In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
matplotlib.use(u'nbAgg')
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
from csv import writer
from sklearn import preprocessing
import pandas as pd
from multiprocessing import Process# this is used for multithreading
import multiprocessing
import codecs# this is used for file operations
import scipy
import random as r
import array
from xgboost import XGBClassifier
import pickle as pkl
from sklearn.model_selection import RandomizedSearchCV
from sklearn.tree import DecisionTreeClassifier
from sklearn.calibration import CalibratedClassifierCV
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import log_loss
from sklearn.metrics import confusion_matrix
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
```

In [2]:
```
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)
    print("Number of misclassified points ",(len(test_y)-np.trace(C))/len(test_y)*100)
    # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predicted class j

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

    # C = [[1, 2],
    #     [3, 4]]
    # C.T = [[1, 3],
    #        [2, 4]]
    # C.sum(axis = 1)  axis=0 corresonds to columns and axis=1 corresponds to rows in two diamensional array
    # C.sum(axix =1) = [[3, 7]]
    # ((C.T)/(C.sum(axis=1))) = [[1/3, 3/7]
    #                            [2/3, 4/7]]

    # ((C.T)/(C.sum(axis=1))).T = [[1/3, 2/3]
    #                            [3/7, 4/7]]
    # sum of row elements = 1

    B =(C/C.sum(axis=0))
    #divid each element of the confusion matrix with the sum of elements in that row
    # C = [[1, 2],
    #     [3, 4]]
    # C.sum(axis = 0)  axis=0 corresonds to columns and axis=1 corresponds to rows in two diamensional array
    # C.sum(axix =0) = [[4, 6]]
    # (C/C.sum(axis=0)) = [[1/4, 2/6],
    #                       [3/4, 4/6]]

    labels = [1,2,3,4,5,6,7,8,9]
    cmap=sns.light_palette("green")
    # representing A in heatmap format
    print("-"*50, "Confusion matrix", "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    print("-"*50, "Precision matrix", "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of columns in precision matrix",B.sum(axis=0))

    # representing B in heatmap format
    print("-"*50, "Recall matrix"    , "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

1.Image Extraction from ASM -files

Image Extraction using : https://github.com/dchad/malware-detection/blob/master/mmcc/feature-extraction.ipynb (https://github.com/dchad/malware-detection/blob/master/mmcc/feature-extraction.ipynb)

In [3]:
```
def entropy(p,n):
    '''Returns entrophy'''
    p_ratio = float(p)/(p+n)
    n_ratio = float(n)/(p+n)
    return -p_ratio*math.log(p_ratio) - n_ratio * math.log(n_ratio)
```

In [4]:
```
def info_gain(p0,n0,p1,n1,p,n):
    '''Return iformation gain'''
    return entropy(p,n) - float(p0+n0)/(p+n)*entropy(p0,n0) - float(p1+n1)/(p+n)*entropy(p1,n1)
```

In [5]:
```
def read_image(filename):
    '''
    Read the image data
    '''
    f = open(filename,'rb')
    ln = os.path.getsize(filename) # length of file in bytes
    width = 256
    rem = ln%width
    a = array.array("B") # uint8 array
    a.fromfile(f,ln-rem)
    f.close()
    g = np.reshape(a,(int(len(a)/width), width))
    g = np.uint8(g)
    g = np.resize(g, (1000,))
    return list(g)
```

In [6]:
```
# Do asm image extraction
def extract_asm_image_features(tfiles):
    asm_files = [i for i in tfiles if '.asm' in i]
    ftot = len(asm_files)

    pid = os.getpid()
    print('Process id:', pid)
    feature_file = str(pid) + '-image-features-asm.csv'
    print('feature file:', feature_file)

    outrows = []
    with open(feature_file,'w') as f:
        fw = writer(f)
        column_names = ['filename'] + [("ASM_{:s}".format(str(x))) for x in range(1000)]
        fw.writerow(column_names)
        for idx, fname in enumerate(asm_files):
            file_id = fname.split('.')[0]
            image_data = read_image('asmFiles/' + fname)
            outrows.append([file_id] + image_data)

            # Print progress
            if (idx+1) % 10 == 0:
              print(pid, idx + 1, 'of', ftot, 'files processed.')
              fw.writerows(outrows)
              outrows = []

        # Write remaining files
        if len(outrows) > 0:
            fw.writerows(outrows)
            outrows = []
```

In [7]:

```
# TRAIN FILES ASM
# Now divide the train files into four groups for multiprocessing
import time
from multiprocessing import Pool
start_time = time.time()
tfiles =  os.listdir('asmFiles')
quart = len(tfiles)//4
train1 = tfiles[:quart]
train2 = tfiles[quart:(2*quart)]
train3 = tfiles[(2*quart):(3*quart)]
train4 = tfiles[(3*quart):]
print (len(tfiles), quart, (len(train1)+len(train2)+len(train3)+len(train4)))
trains = [train1, train2, train3, train4]
p = Pool(4)
p.map(extract_asm_image_features, trains)
print("Elapsed time: {:.2f} hours.".format((time.time() - start_time)//3600.0))
```

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Elapsed time: 0.00 hours.
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Merging the image dataset

In [6]:
```python
file1 = pd.read_csv('1137-image-features-asm.csv')
file2 = pd.read_csv('1138-image-features-asm.csv')
file3 = pd.read_csv('1139-image-features-asm.csv')
file4 = pd.read_csv('1140-image-features-asm.csv')

image_data = np.concatenate([file1,file2,file3,file4],axis=0)
```

In [7]:
```python
file1.columns
```

Out[7]:
```
Index(['filename', 'ASM_0', 'ASM_1', 'ASM_2', 'ASM_3', 'ASM_4', 'ASM_5',
       'ASM_6', 'ASM_7', 'ASM_8',
       ...
       'ASM_990', 'ASM_991', 'ASM_992', 'ASM_993', 'ASM_994', 'ASM_995',
       'ASM_996', 'ASM_997', 'ASM_998', 'ASM_999'],
      dtype='object', length=1001)
```

In [8]:
```python
labels = pd.read_csv('trainLabels.csv')
```

In [9]:
```python
labels.head(5)
```

Out[9]:

	Id	Class
0	01kcPWA9K2BOxQeS5Rju	1
1	04EjIdbPV5e1XroFOpiN	1
2	05EeG39MTRrI6VY21DPd	1
3	05rJTUWYAKNegBk2wE8X	1
4	0AnoOZDNbPXIr2MRBSCJ	1

In [10]:
```python
image_data = pd.DataFrame(data=image_data,columns=file1.columns)
```

In [11]:
```python
image_data.head()
```

Out[11]:

	filename	ASM_0	ASM_1	ASM_2	ASM_3	ASM_4	ASM_5	ASM_6	ASM_7	ASM_8	...	ASM_990	ASM_991	ASM_992	ASM_993	ASM_994	ASM_995	ASM_996	ASM_997	ASM_998	ASM_999
0	JKbYXxOv2Wa8eMNlFq04	46	116	101	120	116	58	48	48	52	...	10	46	116	101	120	116	58	48	48	52
1	1ZYtDkrdm9yVLpeU5cSJ	72	69	65	68	69	82	58	48	48	...	59	32	70	111	114	109	97	116	9	32
2	Hl3iXz1IhS69DCANfRVT	72	69	65	68	69	82	58	48	48	...	116	101	120	116	58	48	48	52	48	49
3	HSyZm4zlbXMT5R37F1wK	46	116	101	120	116	58	48	48	52	...	10	46	116	101	120	116	58	48	48	52
4	ESoHvWkbZ4JgwzlFK6uA	72	69	65	68	69	82	58	48	48	...	59	32	70	111	114	109	97	116	9	32

5 rows × 1001 columns

In [13]:
```python
image_data_sorted = image_data.sort_values(by='filename')
labels_sorted = labels.sort_values(by='Id')

## removing the column file name from the dataset

X_ = image_data.iloc[:,1:]
Y_ = labels.iloc[:,1:]
```

In [14]:
```python
print('Shape of the train data:',X_.shape,' shape of labels:',Y_.shape)
```

```
Shape of the train data: (10868, 1000)  shape of labels: (10868, 1)
```

2.Feature Selection using Chi2- selecting top 50%

refer: [https://github.com/dchad/malware-detection/blob/master/mmcc/feature-reduction.ipynb (https://github.com/dchad/malware-detection/blob/master/mmcc/feature-reduction.ipynb)](https://github.com/dchad/malware-detection/blob/master/mmcc/feature-reduction.ipynb)

In [15]:
```python
from sklearn.feature_selection import SelectKBest, SelectPercentile
from sklearn.feature_selection import chi2
from sklearn.ensemble import RandomForestClassifier, ExtraTreesClassifier
import warnings
warnings.filterwarnings("ignore", category=DeprecationWarning)
warnings.filterwarnings("ignore", category=FutureWarning)
```

In [17]:
```python
# find the top 50 percent variance features, from 1006 -> 503 features
fsp = SelectPercentile(chi2, 50)
X_new_50 = fsp.fit_transform(X_,Y_)
X_new_50.shape
```

Out[17]:
```
(10868, 500)
```

In [18]:
```
selected_names = fsp.get_support(indices=True)
selected_names = selected_names + 1
selected_names
```

Out[18]:
```
array([  15,   21,   22,   29,   30,   32,   33,   34,   35,   41,   42,
         43,   44,   48,   50,  125,  126,  135,  136,  138,  139,  140,
        141,  142,  143,  144,  145,  146,  147,  148,  151,  155,  156,
        157,  158,  160,  161,  162,  163,  164,  165,  167,  169,  173,
        174,  179,  186,  188,  190,  198,  201,  202,  205,  215,  216,
        220,  221,  222,  223,  224,  226,  227,  236,  240,  242,  243,
        244,  245,  246,  247,  248,  249,  252,  253,  260,  261,  262,
        263,  264,  265,  266,  267,  268,  271,  272,  282,  287,  291,
        292,  293,  294,  295,  296,  297,  307,  310,  311,  312,  313,
        314,  315,  317,  318,  323,  326,  327,  328,  330,  334,  337,
        338,  339,  340,  341,  343,  344,  345,  346,  349,  351,  352,
        353,  354,  356,  357,  358,  359,  366,  370,  371,  372,  373,
        374,  375,  376,  378,  379,  380,  381,  384,  399,  400,  401,
        405,  408,  409,  410,  412,  413,  414,  415,  422,  423,  424,
        425,  426,  427,  428,  436,  437,  439,  440,  441,  446,  447,
        448,  449,  450,  451,  452,  453,  457,  460,  461,  464,  465,
        466,  467,  477,  478,  479,  480,  481,  482,  538,  539,  555,
        556,  557,  558,  559,  560,  561,  563,  564,  567,  568,  572,
        573,  580,  581,  582,  583,  584,  585,  586,  587,  588,  589,
        590,  597,  598,  600,  601,  602,  603,  606,  607,  613,  614,
        615,  616,  617,  618,  619,  620,  621,  622,  623,  624,  627,
        628,  629,  630,  631,  632,  633,  634,  635,  636,  637,  638,
        641,  642,  643,  644,  645,  646,  647,  648,  649,  650,  651,
        652,  653,  654,  655,  656,  657,  658,  659,  660,  663,  664,
        665,  667,  668,  669,  670,  671,  672,  673,  674,  675,  676,
        677,  678,  679,  680,  681,  682,  683,  684,  685,  686,  687,
        688,  691,  692,  693,  694,  695,  696,  697,  701,  702,  705,
        706,  707,  708,  709,  710,  711,  712,  713,  714,  715,  717,
        718,  719,  720,  722,  723,  724,  725,  726,  727,  728,  729,
        730,  731,  732,  733,  734,  735,  736,  737,  738,  739,  744,
        746,  747,  748,  749,  751,  752,  753,  754,  755,  756,  758,
        759,  760,  761,  762,  763,  764,  765,  774,  775,  777,  778,
        779,  780,  781,  782,  783,  784,  785,  786,  788,  790,  791,
        792,  793,  794,  795,  797,  798,  799,  800,  801,  802,  813,
        814,  815,  816,  818,  819,  828,  829,  830,  831,  832,  833,
        834,  835,  836,  837,  838,  841,  843,  844,  845,  847,  848,
        849,  850,  851,  852,  853,  854,  855,  856,  857,  865,  866,
        867,  868,  869,  870,  873,  874,  875,  876,  877,  878,  879,
        882,  885,  887,  888,  889,  890,  892,  893,  894,  895,  896,
        898,  900,  901,  902,  903,  904,  905,  906,  916,  917,  918,
        919,  920,  923,  924,  930,  931,  932,  934,  935,  936,  937,
        938,  943,  947,  948,  949,  950,  951,  952,  953,  954,  955,
        956,  957,  958,  959,  960,  961,  962,  963,  964,  965,  966,
        967,  968,  969,  970,  973,  974,  975,  976,  977,  978,  979,
        980,  981,  982,  983,  989,  990,  991,  992,  993,  994,  995,
        996,  997,  998,  999, 1000])
```

In [21]:
```
data_trimmed = image_data_sorted.iloc[:,selected_names]
data_fnames = pd.DataFrame(image_data_sorted['filename'])
data_50 = data_fnames.join(data_trimmed)
data_50.head()
```

Out[21]:

	filename	ASM_14	ASM_20	ASM_21	ASM_28	ASM_29	ASM_31	ASM_32	ASM_33	ASM_34	...	ASM_990	ASM_991	ASM_992	ASM_993	ASM_994	ASM_995	ASM_996	ASM_997	ASM_998	ASM_999
3677	01IsoiSMh5gxyDYTl4CB	9	32	32	13	10	116	101	120	116	...	10	46	116	101	120	116	58	48	48	52
5749	01SuzwMJEIXsK7A8dQbl	48	9	9	68	69	58	48	48	52	...	116	101	120	116	58	48	48	52	48	49
3852	01azqd4InC7m9JpocGv5	48	9	9	68	69	58	48	48	52	...	116	101	120	116	58	48	48	52	48	49
9748	01jsnpXSAlgw6aPeDxrU	48	9	9	68	69	58	48	48	52	...	116	101	120	116	58	48	48	52	48	49
6133	01kcPWA9K2BOxQeS5Rju	48	9	9	68	69	58	49	48	48	...	71	77	69	78	84	32	72	69	65	68

5 rows × 501 columns

In [23]:
```
print('Shape of the data after data reduction with 50% variance features:',data_50.shape)
```

```
Shape of the data after data reduction with 50% variance features: (10868, 501)
```

In [34]:
```
### save the file after performing feature selection
data_50.rename(columns={'filename':'ID'},inplace=True)
data_50.to_csv('asm_50%_variance_data.csv')
```

3. Implemation of different Feature Combination with ASM extracted image

3.1 Asm-uni grams + ASM-Extracted image features

In [127]:
```
labels =pd.read_csv('trainLabels.csv')
```

In [128]:
```
dfasm=pd.read_csv("asmoutputfile.csv")
labels.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, labels,on='ID', how='left')
result_asm.head()
```

Out[128]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:	...	edx	esi	eax	ebx	ecx	edi	ebp	esp	eip	Class
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3	...	18	66	15	43	83	0	17	48	29	1
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3	...	18	29	48	82	12	0	14	0	20	1
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3	...	13	42	10	67	14	0	11	0	9	1
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3	...	6	8	14	7	2	0	8	0	6	1
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3	...	12	9	18	29	5	0	11	0	11	1

5 rows × 53 columns

In [129]:
```
data_50 = pd.read_csv('asm_50%_variance_data.csv')
```

In [130]:
```
data_50.drop(columns=['Unnamed: 0'],inplace=True)
data_50.columns
```

Out[130]:
```
Index(['ID', 'ASM_14', 'ASM_20', 'ASM_21', 'ASM_28', 'ASM_29', 'ASM_31',
       'ASM_32', 'ASM_33', 'ASM_34',
       ...
       'ASM_990', 'ASM_991', 'ASM_992', 'ASM_993', 'ASM_994', 'ASM_995',
       'ASM_996', 'ASM_997', 'ASM_998', 'ASM_999'],
      dtype='object', length=501)
```

In [131]:
```
X_merged = pd.merge(result_asm, data_50, on='ID', how='inner')
X_merged.head()
```

Out[131]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:	...	ASM_990	ASM_991	ASM_992	ASM_993	ASM_994	ASM_995	ASM_996	ASM_997	ASM_998	ASM_999
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3	...	71	77	69	78	84	32	72	69	65	68
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3	...	32	32	32	32	58	9	80	111	114	116
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3	...	59	32	70	111	114	109	97	116	9	32
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3	...	32	32	32	32	58	9	80	111	114	116
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3	...	32	32	32	32	58	9	80	111	114	116

5 rows × 553 columns

In [132]:
```
Y_merged = X_merged['Class']
X_merged = X_merged.drop(['ID','rtn','.BSS:','.CODE','Class'], axis=1)
```

In [133]:
```
### train test split
X_train, X_test, y_train, y_test = train_test_split(X_merged, Y_merged,stratify=Y_merged,test_size=0.20)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_train,test_size=0.20)
```

In [134]:
```
X_train = X_train.apply(pd.to_numeric, errors='coerce')
X_test = X_test.apply(pd.to_numeric, errors='coerce')
X_cv = X_cv.apply(pd.to_numeric, errors='coerce')
```

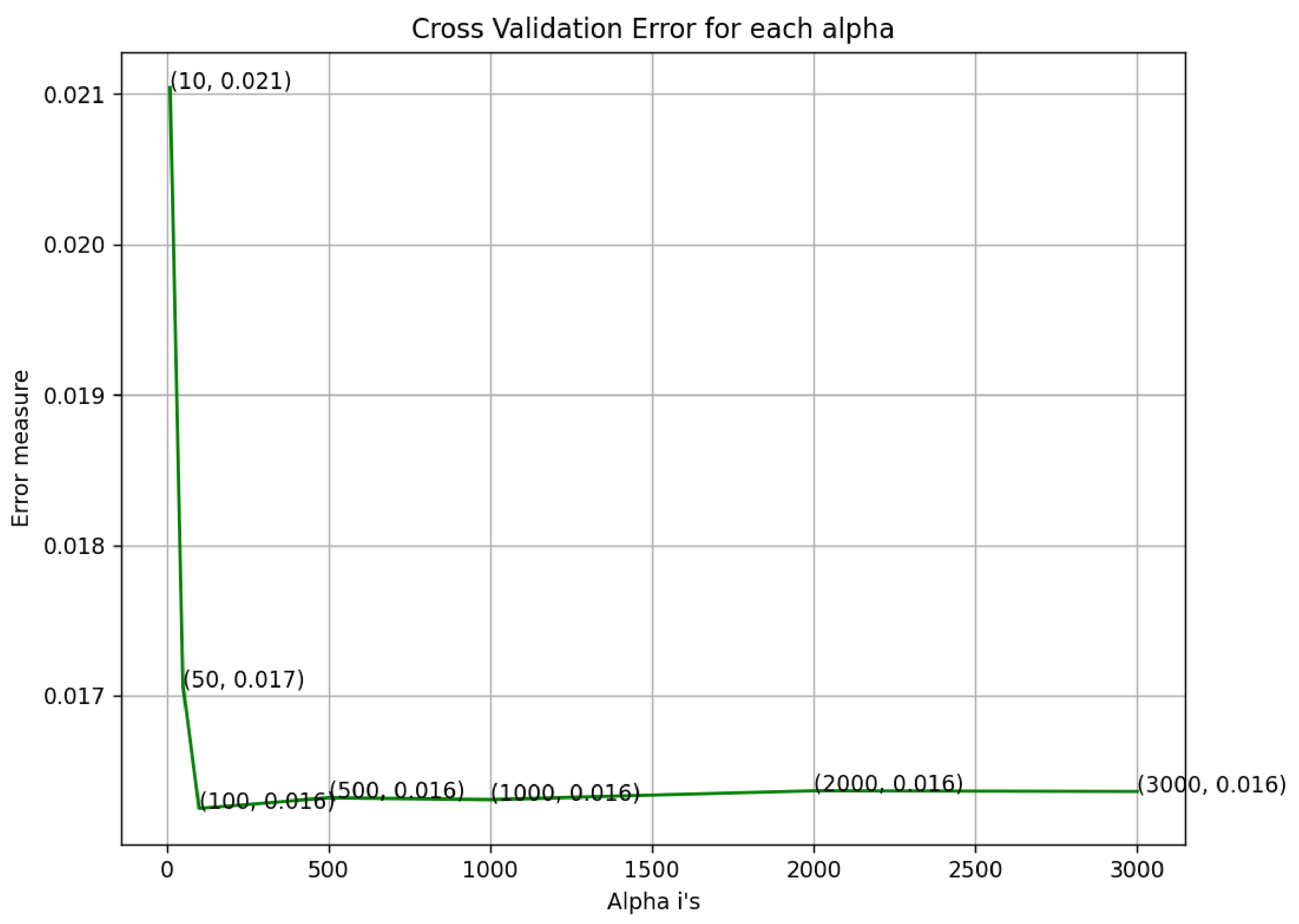
- since random forest and XGB performed better on bytes/asm unigrams we will use both

3.1.1 Random Forest Classifier with Asm-uni grams + ASM-Extracted image features

In [52]:

```
# --------------------------------
# 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/
# --------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
train_log_error_array=[]
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))
    print('Parameter tuning for alpha:',i,' Loss:',log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))
for i in range(len(cv_log_error_array)):
    print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])


best_alpha = np.argmin(cv_log_error_array)

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()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
```

```
Parameter tuning for alpha: 10  Loss: 0.021040358325913156
Parameter tuning for alpha: 50  Loss: 0.01706201515911518
Parameter tuning for alpha: 100  Loss: 0.01624964757759834
Parameter tuning for alpha: 500  Loss: 0.016321154903590304
Parameter tuning for alpha: 1000  Loss: 0.01630844779802613
Parameter tuning for alpha: 2000  Loss: 0.016367377506599643
Parameter tuning for alpha: 3000  Loss: 0.016362740697231582
log_loss for c =  10 is 0.021040358325913156
log_loss for c =  50 is 0.01706201515911518
log_loss for c =  100 is 0.01624964757759834
log_loss for c =  500 is 0.016321154903590304
log_loss for c =  1000 is 0.01630844779802613
log_loss for c =  2000 is 0.016367377506599643
log_loss for c =  3000 is 0.016362740697231582

<IPython.core.display.Javascript object>
```

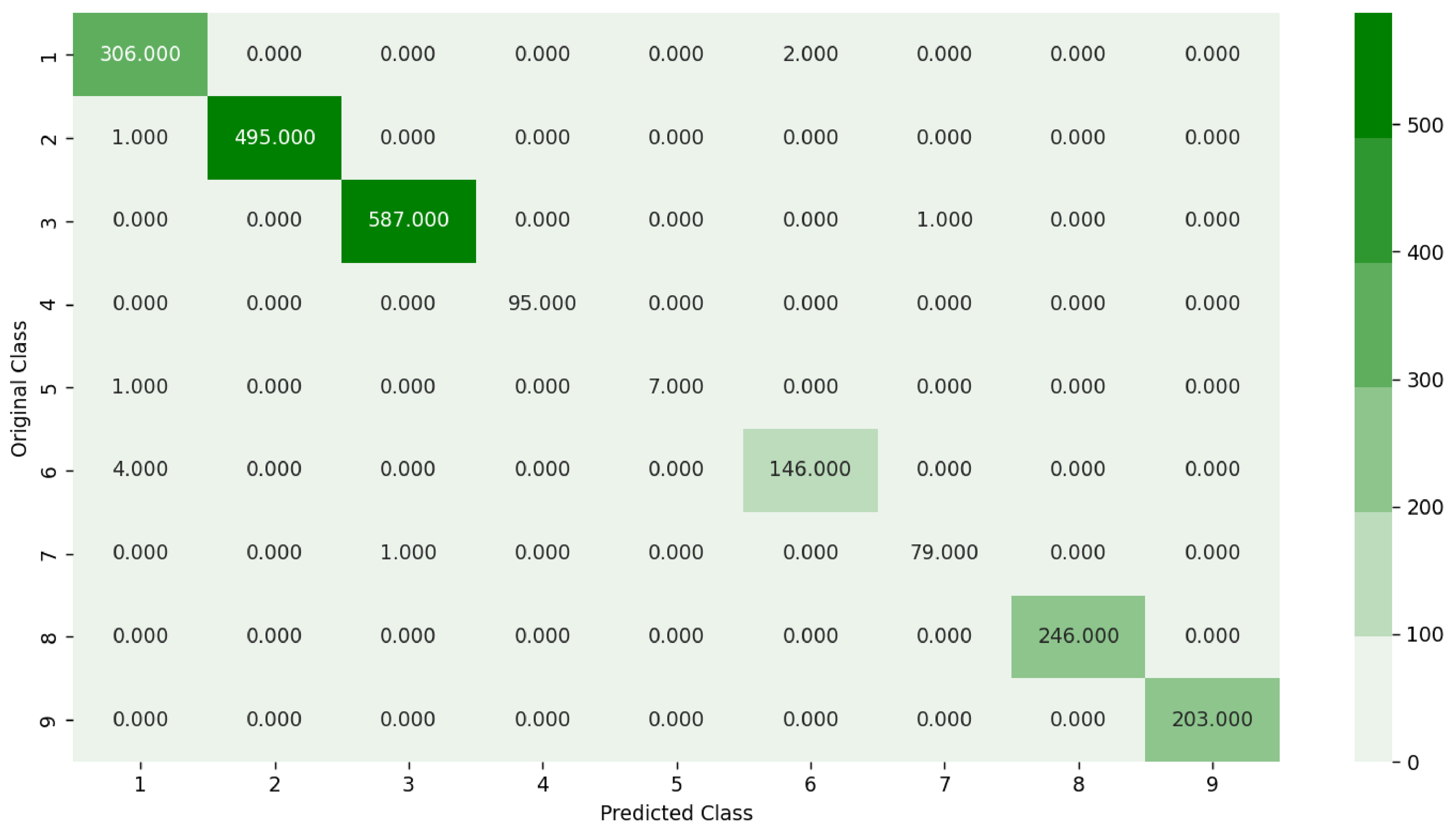



```
For values of best alpha =  100 The train log loss is: 0.012043317011966856
For values of best alpha =  100 The cross validation log loss is: 0.01624964757759834
For values of best alpha =  100 The test log loss is: 0.02383102390750985
```

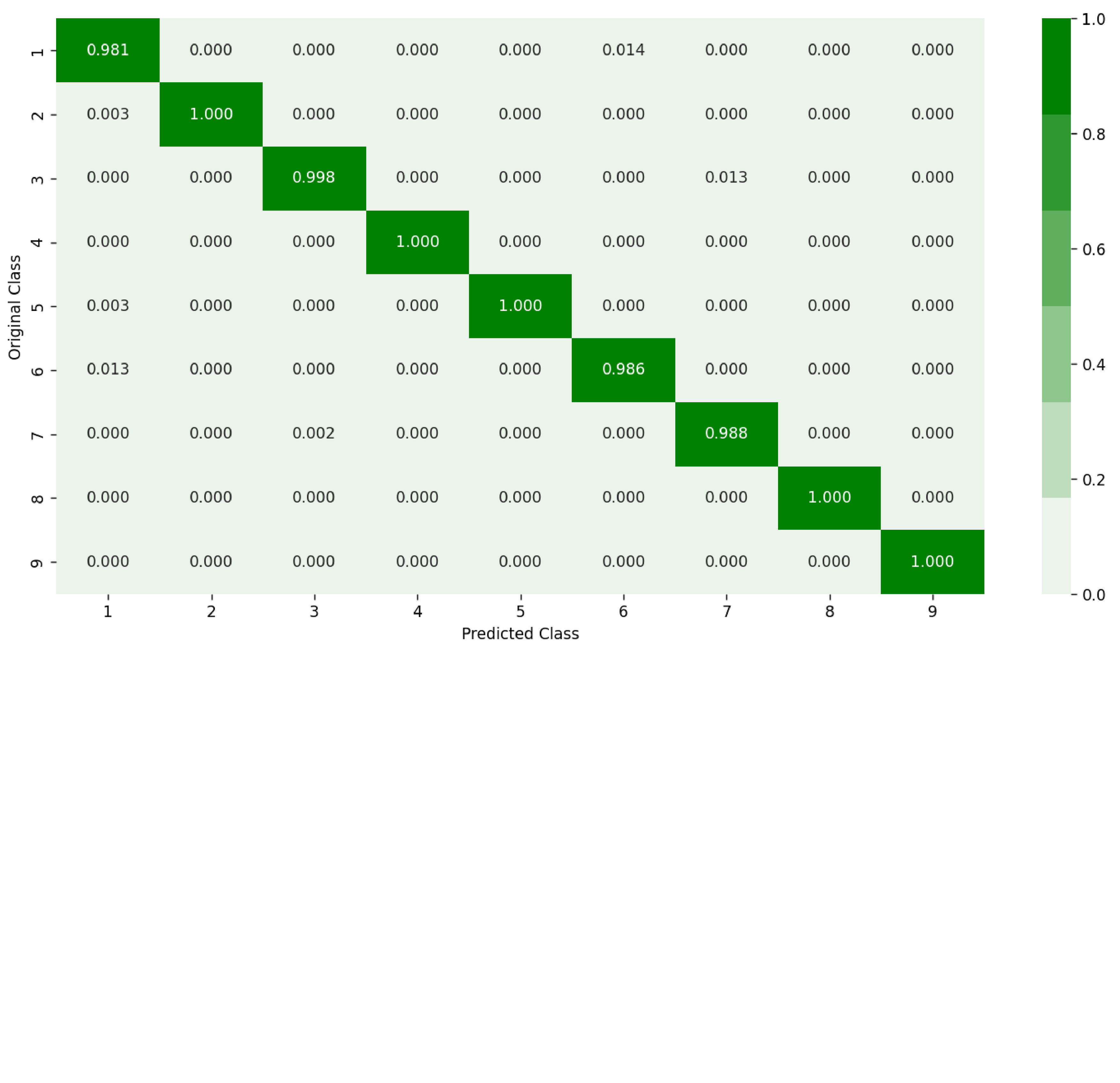
In [54]:

```
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

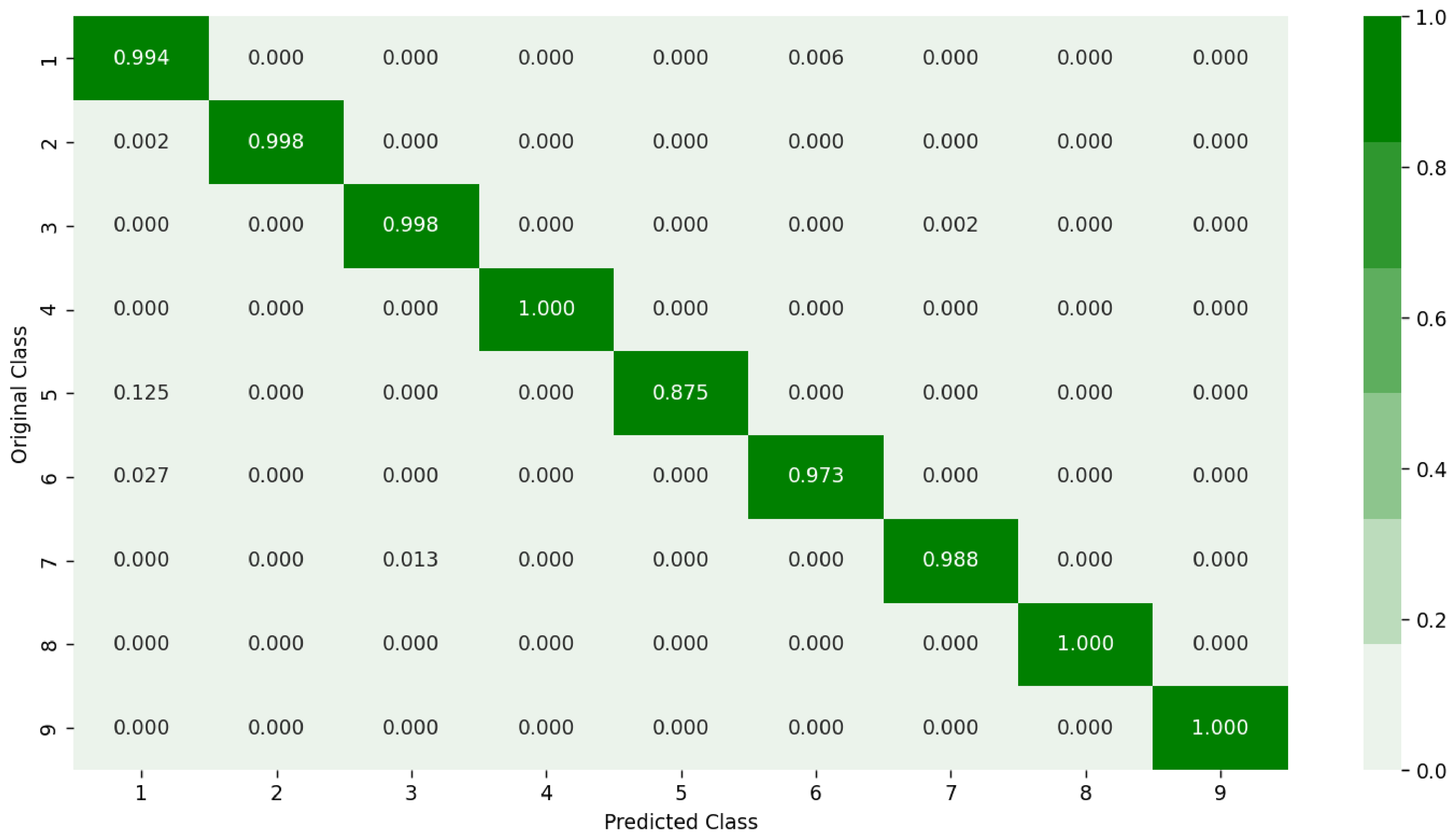
```
Number of misclassified points  0.45998160073597055
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```



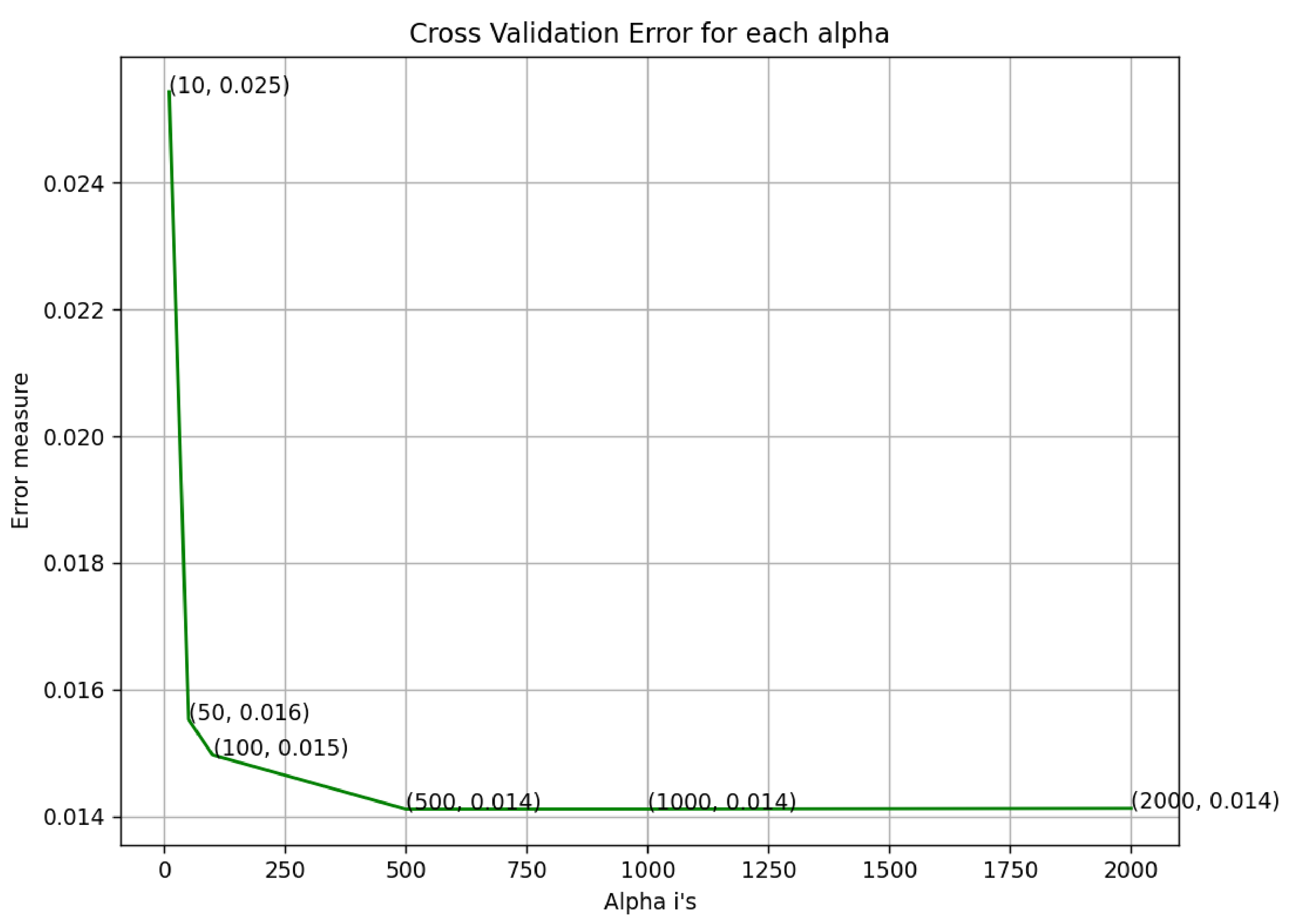

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.1.2 XGB Classifier with Asm-uni grams + ASM-Extracted image features

In [79]:

```
%%time
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This function is not thread safe.
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link1: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/regression-using-decision-trees-2/
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what-are-ensembles/
# -----------------------

alpha=[10,50,100,500,1000,2000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,nthread=-1,silent=True,verbosity=0)
    x_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=x_cfl.classes_, eps=1e-15))
    print('Parameter tuning for alpha:',i,' Loss:',log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))


# for i in range(len(cv_log_error_array)):
#     print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])


best_alpha = np.argmin(cv_log_error_array)

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()

x_cfl=XGBClassifier(n_estimators=alpha[best_alpha],nthread=-1,silent=True,verbosity=0)
x_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
```

```
Parameter tuning for alpha: 10  Loss: 0.025430225353088646
Parameter tuning for alpha: 50  Loss: 0.01553217557088968
Parameter tuning for alpha: 100  Loss: 0.014970418779213806
Parameter tuning for alpha: 500  Loss: 0.014116494279968701
Parameter tuning for alpha: 1000  Loss: 0.014117920024732094
Parameter tuning for alpha: 2000  Loss: 0.014129280344415004
log_loss for c =  10 is 0.025430225353088646
log_loss for c =  50 is 0.01553217557088968
log_loss for c =  100 is 0.014970418779213806
log_loss for c =  500 is 0.014116494279968701
log_loss for c =  1000 is 0.014117920024732094
log_loss for c =  2000 is 0.014129280344415004

<IPython.core.display.Javascript object>
```



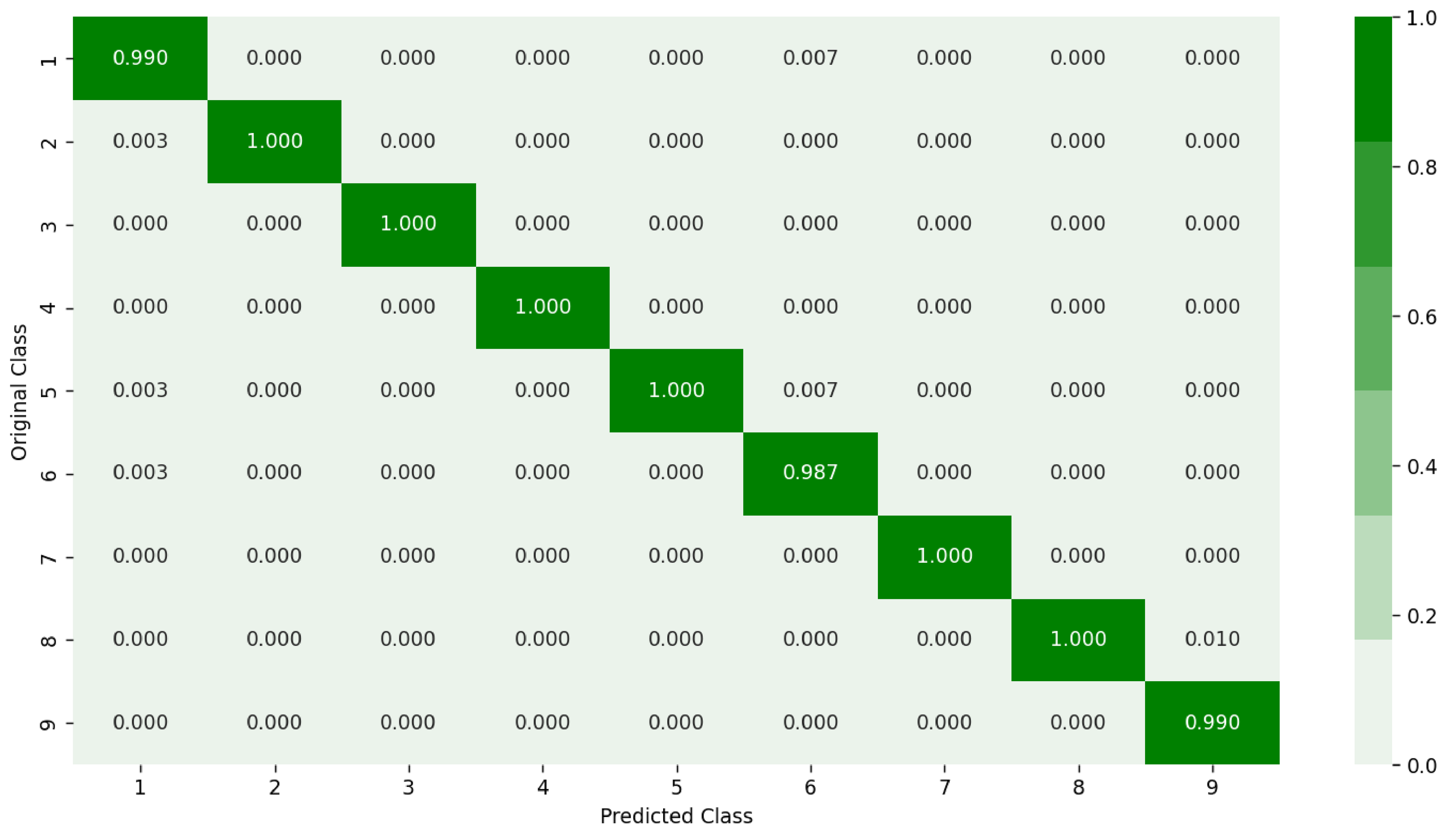

```
For values of best alpha =  500 The train log loss is: 0.010945769938987372
For values of best alpha =  500 The cross validation log loss is: 0.014116494279968701
For values of best alpha =  500 The test log loss is: 0.023801783541974996
```

In [80]:

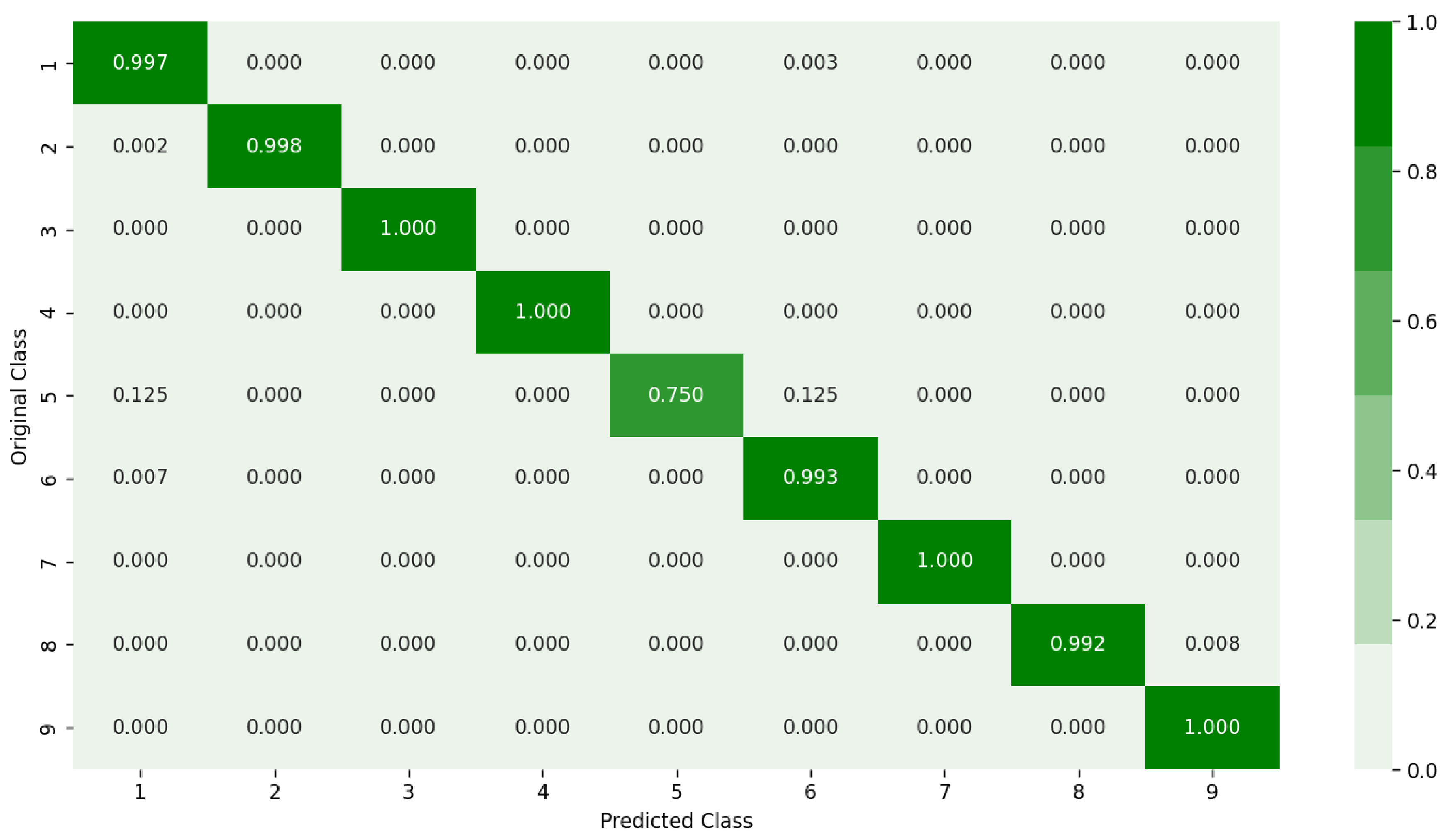
```
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Number of misclassified points  0.3219871205151794
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```


```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.1.3 XGB Classifier with Asm-uni grams + ASM-Extracted image features (with best hyper paramters)

[https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with-codes-python/ (https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with-codes-python/)](https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with-codes-python/)

In [16]:
```
%%time
x_cfl=XGBClassifier(verbosity=0,silent=True)
prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl1=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,cv=4)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 4 folds for each of 10 candidates, totalling 40 fits
[CV 1/4; 1/10] START colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3
[CV 1/4; 1/10] END colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3;, score=0.989 total time=  18.0s
[CV 2/4; 1/10] START colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3
[CV 2/4; 1/10] END colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3;, score=0.992 total time=  32.2s
[CV 3/4; 1/10] START colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3
[CV 3/4; 1/10] END colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3;, score=0.987 total time=  32.5s
[CV 4/4; 1/10] START colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3
[CV 4/4; 1/10] END colsample_bytree=0.3, learning_rate=0.03, max_depth=5, n_estimators=100, subsample=0.3;, score=0.994 total time=  33.0s
[CV 1/4; 2/10] START colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3
[CV 1/4; 2/10] END colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3;, score=0.997 total time=  43.6s
[CV 2/4; 2/10] START colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3
[CV 2/4; 2/10] END colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3;, score=0.997 total time=  43.0s
[CV 3/4; 2/10] START colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3
[CV 3/4; 2/10] END colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3;, score=0.995 total time=  42.8s
[CV 4/4; 2/10] START colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3
[CV 4/4; 2/10] END colsample_bytree=0.1, learning_rate=0.1, max_depth=10, n_estimators=500, subsample=0.3;, score=0.997 total time=  43.4s
[CV 1/4; 3/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 1/4; 3/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.995 total time=  40.0s
[CV 2/4; 3/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 2/4; 3/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.992 total time=  39.3s
[CV 3/4; 3/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 3/4; 3/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.990 total time=  40.5s
[CV 4/4; 3/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 4/4; 3/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.996 total time=  41.0s
[CV 1/4; 4/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 1/4; 4/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.995 total time=  27.7s
[CV 2/4; 4/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 2/4; 4/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.993 total time=  27.0s
[CV 3/4; 4/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 3/4; 4/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.991 total time=  27.5s
[CV 4/4; 4/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1
[CV 4/4; 4/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=10, n_estimators=200, subsample=0.1;, score=0.995 total time=  27.7s
[CV 1/4; 5/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3
[CV 1/4; 5/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3;, score=0.995 total time= 1.6min
[CV 2/4; 5/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3
[CV 2/4; 5/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3;, score=0.995 total time= 1.6min
[CV 3/4; 5/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3
[CV 3/4; 5/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3;, score=0.993 total time= 1.6min
[CV 4/4; 5/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3
[CV 4/4; 5/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.3;, score=0.997 total time= 1.6min
[CV 1/4; 6/10] START colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3
[CV 1/4; 6/10] END colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3;, score=0.997 total time= 1.7min
[CV 2/4; 6/10] START colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3
[CV 2/4; 6/10] END colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3;, score=0.995 total time= 1.7min
[CV 3/4; 6/10] START colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3
[CV 3/4; 6/10] END colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3;, score=0.993 total time= 1.7min
[CV 4/4; 6/10] START colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3
[CV 4/4; 6/10] END colsample_bytree=1, learning_rate=0.2, max_depth=3, n_estimators=200, subsample=0.3;, score=0.996 total time= 1.8min
[CV 1/4; 7/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3
[CV 1/4; 7/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3;, score=0.995 total time=  24.8s
[CV 2/4; 7/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3
[CV 2/4; 7/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3;, score=0.995 total time=  24.3s
[CV 3/4; 7/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3
[CV 3/4; 7/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3;, score=0.993 total time=  24.4s
[CV 4/4; 7/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3
[CV 4/4; 7/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=100, subsample=0.3;, score=0.996 total time=  24.3s
[CV 1/4; 8/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1
[CV 1/4; 8/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1;, score=0.978 total time=  15.3s
[CV 2/4; 8/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1
[CV 2/4; 8/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1;, score=0.979 total time=  15.5s
[CV 3/4; 8/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1
[CV 3/4; 8/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1;, score=0.978 total time=  15.3s
[CV 4/4; 8/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1
[CV 4/4; 8/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=0.1;, score=0.984 total time=  15.0s
[CV 1/4; 9/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1
[CV 1/4; 9/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1;, score=0.995 total time= 1.2min
[CV 2/4; 9/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1
[CV 2/4; 9/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1;, score=0.994 total time= 1.1min
[CV 3/4; 9/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1
[CV 3/4; 9/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1;, score=0.992 total time= 1.2min
[CV 4/4; 9/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1
[CV 4/4; 9/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=10, n_estimators=500, subsample=0.1;, score=0.997 total time= 1.2min
[CV 1/4; 10/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3
[CV 1/4; 10/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3;, score=0.995 total time= 5.4min
[CV 2/4; 10/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3
[CV 2/4; 10/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3;, score=0.996 total time= 5.4min
[CV 3/4; 10/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3
[CV 3/4; 10/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3;, score=0.993 total time= 5.3min
[CV 4/4; 10/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3
[CV 4/4; 10/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=500, subsample=0.3;, score=0.996 total time= 5.4min
CPU times: user 1h 43min 44s, sys: 5.84 s, total: 1h 43min 50s
Wall time: 52min 11s
```

Out[16]:
```
RandomizedSearchCV(cv=4,
                   estimator=XGBClassifier(base_score=None, booster=None,
                                           colsample_bylevel=None,
                                           colsample_bynode=None,
                                           colsample_bytree=None, gamma=None,
                                           gpu_id=None, importance_type='gain',
                                           interaction_constraints=None,
                                           learning_rate=None,
                                           max_delta_step=None, max_depth=None,
                                           min_child_weight=None, missing=nan,
                                           monotone_constraints=None,
                                           n_estimators=100,...
                                           num_parallel_tree=None,
                                           random_state=None, reg_alpha=None,
                                           reg_lambda=None,
                                           scale_pos_weight=None, silent=True,
                                           subsample=None, tree_method=None,
                                           validate_parameters=None,
                                           verbosity=0),
                   param_distributions={'colsample_bytree': [0.1, 0.3, 0.5, 1],
                                        'learning_rate': [0.01, 0.03, 0.05, 0.1,
                                                          0.15, 0.2],
                                        'max_depth': [3, 5, 10],
                                        'n_estimators': [100, 200, 500],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   verbose=10)
```

In [17]:
```
print (random_cfl1.best_params_)
```

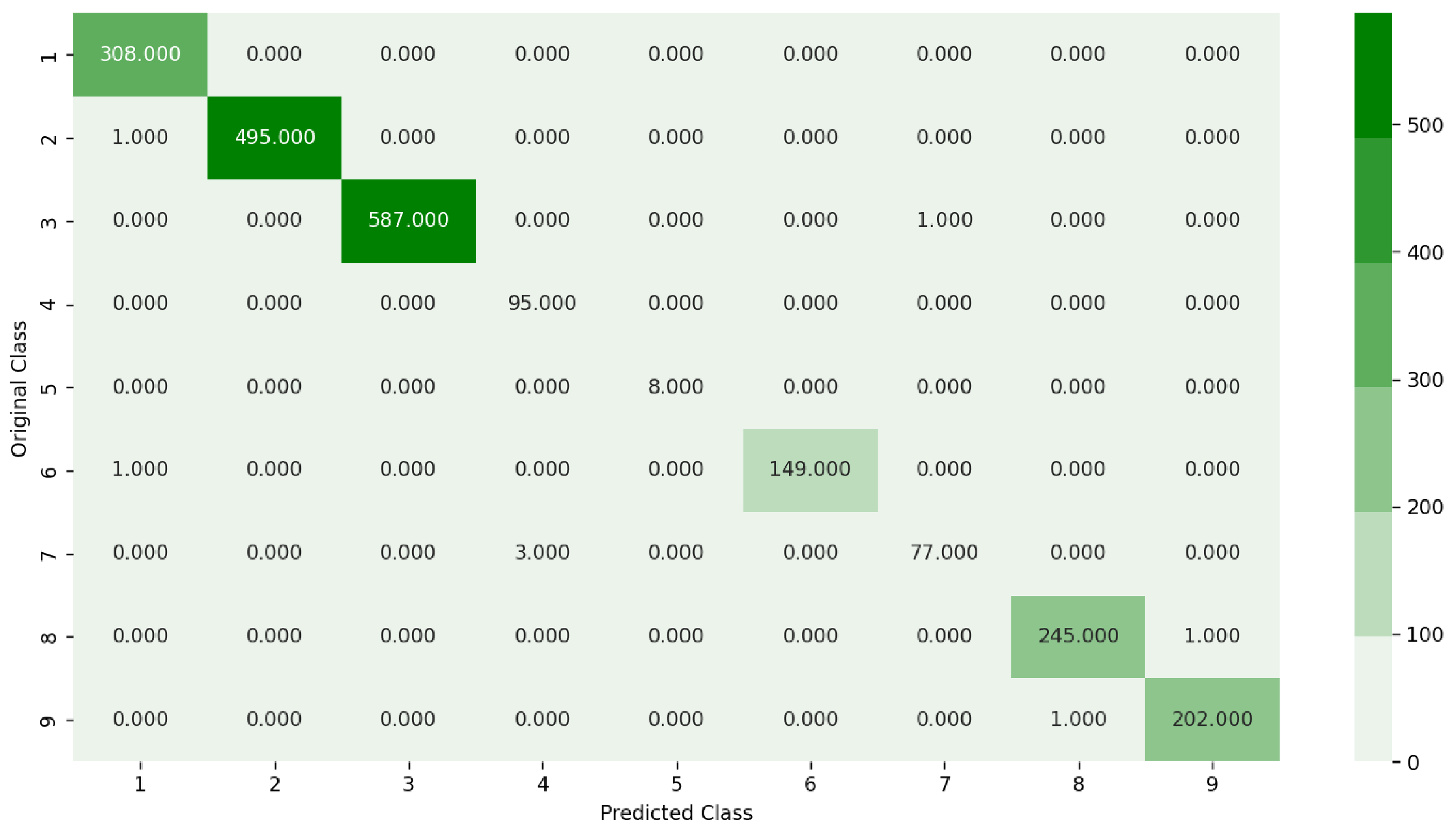
```
{'subsample': 0.3, 'n_estimators': 500, 'max_depth': 10, 'learning_rate': 0.1, 'colsample_bytree': 0.1}
```

In [135]:
```
%%time
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This function is not thread safe.
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what-are-ensembles/
# -----------------------
x_cfl=XGBClassifier(n_estimators=500, subsample=0.3,learning_rate=0.1, colsample_bytree=0.1, max_depth=10)
x_cfl.fit(X_train,y_train)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train,y_train)

predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)

print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
```

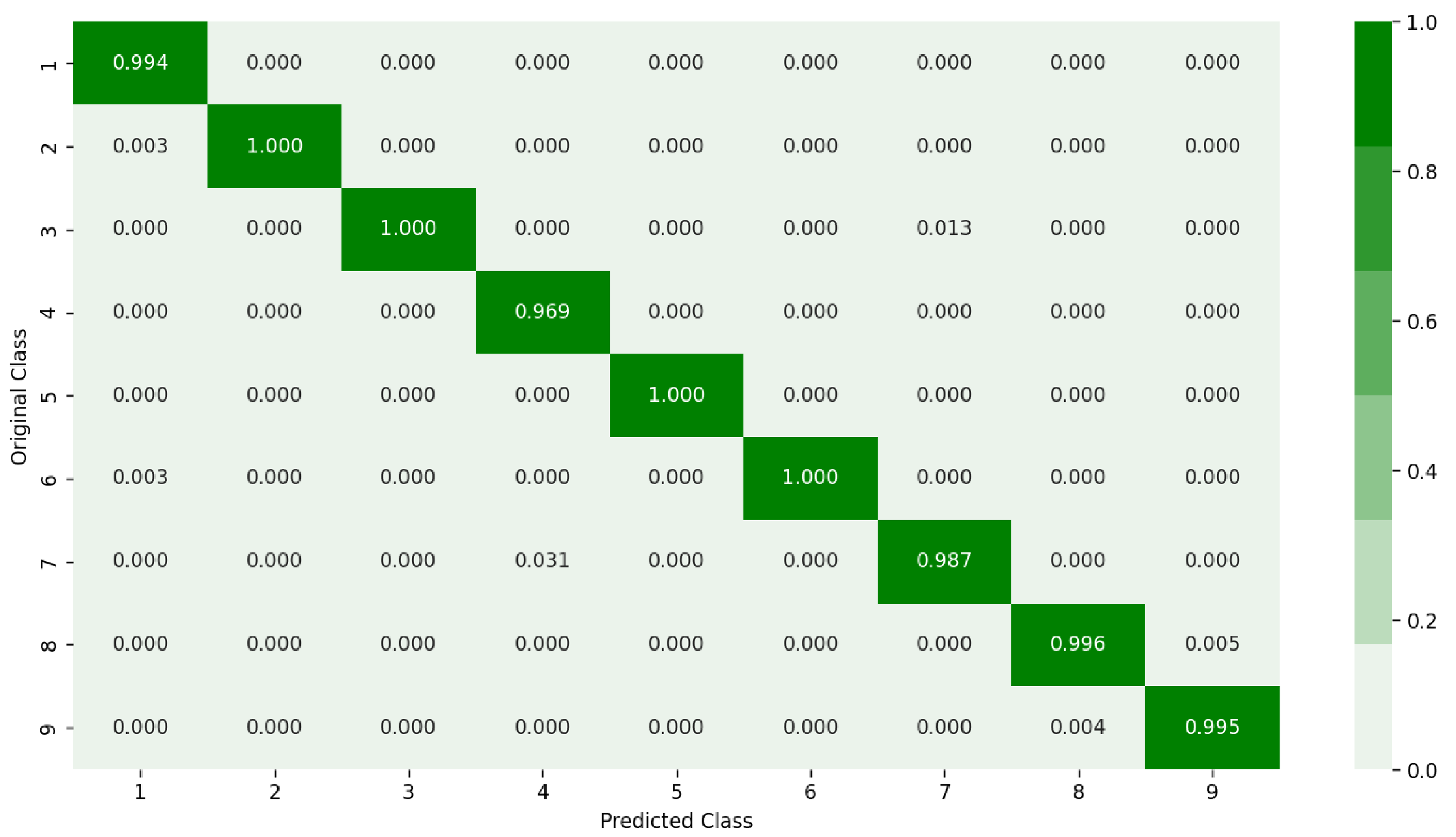
```
train loss 0.011000827447175468
cv loss 0.021335735778038614
test loss 0.025312012599598657
CPU times: user 5min 22s, sys: 530 ms, total: 5min 22s
Wall time: 2min 43s
```

In [136]:
```python
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

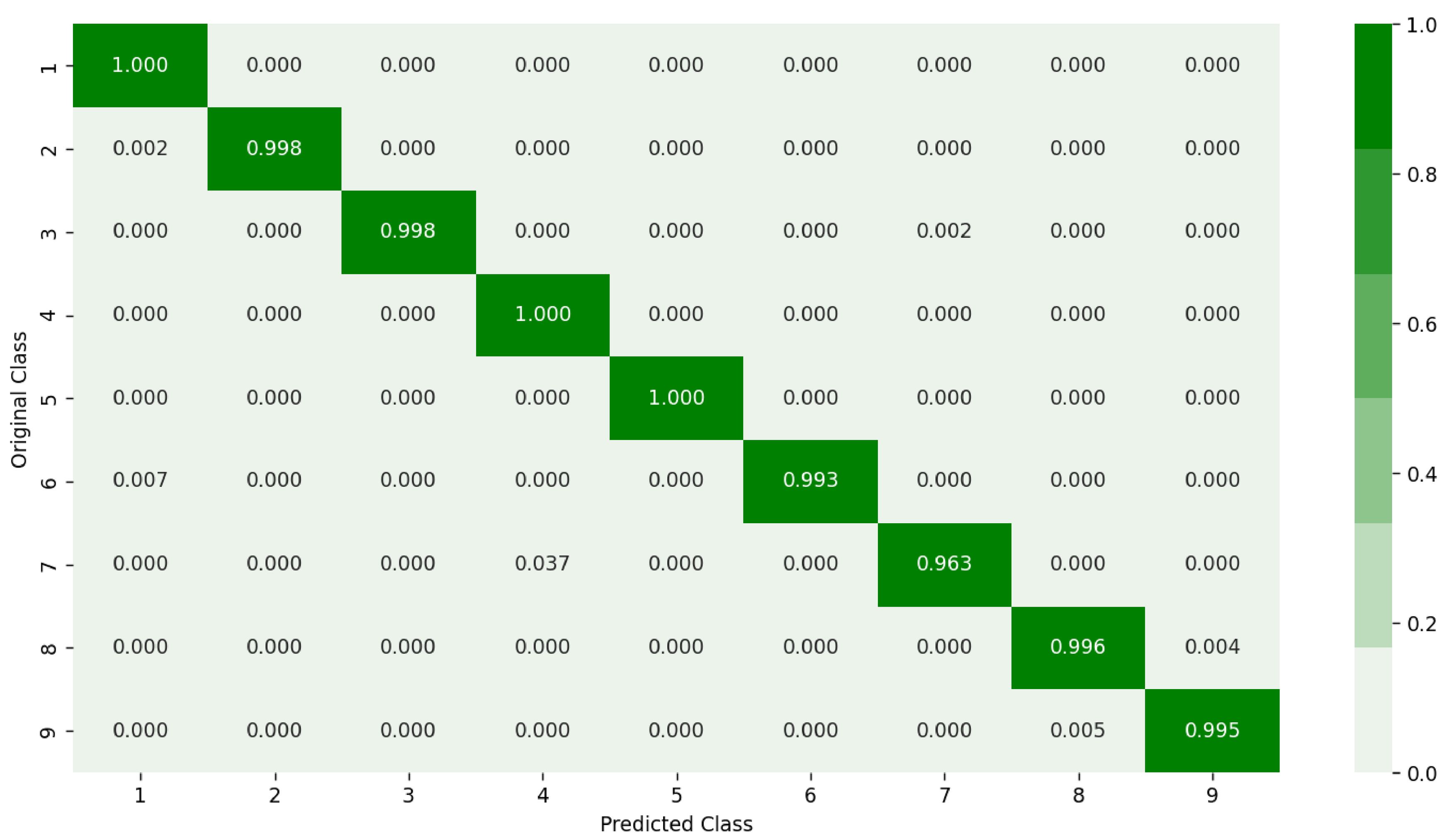
```
Number of misclassified points  0.24798528058877645
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.2 Random Forest Classifier , Asm-uni grams , ASM-Extracted image features , Bytes uni-grams

In [3]:
```
byte_features=pd.read_csv("result.csv")
byte_features['ID']  = byte_features['ID'].str.split('.').str[0]
byte_features.head(2)
```

Out[3]:

	ID	0	1	2	3	4	5	6	7	8	...	f7	f8	f9	fa	fb	fc	fd	fe	ff	??
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	2804	3687	3101	3211	3097	2758	3099	2759	5753	1824
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	451	6536	439	281	302	7639	518	17001	54902	8588

2 rows × 258 columns

In [4]:
```
byte_features_with_size = pd.read_csv("result_with_size.csv")
byte_features_with_size = byte_features_with_size.drop(columns='Unnamed: 0')
byte_features_with_size.head(5)
```

Out[4]:

	ID	0	1	2	3	4	5	6	7	8	...	f9	fa	fb	fc	fd	fe	ff	??	size	Class
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	3101	3211	3097	2758	3099	2759	5753	1824	4.148438	9
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439	281	302	7639	518	17001	54902	8588	5.425781	2
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...	2242	2885	2863	2471	2786	2680	49144	468	3.808594	9
3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	1078	...	485	462	516	1133	471	761	7998	13940	0.562500	1
4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	422	...	350	209	239	653	221	242	2199	9008	0.363281	8

5 rows × 260 columns

In [5]:
```
# https://stackoverflow.com/a/29651514
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - min_value)
    return result1
result = normalize(byte_features_with_size)

```

In [7]:
```
labels = pd.read_csv('trainLabels.csv')
data_50 = pd.read_csv('asm_50%_variance_data.csv')
```

In [8]:
```
result_asm = pd.read_csv("asmoutputfile.csv")

result_asm = normalize(result_asm)

labels.columns = ['ID', 'Class']
result_asm = pd.merge(result_asm, labels,on='ID', how='inner')
result_asm.head()
```

Out[8]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:	...	edx	esi	eax	ebx	ecx	edi	ebp	esp	eip	Class
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	0.0	0.000072	...	0.000343	0.000746	0.000301	0.000360	0.001057	0.0	0.030797	0.001468	0.003173	1
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	0.0	0.000072	...	0.000343	0.000328	0.000965	0.000686	0.000153	0.0	0.025362	0.000000	0.002188	1
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	0.0	0.000072	...	0.000248	0.000475	0.000201	0.000560	0.000178	0.0	0.019928	0.000000	0.000985	1
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	0.0	0.000072	...	0.000114	0.000090	0.000281	0.000059	0.000025	0.0	0.014493	0.000000	0.000657	1
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	0.0	0.000072	...	0.000229	0.000102	0.000362	0.000243	0.000064	0.0	0.019928	0.000000	0.001204	1

5 rows × 53 columns

In [9]:
```
result.head()
```

Out[9]:

	ID	0	1	2	3	4	5	6	7	8	...	f9	fa	fb	fc	fd	fe	ff	??	size	Class
0	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.002058	0.002946	0.002638	...	0.013560	0.013107	0.013634	0.031724	0.014549	0.014348	0.007843	0.000129	0.092219	9
1	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984	0.008267	...	0.001920	0.001147	0.001329	0.087867	0.002432	0.088411	0.074851	0.000606	0.121236	2
2	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155	0.008104	...	0.009804	0.011777	0.012604	0.028423	0.013080	0.013937	0.067001	0.000033	0.084499	9
3	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481	0.000959	...	0.002121	0.001886	0.002272	0.013032	0.002211	0.003957	0.010904	0.000984	0.010759	1
4	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229	0.000376	...	0.001530	0.000853	0.001052	0.007511	0.001038	0.001258	0.002998	0.000636	0.006233	8

5 rows × 260 columns

In [10]:
```
print('total features (asm unigram + bytes-unigram + asm-img):',result.shape[1]+result_asm.shape[1]+data_50.shape[1])
```

```
total features (asm unigram + bytes-unigram + asm-img): 815
```

In [11]:
```
X_merged = pd.merge(result_asm,result.drop(columns=['size','Class']),on='ID',how='inner')
X_merged = pd.merge(X_merged, data_50, on='ID', how='inner')
```

In [12]:
```
X_merged.shape
```

Out[12]:
```
(10868, 811)
```

In [13]:
```
Y_merged = X_merged['Class']
X_merged = X_merged.drop(['ID','rtn','.BSS:','.CODE','Class'], axis=1)
print('shape of x',X_merged.shape,' y:',Y_merged.shape)
```

```
shape of x (10868, 806)  y: (10868,)
```

In [14]:
```
### train test split
X_train, X_test, y_train, y_test = train_test_split(X_merged, Y_merged,stratify=Y_merged,test_size=0.20)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_train,test_size=0.20)
```

In [15]:
```
X_train = X_train.astype(float)
X_test = X_test.astype(float)
X_cv = X_cv.astype(float)
```

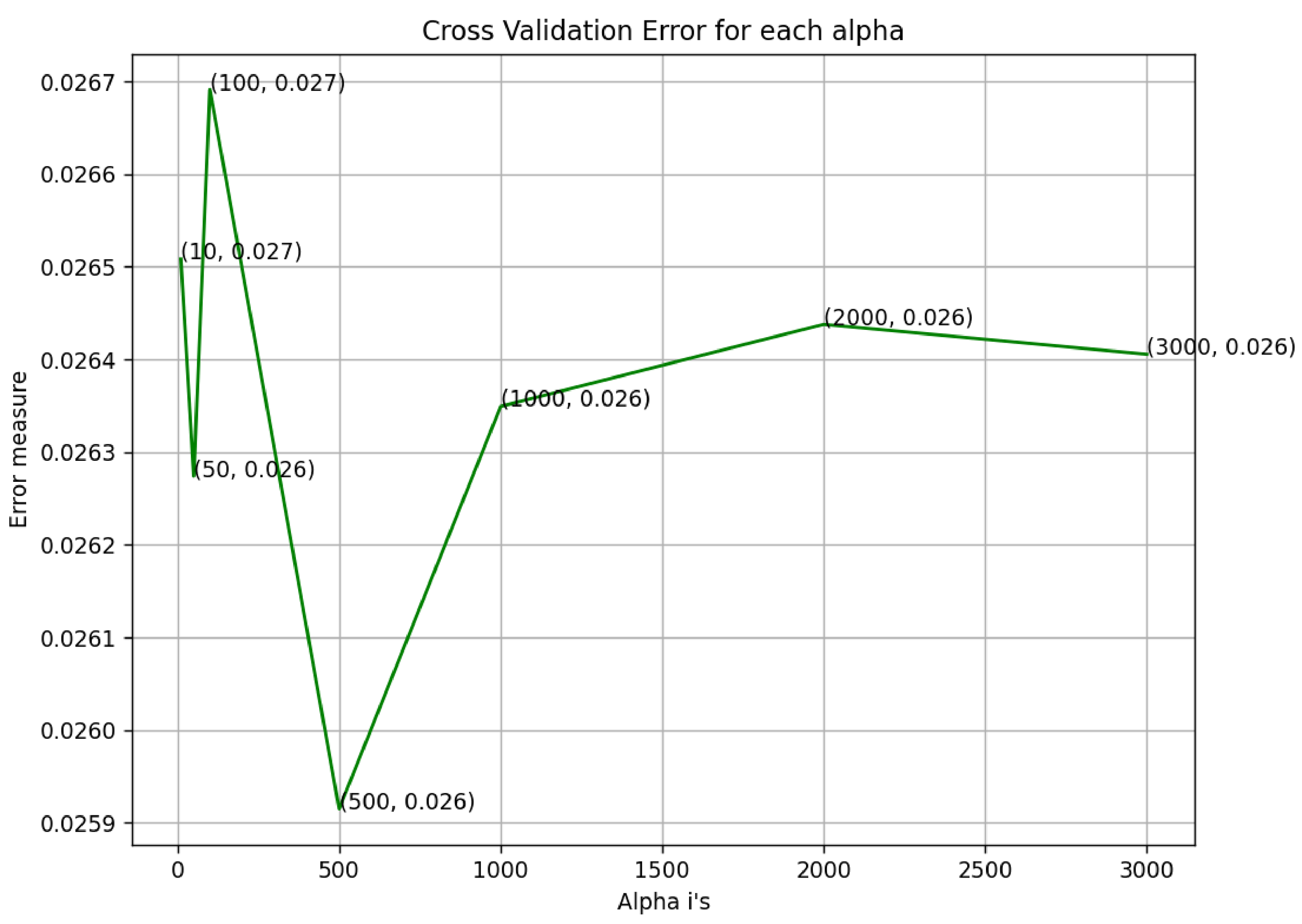
3.2.1 Random Forest Classifier with Asm-uni grams + ASM-Extracted image features + Byte uni gram

In [138]:

```
# --------------------------------
# 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/
# --------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
train_log_error_array=[]
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))
    print('Parameter tuning for alpha:',i,' Loss:',log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))

# for i in range(len(cv_log_error_array)):
#     print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])

best_alpha = np.argmin(cv_log_error_array)

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()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
```

```
Parameter tuning for alpha: 10  Loss: 0.026508445703490754
Parameter tuning for alpha: 50  Loss: 0.026274183912199087
Parameter tuning for alpha: 100  Loss: 0.026691217424787736
Parameter tuning for alpha: 500  Loss: 0.025914948184497147
Parameter tuning for alpha: 1000  Loss: 0.02634931812198413
Parameter tuning for alpha: 2000  Loss: 0.02643794647709983
Parameter tuning for alpha: 3000  Loss: 0.026405623759426712
```

<IPython.core.display.Javascript object>



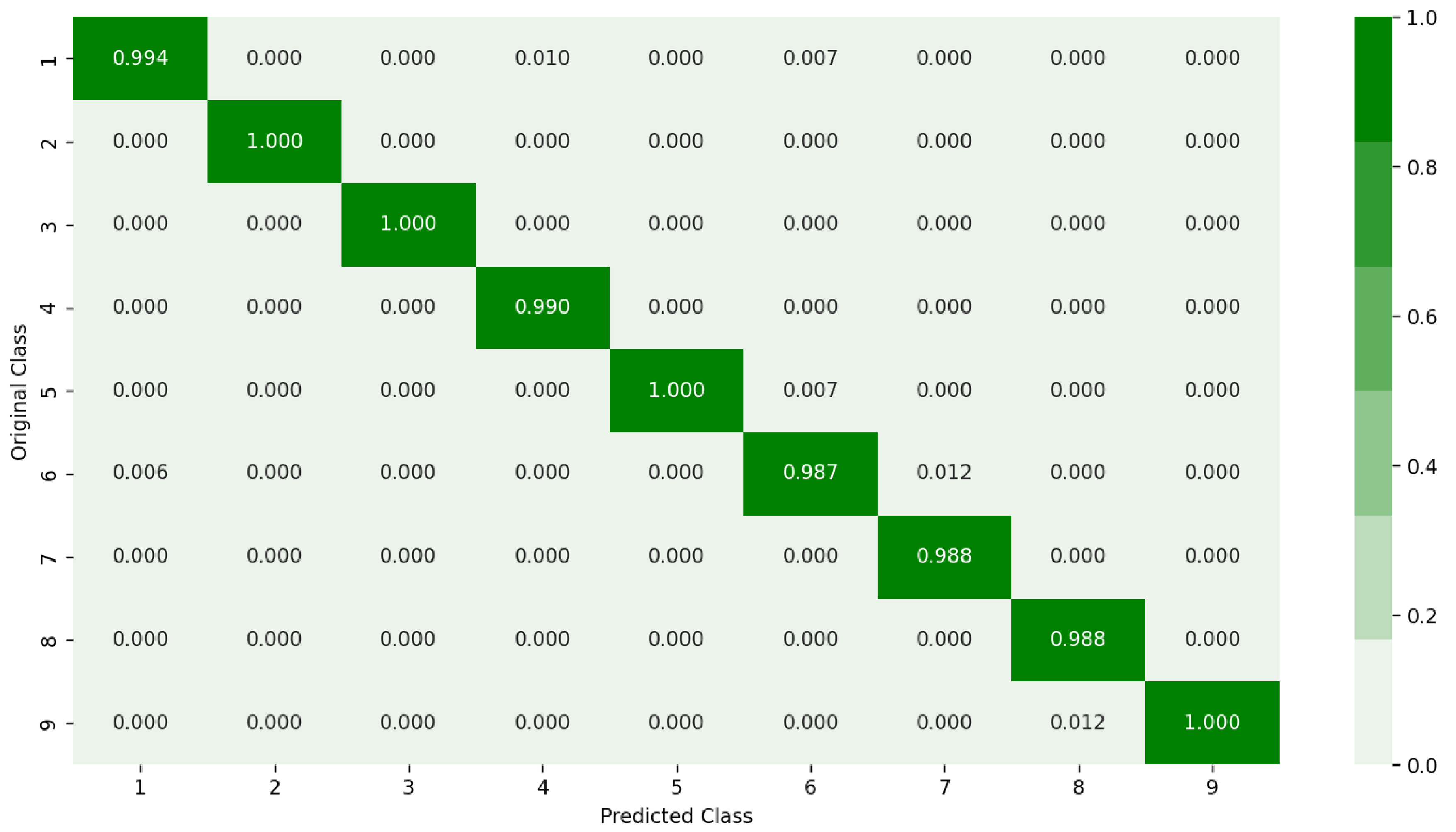

```
For values of best alpha =  500 The train log loss is: 0.010860945011193368
For values of best alpha =  500 The cross validation log loss is: 0.025914948184497147
For values of best alpha =  500 The test log loss is: 0.024136455428315266
```

In [139]:

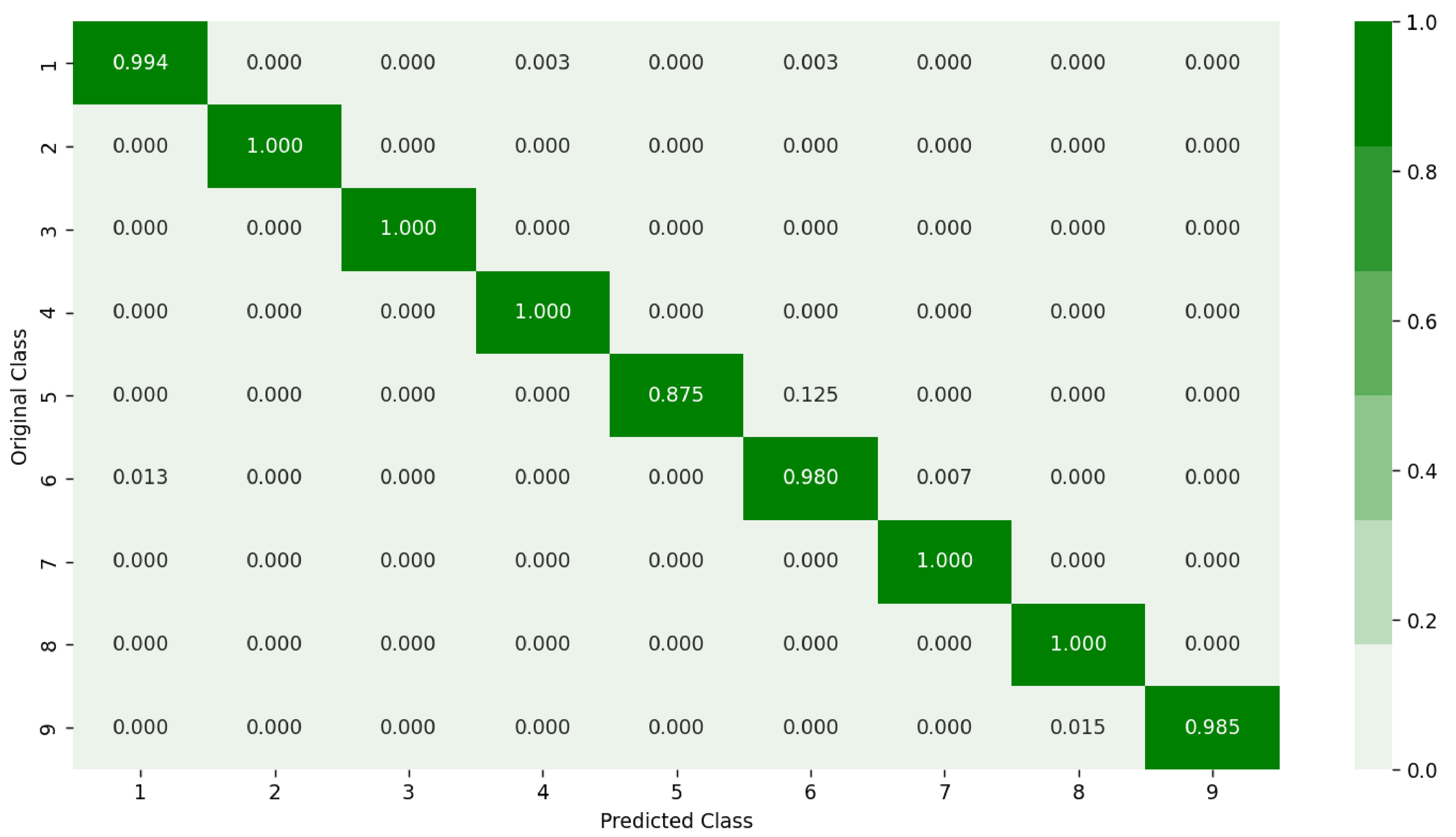
```
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Number of misclassified points  0.41398344066237347
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```


```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.2.2 Xgboost Classifier with best hyperparameters

In [25]:

```
%%time
x_cfl=XGBClassifier(silent=True,verbosity=0)

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10,12],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,cv=4)
random_cfl.fit(X_train,y_train)
```

```
Fitting 4 folds for each of 10 candidates, totalling 40 fits
[CV 1/4; 1/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1
[CV 1/4; 1/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1;, score=0.996 total time= 6.6min
[CV 2/4; 1/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1
[CV 2/4; 1/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1;, score=0.997 total time= 6.5min
[CV 3/4; 1/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1
[CV 3/4; 1/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1;, score=0.993 total time= 6.5min
[CV 4/4; 1/10] START colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1
[CV 4/4; 1/10] END colsample_bytree=0.5, learning_rate=0.1, max_depth=10, n_estimators=1000, subsample=0.1;, score=0.997 total time= 6.6min
[CV 1/4; 2/10] START colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1
[CV 1/4; 2/10] END colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1;, score=0.997 total time=11.4min
[CV 2/4; 2/10] START colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1
[CV 2/4; 2/10] END colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1;, score=0.997 total time=11.3min
[CV 3/4; 2/10] START colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1
[CV 3/4; 2/10] END colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1;, score=0.994 total time=10.9min
[CV 4/4; 2/10] START colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1
[CV 4/4; 2/10] END colsample_bytree=0.3, learning_rate=0.05, max_depth=12, n_estimators=1000, subsample=1;, score=0.995 total time=11.3min
[CV 1/4; 3/10] START colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3
[CV 1/4; 3/10] END colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3;, score=0.996 total time= 5.8min
[CV 2/4; 3/10] START colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3
[CV 2/4; 3/10] END colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3;, score=0.995 total time= 5.6min
[CV 3/4; 3/10] START colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3
[CV 3/4; 3/10] END colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3;, score=0.994 total time= 5.6min
[CV 4/4; 3/10] START colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3
[CV 4/4; 3/10] END colsample_bytree=0.5, learning_rate=0.03, max_depth=5, n_estimators=200, subsample=0.3;, score=0.995 total time= 5.7min
[CV 1/4; 4/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1
[CV 1/4; 4/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1;, score=0.997 total time=95.4min
[CV 2/4; 4/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1
[CV 2/4; 4/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1;, score=0.995 total time=61.4min
[CV 3/4; 4/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1
[CV 3/4; 4/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1;, score=0.996 total time=55.4min
[CV 4/4; 4/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1
[CV 4/4; 4/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=2000, subsample=1;, score=0.994 total time=56.0min
[CV 1/4; 5/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1
[CV 1/4; 5/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1;, score=0.991 total time= 2.3min
[CV 2/4; 5/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1
[CV 2/4; 5/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1;, score=0.989 total time= 2.3min
[CV 3/4; 5/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1
[CV 3/4; 5/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1;, score=0.991 total time= 2.3min
[CV 4/4; 5/10] START colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1
[CV 4/4; 5/10] END colsample_bytree=1, learning_rate=0.05, max_depth=5, n_estimators=200, subsample=0.1;, score=0.994 total time= 2.3min
[CV 1/4; 6/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5
[CV 1/4; 6/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5;, score=0.997 total time= 3.7min
[CV 2/4; 6/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5
[CV 2/4; 6/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5;, score=0.997 total time= 3.7min
[CV 3/4; 6/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5
[CV 3/4; 6/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5;, score=0.995 total time= 3.7min
[CV 4/4; 6/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5
[CV 4/4; 6/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=10, n_estimators=200, subsample=0.5;, score=0.995 total time= 3.7min
[CV 1/4; 7/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1
[CV 1/4; 7/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1;, score=0.997 total time= 8.6min
[CV 2/4; 7/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1
[CV 2/4; 7/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1;, score=0.997 total time= 8.5min
[CV 3/4; 7/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1
[CV 3/4; 7/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1;, score=0.994 total time= 8.2min
[CV 4/4; 7/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1
[CV 4/4; 7/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=5, n_estimators=1000, subsample=1;, score=0.995 total time= 8.7min
[CV 1/4; 8/10] START colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1
[CV 1/4; 8/10] END colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1;, score=0.991 total time=11.5min
[CV 2/4; 8/10] START colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1
[CV 2/4; 8/10] END colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1;, score=0.990 total time=11.6min
[CV 3/4; 8/10] START colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1
[CV 3/4; 8/10] END colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1;, score=0.992 total time=12.0min
[CV 4/4; 8/10] START colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1
[CV 4/4; 8/10] END colsample_bytree=1, learning_rate=0.01, max_depth=5, n_estimators=1000, subsample=0.1;, score=0.993 total time=11.9min
[CV 1/4; 9/10] START colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3
[CV 1/4; 9/10] END colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3;, score=0.991 total time= 2.4min
[CV 2/4; 9/10] START colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3
[CV 2/4; 9/10] END colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3;, score=0.991 total time= 2.4min
[CV 3/4; 9/10] START colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3
[CV 3/4; 9/10] END colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3;, score=0.991 total time= 2.4min
[CV 4/4; 9/10] START colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3
[CV 4/4; 9/10] END colsample_bytree=1, learning_rate=0.03, max_depth=3, n_estimators=100, subsample=0.3;, score=0.992 total time= 2.4min
[CV 1/4; 10/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1
[CV 1/4; 10/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1;, score=0.988 total time= 1.1min
[CV 2/4; 10/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1
[CV 2/4; 10/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1;, score=0.990 total time= 1.1min
[CV 3/4; 10/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1
[CV 3/4; 10/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1;, score=0.987 total time= 1.1min
[CV 4/4; 10/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1
[CV 4/4; 10/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=3, n_estimators=100, subsample=1;, score=0.991 total time= 1.1min
CPU times: user 14h 3min 2s, sys: 55.2 s, total: 14h 3min 58s
Wall time: 8h 6min 31s
```

Out[25]:

```
RandomizedSearchCV(cv=4,
                   estimator=XGBClassifier(base_score=None, booster=None,
                                           colsample_bylevel=None,
                                           colsample_bynode=None,
                                           colsample_bytree=None, gamma=None,
                                           gpu_id=None, importance_type='gain',
                                           interaction_constraints=None,
                                           learning_rate=None,
                                           max_delta_step=None, max_depth=None,
                                           min_child_weight=None, missing=nan,
                                           monotone_constraints=None,
                                           n_estimators=100,...
                                           random_state=None, reg_alpha=None,
                                           reg_lambda=None,
                                           scale_pos_weight=None, silent=True,
                                           subsample=None, tree_method=None,
                                           validate_parameters=None,
                                           verbosity=0),
                   param_distributions={'colsample_bytree': [0.1, 0.3, 0.5, 1],
                                        'learning_rate': [0.01, 0.03, 0.05, 0.1,
                                                          0.15, 0.2],
                                        'max_depth': [3, 5, 10, 12],
                                        'n_estimators': [100, 200, 500, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   verbose=10)
```

In [61]:

```
# files = pd.DataFrame(data=os.listdir('byteFiles'),columns=['ID'])
# files = pd.DataFrame(data = files['ID'].str.replace('.txt',''),columns=['ID'])
# labels = result[['ID','Class']]
```

In [65]:

```
# pd.merge(files,labels,on='ID',how='inner').to_csv('bi_gram_file_label_order.csv')
```

In [67]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 0.5, 'n_estimators': 200, 'max_depth': 10, 'learning_rate': 0.05, 'colsample_bytree': 0.5}
```

In [71]:

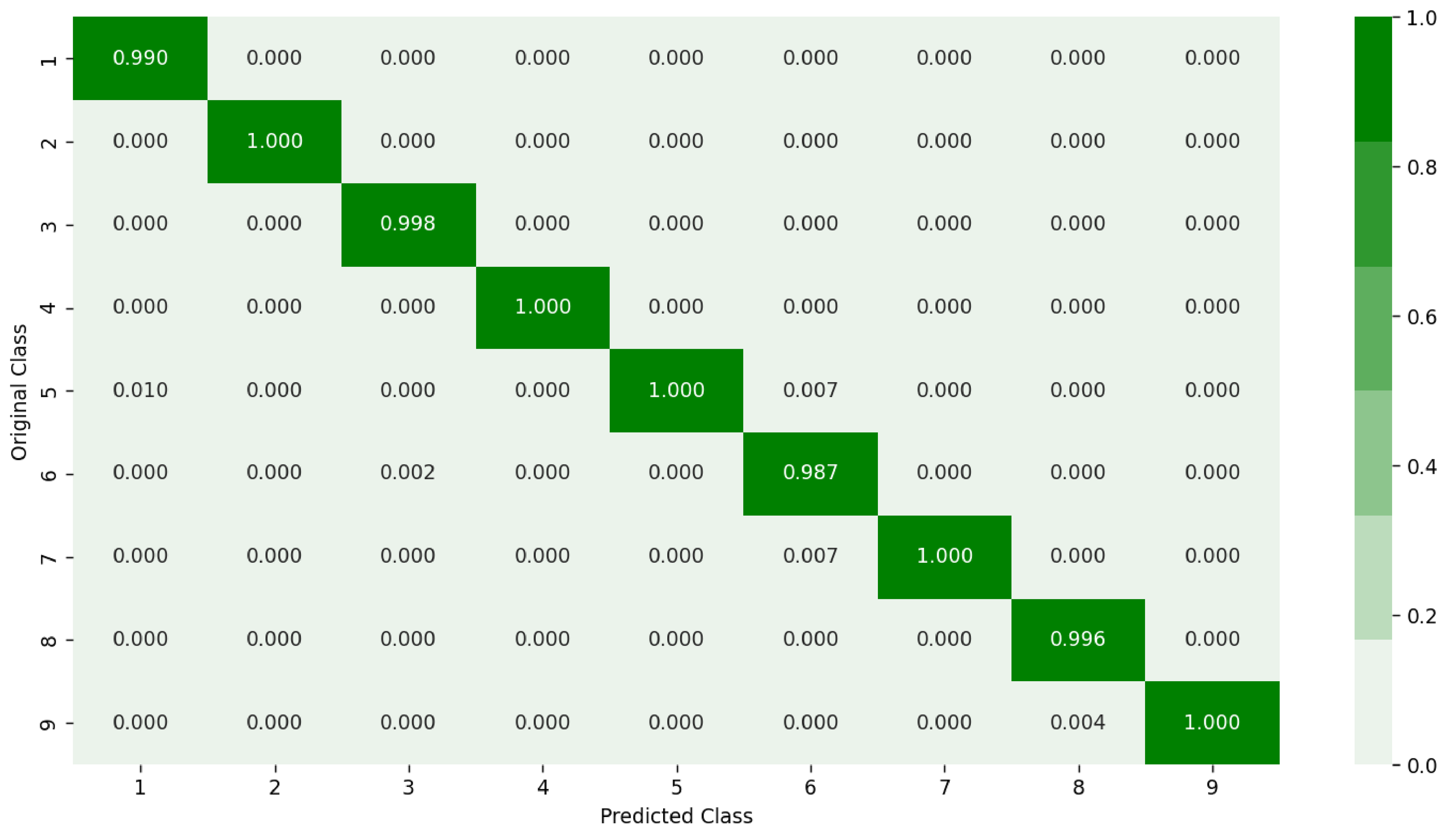
```
%%time
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This function is not thread safe.
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what-are-ensembles/
# -----------------------
x_cfl=XGBClassifier(n_estimators=200, subsample=0.5,learning_rate=0.05, colsample_bytree=0.5, max_depth=10)
x_cfl.fit(X_train,y_train)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train,y_train)

predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)

print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
```

```
train loss 0.011415465124124244
cv loss 0.016410075115980253)
test loss 0.01475890827104327
CPU times: user 45min 36s, sys: 714 ms, total: 45min 37s
Wall time: 22min 55s
```

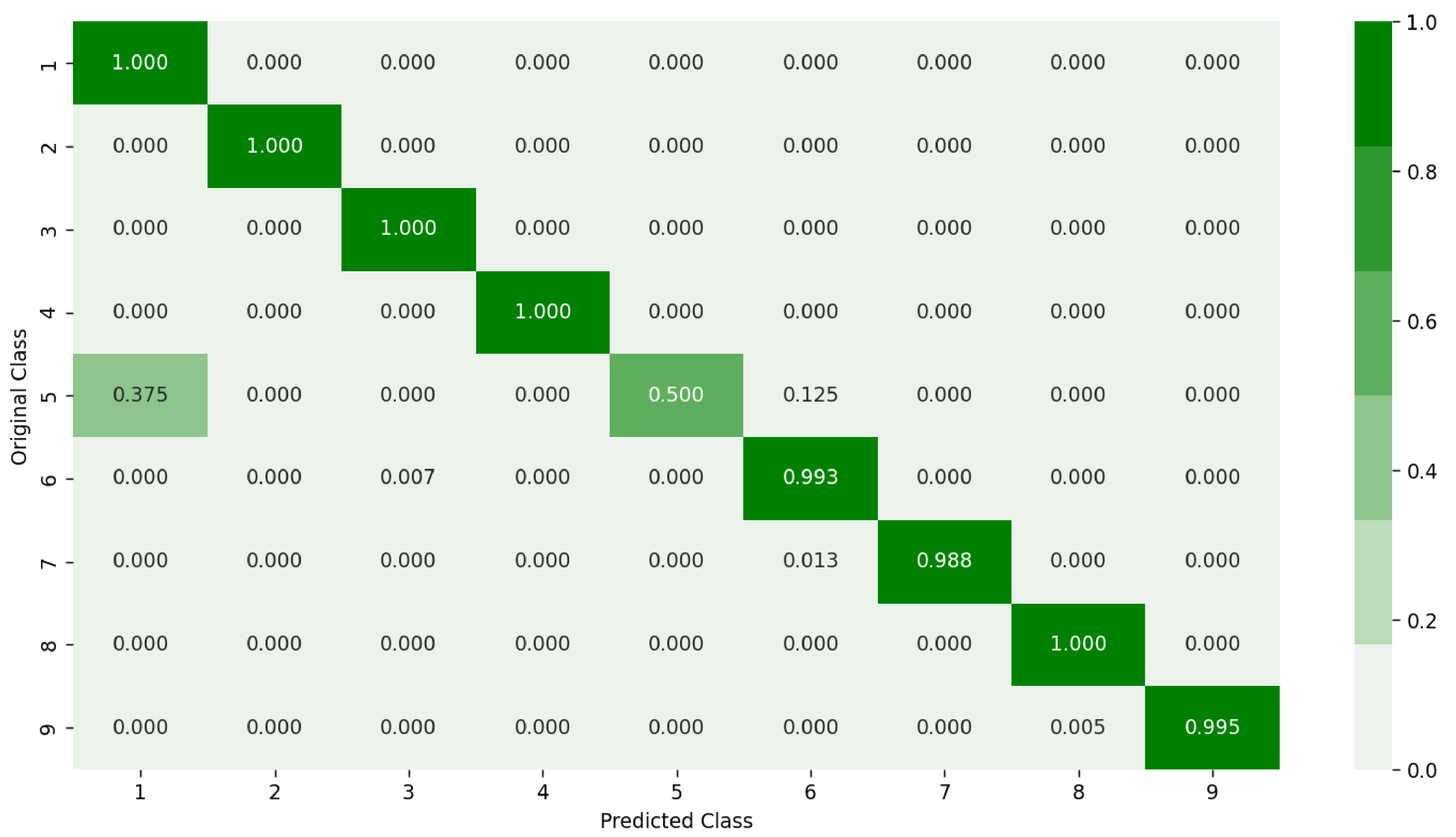
In [101]:
```python
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Number of misclassified points  0.20198712051517942
-------------------------------------------------- Confusion matrix --------------------------------------------------

&lt;IPython.core.display.Javascript object&gt;
```


```
-------------------------------------------------- Precision matrix --------------------------------------------------

&lt;IPython.core.display.Javascript object&gt;
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

&lt;IPython.core.display.Javascript object&gt;
```




```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.3 Byte- uni + ASM - Image Features

In [85]:
```python
X_merged = pd.merge(result.drop(columns=['size']),data_50,on='ID',how='inner')
Y_merged = X_merged['Class']
X_merged = X_merged.drop(columns=['ID'])
print('shape of x',X_merged.shape,' y:',Y_merged.shape)
```

```
shape of x (10868, 759)  y: (10868,)
```

In [86]:
```python
X_merged.columns
```

Out[86]:
```
Index(['0', '1', '2', '3', '4', '5', '6', '7', '8', '9',
       ...
       'ASM_990', 'ASM_991', 'ASM_992', 'ASM_993', 'ASM_994', 'ASM_995',
       'ASM_996', 'ASM_997', 'ASM_998', 'ASM_999'],
      dtype='object', length=759)
```

In [87]:
```python
### train test split
X_train, X_test, y_train, y_test = train_test_split(X_merged, Y_merged,stratify=Y_merged,test_size=0.20)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_train,test_size=0.20)
```

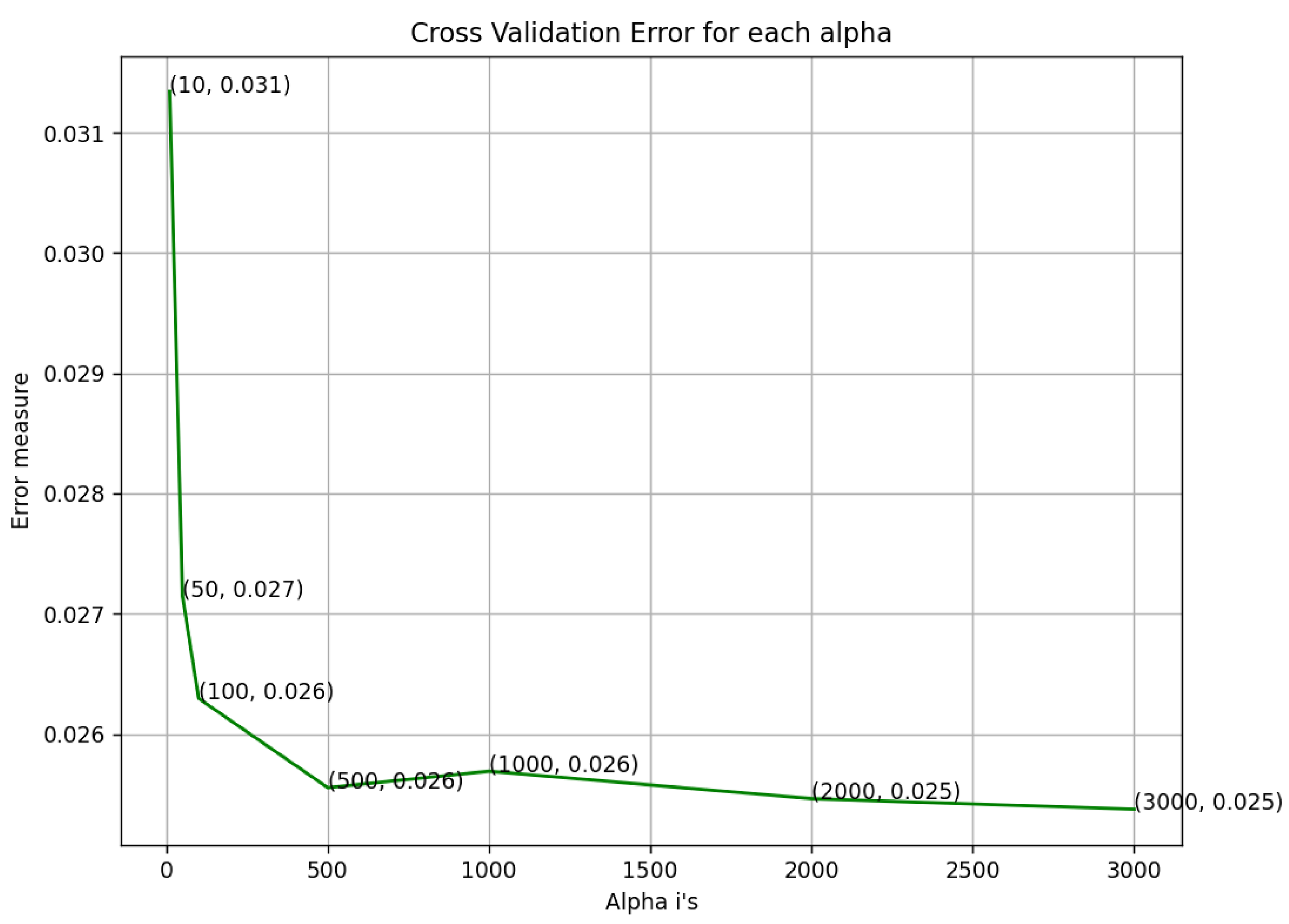
In [88]:
```python
X_train = X_train.astype(float)
X_test = X_test.astype(float)
X_cv = X_cv.astype(float)
```

3.3.1 Random Forest Classifier for ASM-Extracted image features + Byte uni gram

In [89]:

```
# --------------------------------
# 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/
# --------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
train_log_error_array=[]
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    cv_log_error_array.append(log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))
    print('Parameter tuning for alpha:',i,' Loss:',log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15))

# for i in range(len(cv_log_error_array)):
#     print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])


best_alpha = np.argmin(cv_log_error_array)

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()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
```

```
Parameter tuning for alpha: 10  Loss: 0.0313426542602312
Parameter tuning for alpha: 50  Loss: 0.02714685745594213
Parameter tuning for alpha: 100  Loss: 0.026295166349999472
Parameter tuning for alpha: 500  Loss: 0.025554102636726757
Parameter tuning for alpha: 1000  Loss: 0.025690196753958717
Parameter tuning for alpha: 2000  Loss: 0.025462073418468168
Parameter tuning for alpha: 3000  Loss: 0.025374208756105795

<IPython.core.display.Javascript object>
```

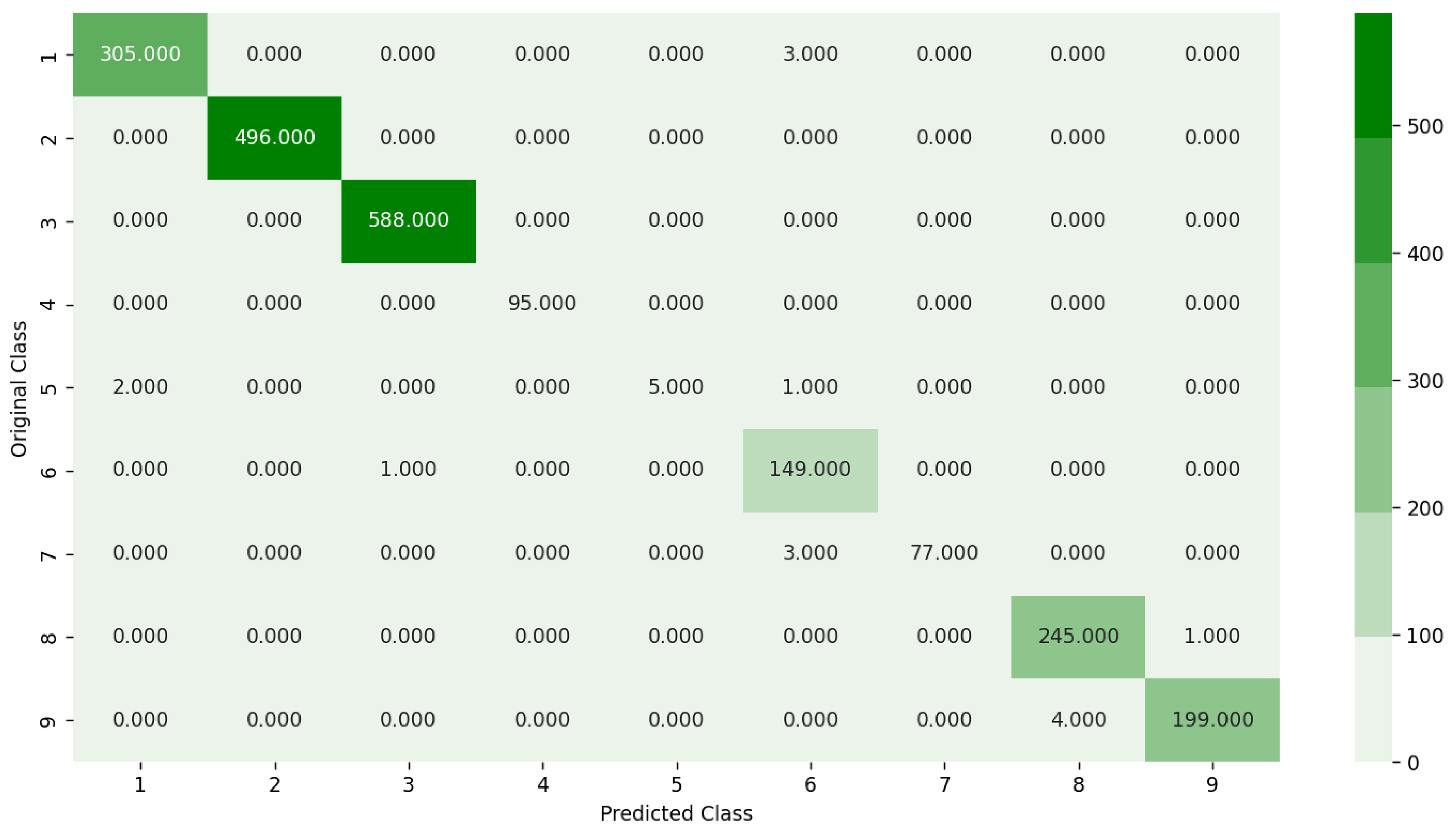



```
For values of best alpha =  3000 The train log loss is: 0.010686512051691533
For values of best alpha =  3000 The cross validation log loss is: 0.025374208756105795
For values of best alpha =  3000 The test log loss is: 0.03933044530569612
```

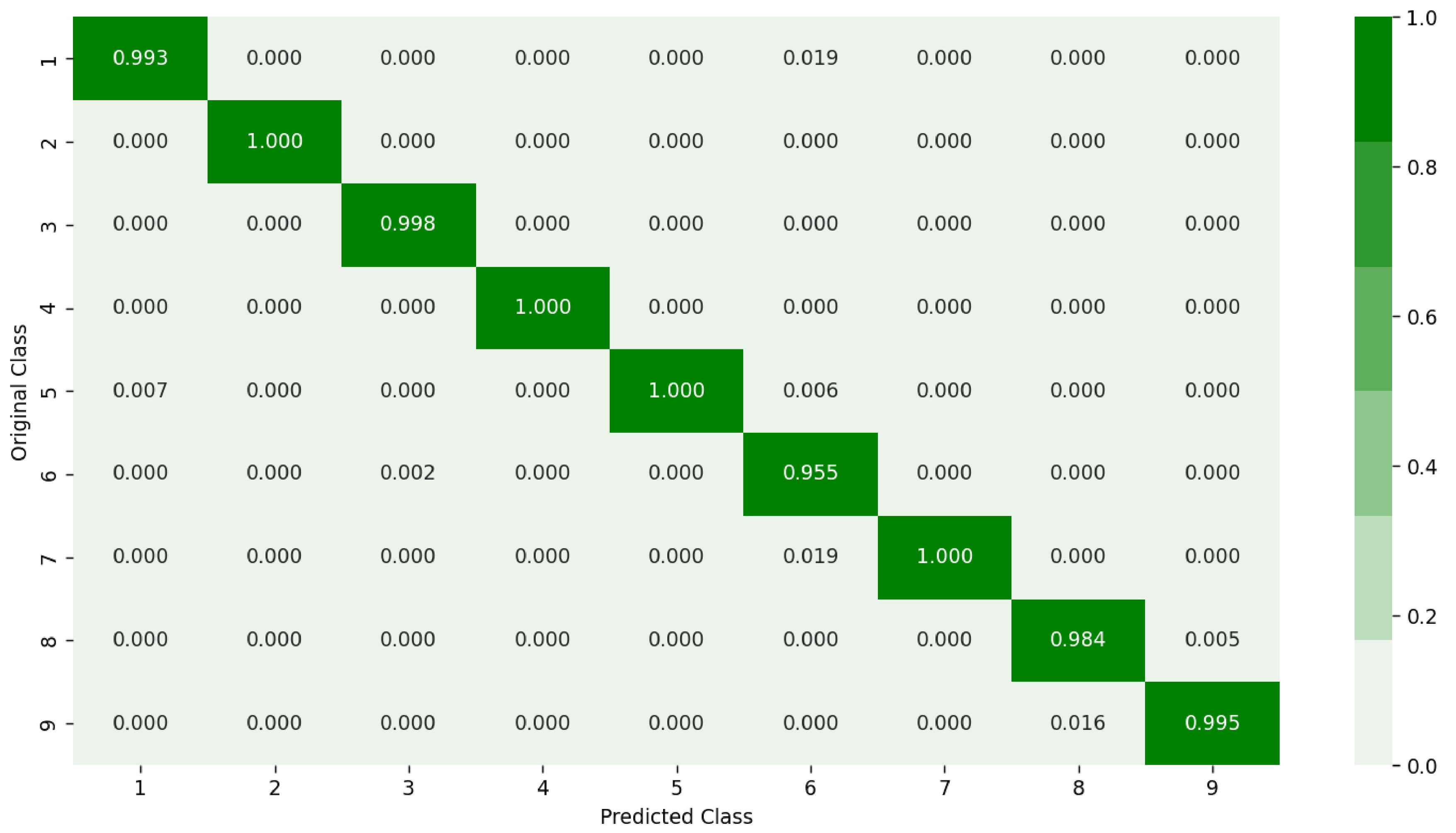
In [90]:

```
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Number of misclassified points  0.6899724011039559
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```


```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

3.3.2 XgBoost Classifier with best params for ASM-Extracted image features + Byte uni gram

In [103]:

```
%%time
x_cfl=XGBClassifier(silent=True,verbosity=0)

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10,12],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,cv=4)
random_cfl.fit(X_train,y_train)
```

```
Fitting 4 folds for each of 10 candidates, totalling 40 fits
[CV 1/4; 1/10] START colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1
[CV 1/4; 1/10] END colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1;, score=0.999 total time=  39.7s
[CV 2/4; 1/10] START colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1
[CV 2/4; 1/10] END colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1;, score=0.999 total time=  40.1s
[CV 3/4; 1/10] START colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1
[CV 3/4; 1/10] END colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1;, score=0.998 total time=  39.5s
[CV 4/4; 1/10] START colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1
[CV 4/4; 1/10] END colsample_bytree=0.5, learning_rate=0.2, max_depth=5, n_estimators=500, subsample=0.1;, score=1.000 total time= 1.3min
[CV 1/4; 2/10] START colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5
[CV 1/4; 2/10] END colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5;, score=0.998 total time= 2.8min
[CV 2/4; 2/10] START colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5
[CV 2/4; 2/10] END colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5;, score=1.000 total time= 2.9min
[CV 3/4; 2/10] START colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5
[CV 3/4; 2/10] END colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5;, score=0.999 total time= 2.8min
[CV 4/4; 2/10] START colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5
[CV 4/4; 2/10] END colsample_bytree=1, learning_rate=0.15, max_depth=10, n_estimators=200, subsample=0.5;, score=1.000 total time= 2.8min
[CV 1/4; 3/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3
[CV 1/4; 3/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3;, score=0.999 total time=17.1min
[CV 2/4; 3/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3
[CV 2/4; 3/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3;, score=1.000 total time=17.2min
[CV 3/4; 3/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3
[CV 3/4; 3/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3;, score=0.999 total time=17.1min
[CV 4/4; 3/10] START colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3
[CV 4/4; 3/10] END colsample_bytree=1, learning_rate=0.01, max_depth=12, n_estimators=1000, subsample=0.3;, score=1.000 total time=17.1min
[CV 1/4; 4/10] START colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5
[CV 1/4; 4/10] END colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5;, score=0.997 total time= 1.7min
[CV 2/4; 4/10] START colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5
[CV 2/4; 4/10] END colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5;, score=0.998 total time= 1.7min
[CV 3/4; 4/10] START colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5
[CV 3/4; 4/10] END colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5;, score=0.996 total time= 1.7min
[CV 4/4; 4/10] START colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5
[CV 4/4; 4/10] END colsample_bytree=0.1, learning_rate=0.03, max_depth=5, n_estimators=500, subsample=0.5;, score=0.997 total time= 1.7min
[CV 1/4; 5/10] START colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1
[CV 1/4; 5/10] END colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1;, score=0.999 total time=  29.3s
[CV 2/4; 5/10] START colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1
[CV 2/4; 5/10] END colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1;, score=0.997 total time=  29.7s
[CV 3/4; 5/10] START colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1
[CV 3/4; 5/10] END colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1;, score=0.997 total time=  29.4s
[CV 4/4; 5/10] START colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1
[CV 4/4; 5/10] END colsample_bytree=0.3, learning_rate=0.15, max_depth=12, n_estimators=200, subsample=0.1;, score=0.998 total time=  29.6s
[CV 1/4; 6/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1
[CV 1/4; 6/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1;, score=0.999 total time= 2.1min
[CV 2/4; 6/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1
[CV 2/4; 6/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1;, score=1.000 total time= 2.1min
[CV 3/4; 6/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1
[CV 3/4; 6/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1;, score=0.999 total time= 2.1min
[CV 4/4; 6/10] START colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1
[CV 4/4; 6/10] END colsample_bytree=0.3, learning_rate=0.1, max_depth=3, n_estimators=500, subsample=1;, score=0.999 total time= 2.1min
[CV 1/4; 7/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1
[CV 1/4; 7/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1;, score=0.995 total time= 1.4min
[CV 2/4; 7/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1
[CV 2/4; 7/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1;, score=0.997 total time= 1.4min
[CV 3/4; 7/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1
[CV 3/4; 7/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1;, score=0.994 total time= 1.4min
[CV 4/4; 7/10] START colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1
[CV 4/4; 7/10] END colsample_bytree=0.3, learning_rate=0.01, max_depth=5, n_estimators=100, subsample=1;, score=0.998 total time= 1.4min
[CV 1/4; 8/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1
[CV 1/4; 8/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1;, score=0.998 total time= 1.5min
[CV 2/4; 8/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1
[CV 2/4; 8/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1;, score=1.000 total time= 1.5min
[CV 3/4; 8/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1
[CV 3/4; 8/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1;, score=0.999 total time= 1.5min
[CV 4/4; 8/10] START colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1
[CV 4/4; 8/10] END colsample_bytree=0.5, learning_rate=0.15, max_depth=3, n_estimators=200, subsample=1;, score=1.000 total time= 1.5min
[CV 1/4; 9/10] START colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3
[CV 1/4; 9/10] END colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3;, score=0.994 total time= 1.6min
[CV 2/4; 9/10] START colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3
[CV 2/4; 9/10] END colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3;, score=0.992 total time= 1.6min
[CV 3/4; 9/10] START colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3
[CV 3/4; 9/10] END colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3;, score=0.989 total time= 1.6min
[CV 4/4; 9/10] START colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3
[CV 4/4; 9/10] END colsample_bytree=0.1, learning_rate=0.01, max_depth=5, n_estimators=500, subsample=0.3;, score=0.996 total time= 1.6min
[CV 1/4; 10/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1
[CV 1/4; 10/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1;, score=0.997 total time=  34.2s
[CV 2/4; 10/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1
[CV 2/4; 10/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1;, score=0.993 total time=  34.0s
[CV 3/4; 10/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1
[CV 3/4; 10/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1;, score=0.993 total time=  33.8s
[CV 4/4; 10/10] START colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1
[CV 4/4; 10/10] END colsample_bytree=0.5, learning_rate=0.05, max_depth=3, n_estimators=100, subsample=0.1;, score=0.996 total time=  34.0s
CPU times: user 4h 45min 26s, sys: 15.3 s, total: 4h 45min 41s
Wall time: 2h 23min 39s
```

Out[103]:

```
RandomizedSearchCV(cv=4,
                   estimator=XGBClassifier(base_score=None, booster=None,
                                           colsample_bylevel=None,
                                           colsample_bynode=None,
                                           colsample_bytree=None, gamma=None,
                                           gpu_id=None, importance_type='gain',
                                           interaction_constraints=None,
                                           learning_rate=None,
                                           max_delta_step=None, max_depth=None,
                                           min_child_weight=None, missing=nan,
                                           monotone_constraints=None,
                                           n_estimators=100,...
                                           random_state=None, reg_alpha=None,
                                           reg_lambda=None,
                                           scale_pos_weight=None, silent=True,
                                           subsample=None, tree_method=None,
                                           validate_parameters=None,
                                           verbosity=0),
                   param_distributions={'colsample_bytree': [0.1, 0.3, 0.5, 1],
                                        'learning_rate': [0.01, 0.03, 0.05, 0.1,
                                                          0.15, 0.2],
                                        'max_depth': [3, 5, 10, 12],
                                        'n_estimators': [100, 200, 500, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   verbose=10)
```

In [106]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 0.3, 'n_estimators': 1000, 'max_depth': 12, 'learning_rate': 0.01, 'colsample_bytree': 1}
```

In [125]:

```
%%time
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This function is not thread safe.
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what-are-ensembles/
# -----------------------
x_cfl=XGBClassifier(n_estimators=1000, subsample=0.3,learning_rate=0.01, colsample_bytree=1, max_depth=12)
x_cfl.fit(X_train,y_train)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train,y_train)

predict_y =random_cfl.best_estimator_.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = random_cfl.best_estimator_.predict_proba(X_cv)

print ('cv loss',log_loss(y_cv, predict_y))
predict_y = random_cfl.best_estimator_.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
```

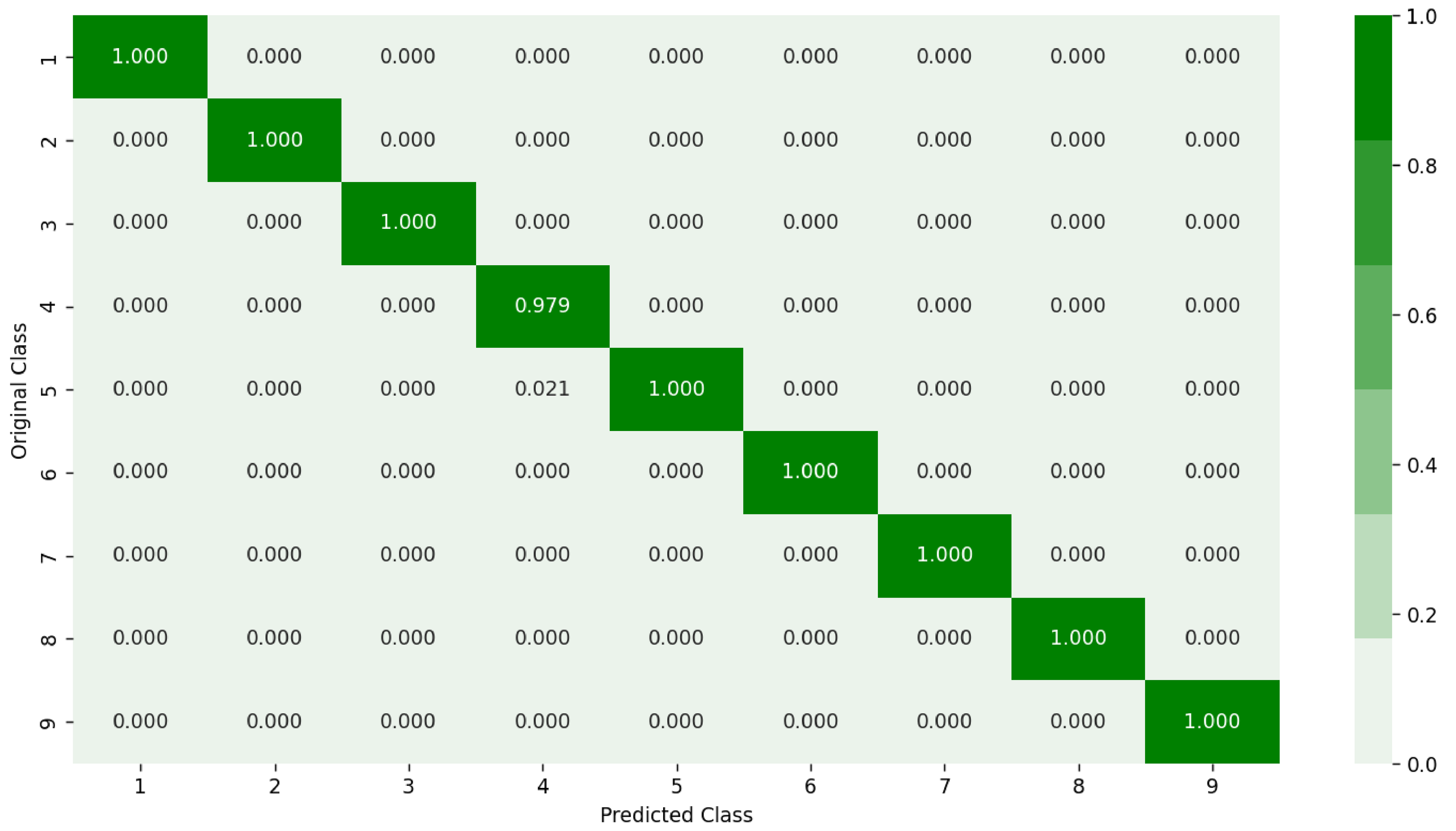
```
train loss 0.002346527399823316
cv loss 0.004251100181973078
test loss 0.007054805073482494
CPU times: user 1.58 s, sys: 5.76 ms, total: 1.59 s
Wall time: 802 ms
```

In [126]:

```
# predict_y is test prediction
predicted_y =np.argmax(predict_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Number of misclassified points  -0.028003679852805885
-------------------------------------------------- Confusion matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```


```
-------------------------------------------------- Precision matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```




```
Sum of columns in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
-------------------------------------------------- Recall matrix --------------------------------------------------

<IPython.core.display.Javascript object>
```


```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

Final Summary

In [139]:

```
from prettytable import PrettyTable
table = PrettyTable()
table.field_names  = ['Model', 'Features','Best HyperParameter','Test Log Loss']

table.add_row(['Random Forest Classifier','Byte-Bigrams',500,0.0538])
table.add_row(['Random Forest Classifier','Byte-Bigrams + ASM Image Features',50,0.0206])
table.add_row(['Random Forest Classifier','ASM-unigrams + ASM Image Features',100,0.0238])
table.add_row(['Random Forest Classifier','Byte-unigrams + ASM Image Features',3000,0.0393])
table.add_row(['Random Forest Classifier','Byte-unigrams + ASM Image Features + ASM-unigrams',500,0.0241])
table.add_row(['','','',''])
table.add_row(['XGB(best_params) Classifier','Byte-Bigrams','500,max_depth=3',0.034])
table.add_row(['XGB(best_params) Classifier','Byte-Bigrams + ASM Image Features',500,0.034])
table.add_row(['XGB(best_params) Classifier','ASM-unigrams + ASM Image Features','500,max_depth=10',0.0253])
table.add_row(['XGB(best_params) Classifier','Byte-unigrams + ASM Image Features',1000,0.007])
table.add_row(['XGB(best_params) Classifier','Byte-unigrams + ASM Image Features + ASM-unigrams','200,max_depth=10',0.0147])

table.add_row(['XGB Classifier','ASM-unigrams + ASM image features',500,0.0238])

print(table)
```

```
+-----------------------------+---------------------------------------------------+---------------------+---------------+
|            Model            |                      Features                     | Best HyperParameter | Test Log Loss |
+-----------------------------+---------------------------------------------------+---------------------+---------------+
|   Random Forest Classifier  |                    Byte-Bigrams                   |         500         |     0.0538    |
|   Random Forest Classifier  |         Byte-Bigrams + ASM Image Features         |          50         |     0.0206    |
|   Random Forest Classifier  |         ASM-unigrams + ASM Image Features         |         100         |     0.0238    |
|   Random Forest Classifier  |         Byte-unigrams + ASM Image Features        |         3000        |     0.0393    |
|   Random Forest Classifier  | Byte-unigrams + ASM Image Features + ASM-unigrams |         500         |     0.0241    |
|                             |                                                   |                     |               |
| XGB(best_params) Classifier |                    Byte-Bigrams                   |   500,max_depth=3   |     0.034     |
| XGB(best_params) Classifier |         Byte-Bigrams + ASM Image Features         |         500         |      0.05     |
| XGB(best_params) Classifier |         ASM-unigrams + ASM Image Features         |   500,max_depth=10  |     0.0253    |
| XGB(best_params) Classifier |         Byte-unigrams + ASM Image Features        |         1000        |     0.007     |
| XGB(best_params) Classifier | Byte-unigrams + ASM Image Features + ASM-unigrams |   200,max_depth=10  |     0.0147    |
|        XGB Classifier       |         ASM-unigrams + ASM image features         |         500         |     0.0238    |
+-----------------------------+---------------------------------------------------+---------------------+---------------+
```

Conclusion :

Carried out the following note-book in the following sequence--

- Created byte-bigrams from the byte files and stored the generated 66000 unique keys in pickle file.
- created bi-gram datamatrix with(10868 rows,~66000 columns).
- Using Randomforest classifier performed feature selection and took top 200 bibram features.
- Created ASM image features then chi square test ,selected optimal features which stores 50% variance.
- Trained multiple models like (RandomForest,XGB) models combination of features like
  - Byte-Bigrams
  - Byte-Bigrams + ASM Image Features
  - ASM-unigrams + ASM Image Features
  - Byte-unigrams + ASM Image Features
  - Byte-unigrams + ASM Image Features + ASM-unigrams

XGB classifier with best parameters featureized using Byte-unigrams + ASM Image Features performed best on test data reducing loss to 0.007