCoding.shape)

print("="*100)

X_Test_text_feature_responseCoding  = get_text_responsecoding(X_Test)
print("Test Text Feature :", X_Test_text_feature_responseCoding.shape)

print("="*100)
X_CV_text_feature_responseCoding  = get_text_responsecoding(X_CV)
print("CV Text Feature :", X_CV_text_feature_responseCoding.shape)

print("="*100)
```

```
Train Text Feature : (2124, 9)
====================================================================================================
Test Text Feature : (665, 9)
====================================================================================================
CV Text Feature : (532, 9)
====================================================================================================
```

```
X_Train_text_feature_responseCoding = (X_Train_text_feature_responseCoding.T/X_Train_text_feature_responseCoding.s
X_Test_text_feature_responseCoding = (X_Test_text_feature_responseCoding.T/X_Test_text_feature_responseCoding.sum(
X_CV_text_feature_responseCoding = (X_CV_text_feature_responseCoding.T/X_CV_text_feature_responseCoding.sum(axis=1
```

Normalize the features

```
from sklearn.preprocessing import normalize

X_Train_feature_onehotCoding = normalize(X_Train_feature_onehotCoding, axis=0)
print("Train Text Feature :", X_Train_feature_onehotCoding.shape)

print("="*100)

X_Test_text_feature_onehotCoding = text_vectorizer.transform(X_Test['TEXT'])
print("Test Text Feature :", X_Test_text_feature_onehotCoding.shape)

print("="*100)

X_Test_text_feature_onehotCoding = normalize(X_Test_text_feature_onehotCoding, axis=0)

X_CV_text_feature_onehotCoding = text_vectorizer.transform(X_CV['TEXT'])
print("CV Text Feature :", X_CV_text_feature_onehotCoding.shape)

print("="*100)

X_CV_text_feature_onehotCoding = normalize(X_CV_text_feature_onehotCoding, axis=0)
```

```
Train Text Feature : (2124, 52882)
====================================================================================================
Test Text Feature : (665, 52882)
====================================================================================================
CV Text Feature : (532, 52882)
====================================================================================================
```

```
For values of alpha =  1e-05 The log loss is: 1.2813491064466804
For values of alpha =  0.0001 The log loss is: 1.1531172509122398
For values of alpha =  0.001 The log loss is: 1.1393878819557273
For values of alpha =  0.01 The log loss is: 1.2716465329687872
For values of alpha =  0.1 The log loss is: 1.4686398010742088
For values of alpha =  1 The log loss is: 1.6626389802062658
```

BUILDING A MACHINE LEARNING MODELS

```
def predict_and_plot_confusionmatrix(X_train,Y_train,X_test,Y_test,clf):
  clf.fit(X_train,Y_train)
  sig_clf=CalibratedClassifierCV(clf,method="sigmoid")
  sig_clf.fit(X_train,Y_train)
  pred_y=sig_clf.predict(X_test)


  print("Log Loss : ",log_loss(Y_test,sig_clf.predict_proba(X_test)))
  print("Number of Misclassified Points :",np.count_nonzero((pred_y - Y_test))/Y_test.shape[0])

  plot_confusion_matrix(Y_test,pred_y)
```

```
def report_log_loss(X_train,Y_train,X_test,Y_test,clf):
  clf.fit(X_Train,Y_train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_train,Y_train)
  sig_clf_probs=sig_clf.predict_proba(X_Test)
  return log_loss(Y_Test, sig_clf_probs, eps=1e-15)
```

Get Feature Names

```
def get_impfeature_names_tfidf(indices, text, gene, var, no_features):
    gene_count_vec = TfidfVectorizer()
    var_count_vec = TfidfVectorizer()
    text_count_vec = TfidfVectorizer(min_df=3)
    print ("Hello")
    gene_vec = gene_count_vec.fit(X_Train['Gene'])
    var_vec  = var_count_vec.fit(X_Train['Variation'])
    text_vec = text_count_vec.fit(X_Train['TEXT'])

    fea1_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 < fea1_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 < fea1_len+fea2_len):
            word = var_vec.get_feature_names()[v-(fea1_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-(fea1_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

```
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 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
from sklearn.linear_model import SGDClassifier
from sklearn.calibration import CalibratedClassifierCV
from sklearn.preprocessing import normalize
from collections import defaultdict
import math
from sklearn.metrics import log_loss
import seaborn as sns
```

```
X_Train_gene_var_onehotcoding = hstack((X_Train_gene_Feature_onehotEncoding,X_Train_variation_Feature_onehotEncodi
X_Test_gene_var_onehotcoding =  hstack((X_Test_gene_Feature_onehotencoding,X_Test_variation_Feature_onehotencoding
X_CV_gene_var_onehotcoding = hstack((X_CV_gene_Feature_onehotencoding,X_CV_variation_Feature_onehotencoding))

X_Train_onehotCoding = hstack((X_Train_gene_var_onehotcoding,X_Train_feature_onehotCoding)).tocsr()
print("Train One Hot Encoding  :", X_Train_onehotCoding.shape)
print("="*100)

X_Test_onehotcoding = hstack((X_Test_gene_var_onehotcoding,X_Test_text_feature_onehotCoding))
print("Test One Hot Encoding  :", X_Test_onehotcoding.shape)
print("="*100)

X_CV_onehotcoding = hstack((X_CV_gene_var_onehotcoding,X_CV_text_feature_onehotCoding))
print("CV One Hot Encoding  :", X_CV_onehotcoding.shape)
print("="*100)


X_Train_gene_var_responseCoding = np.hstack((X_Train_gene_Feature_responsecoding,X_Train_variation_Feature_respons
X_Test_gene_var_responseCoding = np.hstack((X_Test_gen_Feature_responsecoding,X_Test_variation_Feature_responsecod
X_CV_gene_var_responseCoding = np.hstack((X_CV_gene_Feature_responsecoding,X_CV_variation_Feature_responsecoding))

X_Train_responseCoding = np.hstack((X_Train_gene_var_responseCoding, X_Train_text_feature_responseCoding))
print("Train Response Coding  :", X_Train_responseCoding.shape)
print("="*100)

X_Test_responseCoding = np.hstack((X_Test_gene_var_responseCoding, X_Test_text_feature_responseCoding))
```

```
print("Test Response Coding  :", X_Test_responseCoding.shape)
print("="*100)
X_CV_responseCoding = np.hstack((X_CV_gene_var_responseCoding, X_CV_text_feature_responseCoding))
print("CV Response Coding  :", X_CV_responseCoding.shape)
print("="*100)
```

BASE LINE MODEL

NAIVE BAYES ALGORITHM

```
def Naive_Bayes_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test):

  alpha = [0.00001, 0.0001, 0.001, 0.1, 1, 10, 100,1000]
  cv_log_error=[]

  for i in alpha:
    print("for alpha =", i)
    clf = MultinomialNB(alpha=i)
    clf.fit(X_Train_onehotCoding,Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotCoding, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)
    cv_log_error.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

  fig, ax = plt.subplots()
  ax.plot(np.log10(alpha), cv_log_error,c='g')
  for i , txt in enumerate(np.round(cv_log_error,3)):
    ax.annotate((alpha[i],str(txt)), (np.log10(alpha[i]),cv_log_error[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)
  clf = MultinomialNB(alpha=alpha[best_alpha])
  clf.fit(X_Train_onehotCoding, Y_Train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_Train_onehotCoding, Y_Train)

  predict_y = sig_clf.predict_proba(X_Train_onehotCoding)
  print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, la

  predict_y = sig_clf.predict_proba(X_CV_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predi

```

```
    predict_y = sig_clf.predict_proba(X_Test_onehotcoding)
    print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labe

    return alpha,best_alpha
```

```
alpha,best_alpha = Naive_Bayes_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test)
```

```
clf = MultinomialNB(alpha=alpha[best_alpha])
clf.fit(X_Train_onehotCoding, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotCoding, Y_Train)
sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)

print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

print("Number of missclassified point :", np.count_nonzero((sig_clf.predict(X_CV_onehotcoding)- Y_CV))/Y_CV.shape[
plot_confusion_matrix(Y_CV, sig_clf.predict(X_CV_onehotcoding.toarray()))
```

K-NEAREST NEIGHBORS ALGORITHM

```
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(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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.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(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

LOGISTIC REGRESSION (WITH CLASS BALANCING)

```
def Logistic_Regression_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test):

  alpha = [10 ** x for x in range(-6, 3)]
  cv_log_error=[]

  for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(class_weight='balanced', alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_Train_onehotCoding,Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
```

```
    sig_clf.fit(X_Train_onehotCoding, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)
    cv_log_error.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

  fig, ax = plt.subplots()
  ax.plot(np.log10(alpha), cv_log_error,c='g')
  for i , txt in enumerate(np.round(cv_log_error,3)):
    ax.annotate((alpha[i],str(txt)), (np.log10(alpha[i]),cv_log_error[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)
  clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
  clf.fit(X_Train_onehotCoding, Y_Train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_Train_onehotCoding, Y_Train)

  predict_y = sig_clf.predict_proba(X_Train_onehotCoding)
  print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, la

  predict_y = sig_clf.predict_proba(X_CV_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predi

  predict_y = sig_clf.predict_proba(X_Test_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labe

  return alpha,best_alpha
```

```
alpha,best_alpha = Logistic_Regression_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test)
```

```
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotCoding, Y_Train, X_CV_onehotcoding, Y_CV, clf)
```

LOGISTIC REGRESSION WITHOUT CLASS BALANCING

```
def Logistic_Regression_Algo_WithoutClassBalancing(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test):

  alpha = [10 ** x for x in range(-6, 3)]
  cv_log_error=[]

  for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_Train_onehotCoding,Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotCoding, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)
    cv_log_error.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

  fig, ax = plt.subplots()
  ax.plot(np.log10(alpha), cv_log_error,c='g')
  for i , txt in enumerate(np.round(cv_log_error,3)):
    ax.annotate((alpha[i],str(txt)), (np.log10(alpha[i]),cv_log_error[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)
  clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
  clf.fit(X_Train_onehotCoding, Y_Train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_Train_onehotCoding, Y_Train)

  predict_y = sig_clf.predict_proba(X_Train_onehotCoding)
  print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, la

  predict_y = sig_clf.predict_proba(X_CV_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predi

  predict_y = sig_clf.predict_proba(X_Test_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labe

  return alpha,best_alpha
```

```
alpha,best_alpha = Logistic_Regression_Algo_WithoutClassBalancing(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test)
```

```
clf = SGDClassifier( alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotCoding, Y_Train, X_CV_onehotcoding, Y_CV, clf)
```

LINEAR SUPPORT VECTOR MACHINE

```
def LinearSVM_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test):

  alpha = [10 ** x for x in range(-6, 3)]
  cv_log_error=[]

  for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(class_weight='balanced', alpha=i, penalty='l2', loss='hinge', random_state=42)
    clf.fit(X_Train_onehotCoding,Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotCoding, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)
    cv_log_error.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

  fig, ax = plt.subplots()
  ax.plot(np.log10(alpha), cv_log_error,c='g')
  for i , txt in enumerate(np.round(cv_log_error,3)):
    ax.annotate((alpha[i],str(txt)), (np.log10(alpha[i]),cv_log_error[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)
  clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='hinge', random_state=4
  clf.fit(X_Train_onehotCoding, Y_Train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_Train_onehotCoding, Y_Train)

  predict_y = sig_clf.predict_proba(X_Train_onehotCoding)
  print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, la

  predict_y = sig_clf.predict_proba(X_CV_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predi

  predict_y = sig_clf.predict_proba(X_Test_onehotcoding)
  print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labe

  return alpha,best_alpha
```

```
alpha,best_alpha = LinearSVM_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test)
```

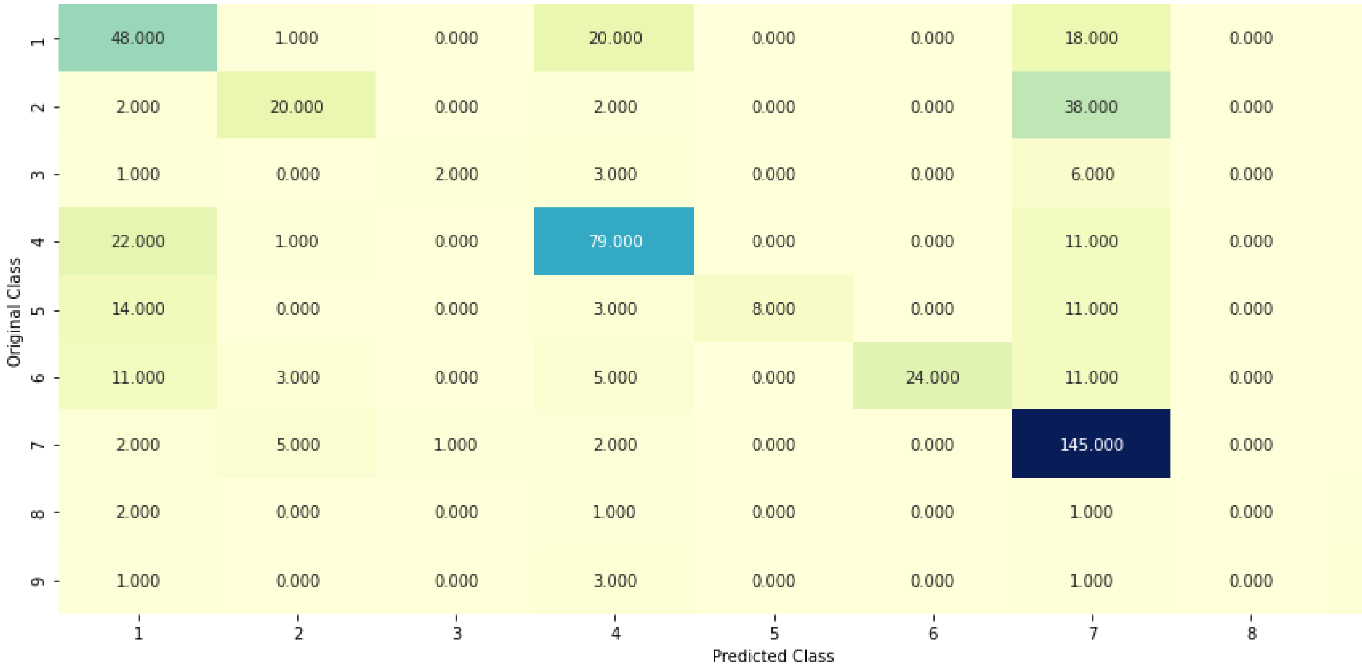
RANDOM FOREST CLASSIFIER

```
def Random_Forest_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test):
  alpha = [100,200,500,1000,2000]
  max_depth = [5, 10]
  cv_log_error = []
  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(X_Train_onehotCoding, Y_Train)
          sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
          sig_clf.fit(X_Train_onehotCoding, Y_Train)
          sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding)
          cv_log_error.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
          print("Log Loss :",log_loss(Y_CV, sig_clf_probs))
  best_alpha = np.argmin(cv_log_error)
  clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/2)], criterion='gini', max_depth=max_depth[int(be
  clf.fit(X_Train_onehotCoding, Y_Train)
  sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
  sig_clf.fit(X_Train_onehotCoding, Y_Train)

  predict_y = sig_clf.predict_proba(X_Train_onehotCoding)
  print('For values of best estimator = ', alpha[int(best_alpha/2)], "The train log loss is:",log_loss(Y_Train, pr
  predict_y = sig_clf.predict_proba(X_CV_onehotcoding)
  print('For values of best estimator = ', alpha[int(best_alpha/2)], "The cross validation log loss is:",log_loss(
  predict_y = sig_clf.predict_proba(X_Test_onehotcoding)
  print('For values of best estimator = ', alpha[int(best_alpha/2)], "The test log loss is:",log_loss(Y_Test, pred
  return alpha ,best_alpha,max_depth
```

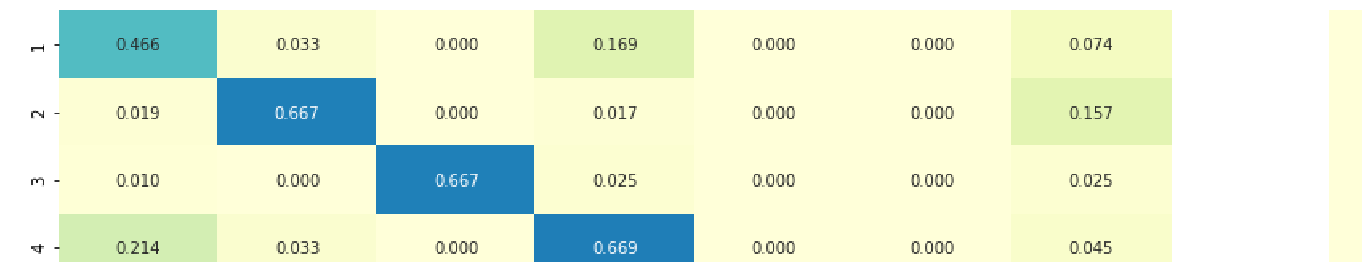
```
alpha,best_alpha,max_depth = Random_Forest_Algo(X_Train,Y_Train,X_CV,Y_CV,X_Test,Y_Test)
```

```
clf = RandomForestClassifier(n_estimators=alpha[int(best_alpha/2)], criterion='gini', max_depth=max_depth[int(best
predict_and_plot_confusionmatrix(X_Train_onehotCoding, Y_Train, X_CV_onehotcoding, Y_CV, clf)
```

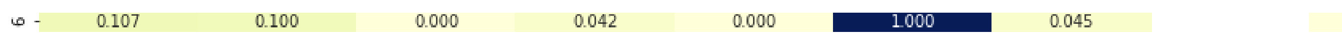
```
Log Loss :  1.1264918458844675
Number of Misclassified Points : 0.3815789473684211
-------------------- Confusion Matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```



TF-IDF FEATURIZATION TECHNIQUE



TF-IDF on Gene Features

```
from sklearn.feature_extraction.text import TfidfVectorizer
gene_vectorizer=TfidfVectorizer()

X_Train_gene_Feature_onehotencoding_tfidf=gene_vectorizer.fit_transform(X_Train["Gene"])
print(" Train Gene Feature :" ,X_Train_gene_Feature_onehotencoding_tfidf.shape)

print("="*100)

X_Test_gene_Feature_onehotencoding_tfidf=gene_vectorizer.transform(X_Test["Gene"])
print(" Test Gene Feature :" ,X_Test_gene_Feature_onehotencoding_tfidf.shape)

print("="*100)


X_CV_gene_Feature_onehotencoding_tfidf=gene_vectorizer.transform(X_CV["Gene"])
print(" CV Gene Feature :" ,X_CV_gene_Feature_onehotencoding_tfidf.shape)

print("="*100)
```

```
 Train Gene Feature : (2124, 225)
====================================================================================================
 Test Gene Feature : (665, 225)
====================================================================================================
 CV Gene Feature : (532, 225)
====================================================================================================
```

TF-IDF on Variation Features

```
variation_vectorizer=TfidfVectorizer()

X_Train_variation_Feature_onehotencoding_tfidf=variation_vectorizer.fit_transform(X_Train["Variation"])
print(" Train Variation Feature :" ,X_Train_variation_Feature_onehotencoding_tfidf.shape)

print("="*100)

X_Test_variation_Feature_onehotencoding_tfidf=variation_vectorizer.transform(X_Test["Variation"])
print(" Test Variation Feature :" ,X_Test_variation_Feature_onehotencoding_tfidf.shape)

print("="*100)


X_CV_variation_Feature_onehotencoding_tfidf=variation_vectorizer.transform(X_CV["Variation"])
print(" CV Variation Feature :" ,X_CV_variation_Feature_onehotencoding_tfidf.shape)

print("="*100)
```

```
 Train Variation Feature : (2124, 1973)
====================================================================================================
 Test Variation Feature : (665, 1973)
====================================================================================================
 CV Variation Feature : (532, 1973)
====================================================================================================
```

TF-IDF on Text Features

```
text_vectorizer = TfidfVectorizer(min_df=5,ngram_range=(1,4),max_features=3000)
X_Train_feature_onehotencoding_tfidf = text_vectorizer.fit_transform(X_Train['TEXT'])
# getting all the feature names (words)
```

```
from sklearn.preprocessing import normalize

X_Train_feature_onehotencoding_tfidf = normalize(X_Train_feature_onehotencoding_tfidf, axis=0)
print("Train Text Feature :", X_Train_feature_onehotencoding_tfidf.shape)

print("="*100)

X_Test_text_feature_onehotencoding_tfidf = text_vectorizer.transform(X_Test['TEXT'])
print("Test Text Feature :", X_Test_text_feature_onehotencoding_tfidf.shape)

print("="*100)

X_Test_text_feature_onehotencoding_tfidf = normalize(X_Test_text_feature_onehotencoding_tfidf, axis=0)

X_CV_text_feature_onehotencoding_tfidf = text_vectorizer.transform(X_CV['TEXT'])
print("CV Text Feature :", X_CV_text_feature_onehotencoding_tfidf.shape)

print("="*100)

X_CV_text_feature_onehotencoding_tfidf = normalize(X_CV_text_feature_onehotencoding_tfidf, axis=0)
```

```
X_CV_text_feature_onehotencoding_tfidf = normalize(X_CV_text_feature_onehotencoding_tfidf, axis=0)
```

```
Train Text Feature : (2124, 3000)
====================================================================================================
Test Text Feature : (665, 3000)
====================================================================================================
CV Text Feature : (532, 3000)
====================================================================================================
```

STACKING THE THREE TYPES OF FEATURES

```
X_Train_gene_var_onehotencoding_tfidf = hstack((X_Train_gene_Feature_onehotencoding_tfidf,X_Train_variation_Featur
X_Test_gene_var_onehotencoding_tfidf =  hstack((X_Test_gene_Feature_onehotencoding_tfidf,X_Test_variation_Feature_
X_CV_gene_var_onehotencoding_tfidf = hstack((X_CV_gene_Feature_onehotencoding_tfidf,X_CV_variation_Feature_onehote

X_Train_onehotcoding_tfidf = hstack((X_Train_gene_var_onehotencoding_tfidf,X_Train_feature_onehotencoding_tfidf)).
print("Train One Hot Encoding  :", X_Train_onehotcoding_tfidf.shape)
print("="*100)

X_Test_onehotcoding_tfidf = hstack((X_Test_gene_var_onehotencoding_tfidf,X_Test_text_feature_onehotencoding_tfidf)
print("Test One Hot Encoding  :", X_Test_onehotcoding_tfidf.shape)
print("="*100)

X_CV_onehotcoding_tfidf = hstack((X_CV_gene_var_onehotencoding_tfidf,X_CV_text_feature_onehotencoding_tfidf)).tocs
print("CV One Hot Encoding  :", X_CV_onehotcoding_tfidf.shape)
print("="*100)
```

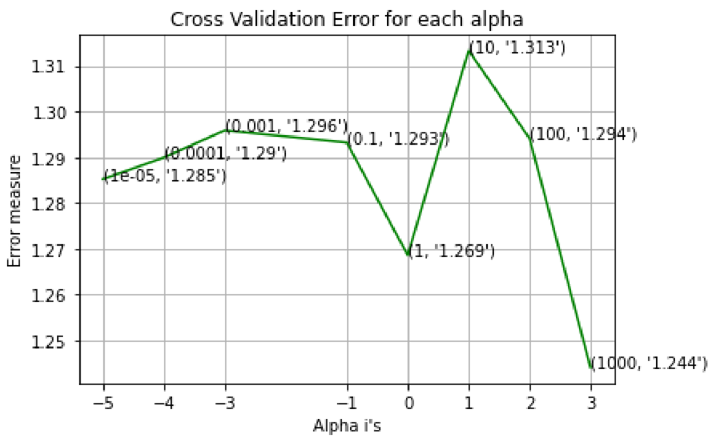
```
Train One Hot Encoding  : (2124, 5198)
====================================================================================================
Test One Hot Encoding  : (665, 5198)
====================================================================================================
CV One Hot Encoding  : (532, 5198)
====================================================================================================
```

NAIVE BAYES ALGORITHM

```
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(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)


predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

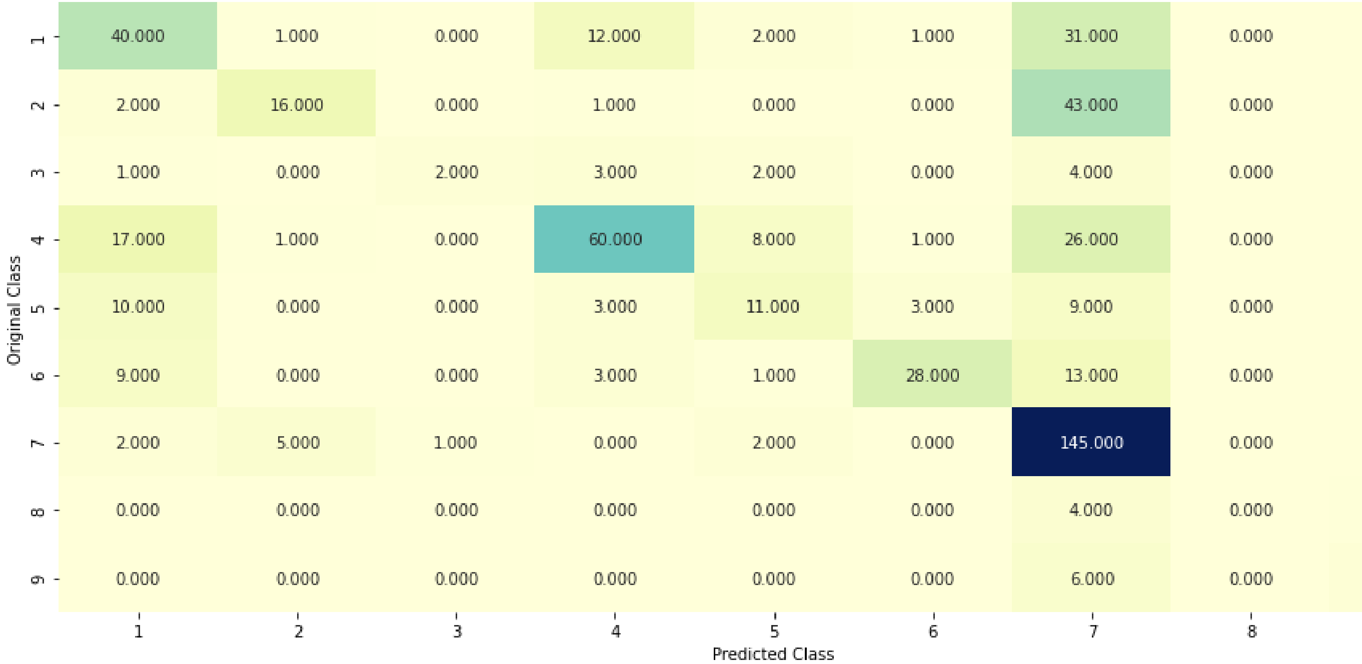
```
for alpha = 1e-05
Log Loss : 1.2852242745511553
for alpha = 0.0001
Log Loss : 1.2899281532020483
for alpha = 0.001
Log Loss : 1.2958675085806037
for alpha = 0.1
Log Loss : 1.293202683703183
for alpha = 1
Log Loss : 1.2686115338014161
for alpha = 10
Log Loss : 1.3132818674896714
for alpha = 100
Log Loss : 1.2940842269235393
for alpha = 1000
Log Loss : 1.2440531436451192
```



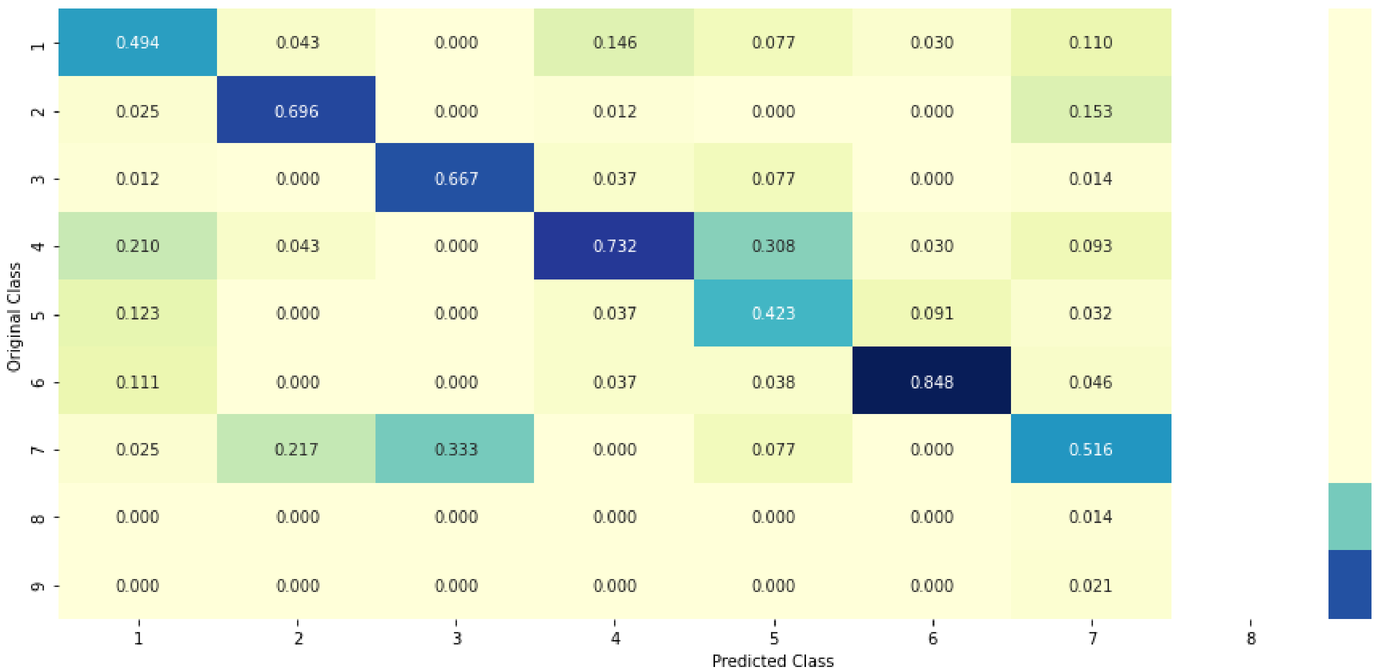

```
For values of best alpha =  1000 The train log loss is: 0.8125492088099504
For values of best alpha =  1000 The cross validation log loss is: 1.2440531436451192
For values of best alpha =  1000 The test log loss is: 1.2117067312528402
```

```
clf = MultinomialNB(alpha=alpha[best_alpha])
clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)

print("Log Loss :",log_loss(Y_CV, sig_clf_probs))

print("Number of missclassified point :", np.count_nonzero((sig_clf.predict(X_CV_onehotcoding_tfidf)- Y_CV))/Y_CV.
plot_confusion_matrix(Y_CV, sig_clf.predict(X_CV_onehotcoding_tfidf.toarray()))
```

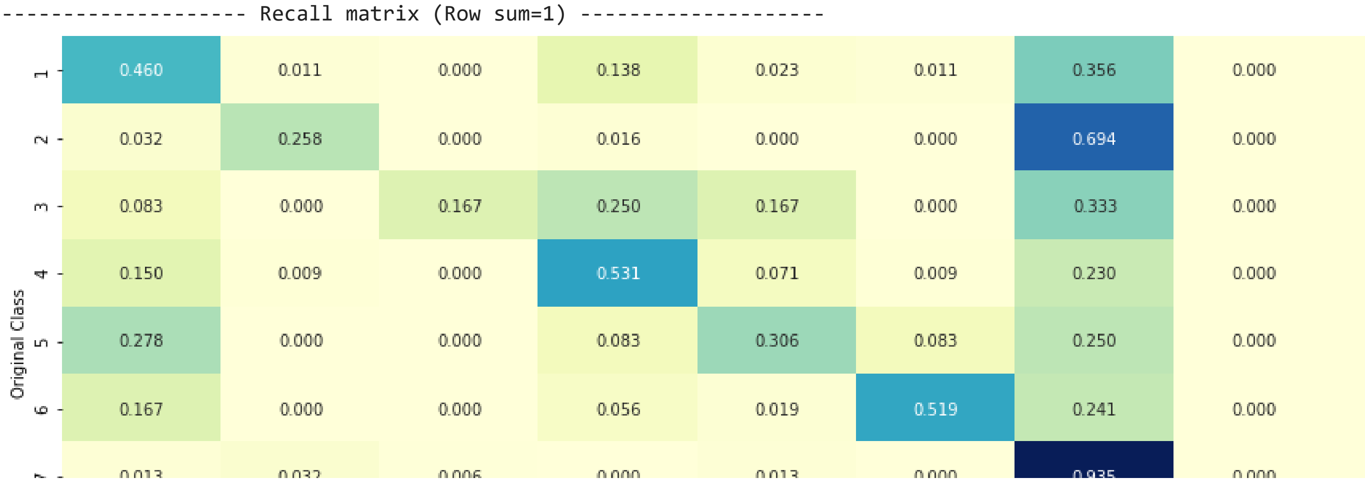
```
Log Loss : 1.2000466448985152
Number of missclassified point : 0.42857142857142855
-------------------- Confusion Matrix --------------------
```

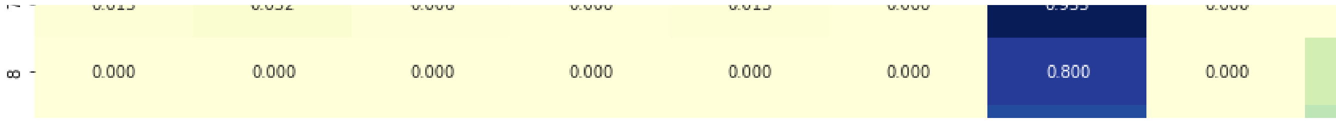



```
-------------------- Precision matrix (Columm Sum=1) --------------------
```




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





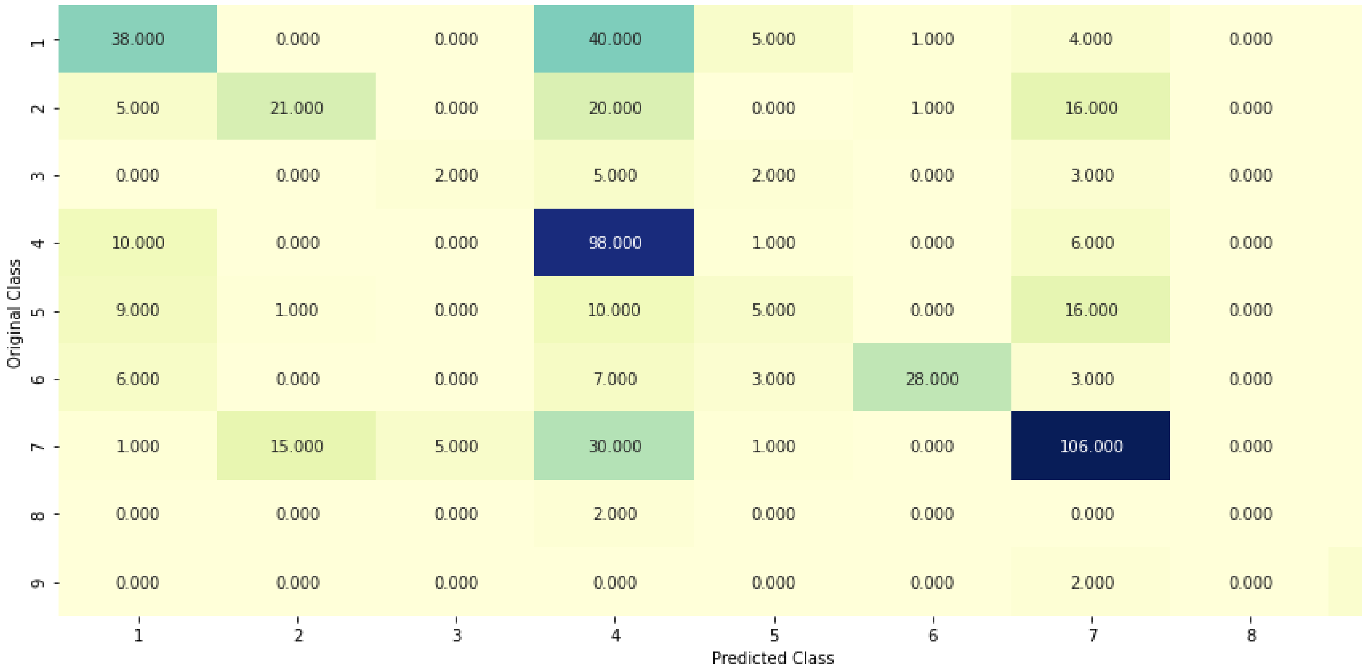
K-NEAREST NEIGHBORS ALGORITHM

```
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(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
for alpha = 5
Log Loss : 1.260740792425099
for alpha = 11
Log Loss : 1.3267641338744462
for alpha = 15
Log Loss : 1.3556204961769065
for alpha = 21
Log Loss : 1.386854135603434
for alpha = 31
Log Loss : 1.4147264394638535
for alpha = 41
Log Loss : 1.4384943533717045
for alpha = 51
Log Loss : 1.4309811480079746
for alpha = 99
Log Loss : 1.4545118320471948
```

```
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
predict_and_plot_confusionmatrix(X_Train_onehotcoding_tfidf, Y_Train, X_CV_onehotcoding_tfidf, Y_CV, clf)
```

```
Log Loss :  1.260740792425099
Number of Misclassified Points : 0.4323308270676692
-------------------- Confusion Matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```

```python
clf = KNeighborsClassifier(n_neighbors=alpha[best_alpha])
clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

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

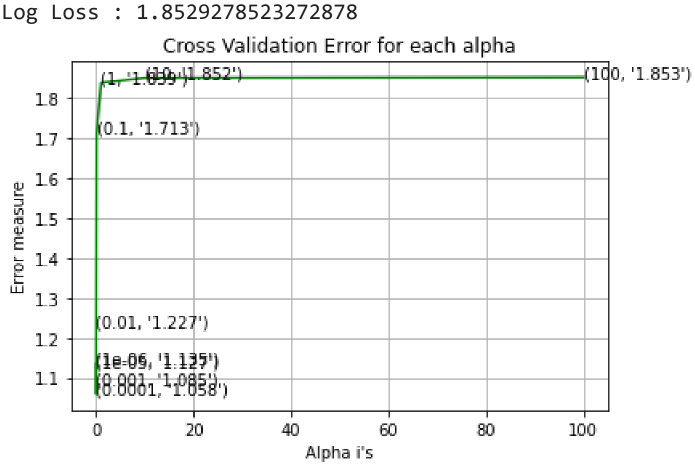
```
Predicted Class : 7
Actual Class : 4
The  5  nearest neighbours of the test points belongs to classes [3 4 1 4 1]
Fequency of nearest points : Counter({4: 2, 1: 2, 3: 1})
```

LOGISTIC REGRESSION WITH CLASS BALANCING

```python
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(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

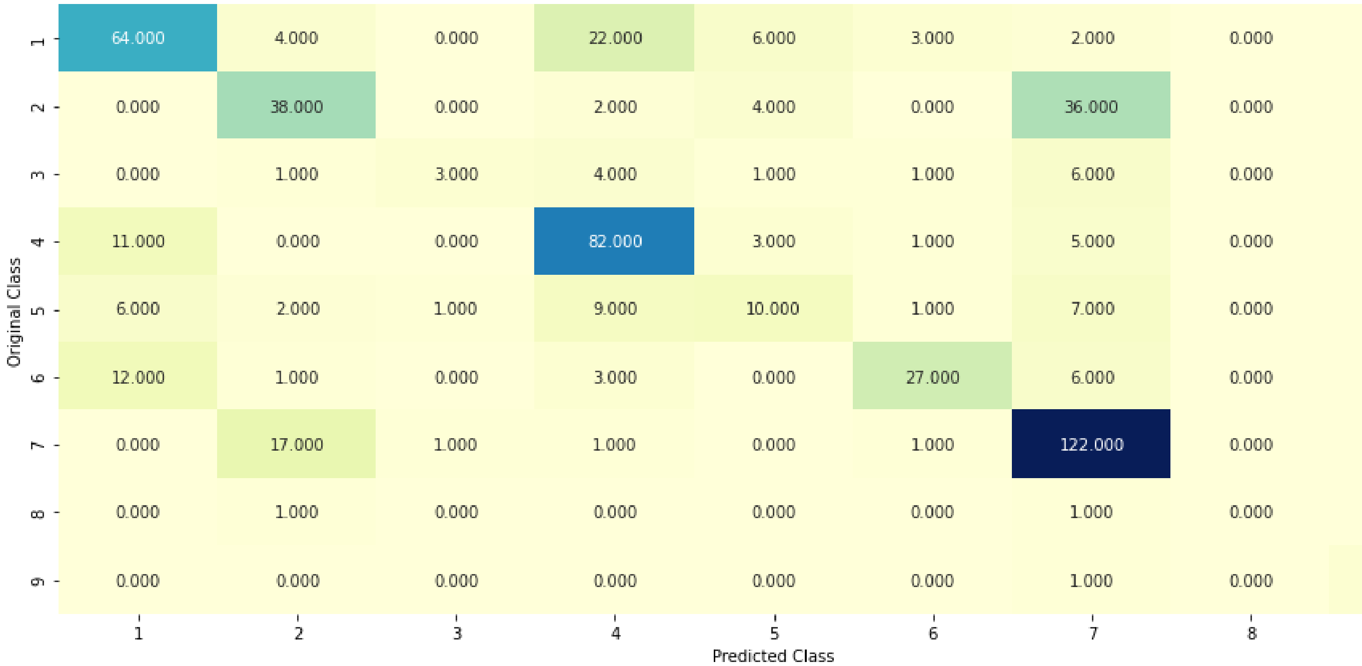
```
for alpha = 1e-06
Log Loss : 1.1349239214992324
for alpha = 1e-05
Log Loss : 1.1270021942239883
for alpha = 0.0001
Log Loss : 1.0584224477093065
for alpha = 0.001
Log Loss : 1.0848800628677302
for alpha = 0.01
Log Loss : 1.2267667992253835
for alpha = 0.1
Log Loss : 1.7127788552336967
for alpha = 1
Log Loss : 1.8391919496093834
for alpha = 10
Log Loss : 1.85154108049996
for alpha = 100
Log Loss : 1.8529278523272878
```



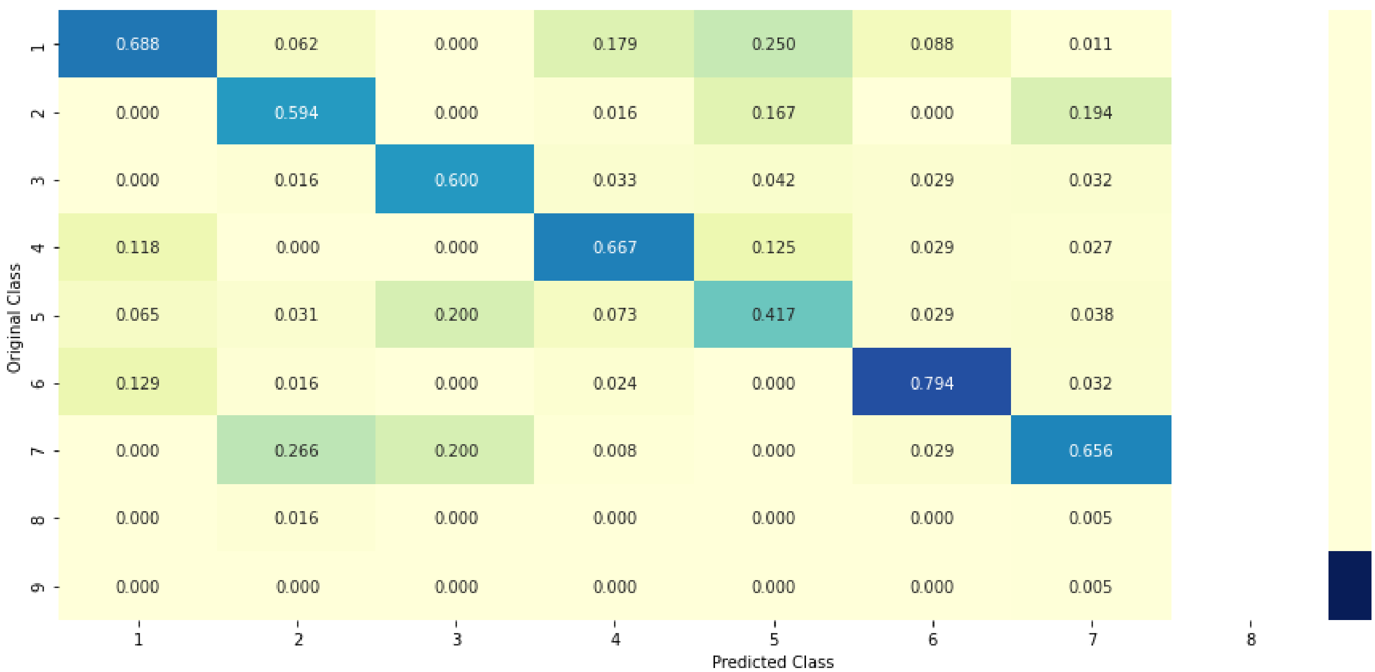

```
For values of best alpha =  0.0001 The train log loss is: 0.36081440897296463
For values of best alpha =  0.0001 The cross validation log loss is: 1.0584224477093065
For values of best alpha =  0.0001 The test log loss is: 1.0564367265738994
```

```
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotcoding_tfidf, Y_Train, X_CV_onehotcoding_tfidf, Y_CV, clf)
```

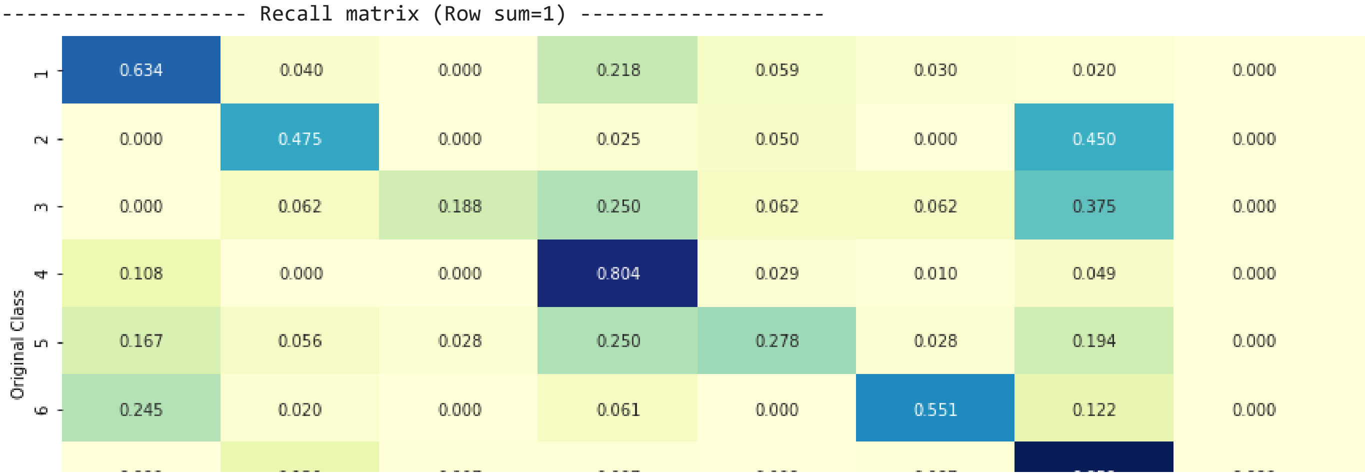
```
Log Loss :  1.0584224477093065
Number of Misclassified Points : 0.34398496240601506
-------------------- Confusion Matrix --------------------
```

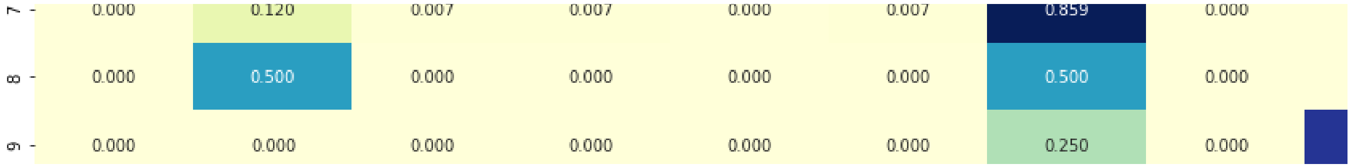



```
-------------------- Precision matrix (Columm Sum=1) --------------------
```




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





LOGISTIC REGRESSION WITHOUT CLASS BALANCING

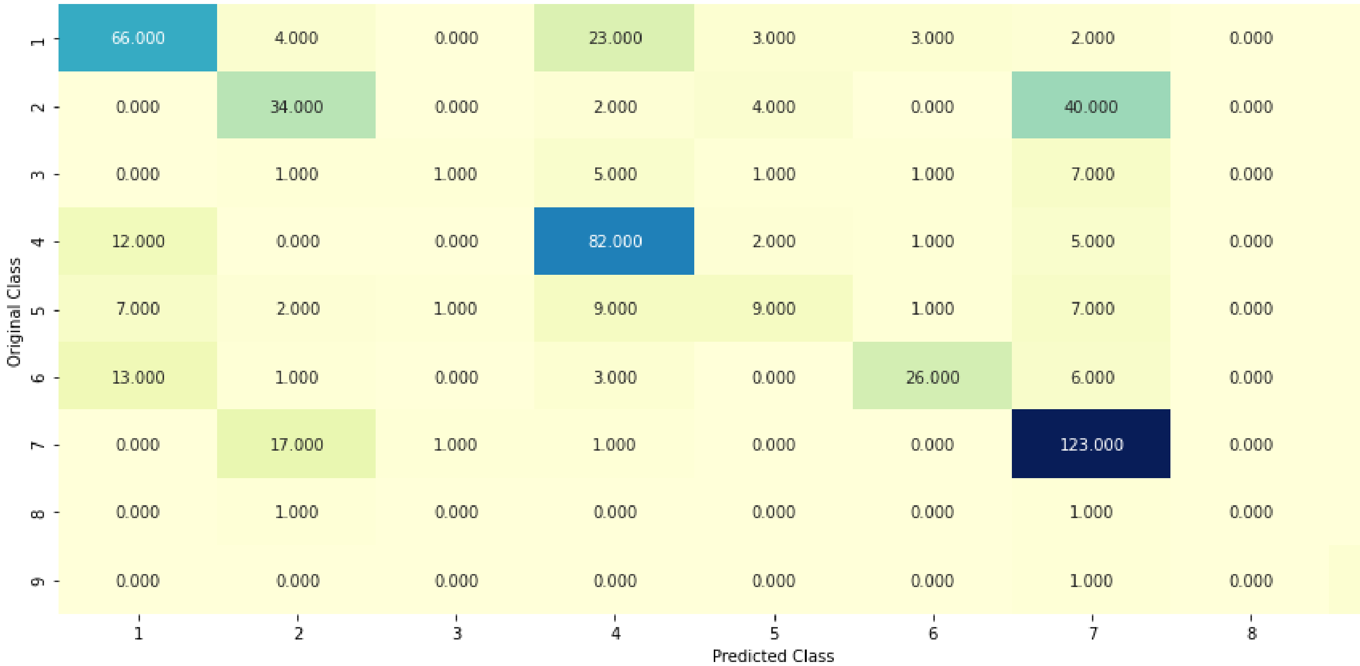
```
alpha = [10 ** x for x in range(-6, 3)]
cv_log_error_array = []
for i in alpha:
    print("for alpha =", i)
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
   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

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
for alpha = 1e-06
Log Loss : 1.1386593648101406
for alpha = 1e-05
Log Loss : 1.1280770426263258
for alpha = 0.0001
Log Loss : 1.0809267874605049
for alpha = 0.001
Log Loss : 1.1599651555818726
for alpha = 0.01
Log Loss : 1.4711079574295722
for alpha = 0.1
Log Loss : 1.7324620156684516
for alpha = 1
Log Loss : 1.862433088524242
for alpha = 10
Log Loss : 1.8771853566934507
for alpha = 100
Log Loss : 1.8788362002968801
```

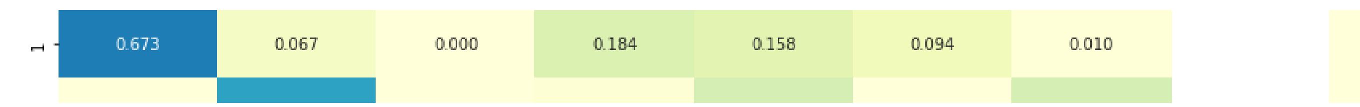
Cross Validation Error for each alpha

```
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotcoding_tfidf, Y_Train, X_CV_onehotcoding_tfidf, Y_CV, clf)
```

```
Log Loss :  1.0809267874605049
Number of Misclassified Points : 0.3533834586466165
-------------------- Confusion Matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```



LINEAR SUPPORT VECTOR MACHINE

```
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='hinge', random_state=42)
    clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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='hinge', random_state=42)
clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

```

```
predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='hinge', random_state=42,class_weight='balanced')
predict_and_plot_confusionmatrix(X_Train_onehotcoding_tfidf, Y_Train,X_CV_onehotcoding_tfidf,Y_CV, clf)
```

RANDOM FOREST CLASSIFIER

```
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(X_Train_onehotcoding_tfidf, Y_Train)
        sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
        sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
        sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
        cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
        print("Log Loss :",log_loss(Y_CV, 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)
```

```
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
clf.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_tfidf, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_tfidf)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The train log loss is:",log_loss(Y_Train, pred
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_tfidf)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The cross validation log loss is:",log_loss(Y_
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_tfidf)
print('For values of best estimator = ', alpha[int(best_alpha/2)], "The test log loss is:",log_loss(Y_Test, predic
```

STACK THE MODELS

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

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

```
clf3 = MultinomialNB(alpha=0.001)
clf3.fit(X_Train_onehotcoding_tfidf, Y_Train)
sig_clf3 = CalibratedClassifierCV(clf3, method="sigmoid")
```

```
sig_clf1.fit(X_Train_onehotcoding_tfidf, Y_Train)
print("Logistic Regression :  Log Loss: %0.2f" % (log_loss(Y_CV, sig_clf1.predict_proba(X_CV_onehotcoding_tfidf)))
sig_clf2.fit(X_Train_onehotcoding_tfidf, Y_Train)
print("Support vector machines : Log Loss: %0.2f" % (log_loss(Y_CV, sig_clf2.predict_proba(X_CV_onehotcoding_tfidf
```

```
sig_clf3.fit(X_Train_onehotcoding_tfidf, Y_Train)
print("Naive Bayes : Log Loss: %0.2f" % (log_loss(Y_CV, sig_clf3.predict_proba(X_CV_onehotcoding_tfidf))))
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(X_Train_onehotcoding_tfidf, Y_Train)
    print("Stacking Classifer : for the value of alpha: %f Log Loss: %0.3f" % (i, log_loss(Y_CV, sclf.predict_prob
    log_error =log_loss(Y_CV , sclf.predict_proba(X_CV_onehotcoding_tfidf))
    if best_alpha > log_error:
        best_alpha = log_error
```

```
lr = LogisticRegression(C=0.1)
sclf = StackingClassifier(classifiers=[sig_clf1, sig_clf2, sig_clf3], meta_classifier=lr, use_probas=True)
sclf.fit(X_Train_onehotcoding_tfidf, Y_Train)

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

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

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

print("Number of missclassified point :", np.count_nonzero((sclf.predict(X_Test_onehotcoding_tfidf)- Y_Test))/Y_Te
plot_confusion_matrix(test_y=Y_Test, predict_y=sclf.predict(X_Test_onehotcoding_tfidf))
```

LOGISTIC REGRESSION WITH COUNTVECTORIZER USING BIGRAM

CountVectorizer on Gene Features

```
from sklearn.feature_extraction.text import CountVectorizer

count_vectorizer_bigram=CountVectorizer(ngram_range=(1,2))

X_Train_gene_Feature_onehotencoding_bigram=count_vectorizer_bigram.fit_transform(X_Train["Gene"])
print(" Train Gene Feature :" ,X_Train_gene_Feature_onehotencoding_bigram.shape)

print("="*100)

X_Test_gene_Feature_onehotencoding_bigram=count_vectorizer_bigram.transform(X_Test["Gene"])
print(" Test Gene Feature :" ,X_Test_gene_Feature_onehotencoding_bigram.shape)

print("="*100)

```

```
X_CV_gene_Feature_onehotencoding_bigram=count_vectorizer_bigram.transform(X_CV["Gene"])
print(" CV Gene Feature :" ,X_CV_gene_Feature_onehotencoding_bigram.shape)

print("="*100)
```

CountVectorizer on Variation Features

```
variation_vectorizer_bigram=CountVectorizer(ngram_range=(1,2))

X_Train_variation_Feature_onehotencoding_bigram=variation_vectorizer_bigram.fit_transform(X_Train["Variation"])
print(" Train Variation Feature :" ,X_Train_variation_Feature_onehotencoding_bigram.shape)

print("="*100)

X_Test_variation_Feature_onehotencoding_bigram=variation_vectorizer_bigram.transform(X_Test["Variation"])
print(" Test Variation Feature :" ,X_Test_variation_Feature_onehotencoding_bigram.shape)

print("="*100)


X_CV_variation_Feature_onehotencoding_bigram=variation_vectorizer_bigram.transform(X_CV["Variation"])
print(" CV Variation Feature :" ,X_CV_variation_Feature_onehotencoding_bigram.shape)

print("="*100)
```

CountVectorizer on Text Features

```
from sklearn.preprocessing import normalize

text_vectorizer_bigram = CountVectorizer(min_df=3,ngram_range=(1,2))
X_Train_feature_onehotencoding_bigram = text_vectorizer_bigram.fit_transform(X_Train['TEXT'])


X_Train_feature_onehotencoding_bigram = normalize(X_Train_feature_onehotencoding_bigram, axis=0)
print("Train Text Feature :", X_Train_feature_onehotencoding_bigram.shape)

print("="*100)

X_Test_text_feature_onehotencoding_bigram = text_vectorizer_bigram.transform(X_Test['TEXT'])
print("Test Text Feature :", X_Test_text_feature_onehotencoding_bigram.shape)

print("="*100)

X_Test_text_feature_onehotencoding_bigram = normalize(X_Test_text_feature_onehotencoding_bigram, axis=0)

```

```
X_CV_text_feature_onehotencoding_bigram = text_vectorizer_bigram.transform(X_CV['TEXT'])
print("CV Text Feature :", X_CV_text_feature_onehotencoding_bigram.shape)

print("="*100)

X_CV_text_feature_onehotencoding_bigram = normalize(X_CV_text_feature_onehotencoding_bigram, axis=0)
```

STACKING THE 3 TYPES OF FEATURES

```
X_Train_gene_var_onehotencoding_bigram = hstack((X_Train_gene_Feature_onehotencoding_bigram,X_Train_variation_Feat
X_Test_gene_var_onehotencoding_bigram =  hstack((X_Test_gene_Feature_onehotencoding_bigram,X_Test_variation_Featur
X_CV_gene_var_onehotencoding_bigram = hstack((X_CV_gene_Feature_onehotencoding_bigram,X_CV_variation_Feature_onehc

X_Train_onehotcoding_bigram = hstack((X_Train_gene_var_onehotencoding_bigram,X_Train_feature_onehotencoding_bigram
print("Train One Hot Encoding  :", X_Train_onehotcoding_bigram.shape)
print("="*100)

X_Test_onehotcoding_bigram = hstack((X_Test_gene_var_onehotencoding_bigram,X_Test_text_feature_onehotencoding_bigr
print("Test One Hot Encoding  :", X_Test_onehotcoding_bigram.shape)
print("="*100)

X_CV_onehotcoding_bigram = hstack((X_CV_gene_var_onehotencoding_bigram,X_CV_text_feature_onehotencoding_bigram)).t
print("CV One Hot Encoding  :", X_CV_onehotcoding_bigram.shape)
print("="*100)
```

LOGISTIC REGRESSION WITH CLASS BALANCING

```
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(X_Train_onehotcoding_bigram, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_bigram, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_bigram)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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(X_Train_onehotcoding_bigram, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_bigram, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
clf = SGDClassifier(class_weight='balanced', alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotcoding_bigram, Y_Train, X_CV_onehotcoding_bigram, Y_CV, clf)
```

LOGISTIC REGRESSION WITHOUT CLASS BALANCING

```
alpha = [10 ** x for x in range(-6, 3)]
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(X_Train_onehotcoding_bigram, Y_Train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_Train_onehotcoding_bigram, Y_Train)
    sig_clf_probs = sig_clf.predict_proba(X_CV_onehotcoding_bigram)
    cv_log_error_array.append(log_loss(Y_CV, sig_clf_probs, labels=clf.classes_, eps=1e-15))
    # to avoid rounding error while multiplying probabilites we use log-probability estimates
    print("Log Loss :",log_loss(Y_CV, 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(X_Train_onehotcoding_bigram, Y_Train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_Train_onehotcoding_bigram, Y_Train)

predict_y = sig_clf.predict_proba(X_Train_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(Y_Train, predict_y, labe
predict_y = sig_clf.predict_proba(X_CV_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(Y_CV, predict
predict_y = sig_clf.predict_proba(X_Test_onehotcoding_bigram)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(Y_Test, predict_y, labels
```

```
clf = SGDClassifier( alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
predict_and_plot_confusionmatrix(X_Train_onehotcoding_bigram, Y_Train, X_CV_onehotcoding_bigram, Y_CV, clf)
```