Microsoft Malware detection

1.Business/Real-world Problem

1.1. What is Malware?

The term malware is a contraction of malicious software. Put simply, malware is any piece of software that was written with the intent of doing harm to data, devices or to people.
Source: https://www.avg.com/en/signal/what-is-malware (https://www.avg.com/en/signal/what-is-malware)

1.2. Problem Statement

In the past few years, the malware industry has grown very rapidly that, the syndicates invest heavily in technologies to evade traditional protection, forcing the anti-malware groups/communities to build more robust softwares to detect and terminate these attacks. The major part of protecting a computer system from a malware attack is to **identify whether a given piece of file/software is a malware.**

1.3 Source/Useful Links

Microsoft has been very active in building anti-malware products over the years and it runs it's anti-malware utilities over 150 million computers around the world. This generates tens of millions of daily data points to be analyzed as potential malware. In order to be effective in analyzing and classifying such large amounts of data, we need to be able to group them into groups and identify their respective families.

This dataset provided by Microsoft contains about 9 classes of malware. ,

Source: https://www.kaggle.com/c/malware-classification

1.4. Real-world/Business objectives and constraints.

1. **Minimize multi-class error.**
2. **Multi-class probability estimates.**
3. **Malware detection should not take hours and block the user's computer. It should fininsh in a few seconds or a minute.**

2. Machine Learning Problem

2.1. Data

2.1.1. Data Overview

- **Source : https://www.kaggle.com/c/malware-classification/data**
- **For every malware, we have two files**
  1. **.asm file (read more: https://www.reviversoft.com/file-extensions/asm)**
  2. **.bytes file (the raw data contains the hexadecimal representation of the file's binary content, without the PE header)**

- **Total train dataset consist of 200GB data out of which 50Gb of data is .bytes files and 150GB of data is .asm files:**
- **Lots of Data for a single-box/computer.**
- **There are total 10,868 .bytes files and 10,868 asm files total 21,736 files**
- **There are 9 types of malwares (9 classes) in our give data**
- **Types of Malware:**
  1. **Ramnit**
  2. **Lollipop**
  3. **Kelihos_ver3**
  4. **Vundo**
  5. **Simda**
  6. **Tracur**
  7. **Kelihos_ver1**
  8. **Obfuscator.ACY**
  9. **Gatak**

2.1.2. Example Data Point

.asm file

```
.text:00401000                                     assume es:nothing, ss:nothing, d
s:_data, fs:nothing, gs:nothing
.text:00401000 56                                  push    esi
.text:00401001 8D 44 24 08                             lea     eax, [esp+8]
.text:00401005 50                                  push    eax
.text:00401006 8B F1                                   mov     esi, ecx
.text:00401008 E8 1C 1B 00 00                              call    ??0exception@std
@@QAE@ABQBD@Z ; std::exception::exception(char const * const &)
.text:0040100D C7 06 08 BB 42 00                           mov     dword ptr [esi],
offset off_42BB08
.text:00401013 8B C6                                   mov     eax, esi
.text:00401015 5E                                  pop     esi
.text:00401016 C2 04 00                                retn    4
.text:00401016                            ; --------------------------------------
-------------------------------------
.text:00401019 CC CC CC CC CC CC CC                        align 10h
.text:00401020 C7 01 08 BB 42 00                           mov     dword ptr [ecx],
offset off_42BB08
.text:00401026 E9 26 1C 00 00                              jmp     sub_402C51
.text:00401026                            ; --------------------------------------
-------------------------------------
.text:0040102B CC CC CC CC CC                              align 10h
.text:00401030 56                                  push    esi
.text:00401031 8B F1                                   mov     esi, ecx
.text:00401033 C7 06 08 BB 42 00                           mov     dword ptr [esi],
offset off_42BB08
.text:00401039 E8 13 1C 00 00                              call    sub_402C51
.text:0040103E F6 44 24 08 01                              test    byte ptr [esp+
8], 1
.text:00401043 74 09                                   jz      short loc_40104E
.text:00401045 56                                  push    esi
.text:00401046 E8 6C 1E 00 00                              call    ??3@YAXPAX@Z
; operator delete(void *)
.text:0040104B 83 C4 04                                add     esp, 4
.text:0040104E
.text:0040104E                            loc_40104E:                 ; CODE XREF:
.text:00401043□j
.text:0040104E 8B C6                                   mov     eax, esi
.text:00401050 5E                                  pop     esi
.text:00401051 C2 04 00                                retn    4
.text:00401051                            ; --------------------------------------
-------------------------------------
```

.bytes file

```
00401000 00 00 80 40 40 28 00 1C 02 42 00 C4 00 20 04 20
00401010 00 00 20 09 2A 02 00 00 00 00 8E 10 41 0A 21 01
00401020 40 00 02 01 00 90 21 00 32 40 00 1C 01 40 C8 18
00401030 40 82 02 63 20 00 00 09 10 01 02 21 00 82 00 04
00401040 82 20 08 83 00 08 00 00 00 00 02 00 60 80 10 80
00401050 18 00 00 20 A9 00 00 00 00 04 04 78 01 02 70 90
00401060 00 02 00 08 20 12 00 00 00 40 10 00 80 00 40 19
00401070 00 00 00 00 11 20 80 04 80 10 00 20 00 00 25 00
00401080 00 00 01 00 00 04 00 10 02 C1 80 80 00 20 20 00
00401090 08 A0 01 01 44 28 00 00 08 10 20 00 02 08 00 00
004010A0 00 40 00 00 00 34 40 40 00 04 00 08 80 08 00 08
004010B0 10 00 40 00 68 02 40 04 E1 00 28 14 00 08 20 0A
004010C0 06 01 02 00 40 00 00 00 00 00 00 20 00 02 00 04
004010D0 80 18 90 00 00 10 A0 00 45 09 00 10 04 40 44 82
004010E0 90 00 26 10 00 00 04 00 82 00 00 00 20 40 00 00
004010F0 B4 00 00 40 00 02 20 25 08 00 00 00 00 00 00 00
00401100 08 00 00 50 00 08 40 50 00 02 06 22 08 85 30 00
00401110 00 80 00 80 60 00 09 00 04 20 00 00 00 00 00 00
00401120 00 82 40 02 00 11 46 01 4A 01 8C 01 E6 00 86 10
00401130 4C 01 22 00 64 00 AE 01 EA 01 2A 11 E8 10 26 11
00401140 4E 11 8E 11 C2 00 6C 00 0C 11 60 01 CA 00 62 10
00401150 6C 01 A0 11 CE 10 2C 11 4E 10 8C 00 CE 01 AE 01
00401160 6C 10 6C 11 A2 01 AE 00 46 11 EE 10 22 00 A8 00
00401170 EC 01 08 11 A2 01 AE 10 6C 00 6E 00 AC 11 8C 00
00401180 EC 01 2A 10 2A 01 AE 00 40 00 C8 10 48 01 4E 11
00401190 0E 00 EC 11 24 10 4A 10 04 01 C8 11 E6 01 C2 00
```

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

2.2.1. Type of Machine Learning Problem

There are nine different classes of malware that we need to classify a given a data point => Multi class classification problem

2.2.2. Performance Metric

Source: [https://www.kaggle.com/c/malware-classification#evaluation (https://www.kaggle.com/c/malware-classification#evaluation)](https://www.kaggle.com/c/malware-classification#evaluation)

Metric(s):

- **Multi class log-loss**
- **Confusion matrix**

2.2.3. Machine Learing Objectives and Constraints

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

Constraints:

- **Class probabilities are needed.**
- **Penalize the errors in class probabilites => Metric is Log-loss.**
- **Some Latency constraints.**

2.3. Train and Test Dataset

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

2.4. Useful blogs, videos and reference papers

http://blog.kaggle.com/2015/05/26/microsoft-malware-winners-interview-1st-place-no-to-overfitting/
https://arxiv.org/pdf/1511.04317.pdf
First place solution in Kaggle competition: https://www.youtube.com/watch?v=VLQTRILGz5Y
https://github.com/dchad/malware-detection
http://vizsec.org/files/2011/Nataraj.pdf
https://www.dropbox.com/sh/gfqzv0ckgs4l1bf/AAB6EelnEjvvuQg2nu_plB6ua?dl=0
" Cross validation is more trustworthy than domain knowledge."

In [0]:
```
!pip install kaggle
```

```
Requirement already satisfied: kaggle in /usr/local/lib/python3.6/dist-packag
es (1.5.5)
Requirement already satisfied: requests in /usr/local/lib/python3.6/dist-pack
ages (from kaggle) (2.21.0)
Requirement already satisfied: python-slugify in /usr/local/lib/python3.6/dis
t-packages (from kaggle) (3.0.3)
Requirement already satisfied: urllib3<1.25,>=1.21.1 in /usr/local/lib/python
3.6/dist-packages (from kaggle) (1.24.3)
Requirement already satisfied: certifi in /usr/local/lib/python3.6/dist-packa
ges (from kaggle) (2019.6.16)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.6/di
st-packages (from kaggle) (2.5.3)
Requirement already satisfied: tqdm in /usr/local/lib/python3.6/dist-packages
(from kaggle) (4.28.1)
Requirement already satisfied: six>=1.10 in /usr/local/lib/python3.6/dist-pac
kages (from kaggle) (1.12.0)
Requirement already satisfied: chardet<3.1.0,>=3.0.2 in /usr/local/lib/python
3.6/dist-packages (from requests->kaggle) (3.0.4)
Requirement already satisfied: idna<2.9,>=2.5 in /usr/local/lib/python3.6/dis
t-packages (from requests->kaggle) (2.8)
Requirement already satisfied: text-unidecode==1.2 in /usr/local/lib/python3.
6/dist-packages (from python-slugify->kaggle) (1.2)
```

In [0]:
```
!mkdir .kaggle
```

In [0]:
```
import json
token = {"username":"dileepteja3","key":"83756491be14de55865bc14e32a61fc0"}
with open('/content/.kaggle/kaggle.json', 'w') as file:
    json.dump(token, file)
```

In [0]:
```
!chmod 600 /content/.kaggle/kaggle.json
```

In [0]:
```
!cp /content/.kaggle/kaggle.json /root/.kaggle/kaggle.json
```

In [8]:
```
!kaggle config set -n path -v{/content}
```

```
- path is now set to: {/content}
```

In [9]:
```
!kaggle competitions download -c malware-classification
```

```
Warning: Looks like you're using an outdated API Version, please consider upd
ating (server 1.5.6 / client 1.5.4)
Downloading sampleSubmission.csv to {/content}/competitions/malware-classific
ation
  0% 0.00/2.01M [00:00<?, ?B/s]
100% 2.01M/2.01M [00:00<00:00, 66.4MB/s]
Downloading trainLabels.csv to {/content}/competitions/malware-classification
  0% 0.00/265k [00:00<?, ?B/s]
100% 265k/265k [00:00<00:00, 85.7MB/s]
Downloading train.7z to {/content}/competitions/malware-classification
100% 17.5G/17.5G [02:09<00:00, 180MB/s]
100% 17.5G/17.5G [02:09<00:00, 145MB/s]
Downloading test.7z to {/content}/competitions/malware-classification
100% 17.8G/17.8G [02:19<00:00, 194MB/s]
100% 17.8G/17.8G [02:19<00:00, 137MB/s]
Downloading dataSample.7z to {/content}/competitions/malware-classification
  0% 0.00/4.06M [00:00<?, ?B/s]
100% 4.06M/4.06M [00:00<00:00, 134MB/s]
```

In [17]:
```
!7z x /content/{/content}/competitions/malware-classification/train.7z
```

```
Output hidden; open in https://colab.research.google.com to view.
```

In [6]:
```
!pip install xgboost
```

```
Collecting xgboost
  Downloading https://files.pythonhosted.org/packages/6a/49/7e10686647f741bd9
c8918b0decdb94135b542fe372ca1100739b8529503/xgboost-0.82-py2.py3-none-manylin
ux1_x86_64.whl (114.0MB)
    100% |████████████████████████████████| 114.0MB 10kB/s  eta 0:00:01
Collecting numpy (from xgboost)
  Downloading https://files.pythonhosted.org/packages/d7/b1/3367ea1f372957f97
a6752ec725b87886e12af1415216feec9067e31df70/numpy-1.16.5-cp27-cp27mu-manylinu
x1_x86_64.whl (17.0MB)
    100% |████████████████████████████████| 17.0MB 70kB/s  eta 0:00:01
Collecting scipy (from xgboost)
  Downloading https://files.pythonhosted.org/packages/1d/f6/7c16d60aeb3694e56
11976cb4f1eaf1c6b7f1e7c55771d691013405a02ea/scipy-1.2.2-cp27-cp27mu-manylinux
1_x86_64.whl (24.8MB)
    100% |████████████████████████████████| 24.8MB 44kB/s  eta 0:00:01
Installing collected packages: numpy, scipy, xgboost
Successfully installed numpy-1.16.5 scipy-1.2.2 xgboost-0.82
```

3. Exploratory Data Analysis

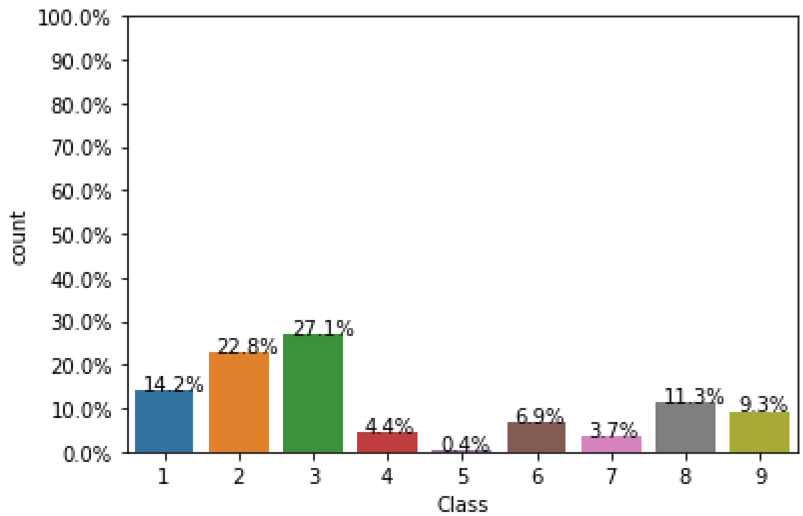
In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
from sklearn import preprocessing
import pandas as pd
from multiprocessing import Process# this is used for multithreading
import multiprocessing
import codecs# this is used for file operations
import random as r
from xgboost import XGBClassifier
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
matplotlib.use(u'nbAgg')
%matplotib inline
```

```
UsageError: Line magic function `%matplotib` not found.
```

In [2]:
```
#separating byte files and asm files

source = 'train'
destination = 'byteFiles'

# we will check if the folder 'byteFiles' exists if it not there we will creat
e a folder with the same name
if not os.path.isdir(destination):
    os.makedirs(destination)

# if we have folder called 'train' (train folder contains both .asm files and
 .bytes files) we will rename it 'asmFiles'
# for every file that we have in our 'asmFiles' directory we check if it is en
ding with .bytes, if yes we will move it to
# 'byteFiles' folder

# so by the end of this snippet we will separate all the .byte files and .asm
 files
if os.path.isdir(source):
    os.rename(source,'asmFiles')
    source='asmFiles'
    data_files = os.listdir(source)
    for file in data_files:
        if (file.endswith("bytes")):
            shutil.move(source+"/"+file,destination)
```

3.1. Distribution of malware classes in whole data set

In [3]:
```
Y=pd.read_csv("trainLabels.csv")
total = len(Y)*1.
ax=sns.countplot(x="Class", data=Y)
for p in ax.patches:
        ax.annotate('{:.1f}%'.format(100*p.get_height()/total), (p.get_x()+0.1
, p.get_height()+5))

#put 11 ticks (therefore 10 steps), from 0 to the total number of rows in the
 dataframe
ax.yaxis.set_ticks(np.linspace(0, total, 11))

#adjust the ticklabel to the desired format, without changing the position of
 the ticks.
ax.set_yticklabels(map('{:.1f}%'.format, 100*ax.yaxis.get_majorticklocs()/tota
l))
plt.show()
```



In [4]:
```
Y
```

Out[4]:

	Id	Class
0	01kcPWA9K2BOxQeS5Rju	1
1	04EjIdbPV5e1XroFOpiN	1
2	05EeG39MTRrI6VY21DPd	1
3	05rJTUWYAKNegBk2wE8X	1
4	0AnoOZDNbPXIr2MRBSCJ	1
...	...	...
10863	KFrZ0Lop1WDGwUtkusCi	9
10864	kg24YRJTB8DNdKMXpwOH	9
10865	kG29BLiFYPgWtpb350sO	9
10866	kGITL4OJxYMWEQ1bKBiP	9
10867	KGorN9J6XAC4bOEkmyup	9

10868 rows × 2 columns

3.2. Feature extraction

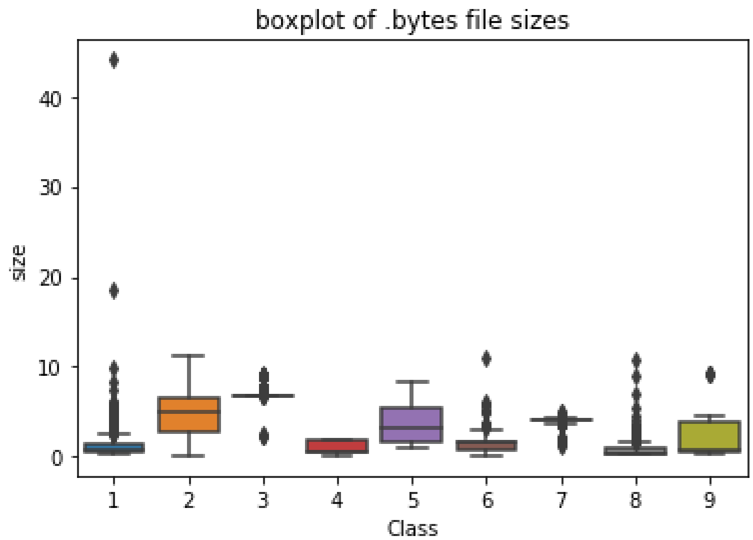
3.2.1 File size of byte files as a feature

In [4]:
```
#file sizes of byte files

files=os.listdir('byteFiles')
filenames=Y['Id'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=356157170
0, st_nlink=1, st_uid=0, st_gid=0,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519
638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_s
tat.htm
    statinfo=os.stat('byteFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file na
me
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
data_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes
})
print (data_size_byte.head())
```

```
   Class                    ID      size
0      2  C4iJQzFIRWB19USfsaVw  5.636719
1      3  1V2h8lnzeGiuxmHR9k5Q  6.703125
2      4  7KHscjvztoka0QpqYFxb  0.199219
3      9  2qpZmcvFs4LCBNi9IX6H  0.773438
4      4  81jMeyEZiOpJkCuBlDYg  1.839844
```

3.2.2 box plots of file size (.byte files) feature

In [5]:
```
#boxplot of byte files
ax = sns.boxplot(x="Class", y="size", data=data_size_byte)
plt.title("boxplot of .bytes file sizes")
plt.show()
```



3.2.3 feature extraction from byte files

In [18]:
```
#removal of addres from byte files
# contents of .byte files
# ----------------
#00401000 56 8D 44 24 08 50 8B F1 E8 1C 1B 00 00 C7 06 08
#-------------------
#we remove the starting address 00401000

files = os.listdir('byteFiles')
filenames=[]
array=[]
for file in files:
    if(file.endswith("bytes")):
        file=file.split('.')[0]
        text_file = open('byteFiles/'+file+".txt", 'w+')
        with open('byteFiles/'+file+'.bytes',"r") as fp:
            lines=""
            for line in fp:
                a=line.rstrip().split(" ")[1:]
                b=' '.join(a)
                b=b+"\n"
                text_file.write(b)
            fp.close()
            os.remove('byteFiles/'+file+'.bytes')
        text_file.close()

files = os.listdir('byteFiles')
filenames2=[]
feature_matrix = np.zeros((len(files),257),dtype=int)
k=0


#program to convert into bag of words of bytefiles
#this is custom-built bag of words this is unigram bag of words
byte_feature_file=open('result.csv','w+')
byte_feature_file.write("ID,0,1,2,3,4,5,6,7,8,9,0a,0b,0c,0d,0e,0f,10,11,12,13,
14,15,16,17,18,19,1a,1b,1c,1d,1e,1f,20,21,22,23,24,25,26,27,28,29,2a,2b,2c,2d,
2e,2f,30,31,32,33,34,35,36,37,38,39,3a,3b,3c,3d,3e,3f,40,41,42,43,44,45,46,47,
48,49,4a,4b,4c,4d,4e,4f,50,51,52,53,54,55,56,57,58,59,5a,5b,5c,5d,5e,5f,60,61,
62,63,64,65,66,67,68,69,6a,6b,6c,6d,6e,6f,70,71,72,73,74,75,76,77,78,79,7a,7b,
7c,7d,7e,7f,80,81,82,83,84,85,86,87,88,89,8a,8b,8c,8d,8e,8f,90,91,92,93,94,95,
96,97,98,99,9a,9b,9c,9d,9e,9f,a0,a1,a2,a3,a4,a5,a6,a7,a8,a9,aa,ab,ac,ad,ae,af,
b0,b1,b2,b3,b4,b5,b6,b7,b8,b9,ba,bb,bc,bd,be,bf,c0,c1,c2,c3,c4,c5,c6,c7,c8,c9,
ca,cb,cc,cd,ce,cf,d0,d1,d2,d3,d4,d5,d6,d7,d8,d9,da,db,dc,dd,de,df,e0,e1,e2,e3,
e4,e5,e6,e7,e8,e9,ea,eb,ec,ed,ee,ef,f0,f1,f2,f3,f4,f5,f6,f7,f8,f9,fa,fb,fc,fd,
fe,ff,??")
for file in files:
    filenames2.append(file)
    byte_feature_file.write(file+",")
    if(file.endswith("txt")):
        with open('byteFiles/'+file,"r") as byte_flie:
            for lines in byte_flie:
                line=lines.rstrip().split(" ")
                for hex_code in line:
                    if hex_code=='??':
                        feature_matrix[k][256]+=1
                    else:
```

```
                        feature_matrix[k][int(hex_code,16)]+=1
            byte_flie.close()
        for i in feature_matrix[k]:
            byte_feature_file.write(str(i)+",")
        byte_feature_file.write("\n")

        k += 1

byte_feature_file.close()
```

In [43]:
```
feature_matrix.shape
```

Out[43]:
```
(10868, 257)
```

In [6]:
```
import pickle
# with open('feature_matrix.pickle', 'wb') as f:
#     pickle.dump(feature_matrix, f)
```

In [7]:
```
with open('feature_matrix.pickle', 'rb') as f:
    feature_matrix = pickle.load(f)
```

In [8]:
```
byte_features=pd.read_csv("result.csv")
byte_features = byte_features[byte_features.columns[:258]]
byte_features.rename(columns={'??C4iJQzFIRWB19USfsaVw.txt':'??'}, inplace=True
)
byte_features['ID'] = byte_features['ID'].str[:-4]
byte_features
```

Out[8]:

	ID	0	1	2	3	4	5	6	7	8	...
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...
3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	1078	...
4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	422	...
...	...	...	...	...	...	...	...	...	...	...	...
10863	IoIP1tiwELF9YNZQjSUO	5268	1177	1072	1222	1238	1159	1143	1126	1149	...
10864	LOP6HaJKXpkic5dyuVnT	3032	298	248	293	274	213	203	222	257	...
10865	LOqA6FX02GWguYrI1Zbe	5671	221	270	323	313	155	248	147	261	...
10866	LoWgaidpb2lUM5ACcSGO	3637	437	453	506	511	390	431	407	405	...
10867	lS0IVqXeJrN6Dzi9Pap1	3534	373	385	432	495	399	393	373	399	...

10868 rows × 258 columns

In [9]:
```
data_size_byte
```

Out[9]:

	Class	ID	size
0	2	C4iJQzFIRWB19USfsaVw	5.636719
1	3	1V2h8InzeGiuxmHR9k5Q	6.703125
2	4	7KHscjvztoka0QpqYFxb	0.199219
3	9	2qpZmcvFs4LCBNi9IX6H	0.773438
4	4	81jMeyEZiOpJkCuBIDYg	1.839844
...	...	...	...
10863	2	hZfoeEcsTJRnNLIF5wG0	6.281250
10864	3	dMr6GYzt8pOD5cQTi2VS	6.703125
10865	3	eT5zyaVgSRMwGc2oQfHW	6.703125
10866	3	1YnwQBXNIKPzcdGWxSA6	6.703125
10867	3	9pVfLJrSuU8iANWPFM15	6.703125

10868 rows × 3 columns

In [10]:
```
result = pd.merge(byte_features, data_size_byte,on='ID', how='left')
result.head()
```

Out[10]:

	ID	0	1	2	3	4	5	6	7	8	...	f9
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	3101
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...	2242
3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	1078	...	485
4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	422	...	350

5 rows × 260 columns

In [44]:
```
#
result = pd.read_csv("result_with_size.csv")
result.head()
```

Out[44]:

	Unnamed: 0	ID	0	1	2	3	4	5	6	7	...
0	0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	...
1	1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	...
2	2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	...
3	3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	...
4	4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	...

5 rows × 261 columns

In [7]:
```
#
# 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_valu
e - min_value)
    return result1
result = normalize(result)
```

In [8]:
```
#
data_y = result['Class']
result.head()
```

Out[8]:

	Unnamed: 0	ID	0	1	2	3	4	
0	0.000000	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001
1	0.000092	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003
2	0.000184	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005
3	0.000276	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000

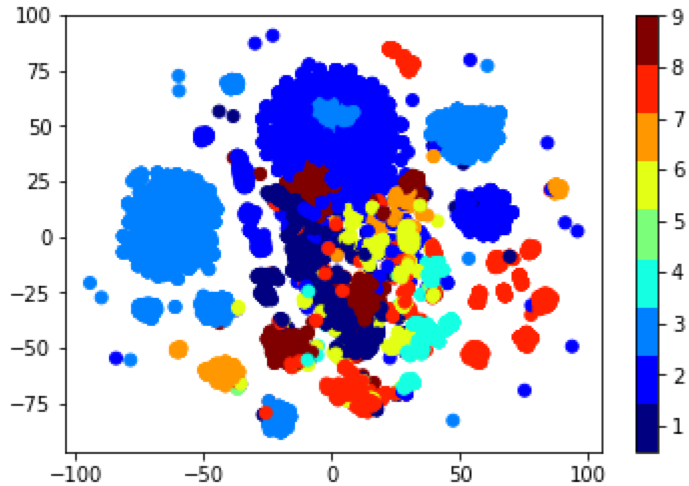
5 rows × 261 columns

3.2.4 Multivariate Analysis

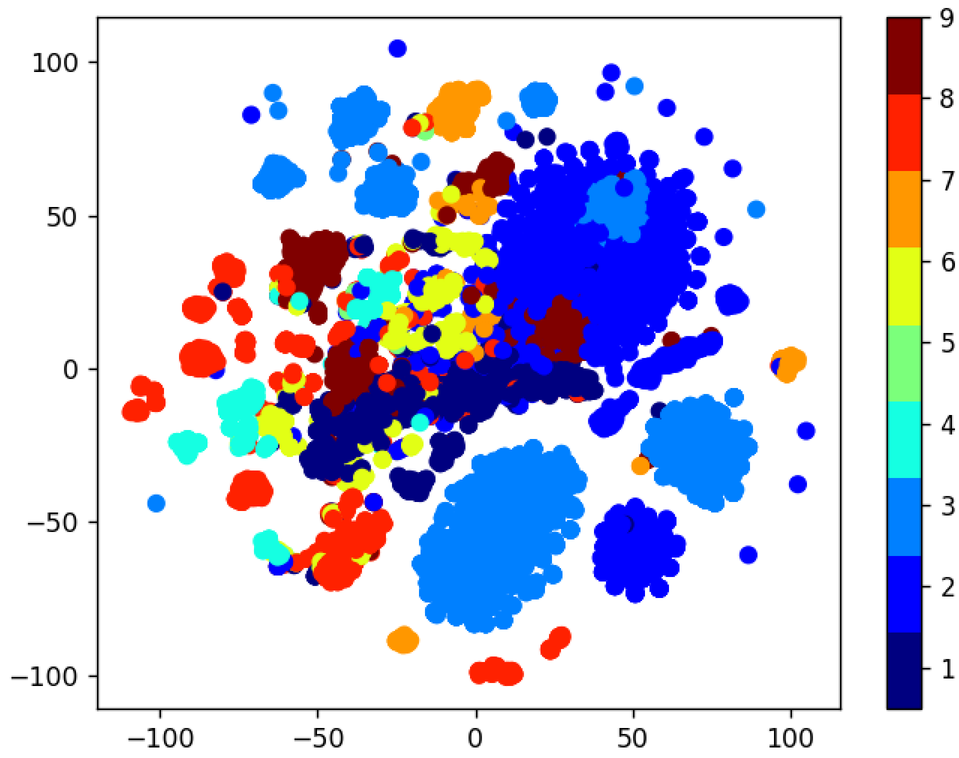
In [32]:
```
results[:].shape
```

Out[32]:
```
(10868, 2)
```

In [31]:
```
#multivariate analysis on byte files
#this is with perplexity 50
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result.drop(['ID','Class'], axis=1))
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



In [0]:
```
#this is with perplexity 30
xtsne=TSNE(perplexity=30)
results=xtsne.fit_transform(result.drop(['ID','Class'], axis=1))
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



Train Test split

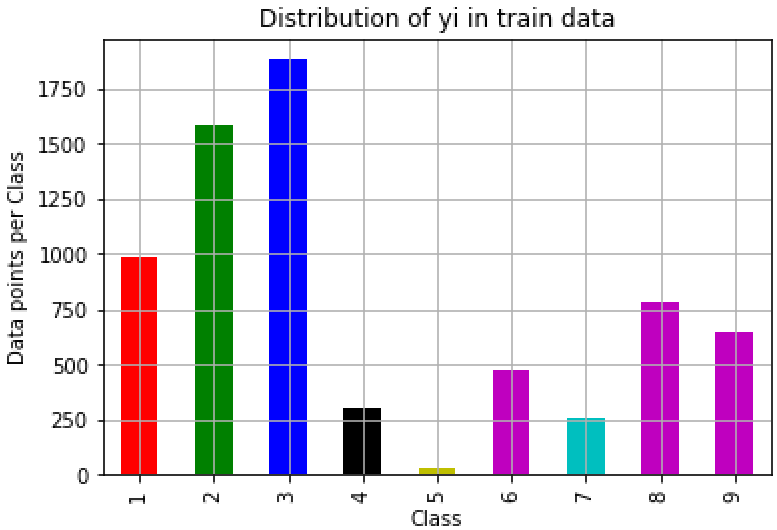
In [33]:
```
data_y = result['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(result.drop(['ID','Class'
], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [34]:
```
print('Number of data points in train data:', X_train.shape[0])
print('Number of data points in test data:', X_test.shape[0])
print('Number of data points in cross validation data:', X_cv.shape[0])
```

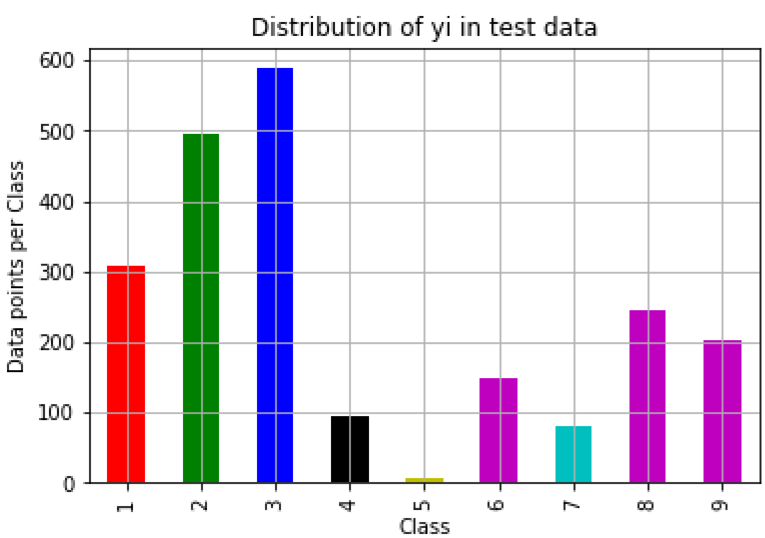
```
Number of data points in train data: 6955
Number of data points in test data: 2174
Number of data points in cross validation data: 1739
```

In [38]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

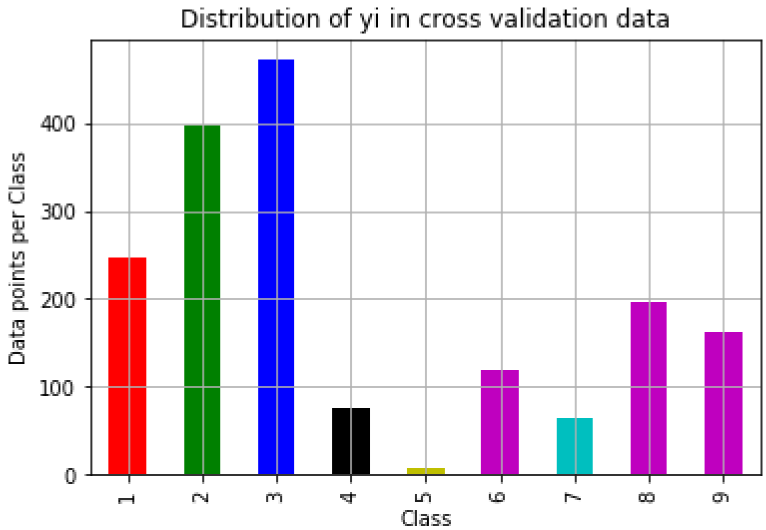
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [0]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

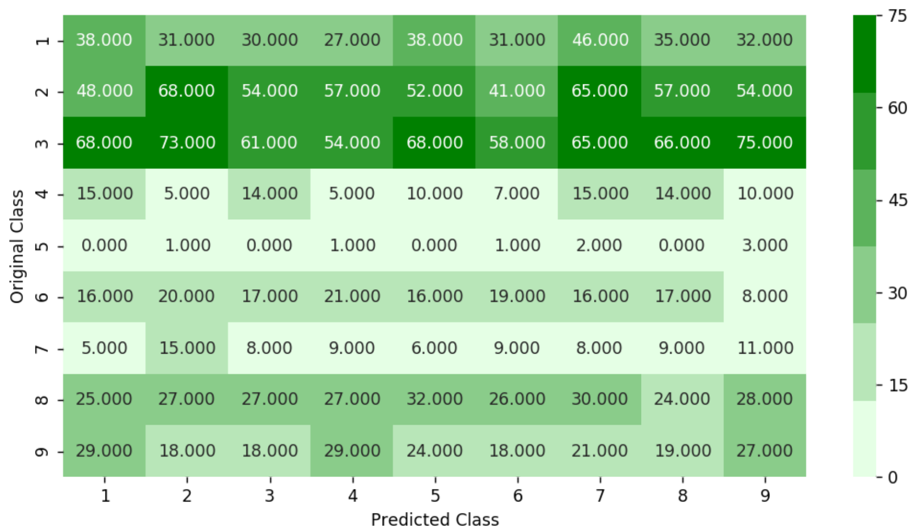
4. Machine Learning Models

4.1. Machine Leaning Models on bytes files

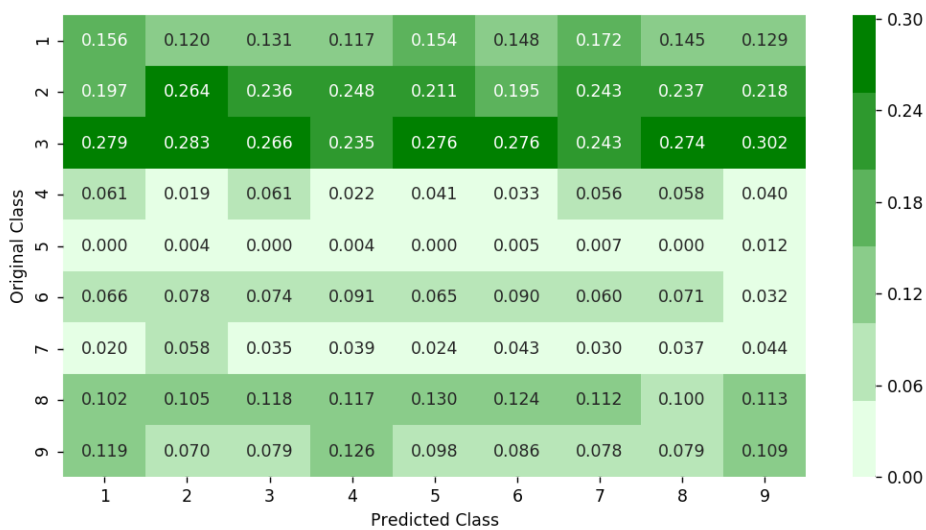
4.1.1. Random Model

In [0]:
```
# we need to generate 9 numbers and the sum of numbers should be 1
# one solution is to genarate 9 numbers and divide each of the numbers by thei
r sum
# ref: https://stackoverflow.com/a/18662466/4084039

test_data_len = X_test.shape[0]
cv_data_len = X_cv.shape[0]

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


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

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

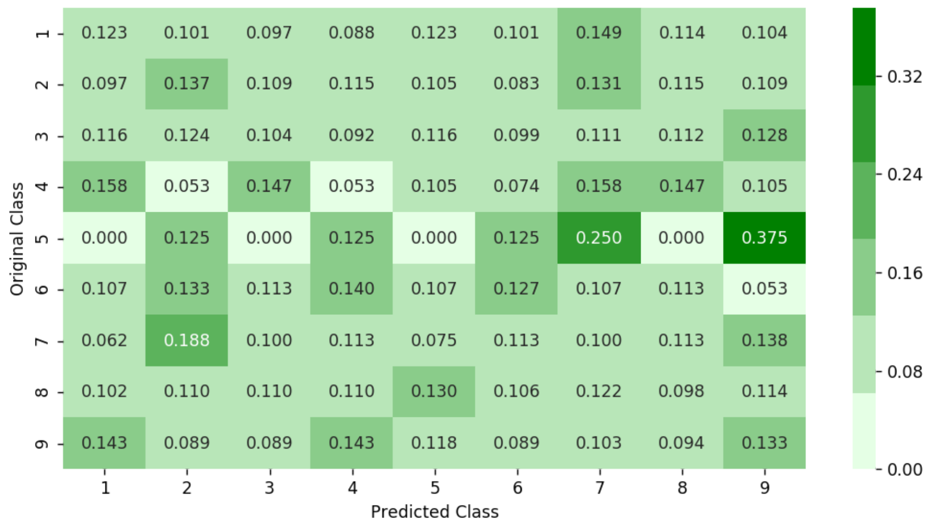
```
Log loss on Cross Validation Data using Random Model 2.45615644965
Log loss on Test Data using Random Model 2.48503905509
Number of misclassified points  88.5004599816
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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



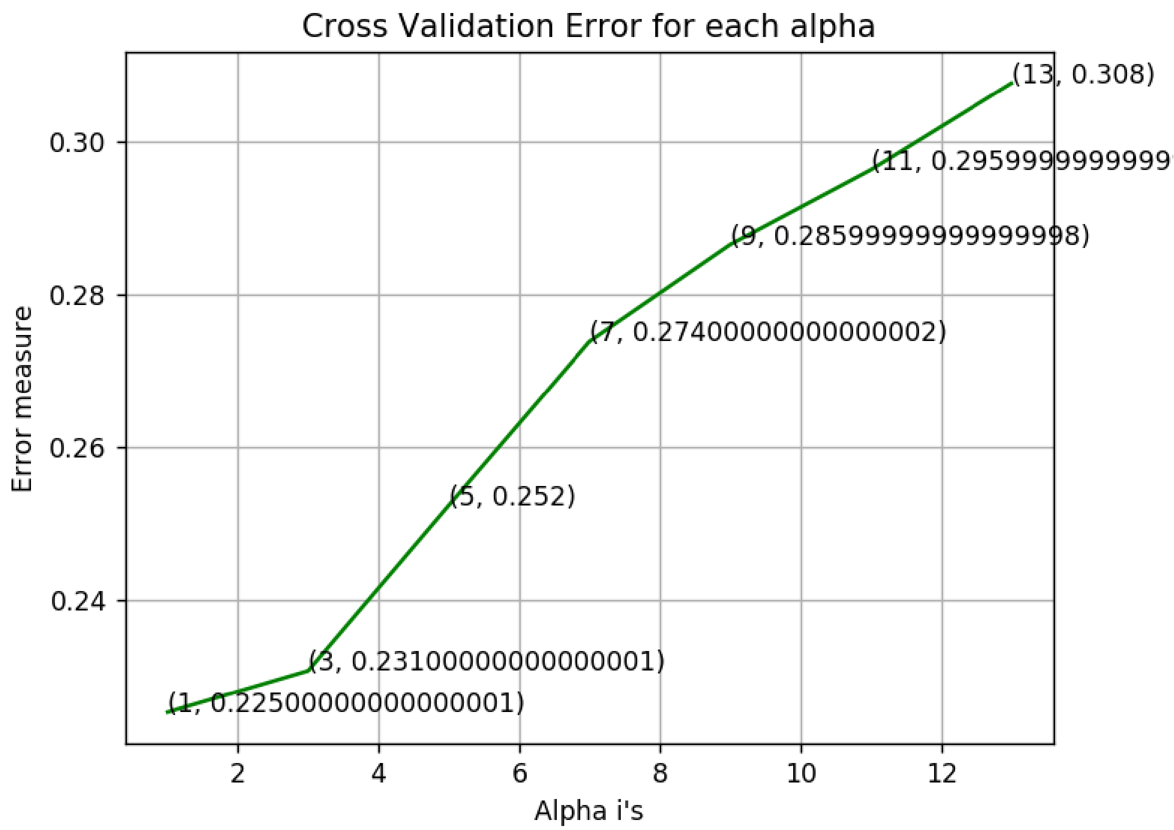

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.1.2. K Nearest Neighbour Classification

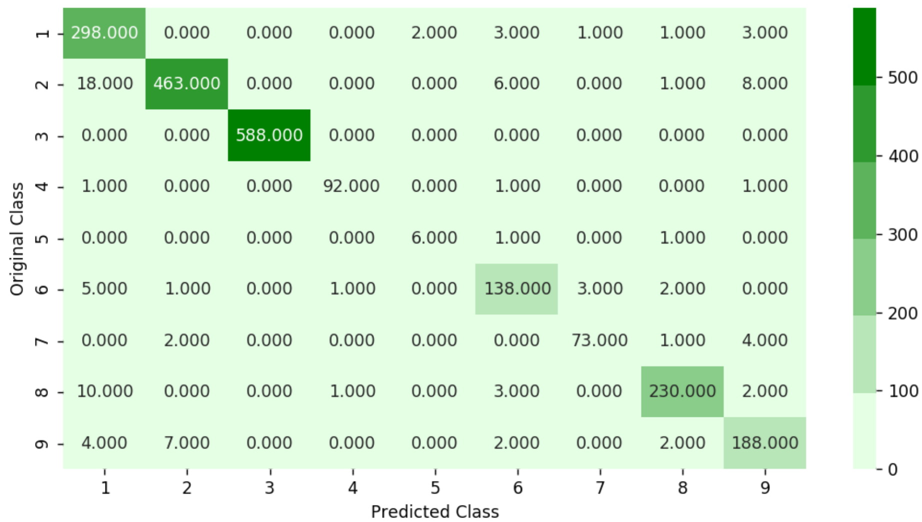
In [0]:
```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/m
odules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', lea
f_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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


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

alpha = [x for x in range(1, 15, 2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(k_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=k_cfl.classes_,
eps=1e-15))

for i in range(len(cv_log_error_array)):
    print ('log_loss for k = ',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()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(k_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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

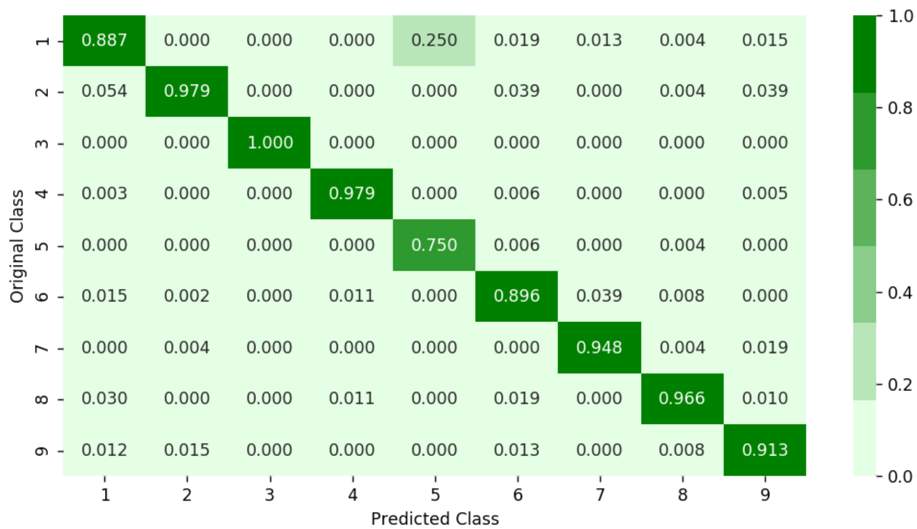
```
log_loss for k =  1 is 0.225386237304
log_loss for k =  3 is 0.230795229168
log_loss for k =  5 is 0.252421408646
log_loss for k =  7 is 0.273827486888
log_loss for k =  9 is 0.286469181555
log_loss for k =  11 is 0.29623391147
log_loss for k =  13 is 0.307551203154
```



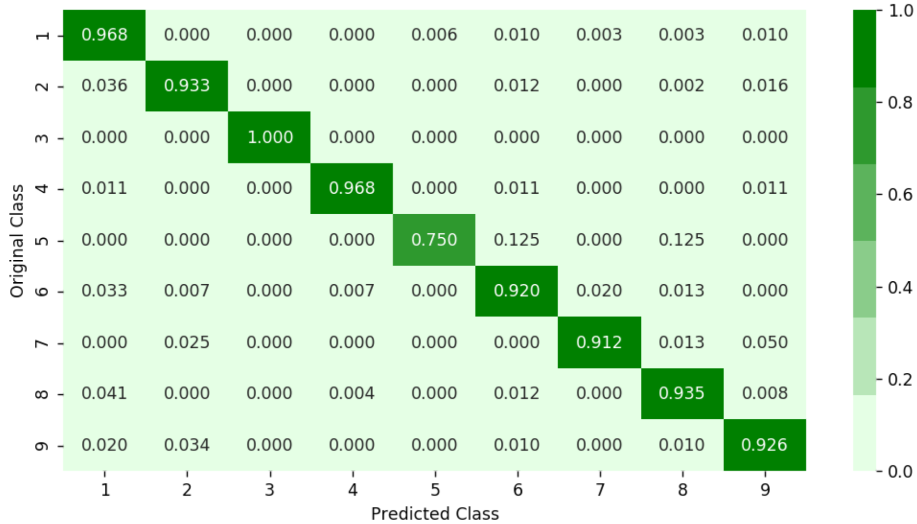

```
For values of best alpha =  1 The train log loss is: 0.0782947669247
For values of best alpha =  1 The cross validation log loss is: 0.22538623730
4
For values of best alpha =  1 The test log loss is: 0.241508604195
Number of misclassified points  4.50781968721
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```



-- Precision matrix ---



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



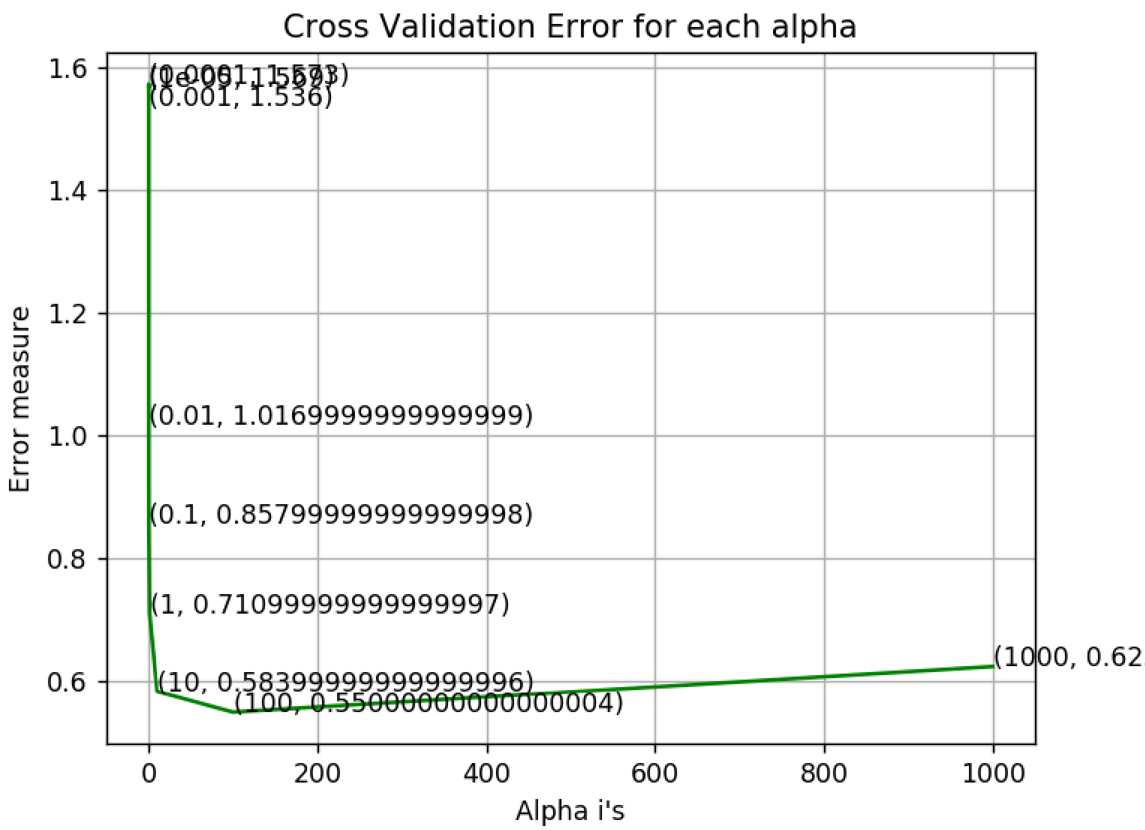

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.1.3. Logistic Regression

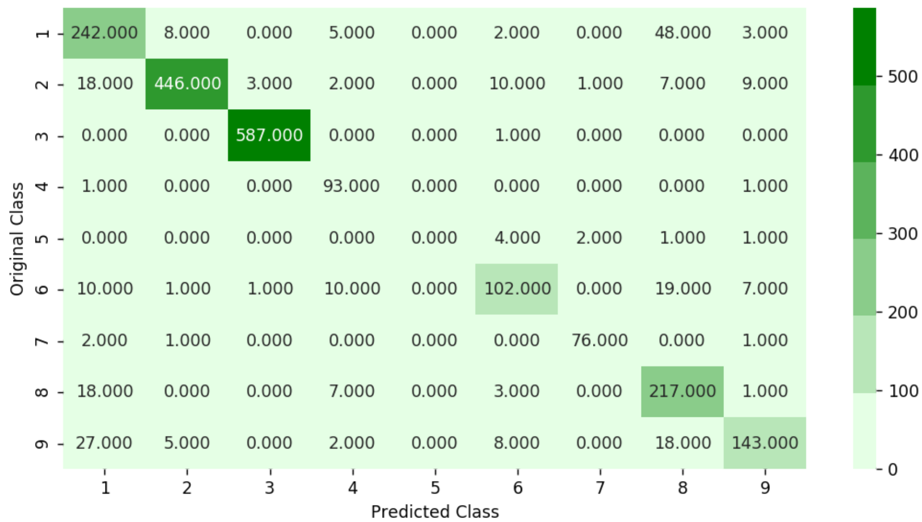
In [0]:
```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/ge
nerated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_i
ntercept=True, max_iter=None,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

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

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

alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(logisticR, 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=logisticR.class
es_, 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()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='ba
lanced')
logisticR.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
sig_clf.fit(X_train, y_train)
pred_y=sig_clf.predict(X_test)

predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR
.classes_, eps=1e-15))
```

```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.class
es_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.c
lasses_, eps=1e-15))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

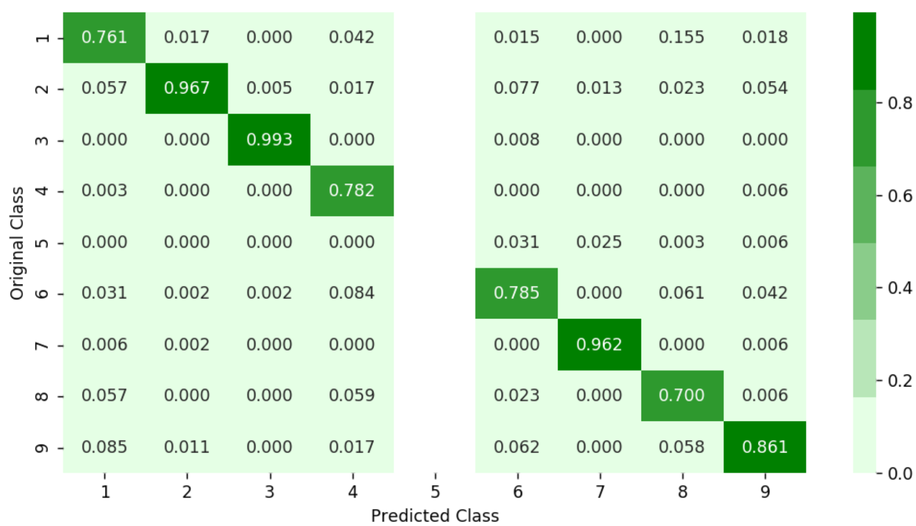
```
log_loss for c =  1e-05 is 1.56916911178
log_loss for c =  0.0001 is 1.57336384417
log_loss for c =  0.001 is 1.53598598273
log_loss for c =  0.01 is 1.01720972418
log_loss for c =  0.1 is 0.857766083873
log_loss for c =  1 is 0.711154393309
log_loss for c =  10 is 0.583929522635
log_loss for c =  100 is 0.549929846589
log_loss for c =  1000 is 0.624746769121
```




```
log loss for train data 0.498923428696
log loss for cv data 0.549929846589
log loss for test data 0.528347316704
Number of misclassified points  12.3275068997
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```

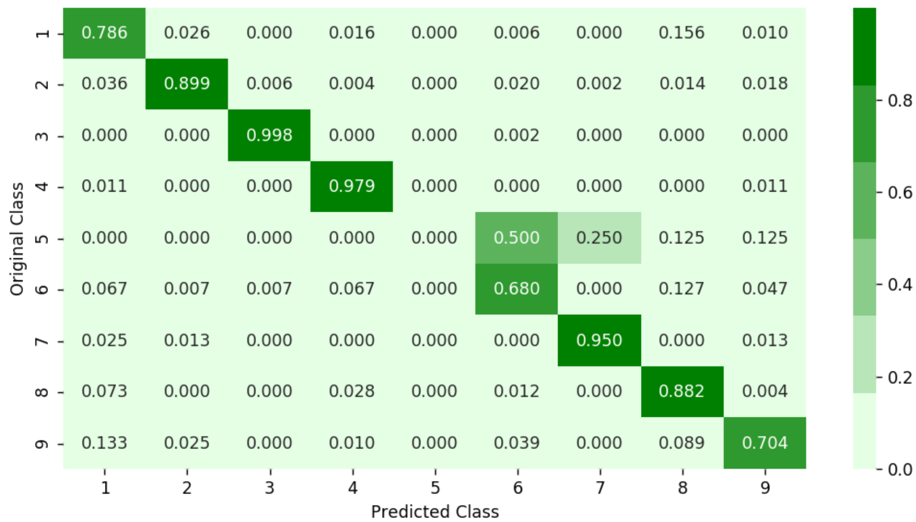


-- Precision matrix --



Sum of columns in precision matrix [1. 1. 1. 1. nan 1. 1. 1. 1.]

-- Recall matrix --



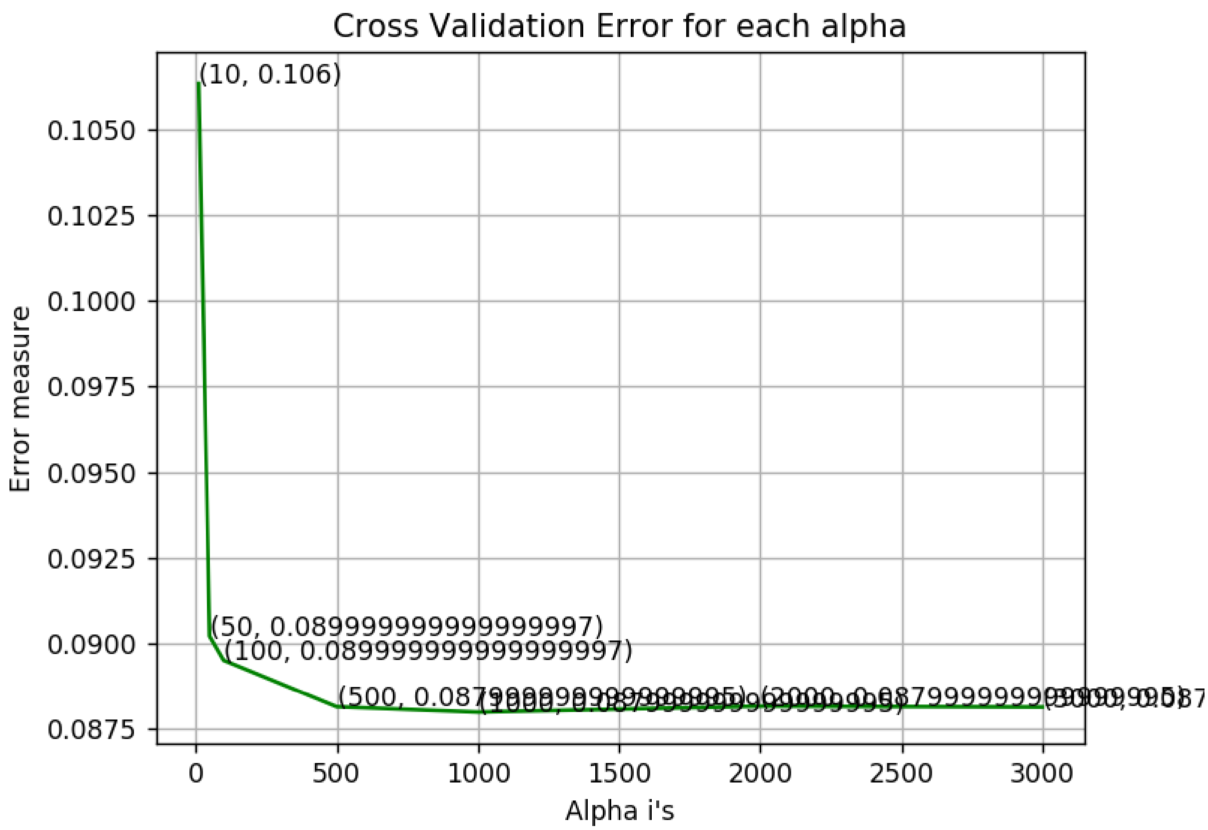

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.1.4. Random Forest Classifier

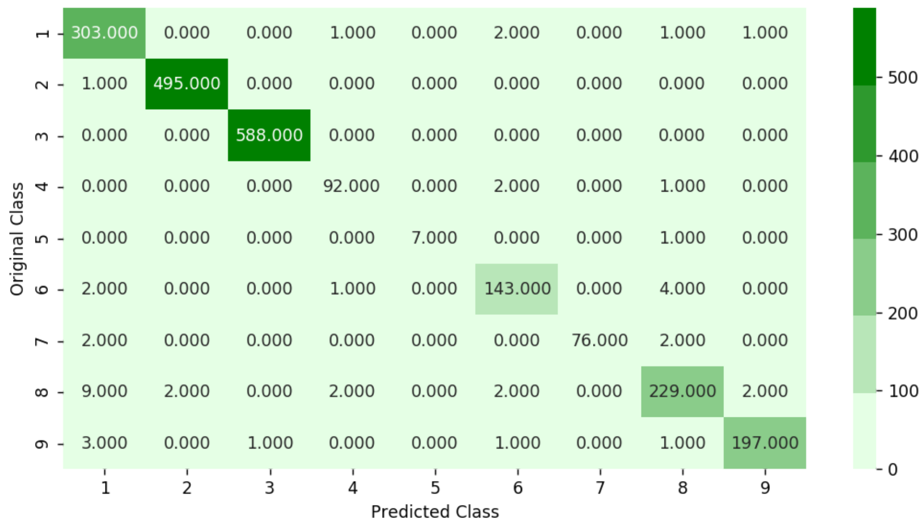
In [0]:
```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

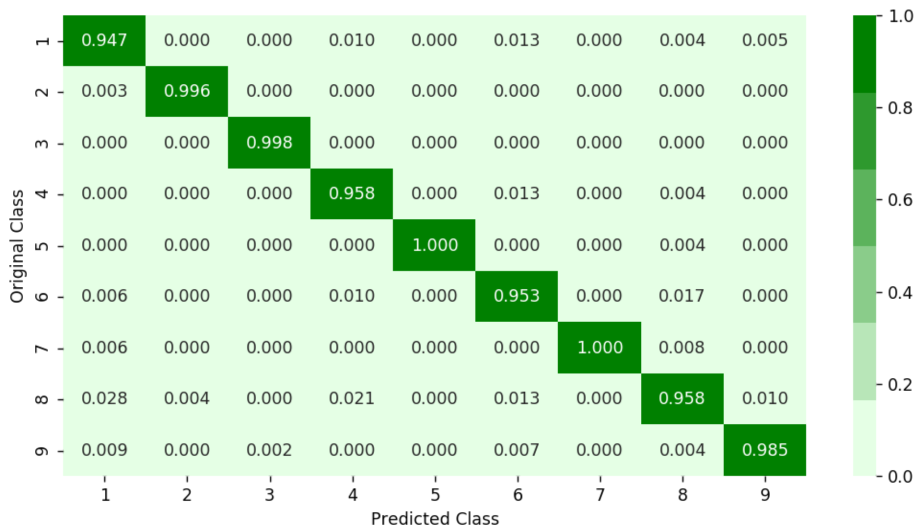
```
log_loss for c =  10 is 0.106357709164
log_loss for c =  50 is 0.0902124124145
log_loss for c =  100 is 0.0895043339776
log_loss for c =  500 is 0.0881420869288
log_loss for c =  1000 is 0.0879849524621
log_loss for c =  2000 is 0.0881566647295
log_loss for c =  3000 is 0.0881318948443
```



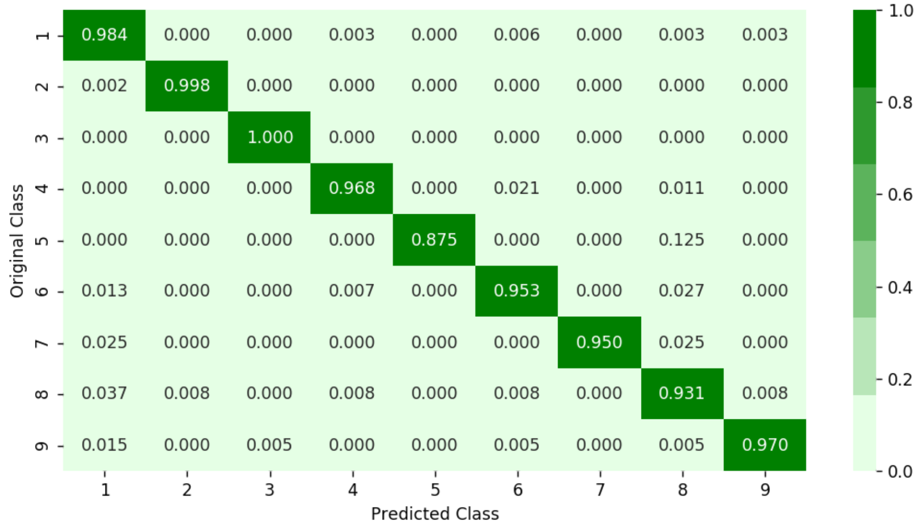

```
For values of best alpha =  1000 The train log loss is: 0.0266476291801
For values of best alpha =  1000 The cross validation log loss is: 0.08798495
24621
For values of best alpha =  1000 The test log loss is: 0.0858346961407
Number of misclassified points  2.02391904324
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```



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



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



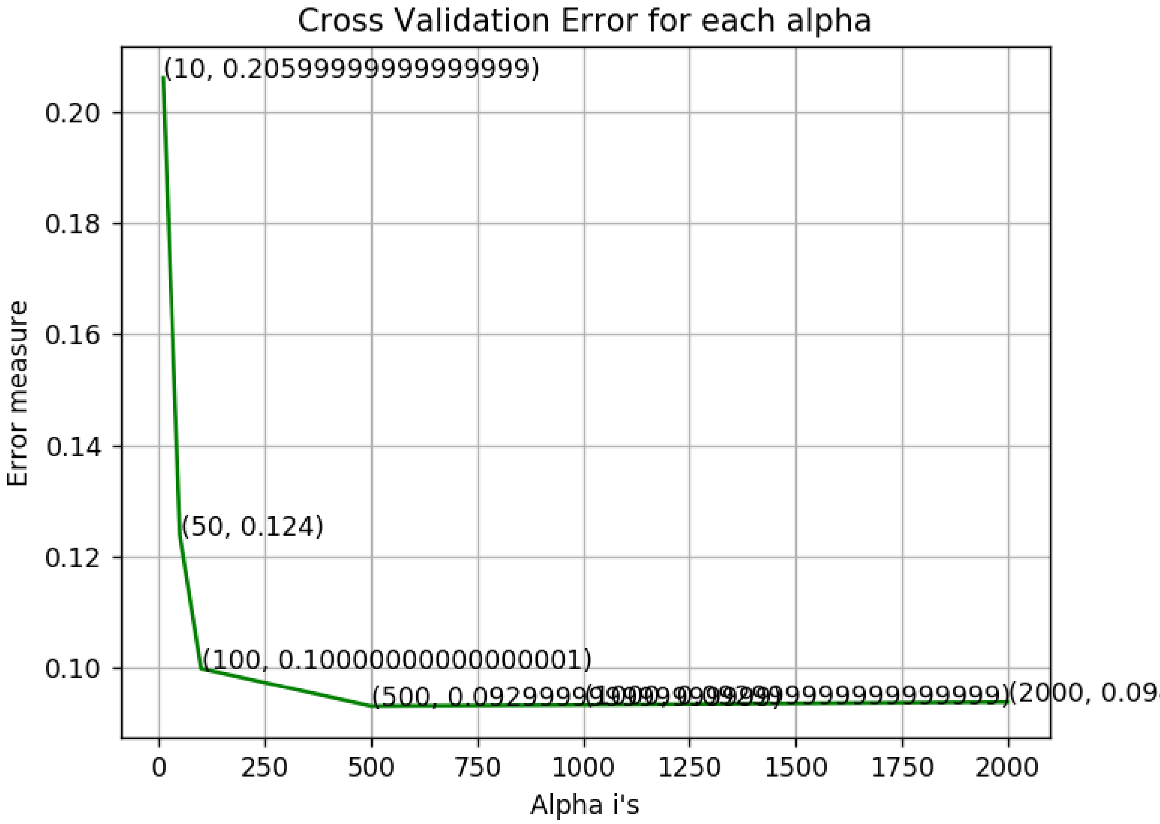

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.1.5. XgBoost Classification

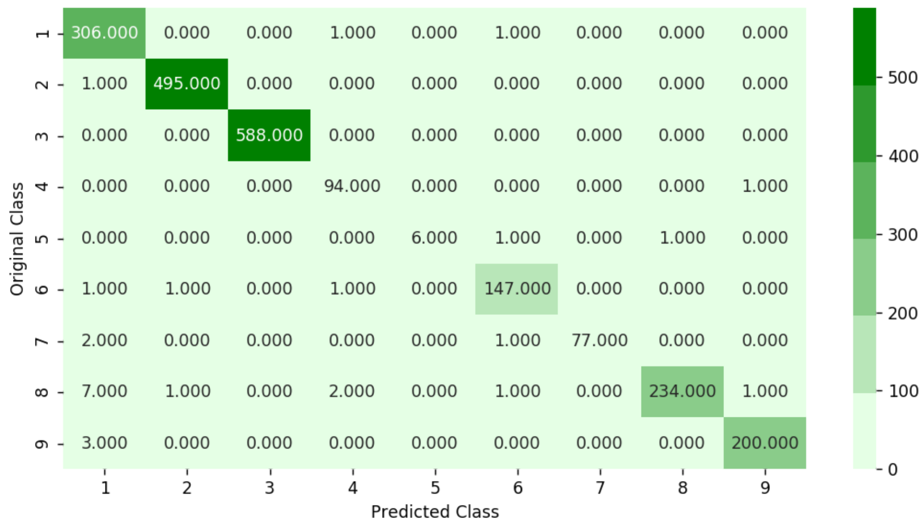
In [0]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/regression-using-decision-trees-2/
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-onlin
e/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)
    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))

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)
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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

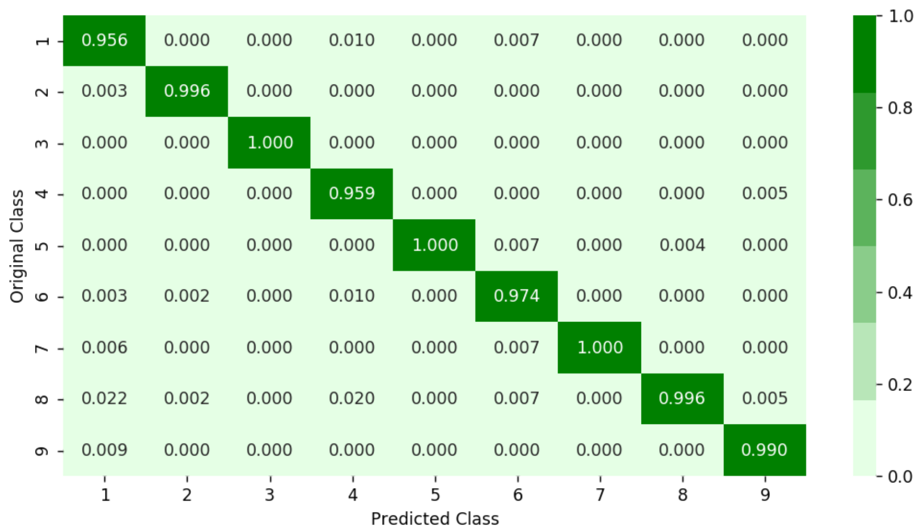
```
log_loss for c =  10 is 0.20615980494
log_loss for c =  50 is 0.123888382365
log_loss for c =  100 is 0.099919437112
log_loss for c =  500 is 0.0931035681289
log_loss for c =  1000 is 0.0933084876012
log_loss for c =  2000 is 0.0938395690309
```



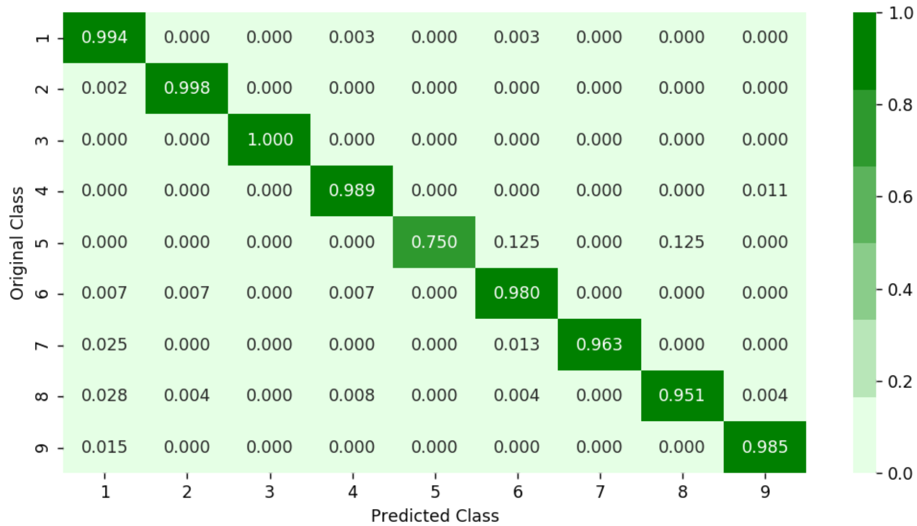

```
For values of best alpha =  500 The train log loss is: 0.0225231805824
For values of best alpha =  500 The cross validation log loss is: 0.093103568
1289
For values of best alpha =  500 The test log loss is: 0.0792067651731
Number of misclassified points  1.24195032199
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [0]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Done   2 tasks      | elapsed:   26.5s
[Parallel(n_jobs=-1)]: Done   9 tasks      | elapsed:  5.8min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  9.3min remaining:  5.4
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 10.1min remaining:  3.1
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 14.0min remaining:  1.6
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 14.2min finished
```

Out[0]:
```
RandomizedSearchCV(cv=None, error_score='raise',
          estimator=XGBClassifier(base_score=0.5, colsample_bylevel=1, colsam
ple_bytree=1,
       gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=3,
       min_child_weight=1, missing=None, n_estimators=100, nthread=-1,
       objective='binary:logistic', reg_alpha=0, reg_lambda=1,
       scale_pos_weight=1, seed=0, silent=True, subsample=1),
          fit_params=None, iid=True, n_iter=10, n_jobs=-1,
          param_distributions={'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],
'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5, 1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score=True, scoring=None, verbose=10)
```

In [0]:
```
print (random_cfl1.best_params_)
```

```
{'subsample': 1, 'n_estimators': 500, 'max_depth': 5, 'learning_rate': 0.05,
'colsample_bytree': 0.5}
```

In [0]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(n_estimators=2000, learning_rate=0.05, colsample_bytree=1,
max_depth=3)
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 0.022540976086
cv loss 0.0928710624158
test loss 0.0782688587098
```

4.2 Modeling with .asm files

```
There are 10868 files of asm
All the files make up about 150 GB
The asm files contains :
1. Address
2. Segments
3. Opcodes
4. Registers
5. function calls
6. APIs
With the help of parallel processing we extracted all the features.In parallel we c
an use all the cores that are present in our computer.


Here we extracted 52 features from all the asm files which are important.

We read the top solutions and handpicked the features from those papers/videos/blog
s.
 Refer:https://www.kaggle.com/c/malware-classification/discussion
```

4.2.1 Feature extraction from asm files

- **To extract the unigram features from the .asm files we need to process ~150GB of data**
- **Note: Below two cells will take lot of time (over 48 hours to complete)**
- **We will provide you the output file of these two cells, which you can directly use it**

In [0]:
```
#intially create five folders
#first
#second
#thrid
#fourth
#fifth
#this code tells us about random split of files into five folders
folder_1 ='first'
folder_2 ='second'
folder_3 ='third'
folder_4 ='fourth'
folder_5 ='fifth'
folder_6 = 'output'
for i in [folder_1,folder_2,folder_3,folder_4,folder_5,folder_6]:
    if not os.path.isdir(i):
        os.makedirs(i)

source='train/'
files = os.listdir('train')
ID=df['Id'].tolist()
data=range(0,10868)
r.shuffle(data)
count=0
for i in range(0,10868):
    if i % 5==0:
        shutil.move(source+files[data[i]],'first')
    elif i%5==1:
        shutil.move(source+files[data[i]],'second')
    elif i%5 ==2:
        shutil.move(source+files[data[i]],'thrid')
    elif i%5 ==3:
        shutil.move(source+files[data[i]],'fourth')
    elif i%5==4:
        shutil.move(source+files[data[i]],'fifth')
```

In [0]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdat
a:','.edata:','.rsrc:','.tls:','.reloc:','.BSS:','.CODE']
    #this are opcodes that are used to get best results
    #https://en.wikipedia.org/wiki/X86_instruction_listings

    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'su
b', 'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ro
r', 'rol', 'jnb','jz','rtn','lea','movzx']
    #best keywords that are taken from different blogs
    keywords = ['.dll','std::',':dword']
    #Below taken registers are general purpose registers and special registers
    #All the registers which are taken are best
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\asmsmallfile.txt","w+")
    files = os.listdir('first')
    for f in files:
        #filling the values with zeros into the arrays
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        # https://docs.python.org/3/library/codecs.html#codecs.ignore_errors
        # https://docs.python.org/3/library/codecs.html#codecs.Codec.encode
        with codecs.open('first/'+f,encoding='cp1252',errors ='replace') as fl
i:
            for lines in fli:
                # https://www.tutorialspoint.com/python3/string_rstrip.htm
                line=lines.rstrip().split()
                l=line[0]
                #counting the prefixs in each and every line
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                #counting the opcodes in each and every line
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                #counting registers in the line
                for i in range(len(registers)):
                    for li in line:
                        # we will use registers only in 'text' and 'CODE' segm
ents
```

```
                        if registers[i] in li and ('text' in l or 'CODE' in l
):
                            registerscount[i]+=1
                #counting keywords in the line
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        #pushing the values into the file after reading whole file
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


#same as above
def secondprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdat
a:','.edata:','.rsrc:','.tls:','.reloc:','.BSS:','.CODE']
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'su
b', 'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ro
r', 'rol', 'jnb','jz','rtn','lea','movzx']
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\mediumasmfile.txt","w+")
    files = os.listdir('second')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('second/'+f,encoding='cp1252',errors ='replace') as f
li:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l
```

```
):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()

# same as smallprocess() functions
def thirdprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdat
a:','.edata:','.rsrc:','.tls:','.reloc:','.BSS:','.CODE']
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'su
b', 'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ro
r', 'rol', 'jnb','jz','rtn','lea','movzx']
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\largeasmfile.txt","w+")
    files = os.listdir('thrid')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('thrid/'+f,encoding='cp1252',errors ='replace') as fl
i:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l
):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
```

```
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def fourthprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdat
a:','.edata:','.rsrc:','.tls:','.reloc:','.BSS:','.CODE']
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'su
b', 'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ro
r', 'rol', 'jnb','jz','rtn','lea','movzx']
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\hugeasmfile.txt","w+")
    files = os.listdir('fourth/')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('fourth/'+f,encoding='cp1252',errors ='replace') as f
li:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l
):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
```

```
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def fifthprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdat
a:','.edata:','.rsrc:','.tls:','.reloc:','.BSS:','.CODE']
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'su
b', 'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ro
r', 'rol', 'jnb','jz','rtn','lea','movzx']
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\trainasmfile.txt","w+")
    files = os.listdir('fifth/')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('fifth/'+f,encoding='cp1252',errors ='replace') as fl
i:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l
):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
```

```
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()

if __name__=="__main__":
    main()
```

In [6]:

```
# asmoutputfile.csv(output genarated from the above two cells) will contain al
l the extracted features from .asm files
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutputfile.csv")
Y.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, Y,on='ID', how='left')
result_asm.head()
```

Out[6]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 53 columns

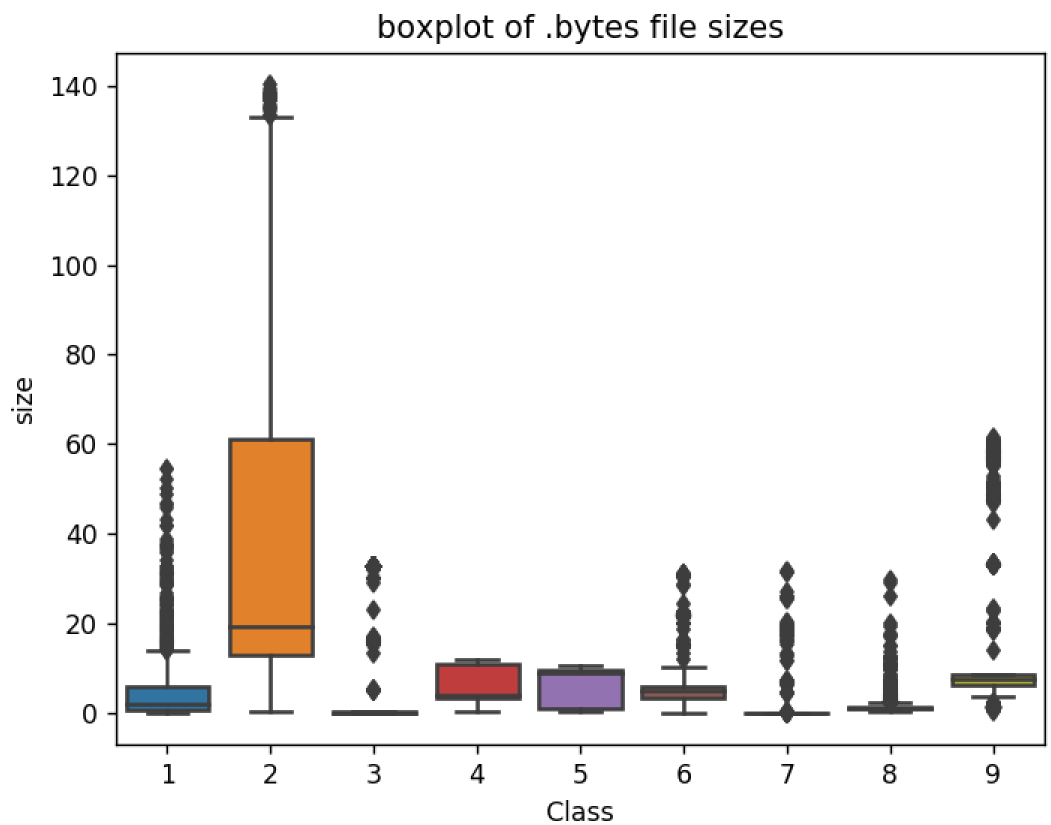
4.2.1.1 Files sizes of each .asm file

In [0]:
```
#file sizes of byte files

files=os.listdir('asmFiles')
filenames=Y['ID'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=356157170
0, st_nlink=1, st_uid=0, st_gid=0,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519
638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_s
tat.htm
    statinfo=os.stat('asmFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file na
me
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
asm_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (asm_size_byte.head())
```

```
   Class                    ID       size
0      9  01azqd4InC7m9JpocGv5  56.229886
1      2  01IsoiSMh5gxyDYTl4CB  13.999378
2      9  01jsnpXSAlgw6aPeDxrU   8.507785
3      1  01kcPWA9K2BOxQeS5Rju   0.078190
4      8  01SuzwMJEIXsK7A8dQbl   0.996723
```

4.2.1.2 Distribution of .asm file sizes

In [0]:
```
#boxplot of asm files
ax = sns.boxplot(x="Class", y="size", data=asm_size_byte)
plt.title("boxplot of .bytes file sizes")
plt.show()
```



In [0]:
```
# add the file size feature to previous extracted features
print(result_asm.shape)
print(asm_size_byte.shape)
result_asm = pd.merge(result_asm, asm_size_byte.drop(['Class'], axis=1),on='I
D', how='left')
result_asm.head()
```

```
(10868, 53)
(10868, 3)
```

Out[0]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [0]:
```
# we normalize the data each column
result_asm = normalize(result_asm)
result_asm.head()
```

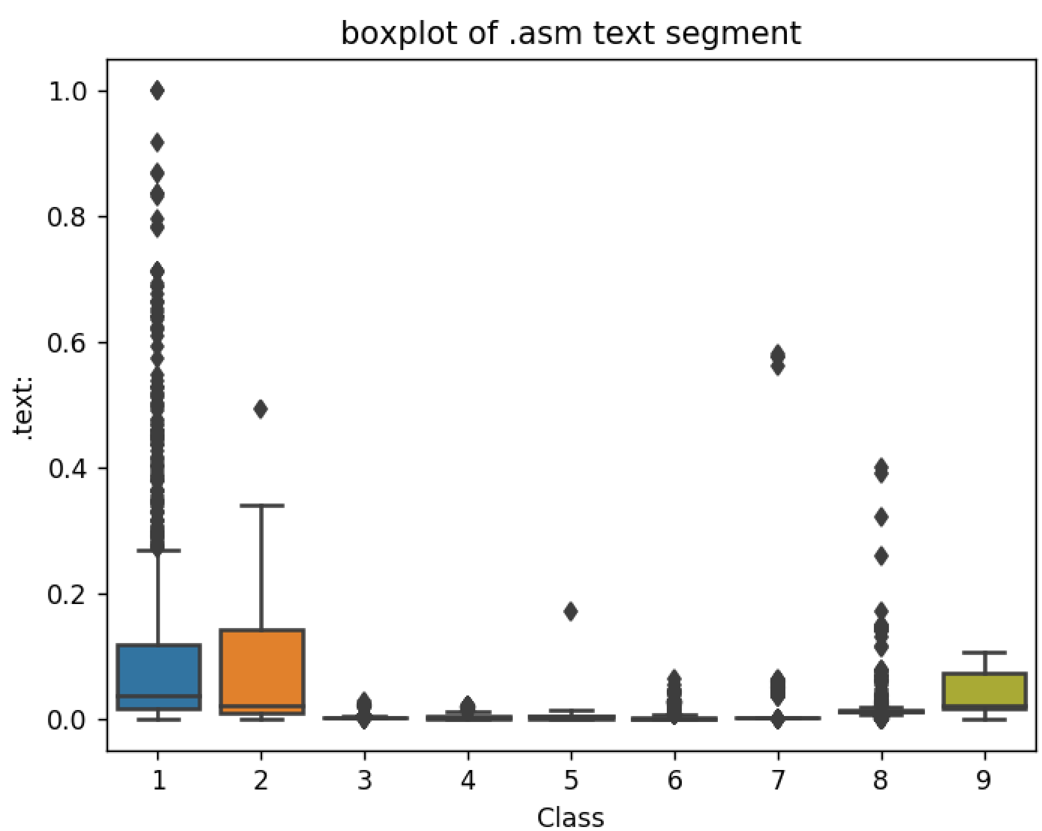
Out[0]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 54 columns

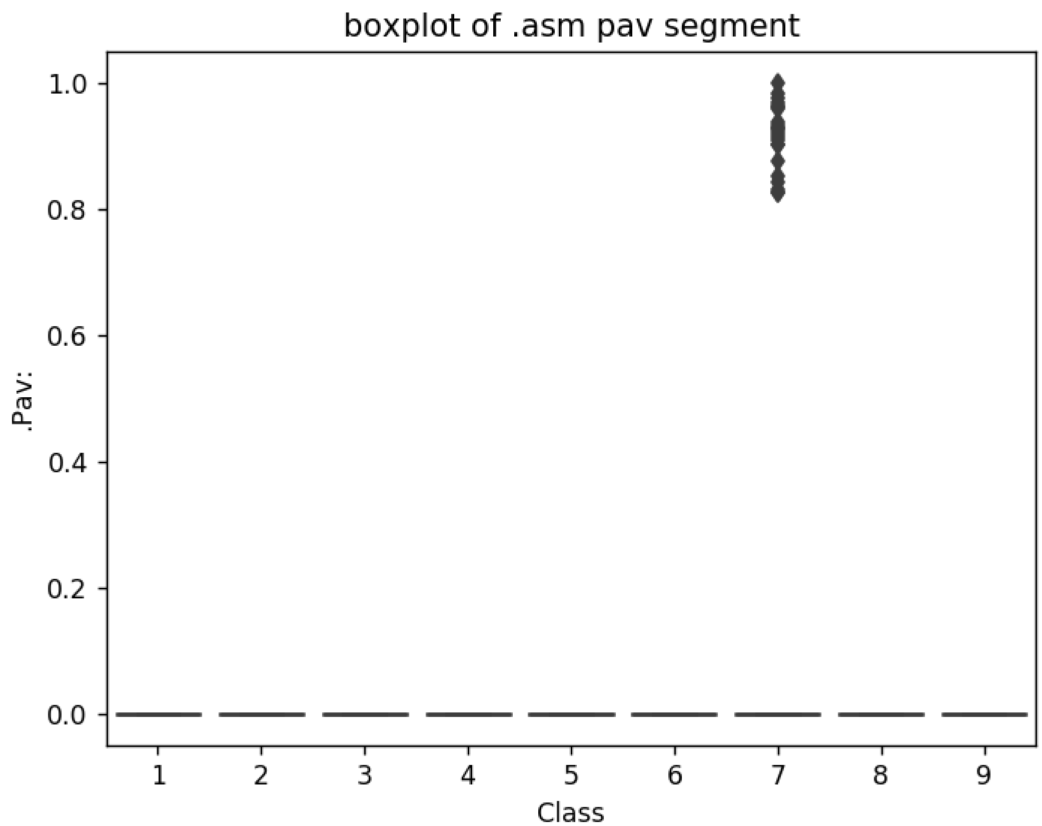
4.2.2 Univariate analysis on asm file features

In [0]:
```
ax = sns.boxplot(x="Class", y=".text:", data=result_asm)
plt.title("boxplot of .asm text segment")
plt.show()
```

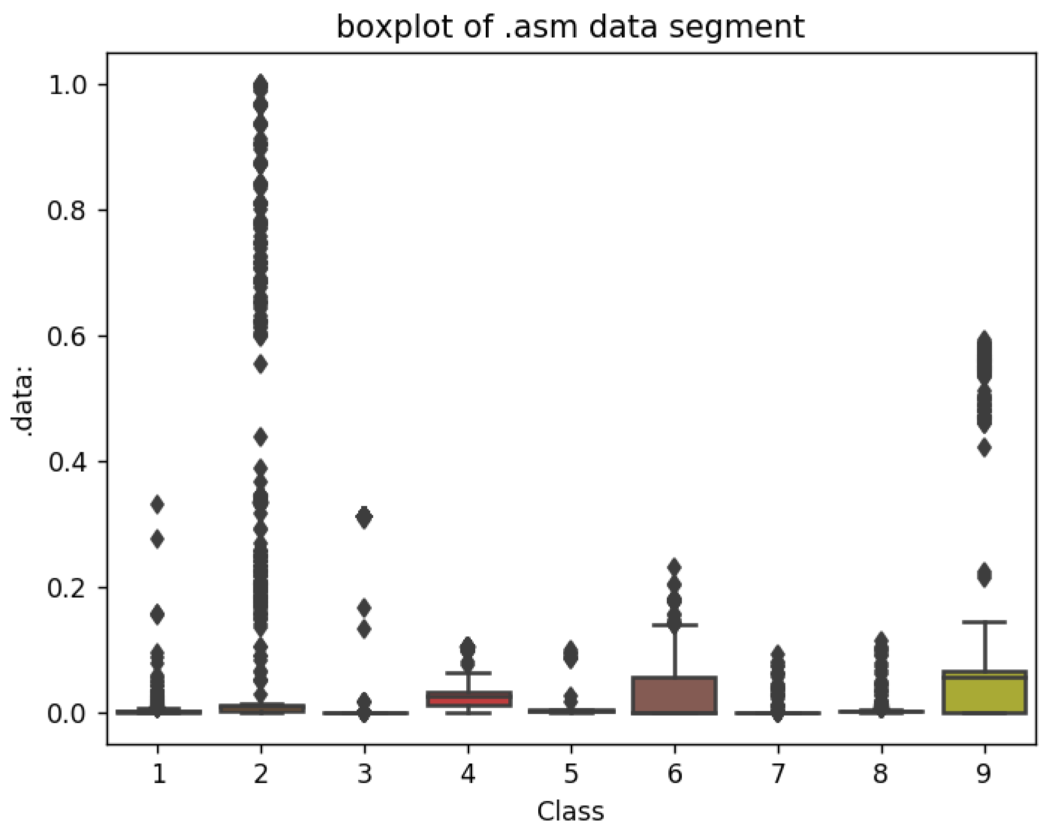


The plot is between Text and class
Class 1,2 and 9 can be easly separated

In [0]:
```
ax = sns.boxplot(x="Class", y=".Pav:", data=result_asm)
plt.title("boxplot of .asm pav segment")
plt.show()
```

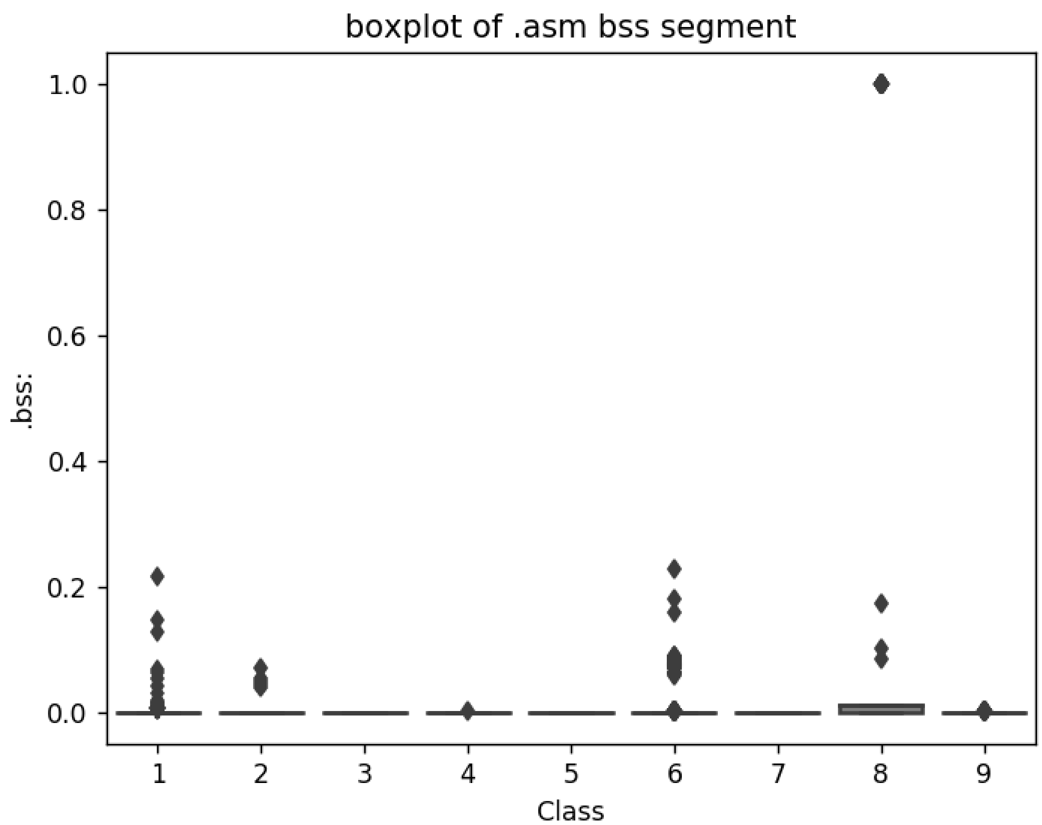


In [0]:
```
ax = sns.boxplot(x="Class", y=".data:", data=result_asm)
plt.title("boxplot of .asm data segment")
plt.show()
```



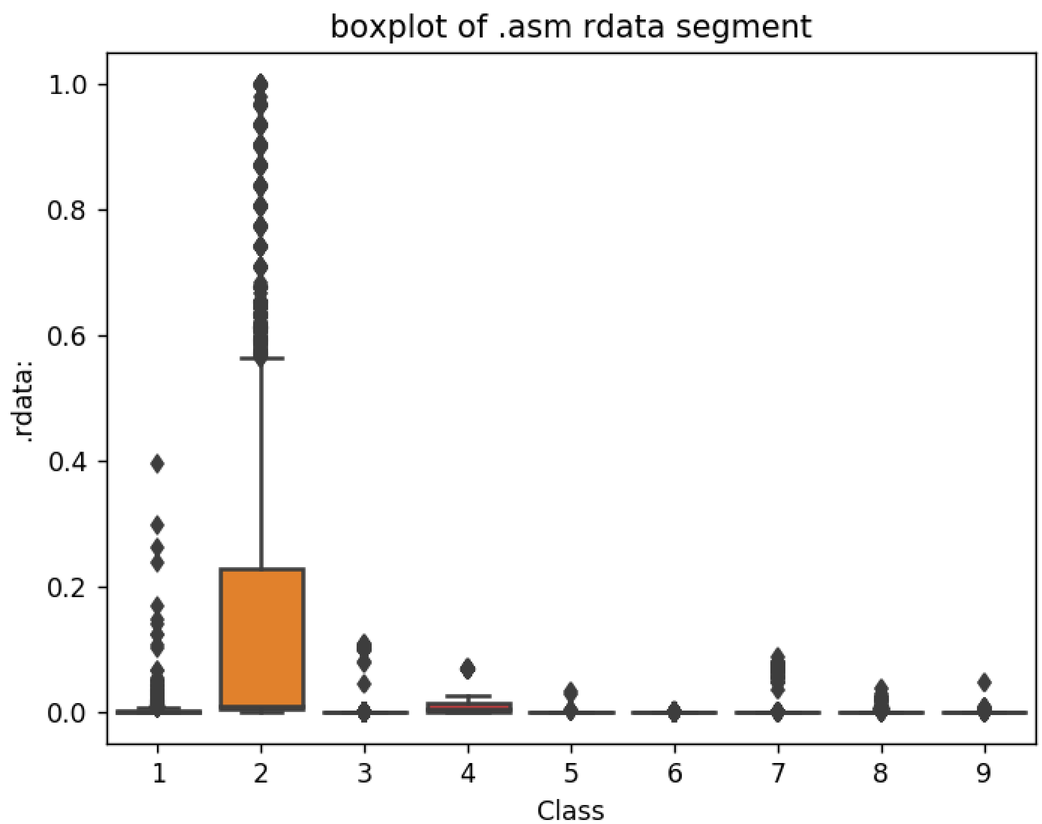
The plot is between data segment and class label
class 6 and class 9 can be easily separated from given points

In [0]:
```
ax = sns.boxplot(x="Class", y=".bss:", data=result_asm)
plt.title("boxplot of .asm bss segment")
plt.show()
```



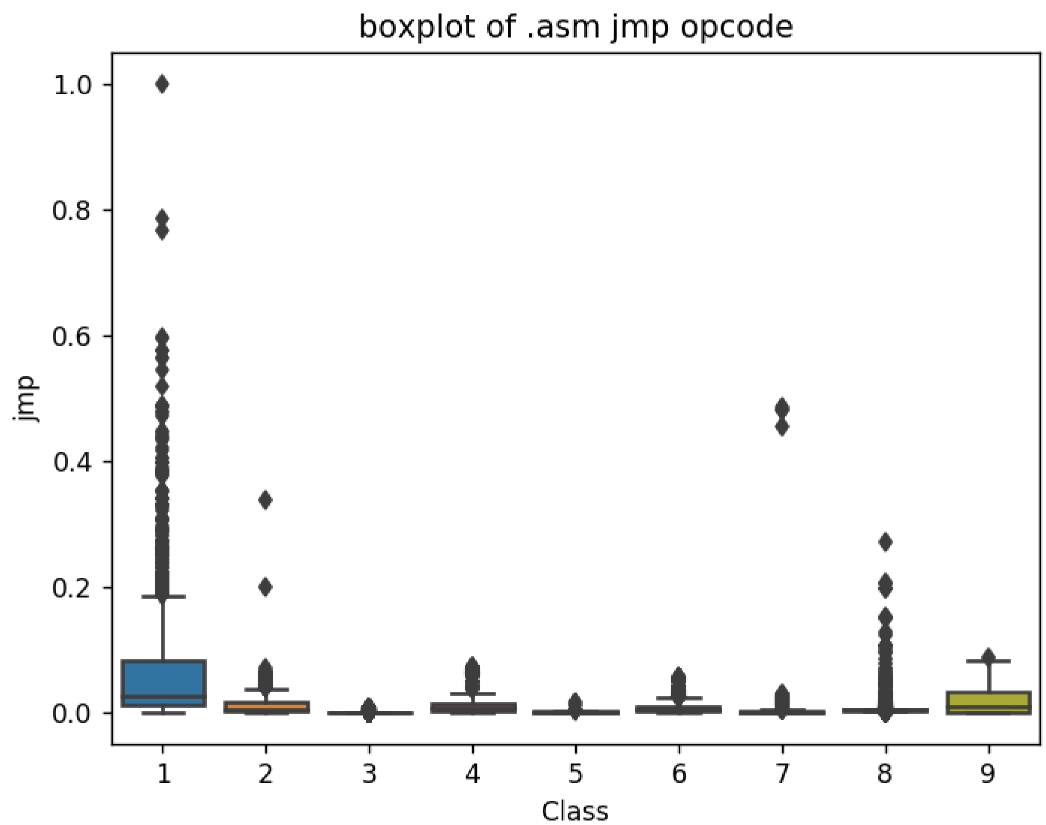
plot between bss segment and class label
very less number of files are having bss segment

In [0]:
```
ax = sns.boxplot(x="Class", y=".rdata:", data=result_asm)
plt.title("boxplot of .asm rdata segment")
plt.show()
```



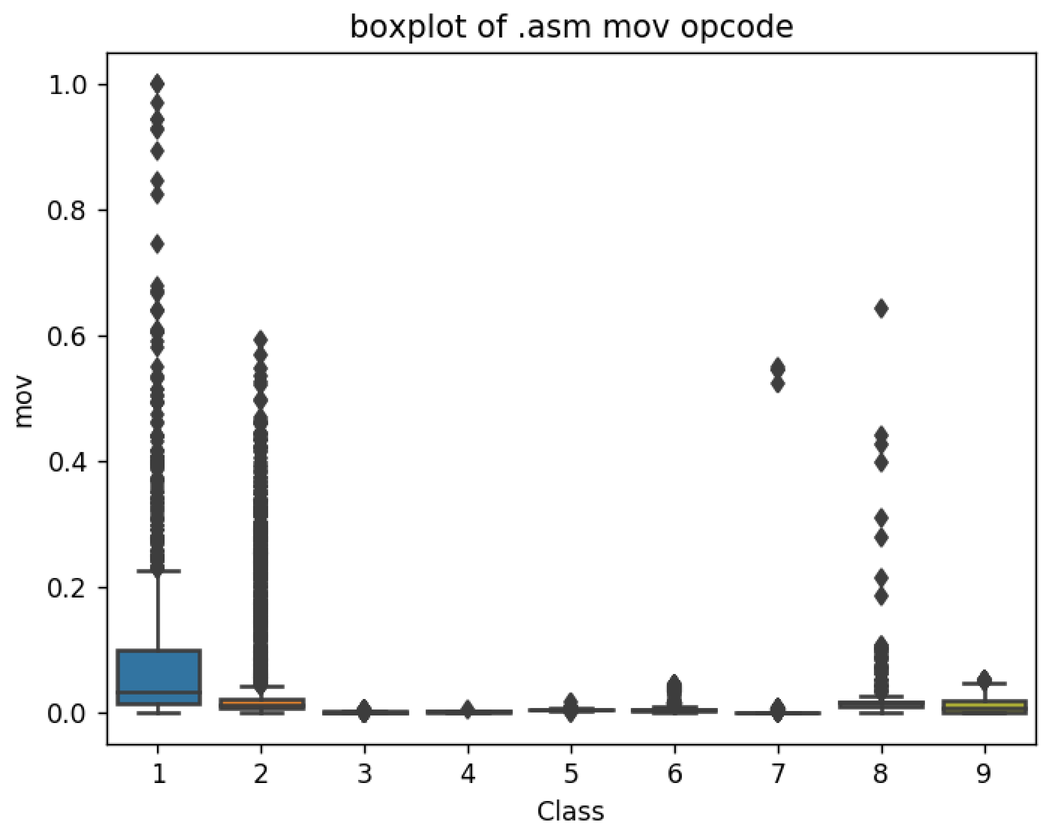
Plot between rdata segment and Class segment
Class 2 can be easily separated 75 pecentile files are having 1M rdata lines

In [0]:
```
ax = sns.boxplot(x="Class", y="jmp", data=result_asm)
plt.title("boxplot of .asm jmp opcode")
plt.show()
```



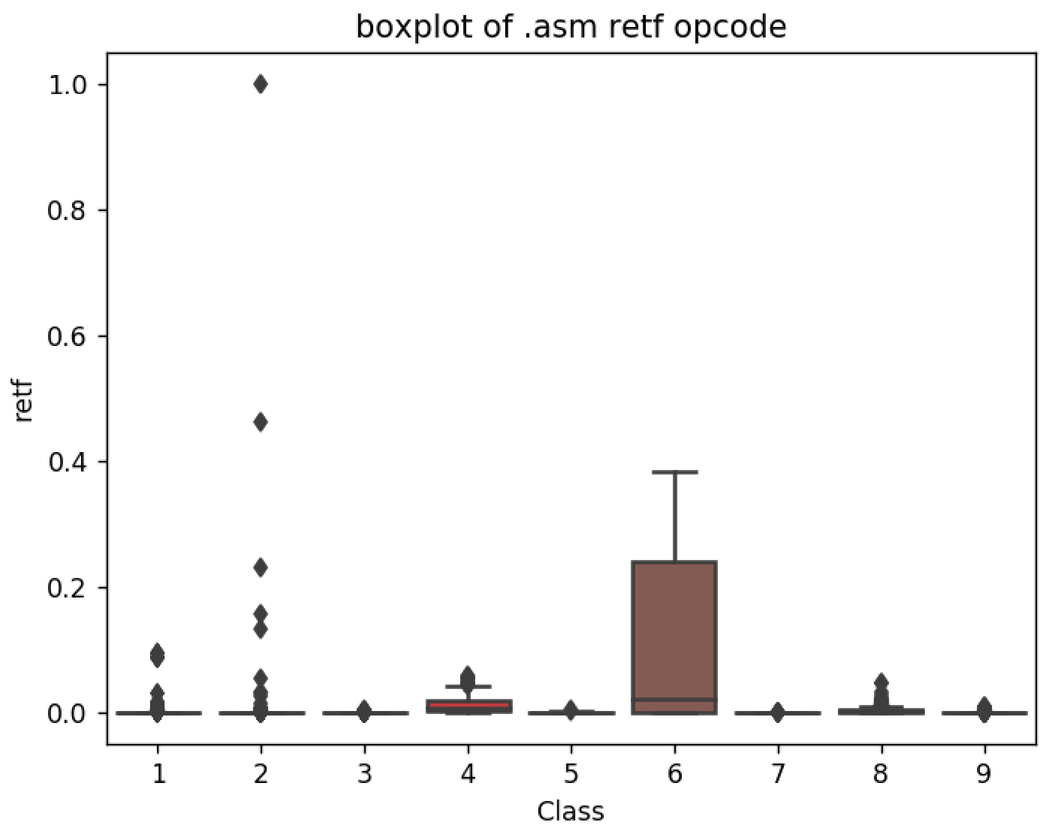
plot between jmp and Class label
Class 1 is having frequency of 2000 approx in 75 perentile of files

In [0]:
```
ax = sns.boxplot(x="Class", y="mov", data=result_asm)
plt.title("boxplot of .asm mov opcode")
plt.show()
```



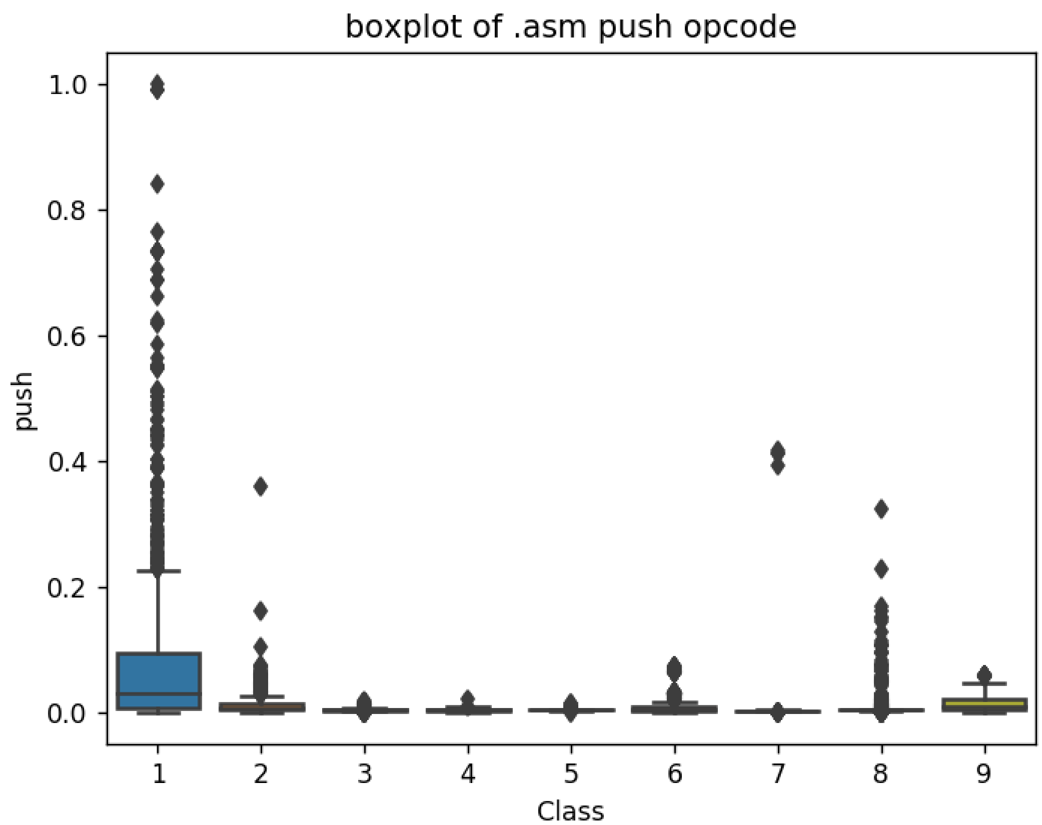
plot between Class label and mov opcode
Class 1 is having frequency of 2000 approx in 75 perentile of files

In [0]:
```
ax = sns.boxplot(x="Class", y="retf", data=result_asm)
plt.title("boxplot of .asm retf opcode")
plt.show()
```



plot between Class label and retf
Class 6 can be easily separated with opcode retf
The frequency of retf is approx of 250.

In [0]:
```
ax = sns.boxplot(x="Class", y="push", data=result_asm)
plt.title("boxplot of .asm push opcode")
plt.show()
```

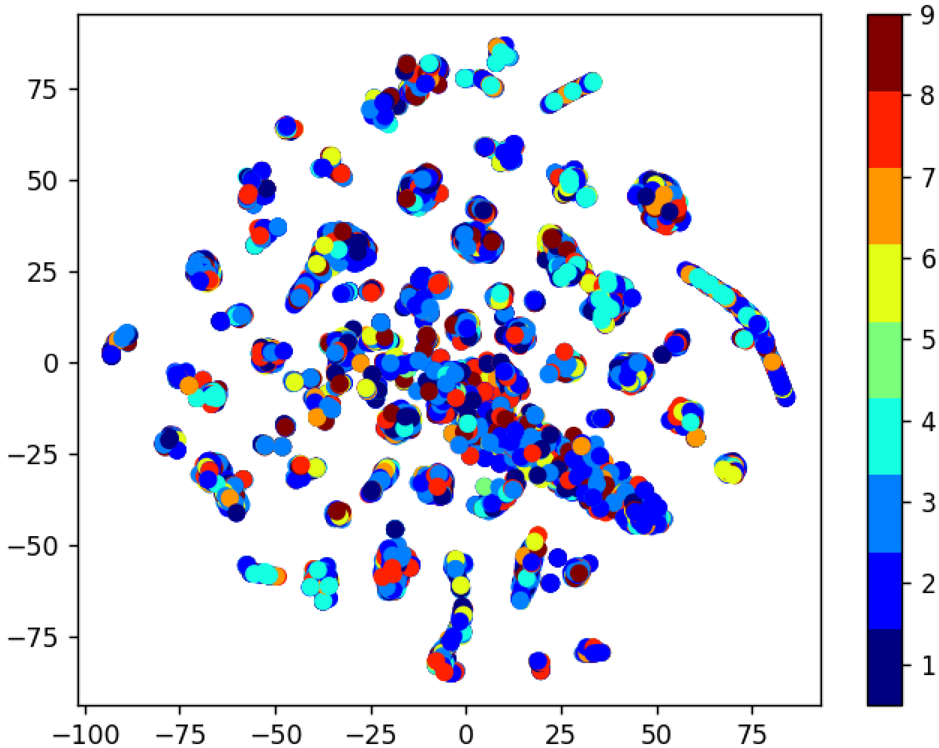


plot between push opcode and Class label
Class 1 is having 75 precentile files with push opcodes of frequency 1000

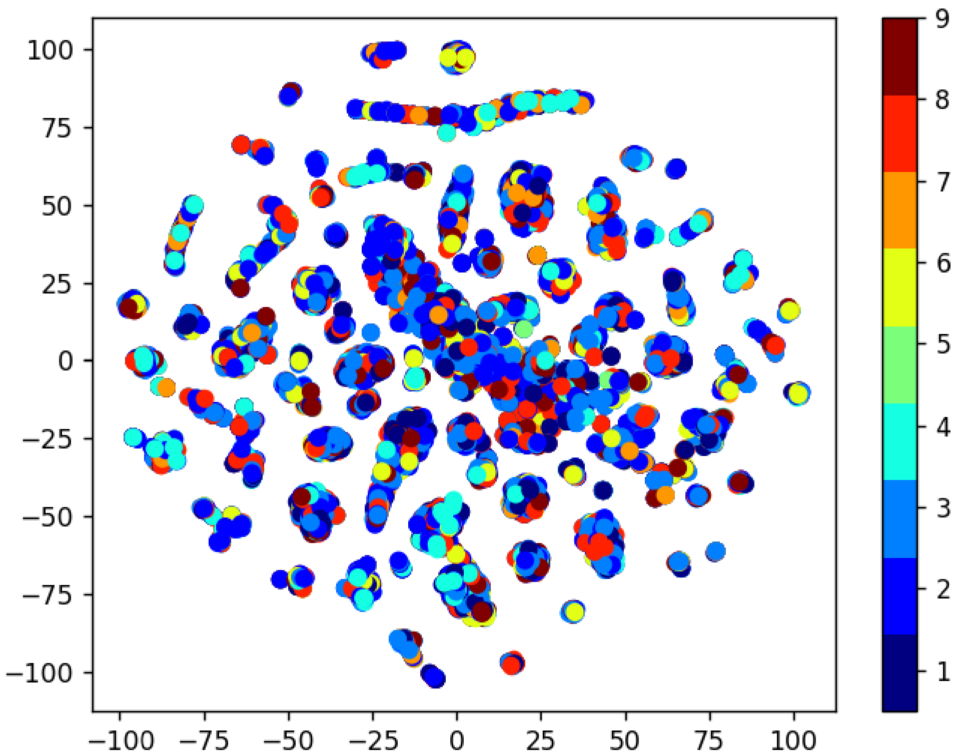
4.2.2 Multivariate Analysis on .asm file features

In [0]:

```
# check out the course content for more explantion on tsne algorithm
# https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/t-distributed-stochastic-neighbourhood-embeddingt-sne-part-1/

#multivariate analysis on byte files
#this is with perplexity 50
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_asm.drop(['ID','Class'], axis=1).fillna(0))
vis_x = results[:, 0]
vis_y = results[:, 1   ]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



In [0]:
```
# by univariate analysis on the .asm file features we are getting very negligi
ble information from
# 'rtn', '.BSS:' '.CODE' features, so heare we are trying multivariate analysi
s after removing those features
# the plot looks very messy

xtsne=TSNE(perplexity=30)
results=xtsne.fit_transform(result_asm.drop(['ID','Class', 'rtn', '.BSS:', '.C
ODE','size'], axis=1))
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



TSNE for asm data with perplexity 50

4.2.3 Conclusion on EDA

- **We have taken only 52 features from asm files (after reading through many blogs and research papers)**
- **The univariate analysis was done only on few important features.**
- **Take-aways**
  - **1. Class 3 can be easily separated because of the frequency of segments,opcodes and keywords being less**
  - **2. Each feature has its unique importance in separating the Class labels.**

4.3 Train and test split

In [0]:

```
asm_y = result_asm['Class']
asm_x = result_asm.drop(['ID','Class','.BSS:','rtn','.CODE'], axis=1)
```

In [0]:

```
X_train_asm, X_test_asm, y_train_asm, y_test_asm = train_test_split(asm_x,asm_
y ,stratify=asm_y,test_size=0.20)
X_train_asm, X_cv_asm, y_train_asm, y_cv_asm = train_test_split(X_train_asm, y
_train_asm,stratify=y_train_asm,test_size=0.20)
```

In [0]:
```
print( X_cv_asm.isnull().all())
```

```
HEADER:    False
.text:     False
.Pav:      False
.idata:    False
.data:     False
.bss:      False
.rdata:    False
.edata:    False
.rsrc:     False
.tls:      False
.reloc:    False
jmp        False
mov        False
retf       False
push       False
pop        False
xor        False
retn       False
nop        False
sub        False
inc        False
dec        False
add        False
imul       False
xchg       False
or         False
shr        False
cmp        False
call       False
shl        False
ror        False
rol        False
jnb        False
jz         False
lea        False
movzx      False
.dll       False
std::      False
:dword     False
edx        False
esi        False
eax        False
ebx        False
ecx        False
edi        False
ebp        False
esp        False
eip        False
size       False
dtype: bool
```

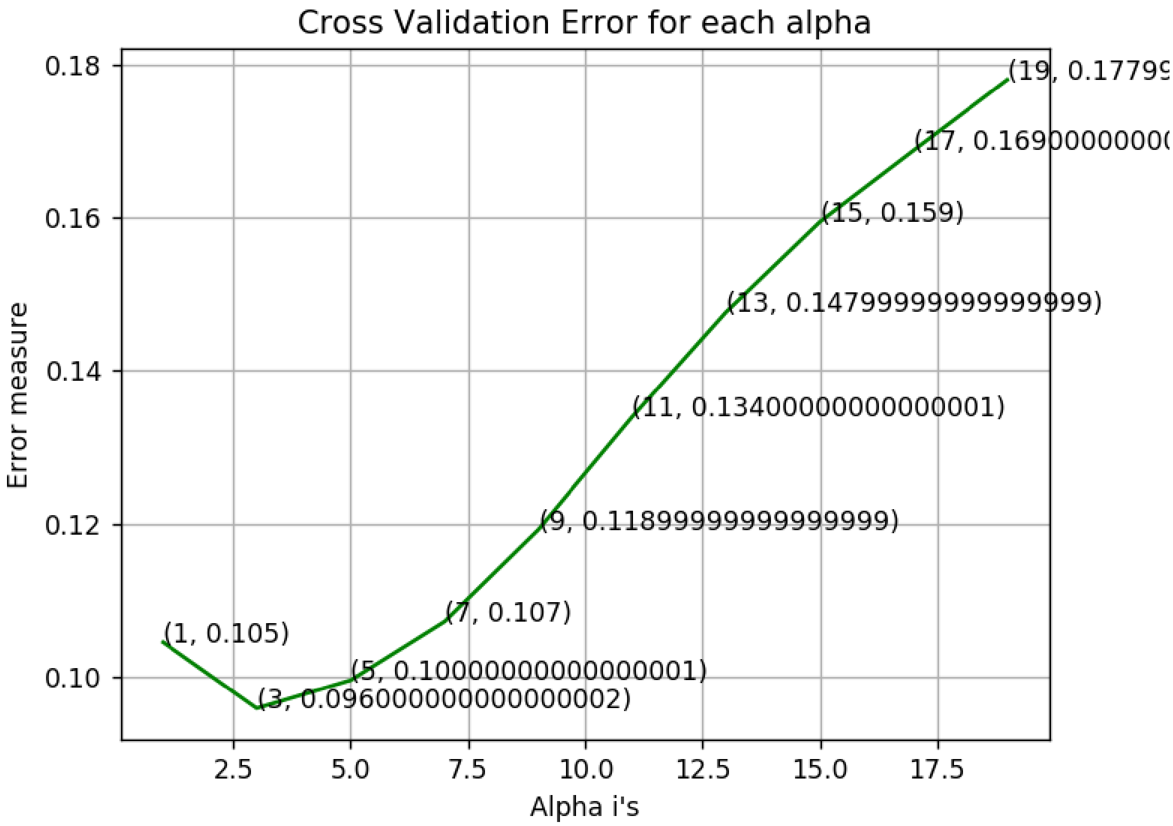
4.4. Machine Learning models on features of .asm files

4.4.1 K-Nearest Neigbors

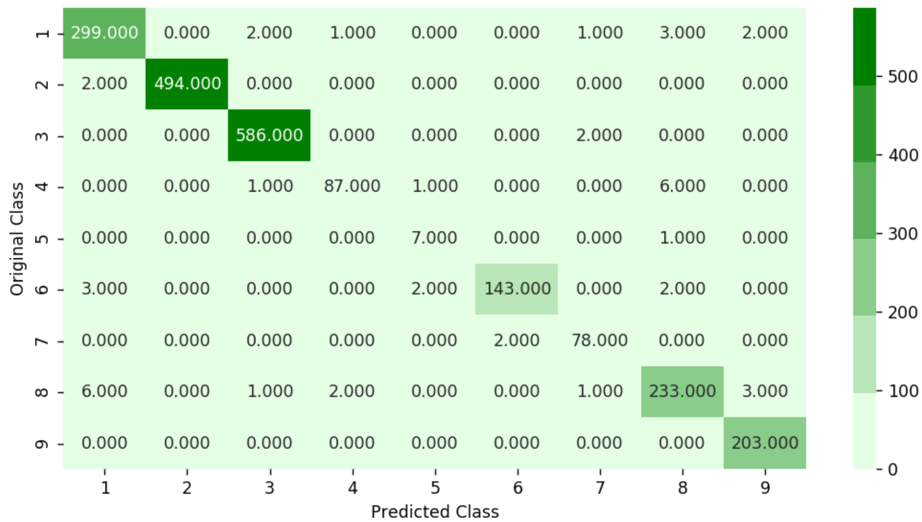
In [0]:
```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/m
odules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', lea
f_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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


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

alpha = [x for x in range(1, 21,2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=k_cfl.class
es_, eps=1e-15))

for i in range(len(cv_log_error_array)):
    print ('log_loss for k = ',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()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)
pred_y=sig_clf.predict(X_test_asm)


predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',log_loss(y_train_asm, predict_y))
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',log_loss(y_cv_asm, predict_y))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',log_loss(y_test_asm, predict_y))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

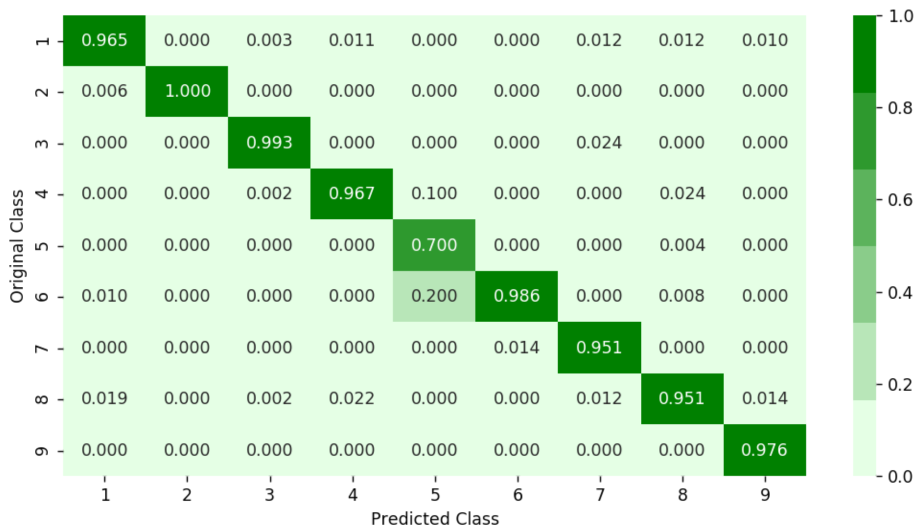
```
log_loss for k =  1 is 0.104531321344
log_loss for k =  3 is 0.0958800580948
log_loss for k =  5 is 0.0995466557335
log_loss for k =  7 is 0.107227274345
log_loss for k =  9 is 0.119239543547
log_loss for k =  11 is 0.133926642781
log_loss for k =  13 is 0.147643793967
log_loss for k =  15 is 0.159439699615
log_loss for k =  17 is 0.16878376444
log_loss for k =  19 is 0.178020728839
```



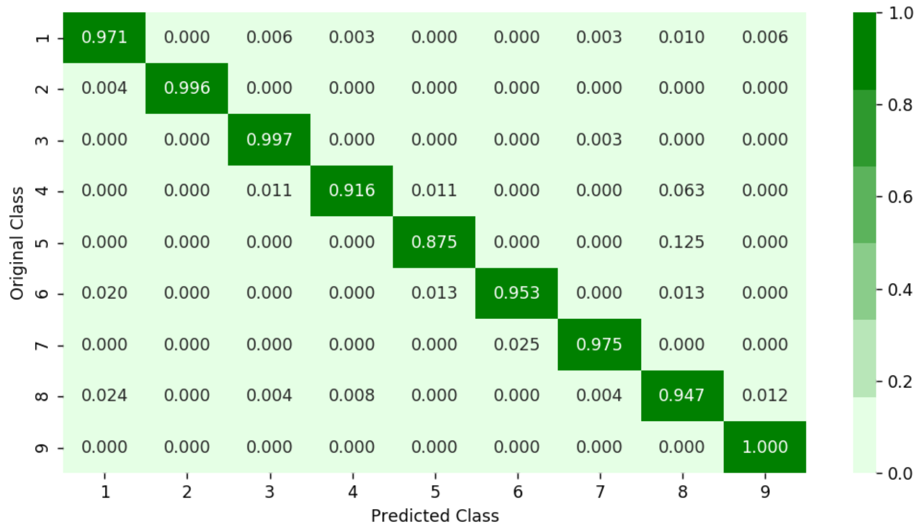

```
log loss for train data 0.0476773462198
log loss for cv data 0.0958800580948
log loss for test data 0.0894810720832
Number of misclassified points  2.02391904324
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```




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




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



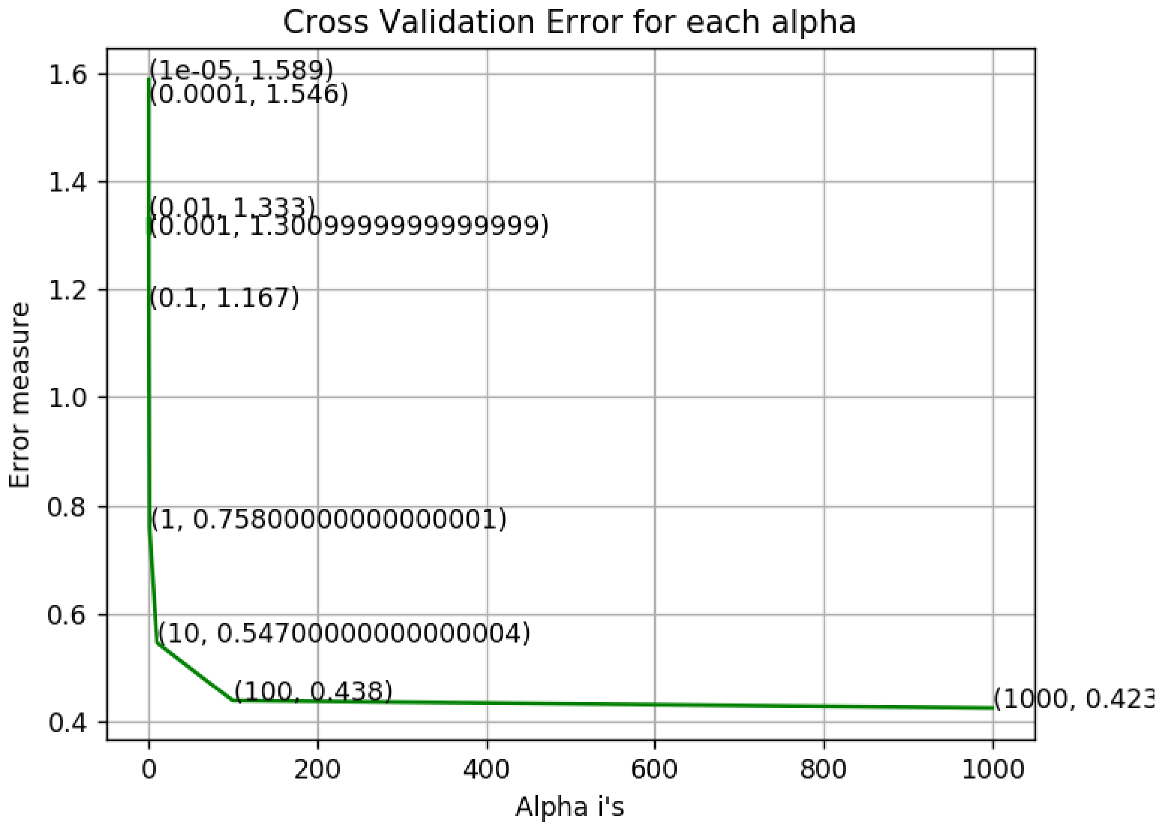

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.4.2 Logistic Regression

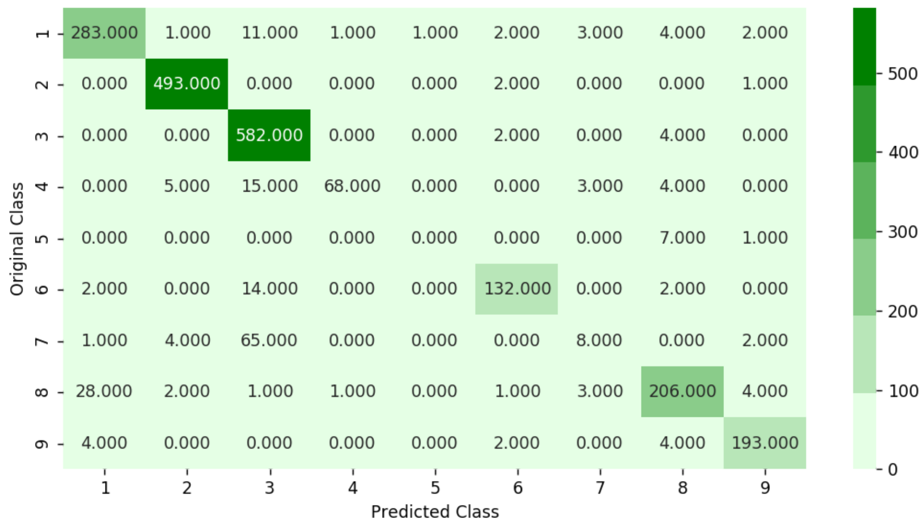
In [0]:
```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/ge
nerated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_i
ntercept=True, max_iter=None,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

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

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


alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=logisticR.c
lasses_, 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()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='ba
lanced')
logisticR.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)

predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',(log_loss(y_train_asm, predict_y, labels=logi
sticR.classes_, eps=1e-15)))
```

```
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=logisticR.
classes_, eps=1e-15)))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',(log_loss(y_test_asm, predict_y, labels=logist
icR.classes_, eps=1e-15)))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

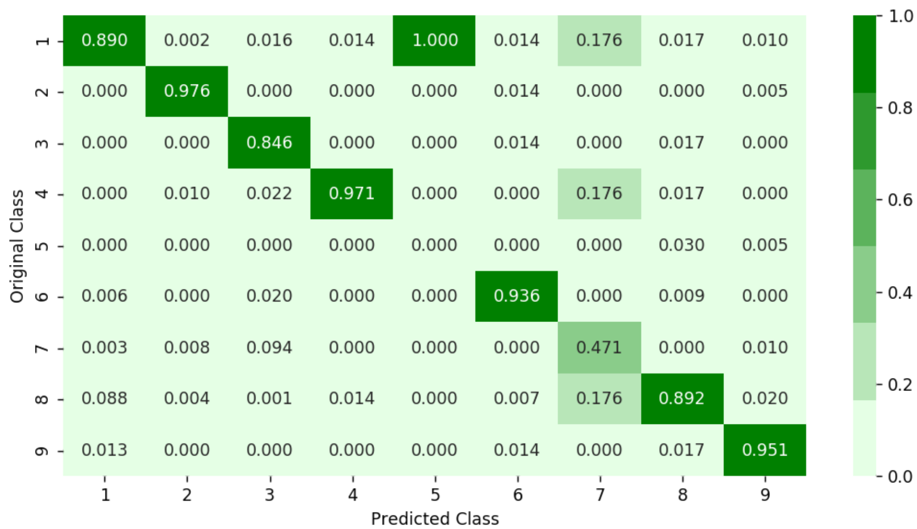
```
log_loss for c =  1e-05 is 1.58867274165
log_loss for c =  0.0001 is 1.54560797884
log_loss for c =  0.001 is 1.30137786807
log_loss for c =  0.01 is 1.33317456931
log_loss for c =  0.1 is 1.16705751378
log_loss for c =  1 is 0.757667807779
log_loss for c =  10 is 0.546533939819
log_loss for c =  100 is 0.438414998062
log_loss for c =  1000 is 0.424423536526
```



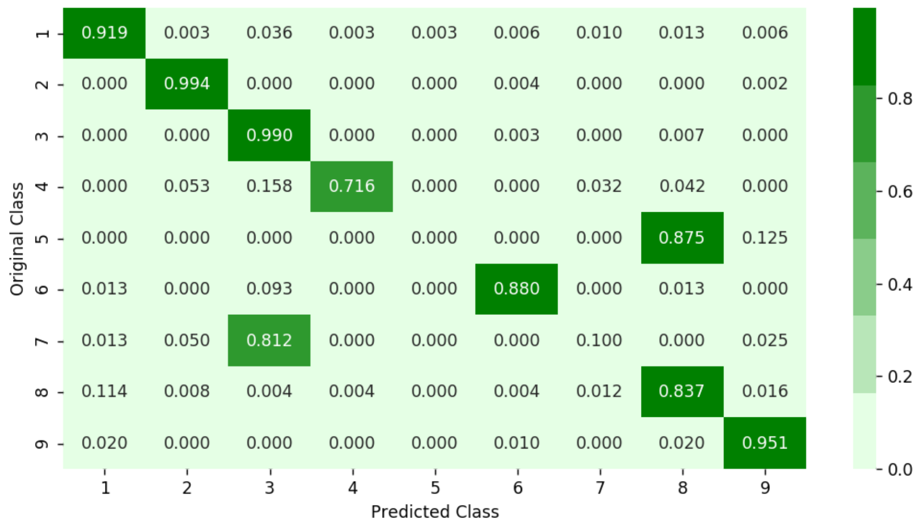

```
log loss for train data 0.396219394701
log loss for cv data 0.424423536526
log loss for test data 0.415685592517
Number of misclassified points  9.61361545538
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```



-- Precision matrix ---



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



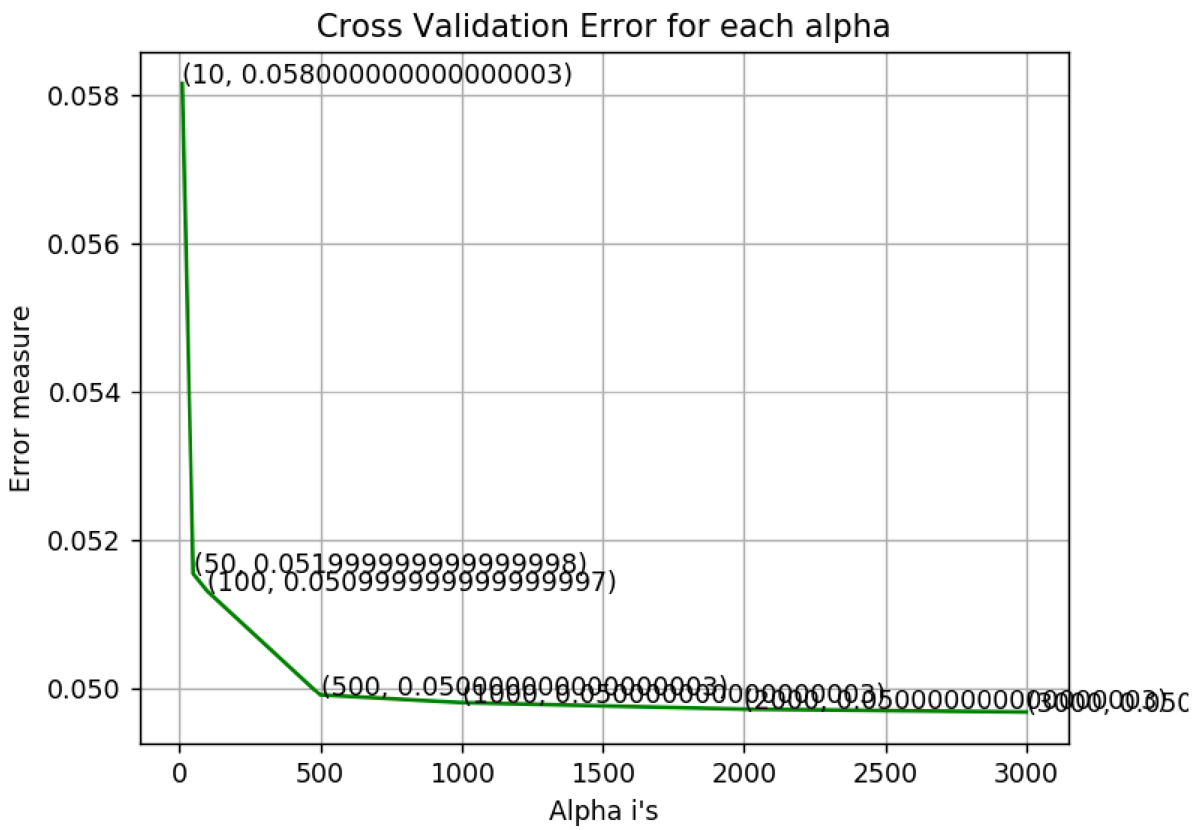

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.4.3 Random Forest Classifier

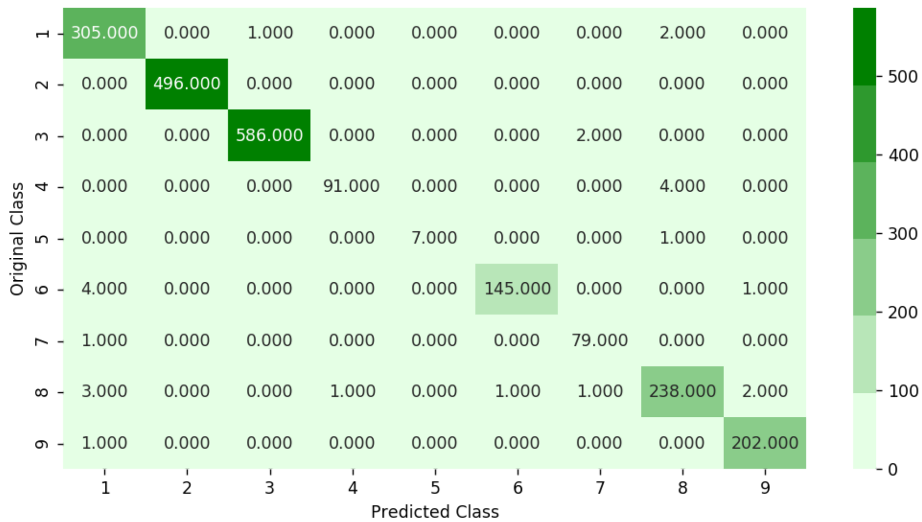
In [0]:
```
# -------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=r_cfl.class
es_, 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_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
```

```
sig_clf.fit(X_train_asm, y_train_asm)
predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',(log_loss(y_train_asm, predict_y, labels=sig_
clf.classes_, eps=1e-15)))
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=sig_clf.cl
asses_, eps=1e-15)))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',(log_loss(y_test_asm, predict_y, labels=sig_cl
f.classes_, eps=1e-15)))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

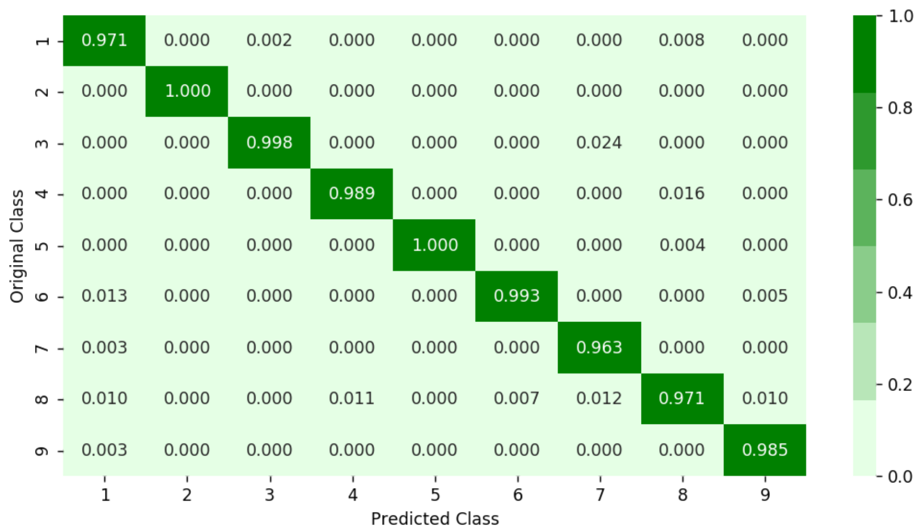
```
log_loss for c =  10 is 0.0581657906023
log_loss for c =  50 is 0.0515443148419
log_loss for c =  100 is 0.0513084973231
log_loss for c =  500 is 0.0499021761479
log_loss for c =  1000 is 0.0497972474298
log_loss for c =  2000 is 0.0497091690815
log_loss for c =  3000 is 0.0496706817633
```



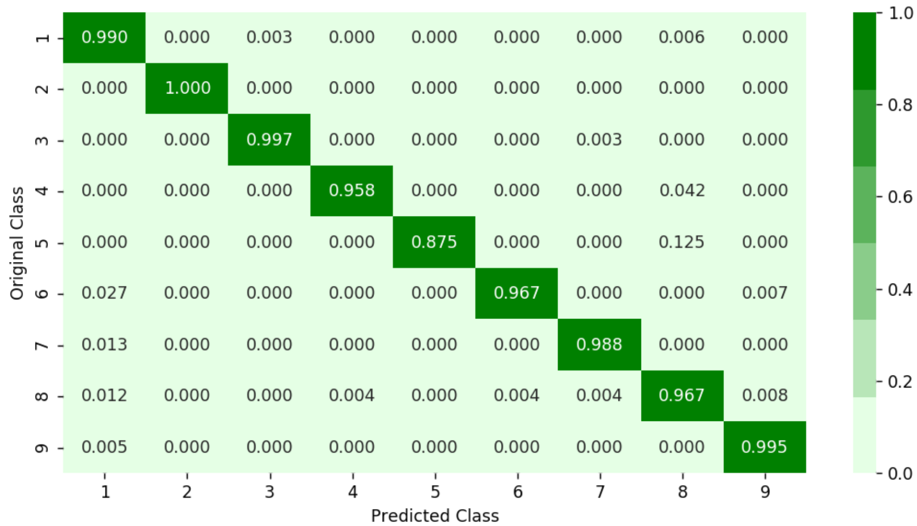

```
log loss for train data 0.0116517052676
log loss for cv data 0.0496706817633
log loss for test data 0.0571239496453
Number of misclassified points  1.14995400184
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```



-- Precision matrix ---



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



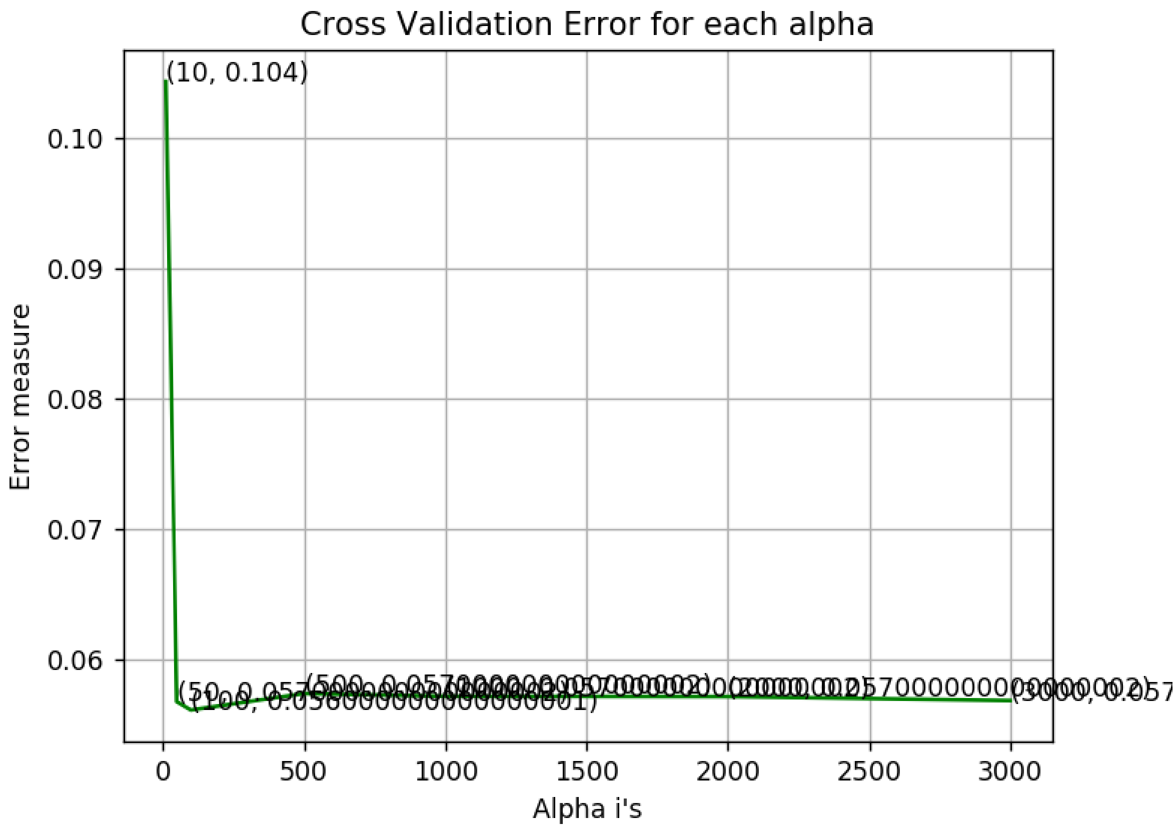

```
Sum of rows in precision matrix [ 1.  1.  1.  1.  1.  1.  1.  1.  1.]
```

4.4.4 XgBoost Classifier

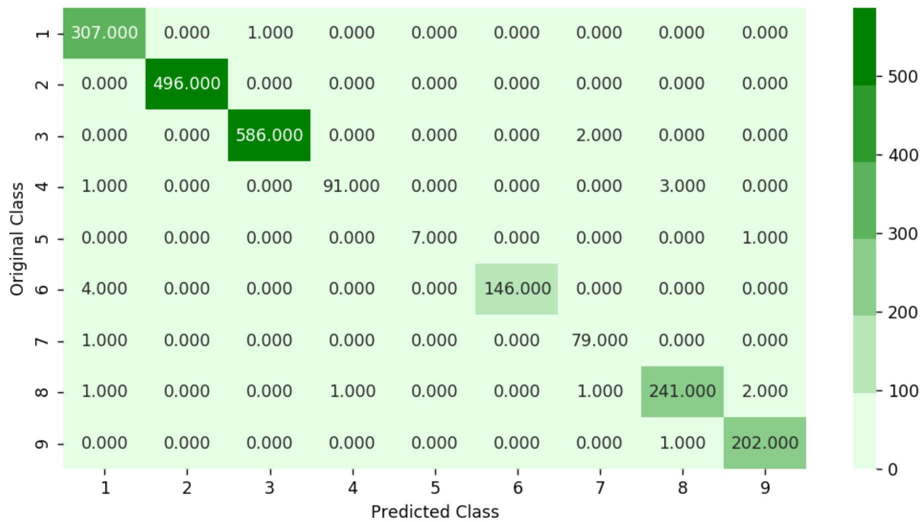
In [0]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,nthread=-1)
    x_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=x_cfl.class
es_, 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)
x_cfl.fit(X_train_asm,y_train_asm)
```

```
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)

predict_y = sig_clf.predict_proba(X_train_asm)

print ('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_asm, predict_y))
predict_y = sig_clf.predict_proba(X_cv_asm)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation
 log loss is:",log_loss(y_cv_asm, predict_y))
predict_y = sig_clf.predict_proba(X_test_asm)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_asm, predict_y))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

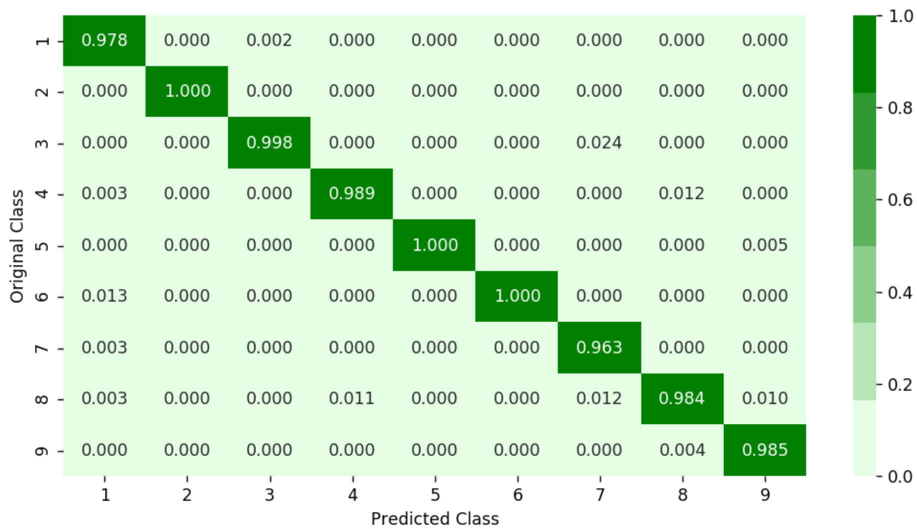
```
log_loss for c =  10 is 0.104344888454
log_loss for c =  50 is 0.0567190635611
log_loss for c =  100 is 0.056075038646
log_loss for c =  500 is 0.057336051683
log_loss for c =  1000 is 0.0571265109903
log_loss for c =  2000 is 0.057103406781
log_loss for c =  3000 is 0.0567993215778
```



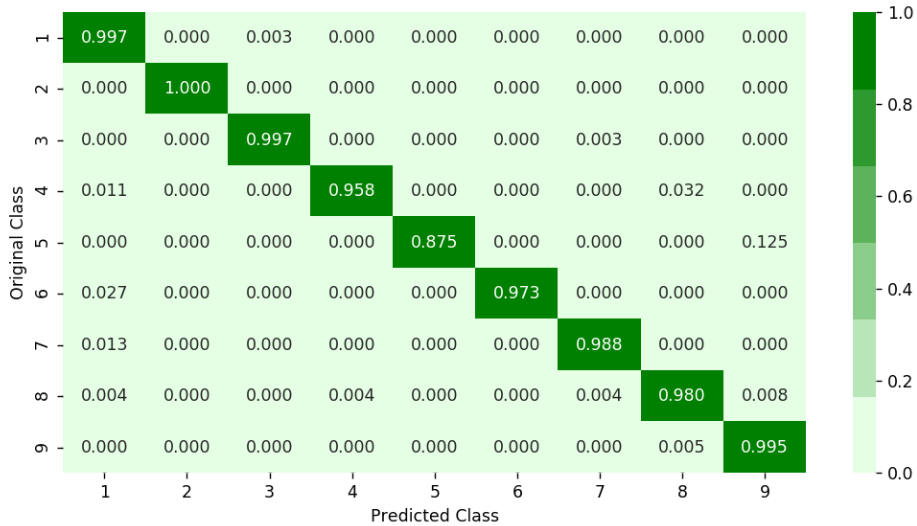

```
For values of best alpha =  100 The train log loss is: 0.0117883742574
For values of best alpha =  100 The cross validation log loss is: 0.056075038
646
For values of best alpha =  100 The test log loss is: 0.0491647763845
Number of misclassified points  0.873965041398
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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




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

4.4.5 Xgboost Classifier with best hyperparameters

In [0]:
```
x_cfl=XGBClassifier()

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],
    '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,n_job
s=-1,)
random_cfl.fit(X_train_asm,y_train_asm)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Done   2 tasks      | elapsed:    8.1s
[Parallel(n_jobs=-1)]: Done   9 tasks      | elapsed:   32.8s
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  1.1min remaining:   3
9.3s
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  1.3min remaining:   2
3.0s
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  1.4min remaining:
9.2s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  2.3min finished
```

Out[0]:
```
RandomizedSearchCV(cv=None, error_score='raise',
          estimator=XGBClassifier(base_score=0.5, colsample_bylevel=1, colsam
ple_bytree=1,
       gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=3,
       min_child_weight=1, missing=None, n_estimators=100, nthread=-1,
       objective='binary:logistic', reg_alpha=0, reg_lambda=1,
       scale_pos_weight=1, seed=0, silent=True, subsample=1),
          fit_params=None, iid=True, n_iter=10, n_jobs=-1,
          param_distributions={'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],
'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5, 1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score=True, scoring=None, verbose=10)
```

In [0]:
```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 200, 'max_depth': 5, 'learning_rate': 0.15,
'colsample_bytree': 0.5}
```

In [0]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(n_estimators=200,subsample=0.5,learning_rate=0.15,colsampl
e_bytree=0.5,max_depth=3)
x_cfl.fit(X_train_asm,y_train_asm)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train_asm,y_train_asm)

predict_y = c_cfl.predict_proba(X_train_asm)
print ('train loss',log_loss(y_train_asm, predict_y))
predict_y = c_cfl.predict_proba(X_cv_asm)
print ('cv loss',log_loss(y_cv_asm, predict_y))
predict_y = c_cfl.predict_proba(X_test_asm)
print ('test loss',log_loss(y_test_asm, predict_y))
```

```
train loss 0.0102661325822
cv loss 0.0501201796687
test loss 0.0483908764397
```

4.5. Machine Learning models on features of both .asm and .bytes files

4.5.1. Merging both asm and byte file features

In [0]:
```
result.head()
```

Out[0]:

	ID	0	1	2	3	4	5	
0	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.0020
1	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.0047
2	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.0050
3	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.0003
4	01SuzwMJEIXsK7A8dQbI	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.0001

5 rows × 260 columns

In [0]:
```
result_asm.head()
```

Out[0]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 54 columns

In [0]:
```
print(result.shape)
print(result_asm.shape)
```

```
(10868, 260)
(10868, 54)
```

In [0]:
```
result_x = pd.merge(result,result_asm.drop(['Class'], axis=1),on='ID', how='left')
result_y = result_x['Class']
result_x = result_x.drop(['ID','rtn','.BSS:','.CODE','Class'], axis=1)
result_x.head()
```

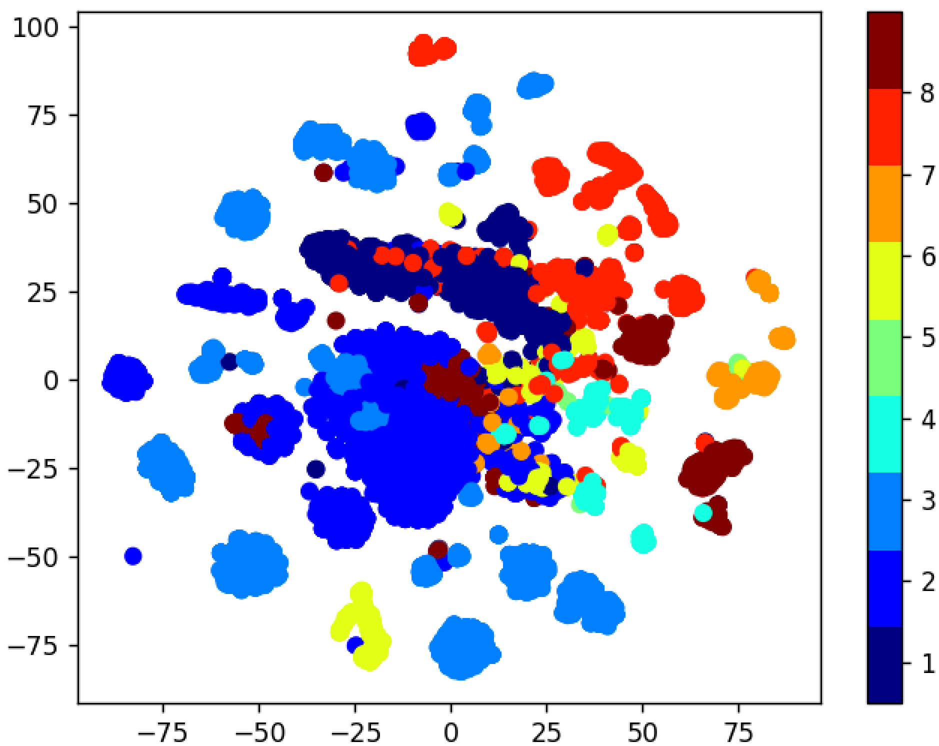
Out[0]:

	0	1	2	3	4	5	6	7	8	
0	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.002058	0.002946	0.002638	0.(
1	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984	0.008267	0.(
2	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155	0.008104	0.(
3	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481	0.000959	0.(
4	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229	0.000376	0.(

5 rows × 307 columns

4.5.2. Multivariate Analysis on final fearures

In [0]:
```
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_x, axis=1))
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=result_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(9))
plt.clim(0.5, 9)
plt.show()
```



4.5.3. Train and Test split

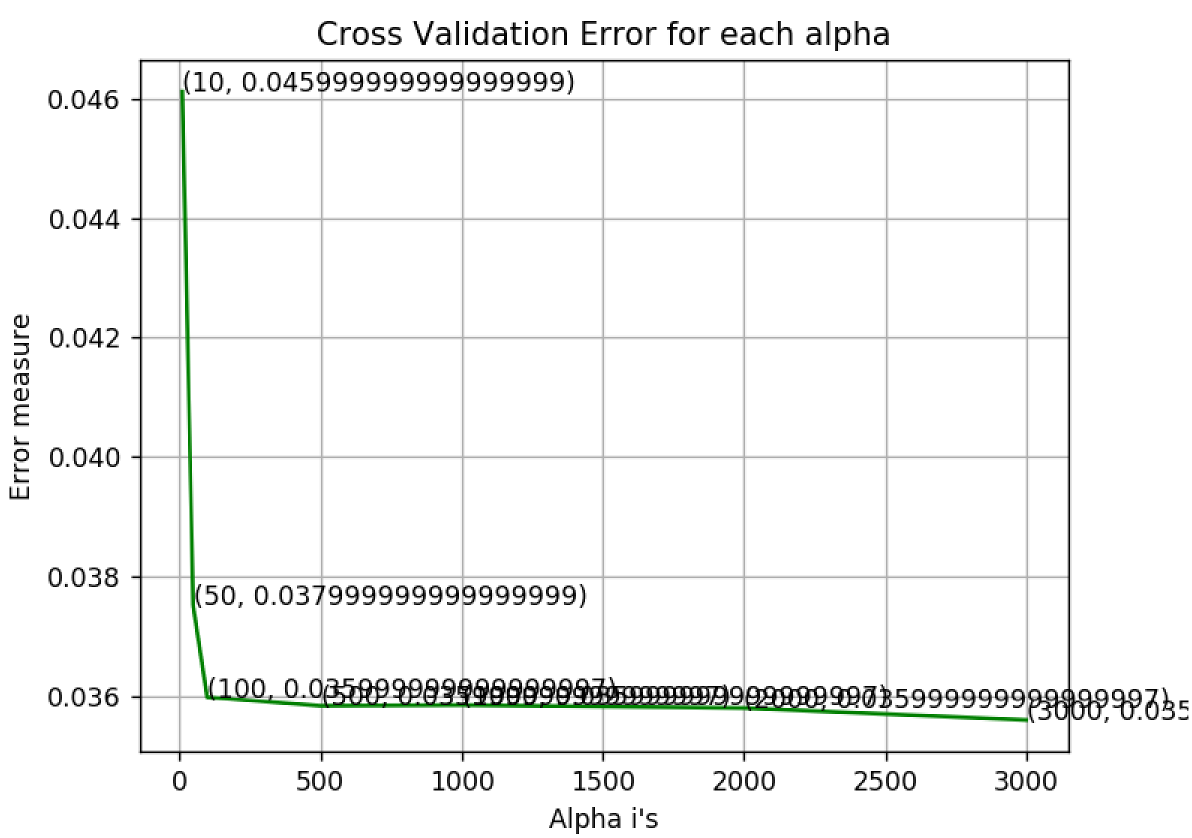
In [0]:
```
X_train, X_test_merge, y_train, y_test_merge = train_test_split(result_x, resu
lt_y,stratify=result_y,test_size=0.20)
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_trai
n, y_train,stratify=y_train,test_size=0.20)
```

4.5.4. Random Forest Classifier on final features

In [0]:
```
# ----------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    cv_log_error_array.append(log_loss(y_cv_merge, predict_y, labels=r_cfl.cla
sses_, 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_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_merge, predict_y))
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation
 log loss is:",log_loss(y_cv_merge, predict_y))
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_merge, predict_y))
```

```
log_loss for c =  10 is 0.0461221662017
log_loss for c =  50 is 0.0375229563452
log_loss for c =  100 is 0.0359765822455
log_loss for c =  500 is 0.0358291883873
log_loss for c =  1000 is 0.0358403093496
log_loss for c =  2000 is 0.0357908022178
log_loss for c =  3000 is 0.0355909487962
```




```
For values of best alpha =  3000 The train log loss is: 0.0166267614753
For values of best alpha =  3000 The cross validation log loss is: 0.03559094
87962
For values of best alpha =  3000 The test log loss is: 0.0401141303589
```

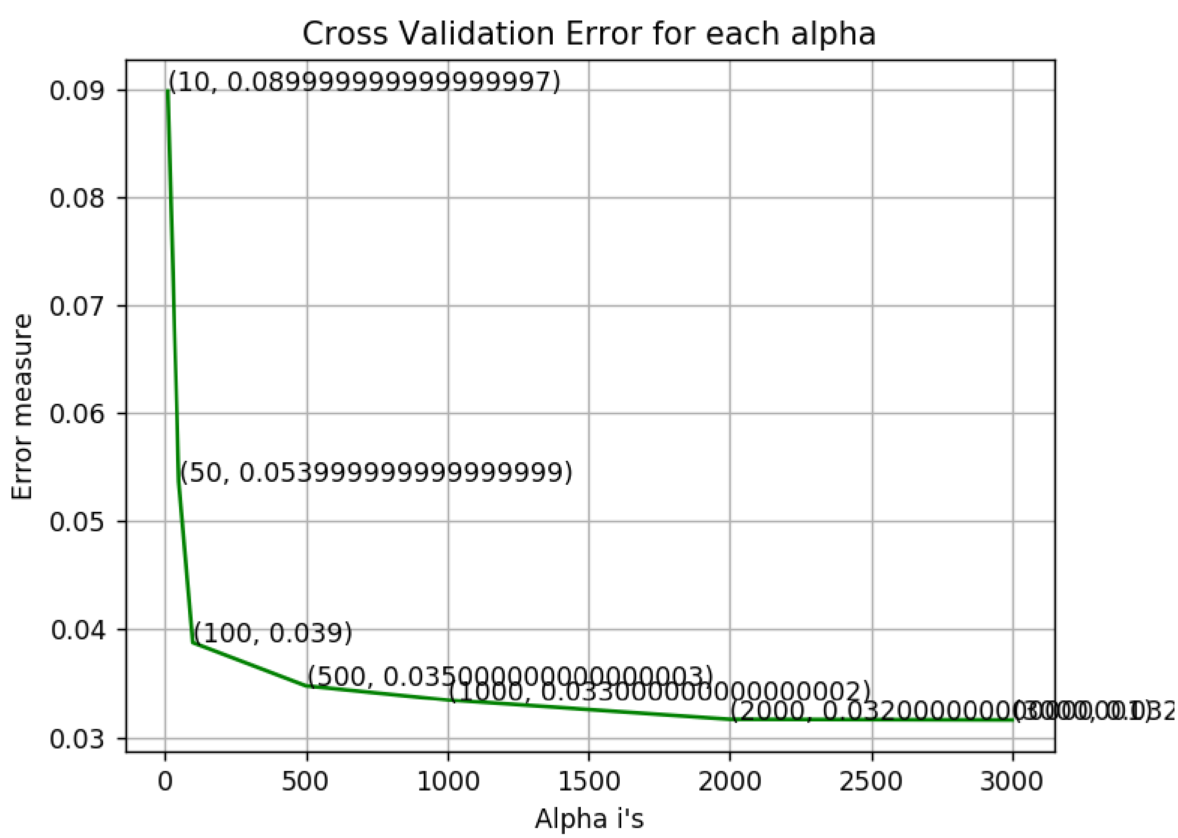
4.5.5. XgBoost Classifier on final features

In [0]:

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

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i)
    x_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    cv_log_error_array.append(log_loss(y_cv_merge, predict_y, labels=x_cfl.cla
sses_, 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=3000,nthread=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
```

```
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_merge, predict_y))
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation
 log loss is:",log_loss(y_cv_merge, predict_y))
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_merge, predict_y))
```

```
log_loss for c =  10 is 0.0898979446265
log_loss for c =  50 is 0.0536946658041
log_loss for c =  100 is 0.0387968186177
log_loss for c =  500 is 0.0347960327293
log_loss for c =  1000 is 0.0334668083237
log_loss for c =  2000 is 0.0316569078846
log_loss for c =  3000 is 0.0315972694477
```




```
For values of best alpha =  3000 The train log loss is: 0.0111918809342
For values of best alpha =  3000 The cross validation log loss is: 0.03159726
94477
For values of best alpha =  3000 The test log loss is: 0.0323978515915
```

4.5.5. XgBoost Classifier on final features with best hyper parameters using Random search

In [0]:
```
x_cfl=XGBClassifier()

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],
    '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,n_job
s=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Done   2 tasks      | elapsed:  1.1min
[Parallel(n_jobs=-1)]: Done   9 tasks      | elapsed:  2.2min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  4.5min remaining:  2.6
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  5.8min remaining:  1.8
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  6.7min remaining:   4
4.5s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  7.4min finished
```

Out[0]:
```
RandomizedSearchCV(cv=None, error_score='raise',
          estimator=XGBClassifier(base_score=0.5, colsample_bylevel=1, colsam
ple_bytree=1,
       gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=3,
       min_child_weight=1, missing=None, n_estimators=100, nthread=-1,
       objective='binary:logistic', reg_alpha=0, reg_lambda=1,
       scale_pos_weight=1, seed=0, silent=True, subsample=1),
          fit_params=None, iid=True, n_iter=10, n_jobs=-1,
          param_distributions={'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],
'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5, 1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score=True, scoring=None, verbose=10)
```

In [0]:
```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 1000, 'max_depth': 10, 'learning_rate': 0.1
5, 'colsample_bytree': 0.3}
```

In [0]:
```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(n_estimators=1000,max_depth=10,learning_rate=0.15,colsampl
e_bytree=0.3,subsample=1,nthread=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_merge, predict_y))
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation
 log loss is:",log_loss(y_cv_merge, predict_y))
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_merge, predict_y))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  3000 The train log loss is: 0.0121922832297
For values of best alpha =  3000 The cross validation log loss is: 0.03449554
87471
For values of best alpha =  3000 The test log loss is: 0.0317041132442
```

5. Assignments

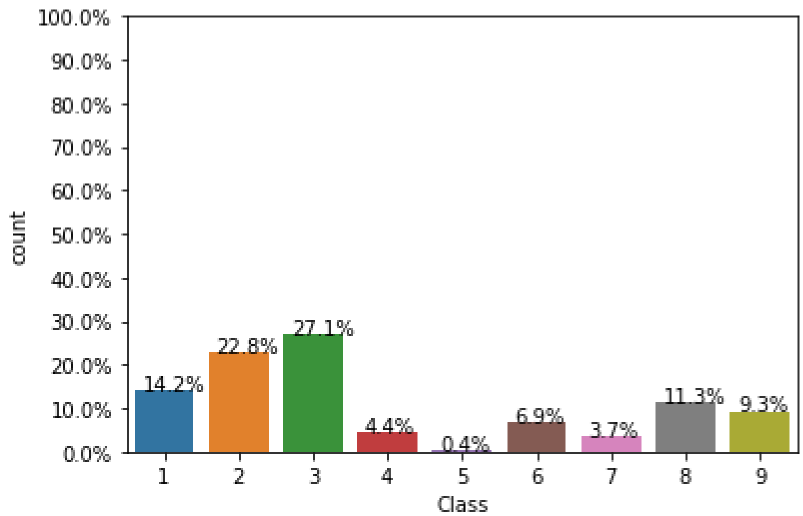
1. **Add bi-grams and n-gram features on byte files and improve the log-loss**
2. **Using the 'dchad' github account (https://github.com/dchad/malware-detection), decrease the logloss to <=0.01**
3. **Watch the video (https://www.youtube.com/watch?v=VLQTRILGz5Y) that was in reference section and implement the image features to improve the logloss**

In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotlib inline
```

In [2]:
```
# #separating byte files and asm files

# source = 'train'
# destination = 'byteFiles'

# # we will check if the folder 'byteFiles' exists if it not there we will cre
ate a folder with the same name
# if not os.path.isdir(destination):
#     os.makedirs(destination)

# # if we have folder called 'train' (train folder contains both .asm files an
d .bytes files) we will rename it 'asmFiles'
# # for every file that we have in our 'asmFiles' directory we check if it is
 ending with .bytes, if yes we will move it to
# # 'byteFiles' folder

# # so by the end of this snippet we will separate all the .byte files and .as
m files
# if os.path.isdir(source):
#     os.rename(source,'asmFiles')
#     source='asmFiles'
#     data_files = os.listdir(source)
#     for file in data_files:
#         if (file.endswith("bytes")):
#             shutil.move(source+"/"+file,destination)
```

3.1. Distribution of malware classes in whole data set

In [2]:
```
Y=pd.read_csv("trainLabels.csv")
total = len(Y)*1.
ax=sns.countplot(x="Class", data=Y)
for p in ax.patches:
        ax.annotate('{:.1f}%'.format(100*p.get_height()/total), (p.get_x()+0.1
, p.get_height()+5))

#put 11 ticks (therefore 10 steps), from 0 to the total number of rows in the
 dataframe
ax.yaxis.set_ticks(np.linspace(0, total, 11))

#adjust the ticklabel to the desired format, without changing the position of
 the ticks.
ax.set_yticklabels(map('{:.1f}%'.format, 100*ax.yaxis.get_majorticklocs()/tota
l))
plt.show()
```



In [3]:
```
Y
```

Out[3]:

	Id	Class
0	01kcPWA9K2BOxQeS5Rju	1
1	04EjIdbPV5e1XroFOpiN	1
2	05EeG39MTRrI6VY21DPd	1
3	05rJTUWYAKNegBk2wE8X	1
4	0AnoOZDNbPXIr2MRBSCJ	1
...	...	...
10863	KFrZ0Lop1WDGwUtkusCi	9
10864	kg24YRJTB8DNdKMXpwOH	9
10865	kG29BLiFYPgWtpb350sO	9
10866	kGITL4OJxYMWEQ1bKBiP	9
10867	KGorN9J6XAC4bOEkmyup	9

10868 rows × 2 columns

In [4]:
```
#'Unnamed: 0'
result = pd.read_csv("result_with_size.csv")
del result['Unnamed: 0']
result.head()
```

Out[4]:

	ID	0	1	2	3	4	5	6	7	8	...	f9
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	3101
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...	2242
3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	1078	...	485
4	01SuzwMJEIXsK7A8dQbI	19764	710	302	433	559	410	262	249	422	...	350

5 rows × 260 columns

In [5]:
```
result.columns
```

Out[5]:
```
Index(['ID', '0', '1', '2', '3', '4', '5', '6', '7', '8',
       ...
       'f9', 'fa', 'fb', 'fc', 'fd', 'fe', 'ff', '??', 'size', 'Class'],
      dtype='object', length=260)
```

In [6]:
```
#
# 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_valu
e - min_value)
    return result1
result = normalize(result)
```

In [7]:
```
#
data_y = result['Class']
result.head()
```

Out[7]:

	ID	0	1	2	3	4	5	
0	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.0020
1	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.0047
2	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.0050
3	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.0003
4	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.0001

5 rows × 260 columns

In [ ]:

In [9]:
```
# asmoutputfile.csv(output genarated from the above two cells) will contain al
l the extracted features from .asm files
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutputfile.csv")
Y.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, Y,on='ID', how='left')
result_asm.head()
```

Out[9]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 53 columns

4.2.1.1 Files sizes of each .asm file

In [10]:
```
#file sizes of byte files

files=os.listdir('asmFiles')
filenames=Y['ID'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=356157170
0, st_nlink=1, st_uid=0, st_gid=0,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519
638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_s
tat.htm
    statinfo=os.stat('asmFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file na
me
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
asm_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (asm_size_byte.head())
```

```
Empty DataFrame
Columns: [Class, ID, size]
Index: []
```

4.2.1.2 Distribution of .asm file sizes

In [14]:
```
#boxplot of asm files
ax = sns.boxplot(x="Class", y="size", data=asm_size_byte)
plt.title("boxplot of .bytes file sizes")
plt.show()
```

In [12]:
```
# add the file size feature to previous extracted features
print(result_asm.shape)
print(asm_size_byte.shape)
result_asm = pd.merge(result_asm, asm_size_byte.drop(['Class'], axis=1),on='I
D', how='left')
result_asm.head()
```

```
(10868, 53)
(0, 3)
```

Out[12]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [31]:
```
# we normalize the data each column
result_asm = normalize(result_asm)
result_asm.head()
```

Out[31]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 54 columns

In [ ]:

4.5.1. Merging both asm and byte file features

In [27]:
```
result.head()
```

Out[27]:

	ID	0	1	2	3	4	5	6	7	8	...	f9
0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	3101
1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...	2242
3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	1078	...	485
4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	422	...	350

5 rows × 260 columns

In [28]:
```
result_asm.head()
```

Out[28]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [29]:
```
print(result.shape)
print(result_asm.shape)
```

```
(10868, 260)
(10868, 54)
```

In [30]:
```
result_x = pd.merge(result,result_asm.drop(['Class'], axis=1),on='ID', how='left')
result_y = result_x['Class']
result_x = result_x.drop(['ID','rtn','.BSS:','.CODE','Class'], axis=1)
result_x.head()
```

Out[30]:

	0	1	2	3	4	5	6	7	8	9	...	edx	esi	eax	ebx
0	601905	3905	2816	3832	3345	3242	3650	3201	2965	3205	...	808	2290	1281	587
1	39755	8337	7249	7186	8663	6844	8420	7589	9291	358	...	260	1090	391	905
2	93506	9542	2568	2438	8925	9330	9007	2342	9107	2457	...	5	547	5	451
3	21091	1213	726	817	1257	625	550	523	1078	473	...	18	66	15	43
4	19764	710	302	433	559	410	262	249	422	223	...	18	1228	24	1546

5 rows × 307 columns

With Byte Bi-grams features

In [1]:
```
# result_x['ID'] = result.ID
```

In [2]:
```
byte_vocab = "00,01,02,03,04,05,06,07,08,09,0a,0b,0c,0d,0e,0f,10,11,12,13,14,15,16,17,18,19,1a,1b,1c,1d,1e,1f,20,21,22,23,24,25,26,27,28,29,2a,2b,2c,2d,2e,2f,30,31,32,33,34,35,36,37,38,39,3a,3b,3c,3d,3e,3f,40,41,42,43,44,45,46,47,48,49,4a,4b,4c,4d,4e,4f,50,51,52,53,54,55,56,57,58,59,5a,5b,5c,5d,5e,5f,60,61,62,63,64,65,66,67,68,69,6a,6b,6c,6d,6e,6f,70,71,72,73,74,75,76,77,78,79,7a,7b,7c,7d,7e,7f,80,81,82,83,84,85,86,87,88,89,8a,8b,8c,8d,8e,8f,90,91,92,93,94,95,96,97,98,99,9a,9b,9c,9d,9e,9f,a0,a1,a2,a3,a4,a5,a6,a7,a8,a9,aa,ab,ac,ad,ae,af,b0,b1,b2,b3,b4,b5,b6,b7,b8,b9,ba,bb,bc,bd,be,bf,c0,c1,c2,c3,c4,c5,c6,c7,c8,c9,ca,cb,cc,cd,ce,cf,d0,d1,d2,d3,d4,d5,d6,d7,d8,d9,da,db,dc,dd,de,df,e0,e1,e2,e3,e4,e5,e6,e7,e8,e9,ea,eb,ec,ed,ee,ef,f0,f1,f2,f3,f4,f5,f6,f7,f8,f9,fa,fb,fc,fd,fe,ff,??"
```

In [3]:
```
len(byte_vocab.split(','))
```

Out[3]: 257

In [4]:
```
byte_bigram_vocab = []
def byte_bigram():
    for i, v in enumerate(byte_vocab.split(',')):
        for j in range(0, len(byte_vocab.split(','))):
            byte_bigram_vocab.append(v + ' ' +byte_vocab.split(',')[j])
    return (byte_bigram_vocab)
```

In [5]:
```
len(byte_bigram())
```

Out[5]: 66049

In [6]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [23]:
```
#intially create five folders
#first
#second
#thrid
#fourth
#fifth
#this code tells us about random split of files into five folders
folder_1 ='first'
folder_2 ='second'
folder_3 ='third'
folder_4 ='fourth'
folder_5 ='fifth'
folder_6 ='sixth'
folder_7 ='seventh'
folder_8 ='eigth'
folder_9 ='ningth'
folder_10 ='tenth'
folder_11='eleventh'
folder_12 ='twelveth'
folder_13 ='thirteenth'
folder_14 ='fourteenth'
folder_15 = 'output'
for i in [folder_1,folder_2,folder_3,folder_4,folder_5,folder_6,folder_7,folder_8,folder_9,folder_10,folder_11,folder_12,folder_13,folder_14,folder_15]:
    if not os.path.isdir(i):
        os.makedirs(i)

source='byteFiles/'
files = os.listdir('byteFiles')
# ID=df['Id'].tolist()
data=list(range(0,10868))
# r.shuffle(data)
count=0
for i in range(0,10868):
    if i>=0 and i<=776:
        shutil.move(source+files[data[i]],'first')
    elif i>=777 and i<=1553:
        shutil.move(source+files[data[i]],'second')
    elif i>=1554 and i<=2330:
        shutil.move(source+files[data[i]],'third')
    elif i>=2331 and i<=3107:
        shutil.move(source+files[data[i]],'fourth')
    elif i>=3108 and i<=3883:
        shutil.move(source+files[data[i]],'fifth')
    elif i>=3884 and i<=4659:
        shutil.move(source+files[data[i]],'sixth')
    elif i>=4660 and i<=5435:
        shutil.move(source+files[data[i]],'seventh')
    elif i>=5436 and i<=6211:
        shutil.move(source+files[data[i]],'eigth')
    elif i>=6212 and i<=6987:
        shutil.move(source+files[data[i]],'ningth')
    elif i>=6988 and i<=7763:
        shutil.move(source+files[data[i]],'tenth')
    elif i>=7764 and i<=8539:
        shutil.move(source+files[data[i]],'eleventh')
```

```
    elif i>=8540 and i<=9315:
        shutil.move(source+files[data[i]],'twelveth')
    elif i>=9316 and i<=10091:
        shutil.move(source+files[data[i]],'thirteenth')
    elif i>=10092 and i<=10867:
        shutil.move(source+files[data[i]],'fourteenth')
```

In [24]:

```
len(os.listdir('first')) + \
len(os.listdir('second')) + \
len(os.listdir('third')) + \
len(os.listdir('fourth')) + \
len(os.listdir('fifth')) + \
len(os.listdir('sixth')) + \
len(os.listdir('seventh')) + \
len(os.listdir('eigth')) + \
len(os.listdir('ningth')) + \
len(os.listdir('tenth')) + \
len(os.listdir('eleventh')) + \
len(os.listdir('twelveth')) + \
len(os.listdir('thirteenth')) + \
len(os.listdir('fourteenth'))
```

Out[24]: 10868

In [25]:

```
print(len(os.listdir('first')),
len(os.listdir('second')),
len(os.listdir('third')),
len(os.listdir('fourth')),
len(os.listdir('fifth')),
len(os.listdir('sixth')),
len(os.listdir('seventh')),
len(os.listdir('eigth')),
len(os.listdir('ningth')),
len(os.listdir('tenth')),
len(os.listdir('eleventh')),
len(os.listdir('twelveth')),
len(os.listdir('thirteenth')),
len(os.listdir('fourteenth')))
```

```
777 777 777 777 776 776 776 776 776 776 776 776 776 776
```

In [12]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect1 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('first'))):
        f = open('first/' + file)
        bytebigram_vect1[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect1 = bytebigram_vect1.todense()
    bytebigram_df1 = pd.DataFrame(bytebigram_vect1, columns = byte_bigram_voca
b)
    bytebigram_df1['ID'] = os.listdir('first')
    bytebigram_df1.to_csv('bytebigram1.csv',index=False)




#same as above
def secondprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect2 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('second'))):
        f = open('second/' + file)
        bytebigram_vect2[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect2 = bytebigram_vect2.todense()
    bytebigram_df2 = pd.DataFrame(bytebigram_vect2, columns = byte_bigram_voca
b)
    bytebigram_df2['ID'] = os.listdir('second')
    bytebigram_df2.to_csv('bytebigram2.csv',index=False)

# same as smallprocess() functions
def thirdprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect3 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('third'))):
        f = open('third/' + file)
        bytebigram_vect3[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect3 = bytebigram_vect3.todense()
    bytebigram_df3 = pd.DataFrame(bytebigram_vect3, columns = byte_bigram_voca
b)
```

```
    bytebigram_df3['ID'] = os.listdir('third')
    bytebigram_df3.to_csv('bytebigram3.csv',index=False)


def fourthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect4 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fourth'))):
        f = open('fourth/' + file)
        bytebigram_vect4[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect4 = bytebigram_vect4.todense()
    bytebigram_df4 = pd.DataFrame(bytebigram_vect4, columns = byte_bigram_voca
b)
    bytebigram_df4['ID'] = os.listdir('fourth')
    bytebigram_df4.to_csv('bytebigram4.csv',index=False)


def fifthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect5 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fifth'))):
        f = open('fifth/' + file)
        bytebigram_vect5[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect5 = bytebigram_vect5.todense()
    bytebigram_df5 = pd.DataFrame(bytebigram_vect5, columns = byte_bigram_voca
b)
    bytebigram_df5['ID'] = os.listdir('fifth')
    bytebigram_df5.to_csv('bytebigram5.csv',index=False)

def sixthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect6 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('sixth'))):
        f = open('sixth/' + file)
        bytebigram_vect6[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect6 = bytebigram_vect6.todense()
    bytebigram_df6 = pd.DataFrame(bytebigram_vect6, columns = byte_bigram_voca
b)
    bytebigram_df6['ID'] = os.listdir('sixth')
    bytebigram_df6.to_csv('bytebigram6.csv',index=False)

def seventhprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
```

```
    bytebigram_vect7 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('seventh'))):
        f = open('seventh/' + file)
        bytebigram_vect7[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect7 = bytebigram_vect7.todense()
    bytebigram_df7 = pd.DataFrame(bytebigram_vect7, columns = byte_bigram_voca
b)
    bytebigram_df7['ID'] = os.listdir('seventh')
    bytebigram_df7.to_csv('bytebigram7.csv',index=False)

def eigthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect8 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('eigth'))):
        f = open('eigth/' + file)
        bytebigram_vect8[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect8 = bytebigram_vect8.todense()
    bytebigram_df8 = pd.DataFrame(bytebigram_vect8, columns = byte_bigram_voca
b)
    bytebigram_df8['ID'] = os.listdir('eigth')
    bytebigram_df8.to_csv('bytebigram8.csv',index=False)

def ningthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect9 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('ningth'))):
        f = open('ningth/' + file)
        bytebigram_vect9[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f.
read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect9 = bytebigram_vect9.todense()
    bytebigram_df9 = pd.DataFrame(bytebigram_vect9, columns = byte_bigram_voca
b)
    bytebigram_df9['ID'] = os.listdir('ningth')
    bytebigram_df9.to_csv('bytebigram9.csv',index=False)

def tenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect10 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('tenth'))):
        f = open('tenth/' + file)
        bytebigram_vect10[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect10 = bytebigram_vect10.todense()
    bytebigram_df10 = pd.DataFrame(bytebigram_vect10, columns = byte_bigram_vo
cab)
```

```
    bytebigram_df10['ID'] = os.listdir('tenth')
    bytebigram_df10.to_csv('bytebigram10.csv',index=False)

def eleventhprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect11 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('eleventh'))):
        f = open('eleventh/' + file)
        bytebigram_vect11[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect11 = bytebigram_vect11.todense()
    bytebigram_df11 = pd.DataFrame(bytebigram_vect11, columns = byte_bigram_vo
cab)
    bytebigram_df11['ID'] = os.listdir('eleventh')
    bytebigram_df11.to_csv('bytebigram11.csv',index=False)

def twelvethprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect12 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('twelveth'))):
        f = open('twelveth/' + file)
        bytebigram_vect12[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect12 = bytebigram_vect12.todense()
    bytebigram_df12 = pd.DataFrame(bytebigram_vect12, columns = byte_bigram_vo
cab)
    bytebigram_df12['ID'] = os.listdir('twelveth')
    bytebigram_df12.to_csv('bytebigram12.csv',index=False)

def thirteenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect13 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('thirteenth'))):
        f = open('thirteenth/' + file)
        bytebigram_vect13[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect13 = bytebigram_vect13.todense()
    bytebigram_df13 = pd.DataFrame(bytebigram_vect13, columns = byte_bigram_vo
cab)
    bytebigram_df13['ID'] = os.listdir('thirteenth')
    bytebigram_df13.to_csv('bytebigram13.csv',index=False)

def fourteenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(2,2), vocabulary=byte_
bigram_vocab)
    bytebigram_vect14 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fourteenth'))):
```

```
        f = open('fourteenth/' + file)
        bytebigram_vect14[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytebigram_vect14 = bytebigram_vect14.todense()
    bytebigram_df14 = pd.DataFrame(bytebigram_vect14, columns = byte_bigram_vo
cab)
    bytebigram_df14['ID'] = os.listdir('fourteenth')
    bytebigram_df14.to_csv('bytebigram14.csv',index=False)


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
```

```
    p12.join()
    p13.join()
    p14.join()

if __name__=="__main__":
    main()
```

In [8]:
```
import pandas as pd
from pebble import concurrent
# https://stackoverflow.com/a/56676389/8089731

@concurrent.process
def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment
    bytebigram1_df = pd.read_csv('bytebigram1.csv')
    return bytebigram1_df

#same as above
@concurrent.process
def secondprocess():

    bytebigram2_df = pd.read_csv('bytebigram2.csv')
    return bytebigram2_df

@concurrent.process
def thirdprocess():

    bytebigram3_df = pd.read_csv('bytebigram3.csv')
    return bytebigram3_df

@concurrent.process
def fourthprocess():

    bytebigram4_df = pd.read_csv('bytebigram4.csv')
    return bytebigram4_df

@concurrent.process
def fifthprocess():

    bytebigram5_df = pd.read_csv('bytebigram5.csv')
    return bytebigram5_df

@concurrent.process
def sixthprocess():

    bytebigram6_df = pd.read_csv('bytebigram6.csv')
    return bytebigram6_df

@concurrent.process
def seventhprocess():

    bytebigram7_df = pd.read_csv('bytebigram7.csv')
    return bytebigram7_df

@concurrent.process
def eigthprocess():

    bytebigram8_df = pd.read_csv('bytebigram8.csv')
    return bytebigram8_df
```

```
@concurrent.process
def ningthprocess():

    bytebigram9_df = pd.read_csv('bytebigram9.csv')
    return bytebigram9_df

@concurrent.process
def tenthprocess():

    bytebigram10_df = pd.read_csv('bytebigram10.csv')
    return bytebigram10_df

@concurrent.process
def eleventhprocess():

    bytebigram11_df = pd.read_csv('bytebigram11.csv')
    return bytebigram11_df

@concurrent.process
def twelvethprocess():

    bytebigram12_df = pd.read_csv('bytebigram12.csv')
    return bytebigram12_df

@concurrent.process
def thirteenthprocess():

    bytebigram13_df = pd.read_csv('bytebigram13.csv')
    return bytebigram13_df

@concurrent.process
def fourteenthprocess():

    bytebigram14_df = pd.read_csv('bytebigram14.csv')
    return bytebigram14_df

# def
bytebigram1_df = firstprocess()
bytebigram2_df = secondprocess()
bytebigram3_df = thirdprocess()
bytebigram4_df = fourthprocess()
bytebigram5_df = fifthprocess()
bytebigram6_df = sixthprocess()
bytebigram7_df = seventhprocess()
bytebigram8_df = eigthprocess()
bytebigram9_df = ningthprocess()
bytebigram10_df = tenthprocess()
bytebigram11_df = eleventhprocess()
bytebigram12_df = twelvethprocess()
bytebigram13_df = thirteenthprocess()
bytebigram14_df = fourteenthprocess()
```

In [9]:

```
bytebigram1_df = (bytebigram1_df.result())
bytebigram2_df = (bytebigram2_df.result())
bytebigram3_df = (bytebigram3_df.result())
bytebigram4_df = (bytebigram4_df.result())
bytebigram5_df = (bytebigram5_df.result())
bytebigram6_df = (bytebigram6_df.result())
bytebigram7_df = (bytebigram7_df.result())
bytebigram8_df = (bytebigram8_df.result())
bytebigram9_df = (bytebigram9_df.result())
bytebigram10_df = (bytebigram10_df.result())
bytebigram11_df = (bytebigram11_df.result())
bytebigram12_df = (bytebigram12_df.result())
bytebigram13_df = (bytebigram13_df.result())
bytebigram14_df = (bytebigram14_df.result())
```

In [10]:

```
bytebigram1_df.head()
```

Out[10]:

	00 00	00 01	00 02	00 03	00 04	00 05	00 06	00 07	00 08	00 09	...	?? f8	?? f9	?? fa	?? fb
0	20272.0	90.0	20.0	100.0	11.0	11.0	5.0	19.0	7.0	1.0	...	0.0	0.0	0.0	0.0
1	9622.0	28.0	5.0	1.0	5.0	6.0	4.0	4.0	5.0	1.0	...	0.0	0.0	0.0	0.0
2	6098.0	41.0	27.0	73.0	18.0	54.0	24.0	45.0	19.0	45.0	...	0.0	0.0	0.0	0.0
3	136125.0	1721.0	730.0	972.0	570.0	409.0	351.0	419.0	575.0	289.0	...	0.0	0.0	0.0	0.0
4	5597.0	48.0	32.0	80.0	25.0	76.0	30.0	48.0	35.0	55.0	...	0.0	0.0	0.0	0.0

5 rows × 66050 columns

In [11]:

```
bytebigram_df = pd.concat([bytebigram1_df,bytebigram2_df,bytebigram3_df,bytebi
gram4_df,bytebigram5_df,bytebigram6_df,bytebigram7_df,bytebigram8_df,bytebigra
m9_df,bytebigram10_df,bytebigram11_df,bytebigram12_df,bytebigram13_df,bytebigr
am14_df])
```

In [12]:
```
bytebigram_df
```

Out[12]:

	00 00	00 01	00 02	00 03	00 04	00 05	00 06	00 07	00 08	00 09	...	?? f8	?? f9	?? fa
0	20272.0	90.0	20.0	100.0	11.0	11.0	5.0	19.0	7.0	1.0	...	0.0	0.0	0.0
1	9622.0	28.0	5.0	1.0	5.0	6.0	4.0	4.0	5.0	1.0	...	0.0	0.0	0.0
2	6098.0	41.0	27.0	73.0	18.0	54.0	24.0	45.0	19.0	45.0	...	0.0	0.0	0.0
3	136125.0	1721.0	730.0	972.0	570.0	409.0	351.0	419.0	575.0	289.0	...	0.0	0.0	0.0
4	5597.0	48.0	32.0	80.0	25.0	76.0	30.0	48.0	35.0	55.0	...	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
771	6360.0	49.0	26.0	82.0	17.0	51.0	75.0	38.0	23.0	48.0	...	0.0	0.0	0.0
772	1355.0	15.0	5.0	9.0	22.0	17.0	11.0	12.0	6.0	5.0	...	0.0	0.0	0.0
773	3620.0	35.0	2.0	8.0	9.0	1.0	2.0	2.0	14.0	2.0	...	0.0	0.0	0.0
774	22352.0	255.0	78.0	162.0	157.0	37.0	22.0	155.0	35.0	79.0	...	0.0	0.0	0.0
775	10879.0	553.0	120.0	123.0	552.0	568.0	519.0	176.0	541.0	144.0	...	0.0	0.0	0.0

10868 rows × 66050 columns

In [13]:
```
bytebigram_df['ID'] = bytebigram_df['ID'].str[:-6]
bytebigram_df.head()
```

Out[13]:

	00 00	00 01	00 02	00 03	00 04	00 05	00 06	00 07	00 08	00 09	...	?? f8	?? f9	?? fa	?? fb
0	20272.0	90.0	20.0	100.0	11.0	11.0	5.0	19.0	7.0	1.0	...	0.0	0.0	0.0	0.0
1	9622.0	28.0	5.0	1.0	5.0	6.0	4.0	4.0	5.0	1.0	...	0.0	0.0	0.0	0.0
2	6098.0	41.0	27.0	73.0	18.0	54.0	24.0	45.0	19.0	45.0	...	0.0	0.0	0.0	0.0
3	136125.0	1721.0	730.0	972.0	570.0	409.0	351.0	419.0	575.0	289.0	...	0.0	0.0	0.0	0.0
4	5597.0	48.0	32.0	80.0	25.0	76.0	30.0	48.0	35.0	55.0	...	0.0	0.0	0.0	0.0

5 rows × 66050 columns

In [14]:
```
result_with_size = pd.read_csv("result_with_size.csv")
result_with_size = result_with_size[['size','ID','Class']]
bytebigram_df = pd.merge(bytebigram_df, result_with_size,on='ID', how='left')
bytebigram_df.head()
```

Out[14]:

	00 00	00 01	00 02	00 03	00 04	00 05	00 06	00 07	00 08	00 09	...	?? fa	?? fb	?? fc	?? fc
0	20272.0	90.0	20.0	100.0	11.0	11.0	5.0	19.0	7.0	1.0	...	0.0	0.0	0.0	0.0
1	9622.0	28.0	5.0	1.0	5.0	6.0	4.0	4.0	5.0	1.0	...	0.0	0.0	0.0	0.0
2	6098.0	41.0	27.0	73.0	18.0	54.0	24.0	45.0	19.0	45.0	...	0.0	0.0	0.0	0.0
3	136125.0	1721.0	730.0	972.0	570.0	409.0	351.0	419.0	575.0	289.0	...	0.0	0.0	0.0	0.0
4	5597.0	48.0	32.0	80.0	25.0	76.0	30.0	48.0	35.0	55.0	...	0.0	0.0	0.0	0.0

5 rows × 66052 columns

In [15]:
```
# 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')
and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            if (max_value-min_value)!=0:
                result1[feature_name] = (df[feature_name] - min_value) / (max_
value - min_value)
    return result1
```

In [16]:
```
bytebigram_df = normalize(bytebigram_df)
bytebigram_df.head()
```

Out[16]:

	00 00	00 01	00 02	00 03	00 04	00 05	00 06	00 07	00 08	
0	0.009458	0.007180	0.001356	0.007605	0.000758	0.001183	0.000486	0.002309	0.000470	0.0
1	0.004489	0.002234	0.000339	0.000076	0.000344	0.000645	0.000388	0.000486	0.000336	0.0
2	0.002845	0.003271	0.001831	0.005552	0.001240	0.005805	0.002331	0.005469	0.001276	0.0
3	0.063507	0.137307	0.049508	0.073922	0.039272	0.043969	0.034088	0.050924	0.038627	0.0
4	0.002611	0.003830	0.002170	0.006084	0.001722	0.008170	0.002913	0.005834	0.002351	0.0

5 rows × 66052 columns

In [17]:
```
len(bytebigram_df.columns[:66049])
```

Out[17]: 66049

In [1]:
```
import dill                                    #pip install dill --user
# filename = 'globalsave.pkl'
# dill.dump_session('notebook_env1.db')

# and to load the session again:
dill.load_session('notebook_env1.db')
```

In [2]:
```
# bytebigram_df.to_pickle('bytebigram_final_df')
```

In [ ]:
```
bytebigram_df = pd.read_pickle('bytebigram_final_df')
```

In [ ]:
```
bytebigram_df.head()
```

Selecting important features

In [13]:
```
#'Unnamed: 0'
data_y = bytebigram_df['Class']
```

In [14]:
```
def imp_features(data, features):
    rf = RandomForestClassifier(n_estimators = 35, n_jobs = -1,verbose=5)
    rf.fit(data, data_y)
    imp_feature_indx = np.argsort(rf.feature_importances_)[::-1]
    print(len(features),  len(imp_feature_indx))
    imp_feature_name = np.take(features, imp_feature_indx)
    return imp_feature_name
```

In [15]:
```
byte_bi_names = imp_features(bytebigram_df.drop(['ID','Class','size'],axis=1,i
nplace=False), byte_bigram_vocab)
```

```
[Parallel(n_jobs=-1)]: Using backend ThreadingBackend with 16 concurrent work
ers.

building tree 1 of 35
building tree 2 of 35
building tree 3 of 35
building tree 4 of 35
building tree 5 of 35
building tree 6 of 35
building tree 7 of 35
building tree 8 of 35
building tree 9 of 35
building tree 10 of 35
building tree 11 of 35
building tree 12 of 35
building tree 13 of 35
building tree 14 of 35
building tree 15 of 35
building tree 16 of 35
building tree 17 of 35
building tree 18 of 35
building tree 19 of 35
building tree 20 of 35
building tree 21 of 35
building tree 22 of 35
building tree 23 of 35
building tree 24 of 35
building tree 25 of 35
building tree 26 of 35building tree 27 of 35

building tree 28 of 35
building tree 29 of 35
building tree 30 of 35
building tree 31 of 35
building tree 32 of 35

[Parallel(n_jobs=-1)]: Done  12 out of  35 | elapsed:    0.9s remaining:
1.7s

building tree 33 of 35
building tree 34 of 35
building tree 35 of 35

[Parallel(n_jobs=-1)]: Done  20 out of  35 | elapsed:    1.6s remaining:
1.2s
[Parallel(n_jobs=-1)]: Done  28 out of  35 | elapsed:    1.7s remaining:
0.4s
[Parallel(n_jobs=-1)]: Done  35 out of  35 | elapsed:    2.3s finished

66049 66049
```

In [16]:
```
# with open('bytebigram_imp_features.pkl','wb') as f:
#     pickle.dump(byte_bi_names, f)
with open('bytebigram_imp_features.pkl','rb') as f:
    byte_bi_names = pickle.load(f)
```

In [17]:
```
byte_bi_names
```

Out[17]:
```
array(['98 87', 'f1 b3', 'ae ef', ..., 'a3 48', 'a3 47', '?? ??'],
      dtype='<U5')
```

In [18]:
```
len(byte_bi_names)
```

Out[18]:
```
66049
```

In [19]:
```
byte_bi_names = list(byte_bi_names[:1000])
byte_bi_names.append('ID')
byte_bi_names.append('Class')
byte_bi_names.append('size')
len(byte_bi_names)
```

Out[19]:
```
1003
```

In [20]:
```
bytebigram_df = bytebigram_df[byte_bi_names]
```

In [21]:
```
len(bytebigram_df.columns)
```

Out[21]:
```
1003
```

In [22]:
```
bytebigram_df.head()
```

Out[22]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1003 columns

In [23]:
```
# bytebigram_df.to_csv('bytebigram_final_rf_reduced_df',index=False)
```

In [3]:
```
bytebigram_df = pd.read_csv('bytebigram_final_rf_reduced_df')
bytebigram_df.head()
```

Out[3]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1003 columns

Train Test split

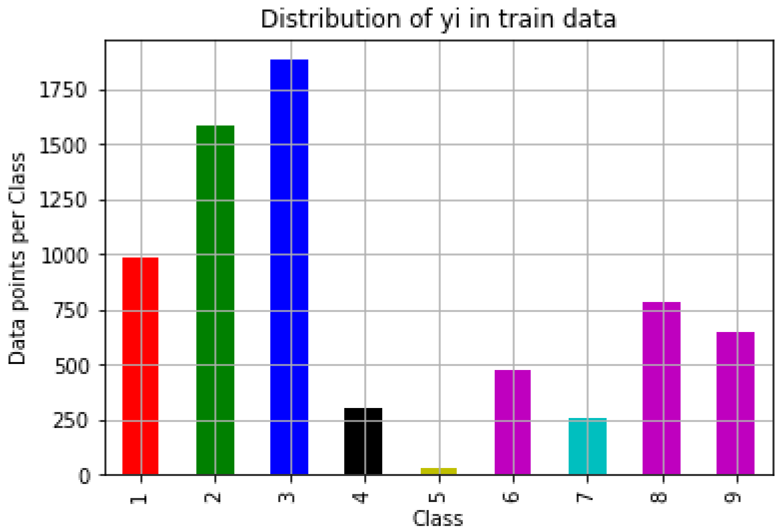
In [4]:
```
data_y = bytebigram_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(bytebigram_df.drop(['ID',
'Class'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [5]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

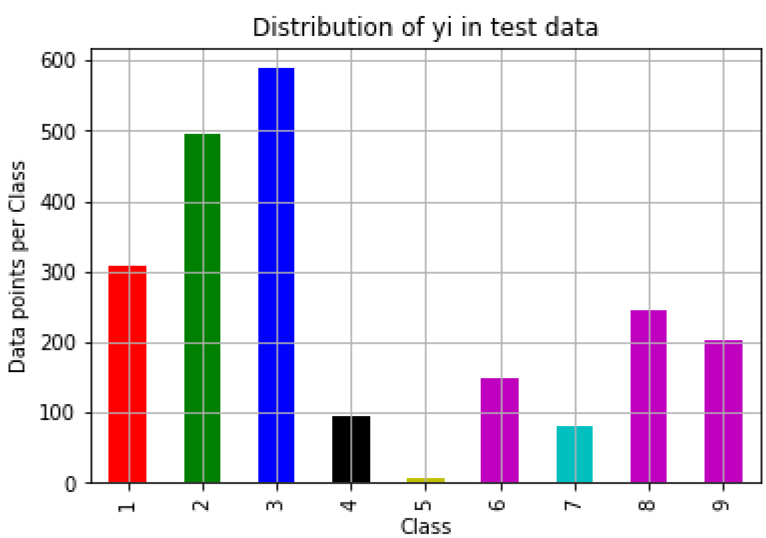
```
Number of data points in train data: (6955, 1001)
Number of data points in test data: (2174, 1001)
Number of data points in cross validation data: (1739, 1001)
```

In [6]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

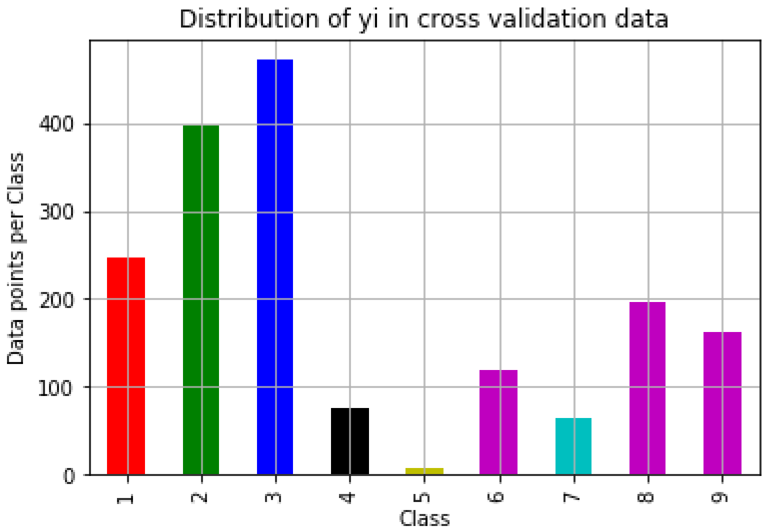
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [7]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes bigrams features

In [8]:
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

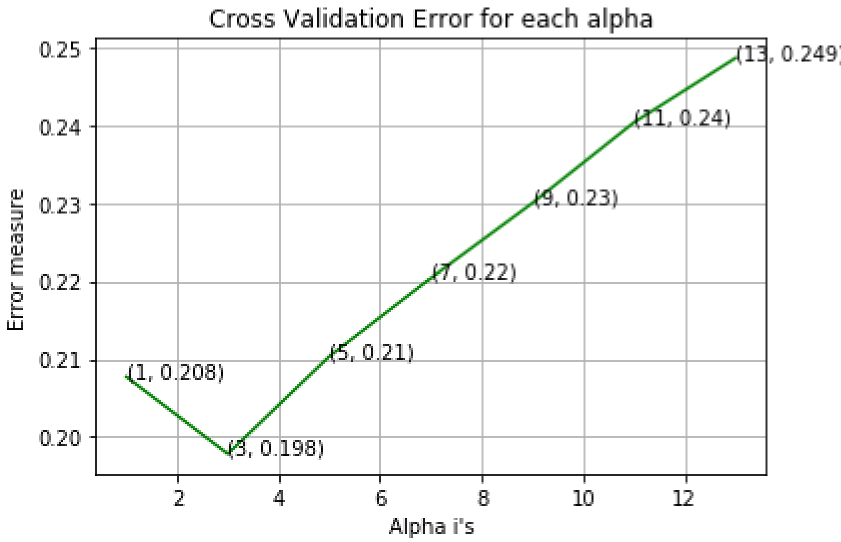
4.1.2. K Nearest Neighbour Classification

In [14]:

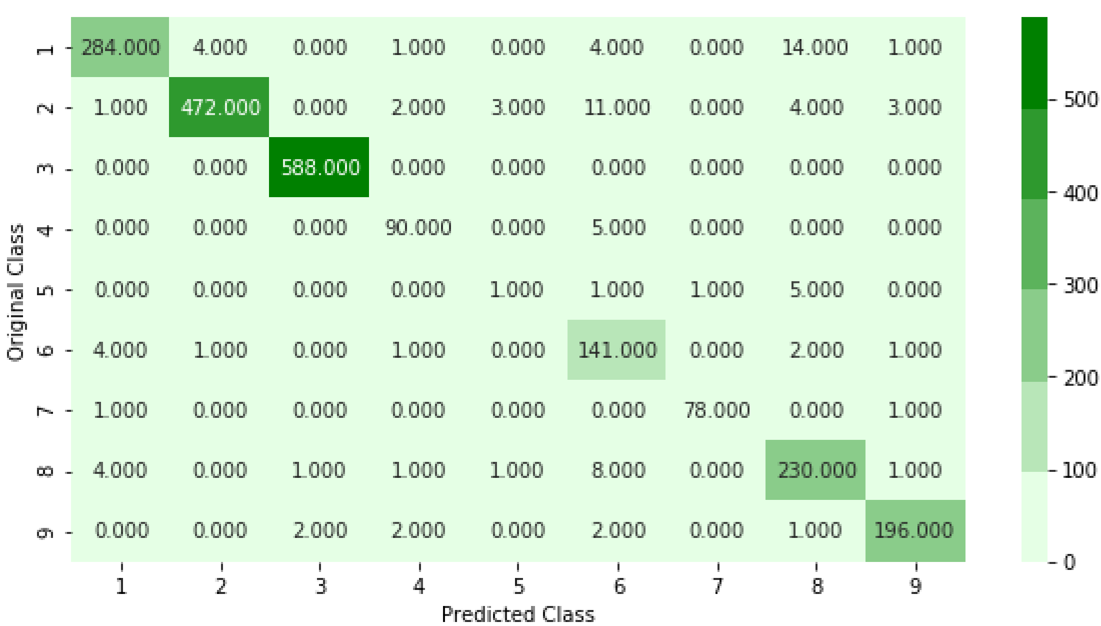
```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/m
odules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', lea
f_size=30, p=2,
# metric='minkowski',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

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


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

alpha = [x for x in range(1, 15, 2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
    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=k_cfl.classes_,
eps=1e-15))

for i in range(len(cv_log_error_array)):
    print ('log_loss for k = ',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()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

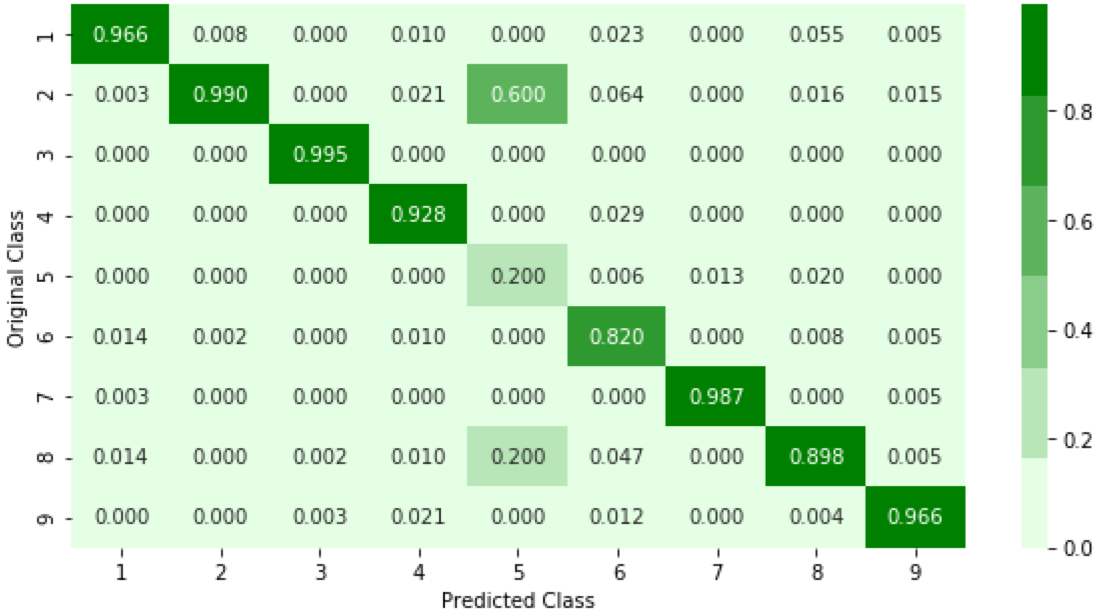
```
log_loss for k =  1 is 0.20771912080648341
log_loss for k =  3 is 0.1978249822431406
log_loss for k =  5 is 0.21033470490456138
log_loss for k =  7 is 0.22039184443713247
log_loss for k =  9 is 0.2299952298417246
log_loss for k =  11 is 0.24033986786363754
log_loss for k =  13 is 0.24860196960498007
```




```
For values of best alpha =  3 The train log loss is: 0.08572468169360963
For values of best alpha =  3 The cross validation log loss is: 0.19782498224
31406
For values of best alpha =  3 The test log loss is: 0.18726276834434555
Number of misclassified points  4.323827046918123
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```




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




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


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

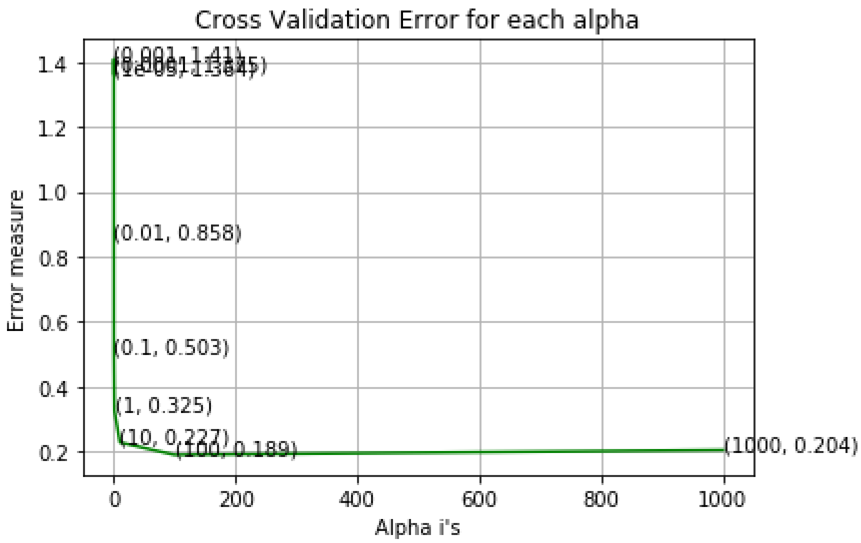
4.1.3. Logistic Regression

In [15]:

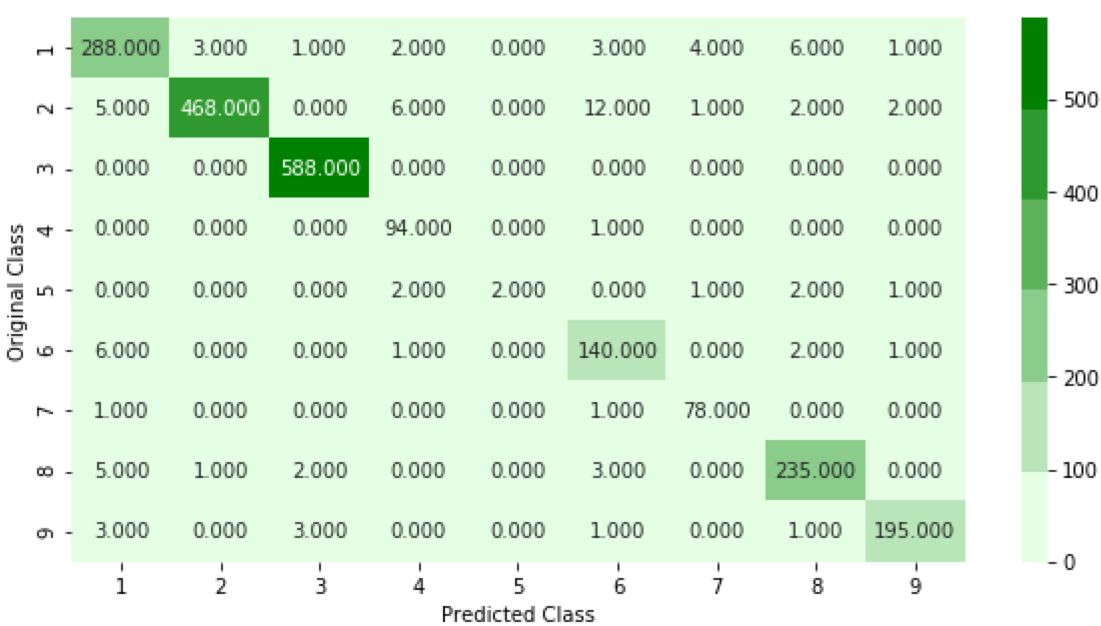
```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/ge
nerated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_i
ntercept=True, max_iter=None, tol=None,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

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

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

alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
    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=logisticR.class
es_, 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()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='ba
lanced')
logisticR.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
sig_clf.fit(X_train, y_train)
pred_y=sig_clf.predict(X_test)

predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR
.classes_, eps=1e-15))
```

```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.class
es_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.c
lasses_, eps=1e-15))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

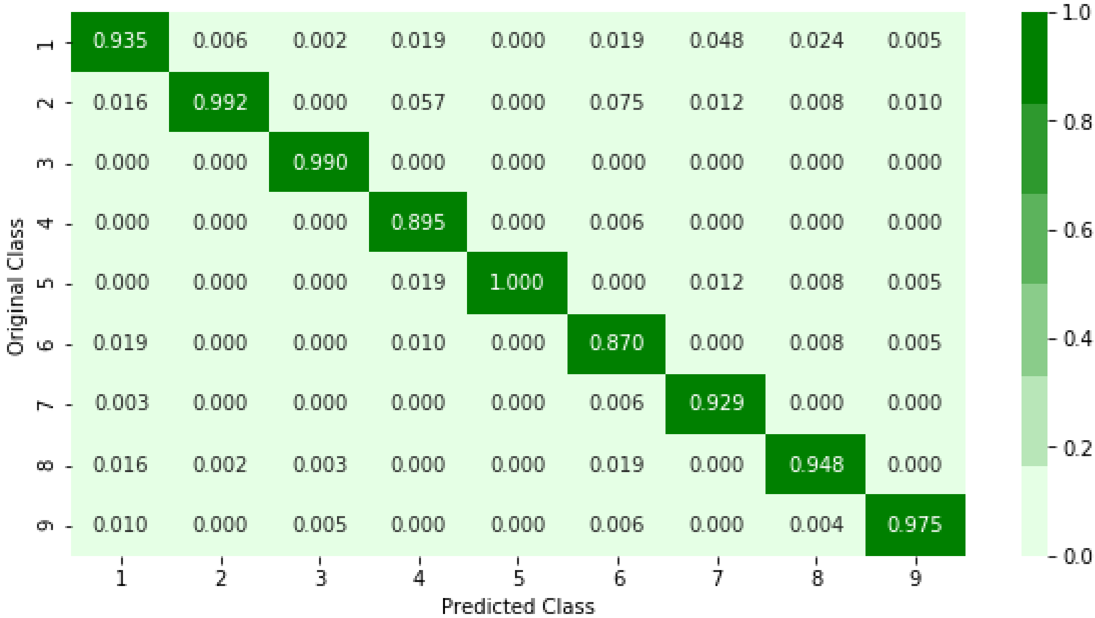
```
log_loss for c =  1e-05 is 1.3643575716090401
log_loss for c =  0.0001 is 1.3745366745151122
log_loss for c =  0.001 is 1.409786683014128
log_loss for c =  0.01 is 0.8575757630061275
log_loss for c =  0.1 is 0.5033783854842001
log_loss for c =  1 is 0.32459063858093135
log_loss for c =  10 is 0.22703952361235605
log_loss for c =  100 is 0.18854822949204045
log_loss for c =  1000 is 0.20357939859011398
```



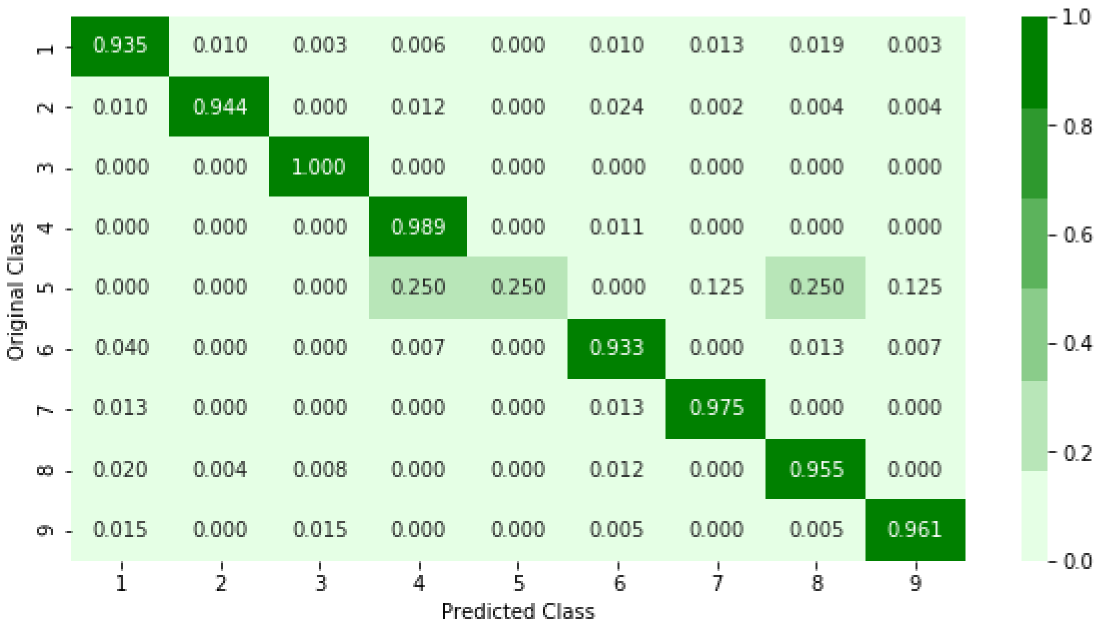

```
log loss for train data 0.11946709063801976
log loss for cv data 0.18854822949204045
log loss for test data 0.20050829473332624
Number of misclassified points  3.9558417663293466
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```




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




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



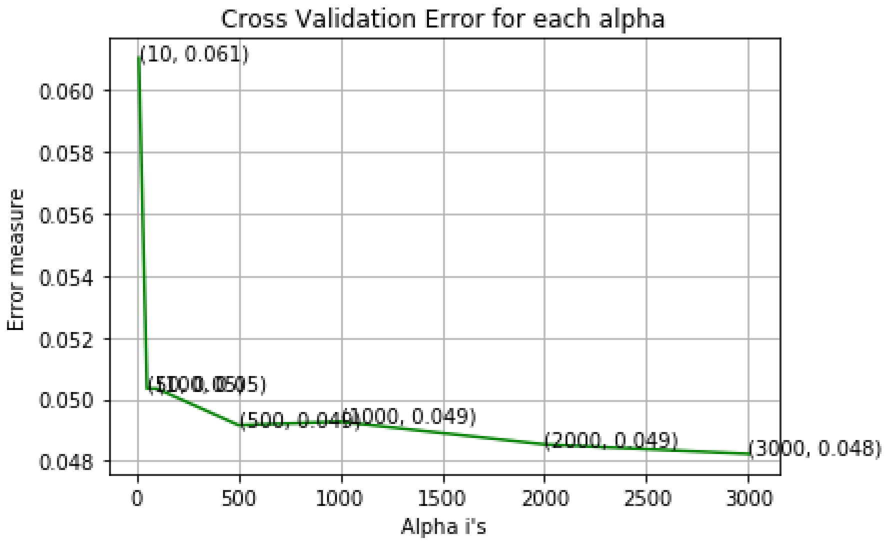

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.4. Random Forest Classifier

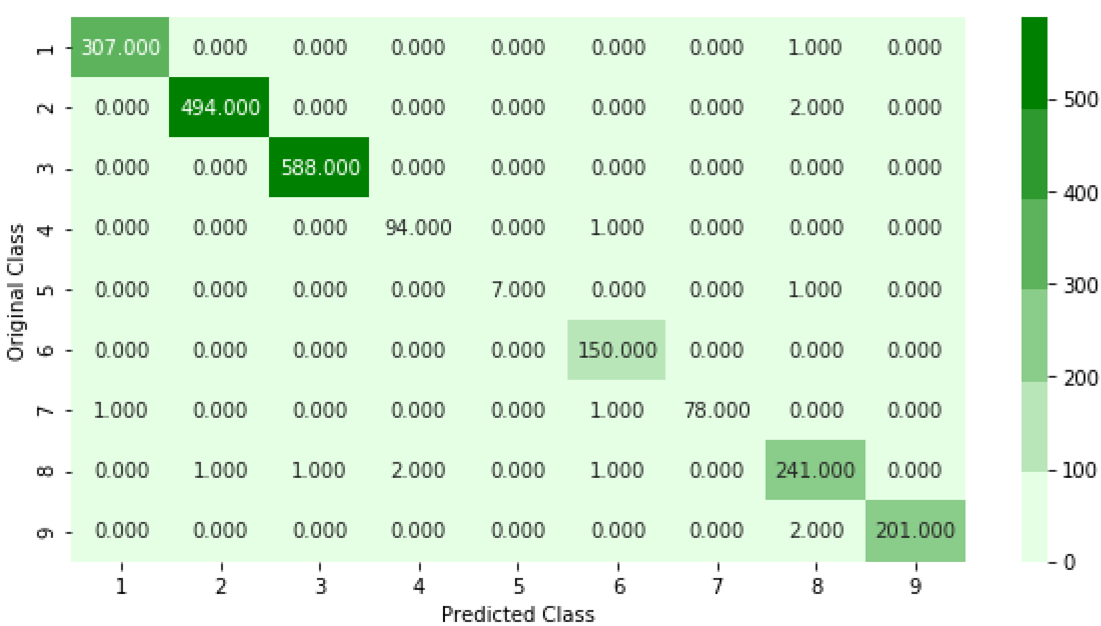
In [16]:
```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

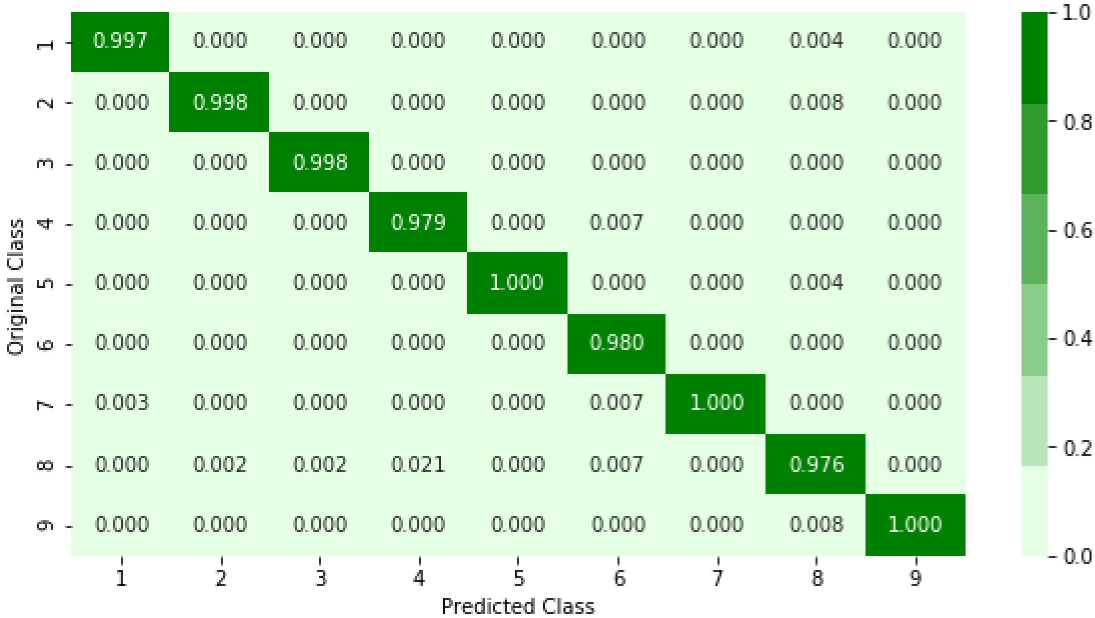
```
log_loss for c =  10 is 0.0610376547427536
log_loss for c =  50 is 0.050344357351918424
log_loss for c =  100 is 0.05034202503850251
log_loss for c =  500 is 0.04915897681870307
log_loss for c =  1000 is 0.04927168465279413
log_loss for c =  2000 is 0.048536592971174186
log_loss for c =  3000 is 0.04823060068036552
```



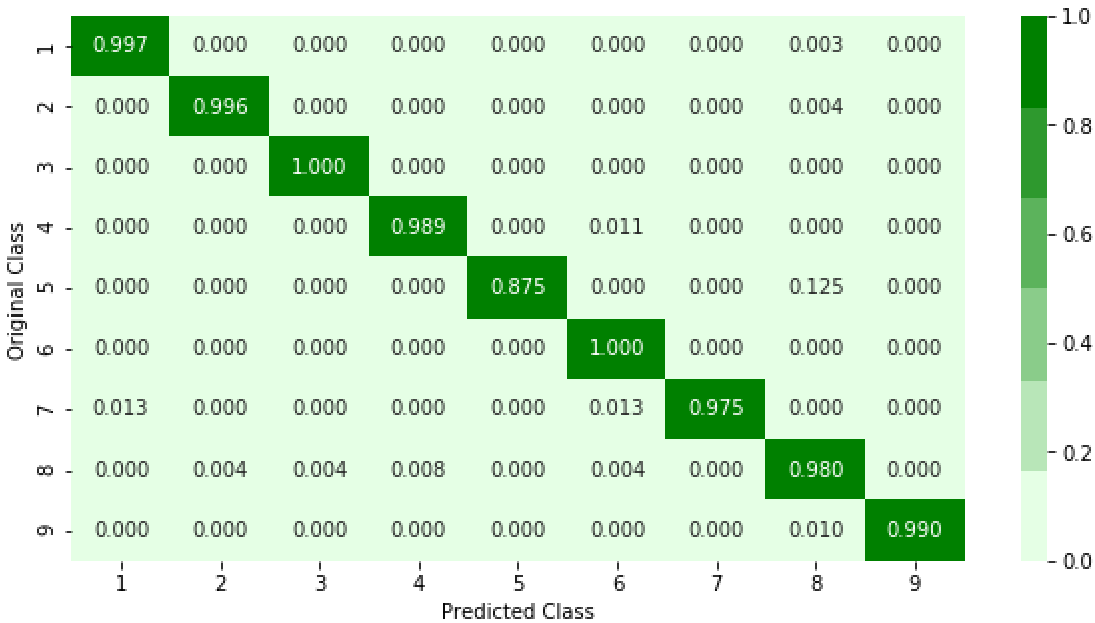

```
For values of best alpha =  3000 The train log loss is: 0.016007472330591885
For values of best alpha =  3000 The cross validation log loss is: 0.04823060
068036552
For values of best alpha =  3000 The test log loss is: 0.03671922339651359
Number of misclassified points  0.6439742410303588
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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



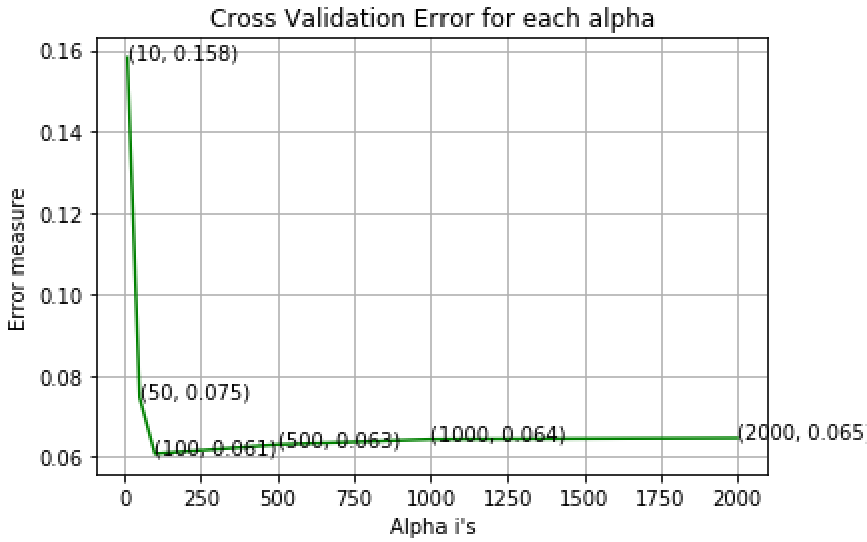

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.5. XgBoost Classification

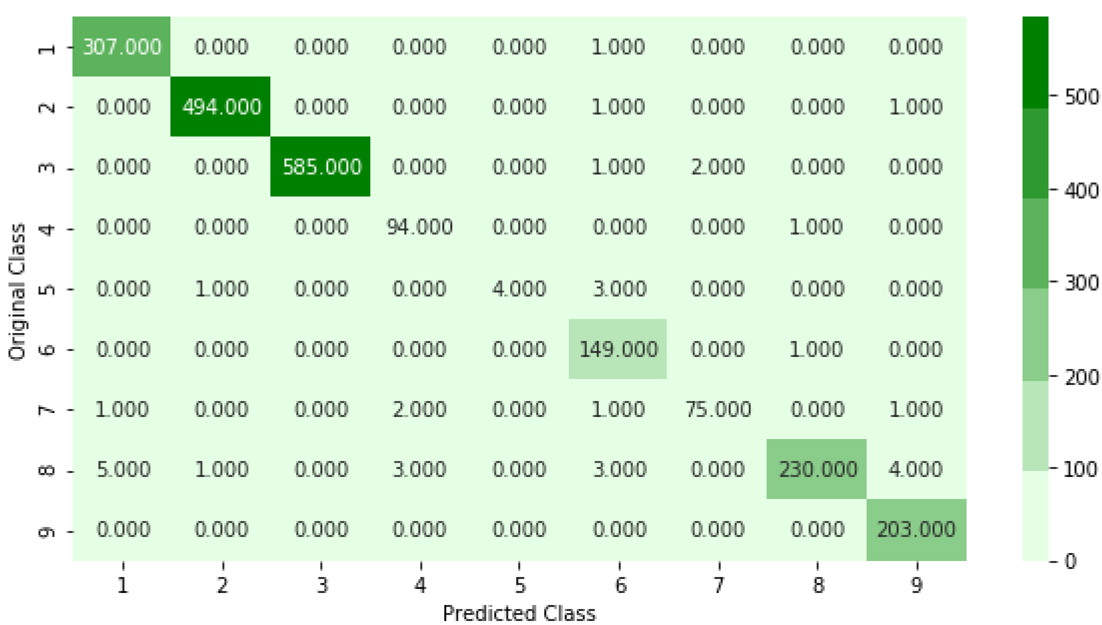
In [38]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/regression-using-decision-trees-2/
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-onlin
e/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)
    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))

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)
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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  10 is 0.15818400630525287
log_loss for c =  50 is 0.07463166373282179
log_loss for c =  100 is 0.06071110372719098
log_loss for c =  500 is 0.06298843290508595
log_loss for c =  1000 is 0.0642824500375936
log_loss for c =  2000 is 0.0646071546550603
```

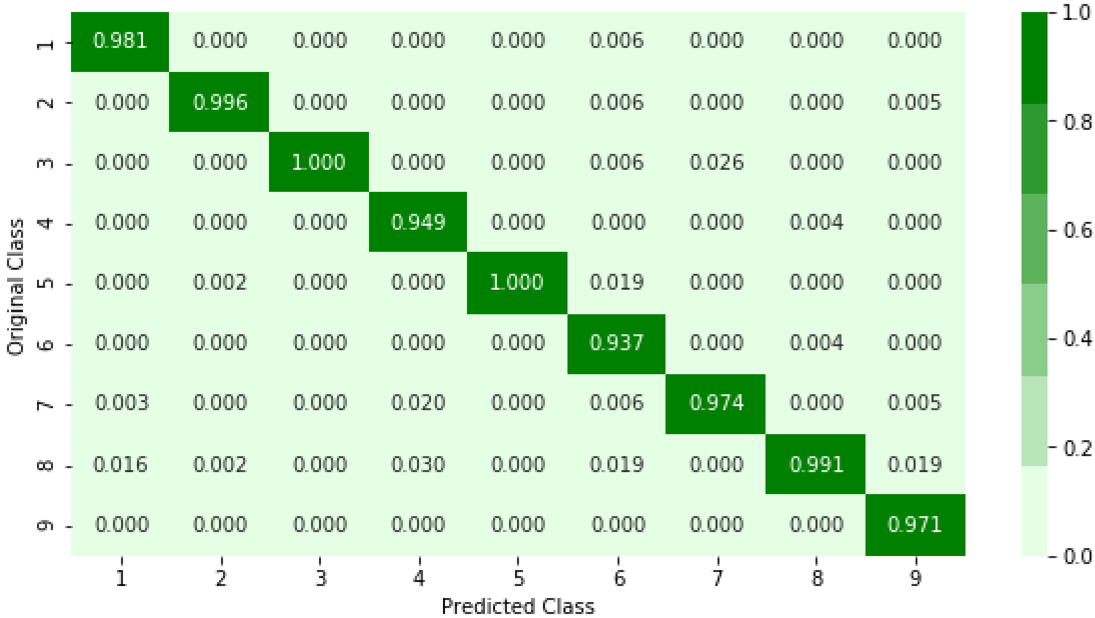



```
For values of best alpha =  100 The train log loss is: 0.017685102096223693
For values of best alpha =  100 The cross validation log loss is: 0.060711103
72719098
For values of best alpha =  100 The test log loss is: 0.07136470795873413
Number of misclassified points  1.517939282428703
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```

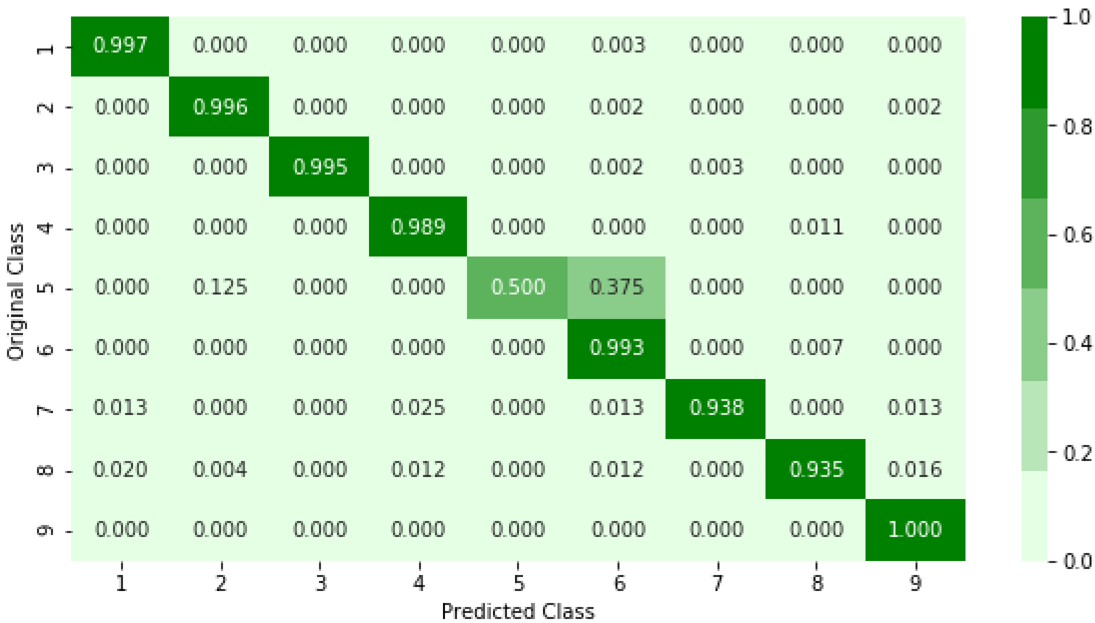


	1	2	3	4	5	6	7	8	9
1	307.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
2	0.000	494.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000
3	0.000	0.000	585.000	0.000	0.000	1.000	2.000	0.000	0.000
4	0.000	0.000	0.000	94.000	0.000	0.000	0.000	1.000	0.000
5	0.000	1.000	0.000	0.000	4.000	3.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	149.000	0.000	1.000	0.000
7	1.000	0.000	0.000	2.000	0.000	1.000	75.000	0.000	1.000
8	5.000	1.000	0.000	3.000	0.000	3.000	0.000	230.000	4.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	203.000

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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [17]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:   35.6s remaining:  5.3
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:  4.5min remaining: 14.7
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  7.8min remaining: 13.5
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  9.4min remaining:  9.4
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed: 12.2min remaining:  7.0
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 16.3min remaining:  4.9
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 17.4min remaining:  1.9
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 30.0min finished
```

Out[17]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

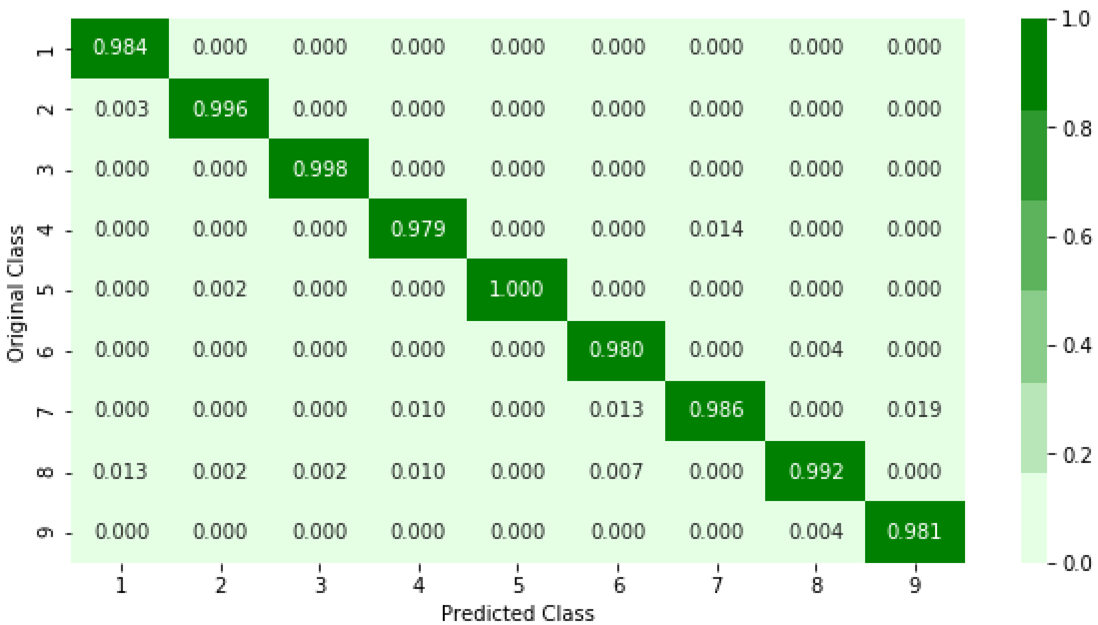
In [12]:
```
print (random_cfl1.best_params_)
```

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

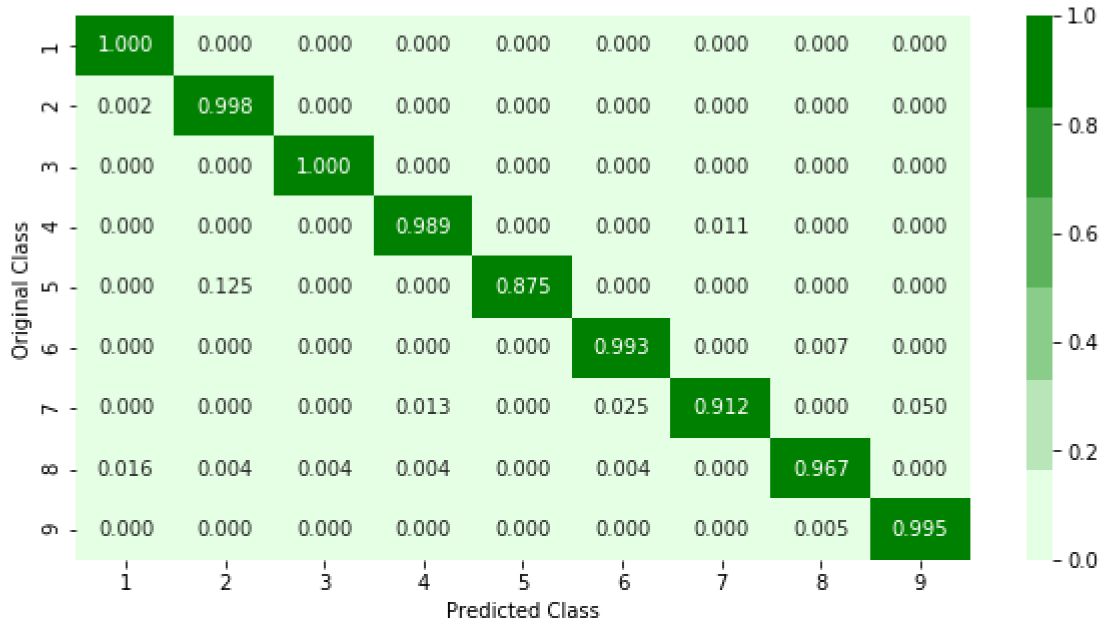
In [9]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 500, col
sample_bytree= 0.1, max_depth= 10,n_jobs=-1,verbose=5)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.015744018559108872
cv loss 0.047778866186683235
test loss 0.041630821531447065
Number of misclassified points  0.9199632014719411
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```


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




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




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

With Byte Tri-gram features

In [1]:

```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [4]:
```
byte_vocab = "00,01,02,03,04,05,06,07,08,09,0a,0b,0c,0d,0e,0f,10,11,12,13,14,1
5,16,17,18,19,1a,1b,1c,1d,1e,1f,20,21,22,23,24,25,26,27,28,29,2a,2b,2c,2d,2e,2
f,30,31,32,33,34,35,36,37,38,39,3a,3b,3c,3d,3e,3f,40,41,42,43,44,45,46,47,48,4
9,4a,4b,4c,4d,4e,4f,50,51,52,53,54,55,56,57,58,59,5a,5b,5c,5d,5e,5f,60,61,62,6
3,64,65,66,67,68,69,6a,6b,6c,6d,6e,6f,70,71,72,73,74,75,76,77,78,79,7a,7b,7c,7
d,7e,7f,80,81,82,83,84,85,86,87,88,89,8a,8b,8c,8d,8e,8f,90,91,92,93,94,95,96,9
7,98,99,9a,9b,9c,9d,9e,9f,a0,a1,a2,a3,a4,a5,a6,a7,a8,a9,aa,ab,ac,ad,ae,af,b0,b
1,b2,b3,b4,b5,b6,b7,b8,b9,ba,bb,bc,bd,be,bf,c0,c1,c2,c3,c4,c5,c6,c7,c8,c9,ca,c
b,cc,cd,ce,cf,d0,d1,d2,d3,d4,d5,d6,d7,d8,d9,da,db,dc,dd,de,df,e0,e1,e2,e3,e4,e
5,e6,e7,e8,e9,ea,eb,ec,ed,ee,ef,f0,f1,f2,f3,f4,f5,f6,f7,f8,f9,fa,fb,fc,fd,fe,f
f,??"
```

In [5]:
```
len(byte_vocab.split(','))
```

Out[5]: 257

In [6]:
```
byte_trigram_vocab = []
def byte_trigram():
    for i, v in enumerate(byte_vocab.split(',')):
        for j in range(0, len(byte_vocab.split(','))):
            for k in range(0, len(byte_vocab.split(','))):
                byte_trigram_vocab.append(v + ' ' +byte_vocab.split(',')[j]+'
 '+byte_vocab.split(',')[k])
```

In [7]:
```
byte_trigram()
```

In [8]:
```
len(byte_trigram_vocab)
```

Out[8]: 16974593

In [9]:
```
# I'm getting memory error even to see feature importance through random fores
t,
# so i'll take some features from 16974593 and then perform random forest for
 feature reduction
```

In [10]:
```
byte_trigram_vocab = (byte_trigram_vocab[:66049 ])
```

In [11]:
```
len(byte_trigram_vocab)
```

Out[11]: 66049

In [12]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [14]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect1 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('first'))):
        f = open('first/' + file)
        bytetrigram_vect1[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect1 = bytetrigram_vect1.todense()
    bytetrigram_df1 = pd.DataFrame(bytetrigram_vect1, columns = byte_trigram_v
ocab)
    bytetrigram_df1['ID'] = os.listdir('first')
    bytetrigram_df1.to_csv('bytetrigram1.csv',index=False)




#same as above
def secondprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect2 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('second'))):
        f = open('second/' + file)
        bytetrigram_vect2[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect2 = bytetrigram_vect2.todense()
    bytetrigram_df2 = pd.DataFrame(bytetrigram_vect2, columns = byte_trigram_v
ocab)
    bytetrigram_df2['ID'] = os.listdir('second')
    bytetrigram_df2.to_csv('bytetrigram2.csv',index=False)

# same as smallprocess() functions
def thirdprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect3 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('third'))):
        f = open('third/' + file)
        bytetrigram_vect3[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect3 = bytetrigram_vect3.todense()
    bytetrigram_df3 = pd.DataFrame(bytetrigram_vect3, columns = byte_trigram_v
ocab)
```

```
    bytetrigram_df3['ID'] = os.listdir('third')
    bytetrigram_df3.to_csv('bytetrigram3.csv',index=False)


def fourthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect4 = scipy.sparse.csr_matrix((777, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fourth'))):
        f = open('fourth/' + file)
        bytetrigram_vect4[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect4 = bytetrigram_vect4.todense()
    bytetrigram_df4 = pd.DataFrame(bytetrigram_vect4, columns = byte_trigram_v
ocab)
    bytetrigram_df4['ID'] = os.listdir('fourth')
    bytetrigram_df4.to_csv('bytetrigram4.csv',index=False)


def fifthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect5 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fifth'))):
        f = open('fifth/' + file)
        bytetrigram_vect5[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect5 = bytetrigram_vect5.todense()
    bytetrigram_df5 = pd.DataFrame(bytetrigram_vect5, columns = byte_trigram_v
ocab)
    bytetrigram_df5['ID'] = os.listdir('fifth')
    bytetrigram_df5.to_csv('bytetrigram5.csv',index=False)

def sixthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect6 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('sixth'))):
        f = open('sixth/' + file)
        bytetrigram_vect6[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect6 = bytetrigram_vect6.todense()
    bytetrigram_df6 = pd.DataFrame(bytetrigram_vect6, columns = byte_trigram_v
ocab)
    bytetrigram_df6['ID'] = os.listdir('sixth')
    bytetrigram_df6.to_csv('bytetrigram6.csv',index=False)

def seventhprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
```

```
    bytetrigram_vect7 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('seventh'))):
        f = open('seventh/' + file)
        bytetrigram_vect7[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect7 = bytetrigram_vect7.todense()
    bytetrigram_df7 = pd.DataFrame(bytetrigram_vect7, columns = byte_trigram_v
ocab)
    bytetrigram_df7['ID'] = os.listdir('seventh')
    bytetrigram_df7.to_csv('bytetrigram7.csv',index=False)

def eigthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect8 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('eigth'))):
        f = open('eigth/' + file)
        bytetrigram_vect8[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect8 = bytetrigram_vect8.todense()
    bytetrigram_df8 = pd.DataFrame(bytetrigram_vect8, columns = byte_trigram_v
ocab)
    bytetrigram_df8['ID'] = os.listdir('eigth')
    bytetrigram_df8.to_csv('bytetrigram8.csv',index=False)

def ningthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect9 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('ningth'))):
        f = open('ningth/' + file)
        bytetrigram_vect9[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([f
.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect9 = bytetrigram_vect9.todense()
    bytetrigram_df9 = pd.DataFrame(bytetrigram_vect9, columns = byte_trigram_v
ocab)
    bytetrigram_df9['ID'] = os.listdir('ningth')
    bytetrigram_df9.to_csv('bytetrigram9.csv',index=False)

def tenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect10 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('tenth'))):
        f = open('tenth/' + file)
        bytetrigram_vect10[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([
f.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect10 = bytetrigram_vect10.todense()
    bytetrigram_df10 = pd.DataFrame(bytetrigram_vect10, columns = byte_trigram
_vocab)
```

```
    bytetrigram_df10['ID'] = os.listdir('tenth')
    bytetrigram_df10.to_csv('bytetrigram10.csv',index=False)

def eleventhprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect11 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('eleventh'))):
        f = open('eleventh/' + file)
        bytetrigram_vect11[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([
f.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect11 = bytetrigram_vect11.todense()
    bytetrigram_df11 = pd.DataFrame(bytetrigram_vect11, columns = byte_trigram
_vocab)
    bytetrigram_df11['ID'] = os.listdir('eleventh')
    bytetrigram_df11.to_csv('bytetrigram11.csv',index=False)

def twelvethprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect12 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('twelveth'))):
        f = open('twelveth/' + file)
        bytetrigram_vect12[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([
f.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect12 = bytetrigram_vect12.todense()
    bytetrigram_df12 = pd.DataFrame(bytetrigram_vect12, columns = byte_trigram
_vocab)
    bytetrigram_df12['ID'] = os.listdir('twelveth')
    bytetrigram_df12.to_csv('bytetrigram12.csv',index=False)

def thirteenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect13 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('thirteenth'))):
        f = open('thirteenth/' + file)
        bytetrigram_vect13[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([
f.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect13 = bytetrigram_vect13.todense()
    bytetrigram_df13 = pd.DataFrame(bytetrigram_vect13, columns = byte_trigram
_vocab)
    bytetrigram_df13['ID'] = os.listdir('thirteenth')
    bytetrigram_df13.to_csv('bytetrigram13.csv',index=False)

def fourteenthprocess():

    vect = CountVectorizer(lowercase=False,ngram_range=(3,3), vocabulary=byte_
trigram_vocab)
    bytetrigram_vect14 = scipy.sparse.csr_matrix((776, 66049))
    for i, file in tqdm1(enumerate(os.listdir('fourteenth'))):
```

```
        f = open('fourteenth/' + file)
        bytetrigram_vect14[i,:]+= scipy.sparse.csr_matrix(vect.fit_transform([
f.read().replace('\n', ' ').lower()]))
        f.close()
    bytetrigram_vect14 = bytetrigram_vect14.todense()
    bytetrigram_df14 = pd.DataFrame(bytetrigram_vect14, columns = byte_trigram
_vocab)
    bytetrigram_df14['ID'] = os.listdir('fourteenth')
    bytetrigram_df14.to_csv('bytetrigram14.csv',index=False)


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
```

```
    p12.join()
    p13.join()
    p14.join()

if __name__=="__main__":
    main()
```

In [13]:
```
import pandas as pd
from pebble import concurrent
# https://stackoverflow.com/a/56676389/8089731

@concurrent.process
def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment
    bytebtrigram1_df = pd.read_csv('bytetrigram1.csv')
    return bytebtrigram1_df

#same as above
@concurrent.process
def secondprocess():

    bytebtrigram2_df = pd.read_csv('bytetrigram2.csv')
    return bytebtrigram2_df

@concurrent.process
def thirdprocess():

    bytebtrigram3_df = pd.read_csv('bytetrigram3.csv')
    return bytebtrigram3_df

@concurrent.process
def fourthprocess():

    bytebtrigram4_df = pd.read_csv('bytetrigram4.csv')
    return bytebtrigram4_df

@concurrent.process
def fifthprocess():

    bytebtrigram5_df = pd.read_csv('bytetrigram5.csv')
    return bytebtrigram5_df

@concurrent.process
def sixthprocess():

    bytebtrigram6_df = pd.read_csv('bytetrigram6.csv')
    return bytebtrigram6_df

@concurrent.process
def seventhprocess():

    bytebtrigram7_df = pd.read_csv('bytetrigram7.csv')
    return bytebtrigram7_df

@concurrent.process
def eigthprocess():

    bytebtrigram8_df = pd.read_csv('bytetrigram8.csv')
    return bytebtrigram8_df
```

```
@concurrent.process
def ningthprocess():

    bytebtrigram9_df = pd.read_csv('bytetrigram9.csv')
    return bytebtrigram9_df

@concurrent.process
def tenthprocess():

    bytebtrigram10_df = pd.read_csv('bytetrigram10.csv')
    return bytebtrigram10_df

@concurrent.process
def eleventhprocess():

    bytebtrigram11_df = pd.read_csv('bytetrigram11.csv')
    return bytebtrigram11_df

@concurrent.process
def twelvethprocess():

    bytebtrigram12_df = pd.read_csv('bytetrigram12.csv')
    return bytebtrigram12_df

@concurrent.process
def thirteenthprocess():

    bytebtrigram13_df = pd.read_csv('bytetrigram13.csv')
    return bytebtrigram13_df

@concurrent.process
def fourteenthprocess():

    bytebtrigram14_df = pd.read_csv('bytetrigram14.csv')
    return bytebtrigram14_df

# def
bytetrigram1_df = firstprocess()
bytetrigram2_df = secondprocess()
bytetrigram3_df = thirdprocess()
bytetrigram4_df = fourthprocess()
bytetrigram5_df = fifthprocess()
bytetrigram6_df = sixthprocess()
bytetrigram7_df = seventhprocess()
bytetrigram8_df = eigthprocess()
bytetrigram9_df = ningthprocess()
bytetrigram10_df = tenthprocess()
bytetrigram11_df = eleventhprocess()
bytetrigram12_df = twelvethprocess()
bytetrigram13_df = thirteenthprocess()
bytetrigram14_df = fourteenthprocess()
```

In [14]:
```
bytetrigram1_df = (bytetrigram1_df.result())
bytetrigram2_df = (bytetrigram2_df.result())
bytetrigram3_df = (bytetrigram3_df.result())
bytetrigram4_df = (bytetrigram4_df.result())
bytetrigram5_df = (bytetrigram5_df.result())
bytetrigram6_df = (bytetrigram6_df.result())
bytetrigram7_df = (bytetrigram7_df.result())
bytetrigram8_df = (bytetrigram8_df.result())
bytetrigram9_df = (bytetrigram9_df.result())
bytetrigram10_df = (bytetrigram10_df.result())
bytetrigram11_df = (bytetrigram11_df.result())
bytetrigram12_df = (bytetrigram12_df.result())
bytetrigram13_df = (bytetrigram13_df.result())
bytetrigram14_df = (bytetrigram14_df.result())
```

In [15]:
```
bytetrigram1_df.head()
```

Out[15]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00 00 09	...	00 ?? f8	00 ?? f9	00 ?? fa	00 ?? fb
0	17808.0	73.0	2.0	4.0	6.0	2.0	1.0	1.0	4.0	0.0	...	0.0	0.0	0.0	0.0
1	8663.0	20.0	3.0	1.0	4.0	0.0	0.0	1.0	1.0	0.0	...	0.0	0.0	0.0	0.0
2	4583.0	20.0	4.0	52.0	0.0	34.0	0.0	22.0	4.0	24.0	...	0.0	0.0	0.0	0.0
3	79187.0	961.0	427.0	752.0	380.0	270.0	295.0	343.0	430.0	202.0	...	0.0	0.0	0.0	0.0
4	4294.0	22.0	4.0	54.0	0.0	34.0	2.0	18.0	2.0	26.0	...	0.0	0.0	0.0	0.0

5 rows × 66050 columns

In [16]:
```
bytetrigram_df = pd.concat([bytetrigram1_df,bytetrigram2_df,bytetrigram3_df,bytetrigram4_df,bytetrigram5_df,bytetrigram6_df,bytetrigram7_df,bytetrigram8_df,bytetrigram9_df,bytetrigram10_df,bytetrigram11_df,bytetrigram12_df,bytetrigram13_df,bytetrigram14_df])
```

In [17]:
```
bytetrigram_df
```

Out[17]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00 00 09	...	00 ?? f8	00 ?? f9	00 ?? fa	00 ?? fb
0	17808.0	73.0	2.0	4.0	6.0	2.0	1.0	1.0	4.0	0.0	...	0.0	0.0	0.0	0.0
1	8663.0	20.0	3.0	1.0	4.0	0.0	0.0	1.0	1.0	0.0	...	0.0	0.0	0.0	0.0
2	4583.0	20.0	4.0	52.0	0.0	34.0	0.0	22.0	4.0	24.0	...	0.0	0.0	0.0	0.0
3	79187.0	961.0	427.0	752.0	380.0	270.0	295.0	343.0	430.0	202.0	...	0.0	0.0	0.0	0.0
4	4294.0	22.0	4.0	54.0	0.0	34.0	2.0	18.0	2.0	26.0	...	0.0	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
771	5048.0	20.0	4.0	54.0	1.0	34.0	4.0	22.0	4.0	26.0	...	0.0	0.0	0.0	0.0
772	906.0	9.0	4.0	4.0	4.0	3.0	5.0	3.0	2.0	0.0	...	0.0	0.0	0.0	0.0
773	2976.0	30.0	1.0	6.0	9.0	1.0	2.0	2.0	6.0	1.0	...	0.0	0.0	0.0	0.0
774	17368.0	185.0	25.0	108.0	96.0	16.0	7.0	18.0	16.0	55.0	...	0.0	0.0	0.0	0.0
775	4315.0	53.0	25.0	14.0	30.0	30.0	18.0	17.0	19.0	28.0	...	0.0	0.0	0.0	0.0

10868 rows × 66050 columns

In [18]:
```
len(bytetrigram_df.columns[:66049])
```

Out[18]: 66049

In [19]:
```
bytetrigram_df['ID'] = bytetrigram_df['ID'].str[:-6]
bytetrigram_df.head()
```

Out[19]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00 00 09	...	00 ?? f8	00 ?? f9	00 ?? fa	00 ?? fb
0	17808.0	73.0	2.0	4.0	6.0	2.0	1.0	1.0	4.0	0.0	...	0.0	0.0	0.0	0.0
1	8663.0	20.0	3.0	1.0	4.0	0.0	0.0	1.0	1.0	0.0	...	0.0	0.0	0.0	0.0
2	4583.0	20.0	4.0	52.0	0.0	34.0	0.0	22.0	4.0	24.0	...	0.0	0.0	0.0	0.0
3	79187.0	961.0	427.0	752.0	380.0	270.0	295.0	343.0	430.0	202.0	...	0.0	0.0	0.0	0.0
4	4294.0	22.0	4.0	54.0	0.0	34.0	2.0	18.0	2.0	26.0	...	0.0	0.0	0.0	0.0

5 rows × 66050 columns

In [20]:
```
result_with_size = pd.read_csv("result_with_size.csv")
result_with_size = result_with_size[['size','ID','Class']]
bytetrigram_df = pd.merge(bytetrigram_df, result_with_size,on='ID', how='left'
)
bytetrigram_df.head()
```

Out[20]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00 00 09	...	00 ?? fa	00 ?? fb	00 ?? fc	00 ?? fd
0	17808.0	73.0	2.0	4.0	6.0	2.0	1.0	1.0	4.0	0.0	...	0.0	0.0	0.0	0.0
1	8663.0	20.0	3.0	1.0	4.0	0.0	0.0	1.0	1.0	0.0	...	0.0	0.0	0.0	0.0
2	4583.0	20.0	4.0	52.0	0.0	34.0	0.0	22.0	4.0	24.0	...	0.0	0.0	0.0	0.0
3	79187.0	961.0	427.0	752.0	380.0	270.0	295.0	343.0	430.0	202.0	...	0.0	0.0	0.0	0.0
4	4294.0	22.0	4.0	54.0	0.0	34.0	2.0	18.0	2.0	26.0	...	0.0	0.0	0.0	0.0

5 rows × 66052 columns

In [21]:
```
# 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')
and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            if (max_value-min_value)!=0:
                result1[feature_name] = (df[feature_name] - min_value) / (max_
value - min_value)
    return result1
```

In [22]:
```
bytetrigram_df = normalize(bytetrigram_df)
bytetrigram_df.head()
```

Out[22]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00
0	0.008908	0.010748	0.000231	0.001348	0.000981	0.000693	0.000308	0.00016	0.000453	0.0(
1	0.004334	0.002945	0.000346	0.000337	0.000654	0.000000	0.000000	0.00016	0.000113	0.0(
2	0.002293	0.002945	0.000462	0.017520	0.000000	0.011777	0.000000	0.00352	0.000453	0.0(
3	0.039613	0.141490	0.049313	0.253369	0.062102	0.093523	0.090713	0.05488	0.048709	0.0'
4	0.002148	0.003239	0.000462	0.018194	0.000000	0.011777	0.000615	0.00288	0.000227	0.0(

5 rows × 66052 columns

In [23]:
```
# bytetrigram_df.to_pickle('bytetrigram_final_df')
```

In [24]:
```
bytetrigram_df = pd.read_pickle('bytetrigram_final_df')
```

In [25]:
```
bytetrigram_df.head()
```

Out[25]:

	00 00 00	00 00 01	00 00 02	00 00 03	00 00 04	00 00 05	00 00 06	00 00 07	00 00 08	00
0	0.008908	0.010748	0.000231	0.001348	0.000981	0.000693	0.000308	0.00016	0.000453	0.0(
1	0.004334	0.002945	0.000346	0.000337	0.000654	0.000000	0.000000	0.00016	0.000113	0.0(
2	0.002293	0.002945	0.000462	0.017520	0.000000	0.011777	0.000000	0.00352	0.000453	0.0(
3	0.039613	0.141490	0.049313	0.253369	0.062102	0.093523	0.090713	0.05488	0.048709	0.0⁻
4	0.002148	0.003239	0.000462	0.018194	0.000000	0.011777	0.000615	0.00288	0.000227	0.0(

5 rows × 66052 columns

Selecting important features

In [28]:
```
#'Unnamed: 0'
data_y = bytetrigram_df['Class']
```

In [29]:
```
def imp_features(data, features):
    rf = RandomForestClassifier(n_estimators = 33, n_jobs = -1,verbose=5)
    rf.fit(data, data_y)
    imp_feature_indx = np.argsort(rf.feature_importances_)[::-1]
    imp_feature_name = np.take(features, imp_feature_indx)
    return imp_feature_name
```

In [30]:
```
byte_tri_names = imp_features(bytetrigram_df.drop(['ID','Class','size'],axis=1
,inplace=False), byte_trigram_vocab)
```

```
[Parallel(n_jobs=-1)]: Using backend ThreadingBackend with 16 concurrent work
ers.

building tree 1 of 33
building tree 2 of 33
building tree 3 of 33
building tree 4 of 33
building tree 5 of 33
building tree 6 of 33
building tree 7 of 33
building tree 8 of 33
building tree 9 of 33
building tree 10 of 33
building tree 11 of 33
building tree 12 of 33
building tree 13 of 33
building tree 14 of 33
building tree 15 of 33
building tree 16 of 33
building tree 17 of 33
building tree 18 of 33
building tree 19 of 33
building tree 20 of 33
building tree 21 of 33
building tree 22 of 33
building tree 23 of 33
building tree 24 of 33
building tree 25 of 33
building tree 26 of 33
building tree 27 of 33
building tree 28 of 33
building tree 29 of 33
building tree 30 of 33
building tree 31 of 33
building tree 32 of 33

[Parallel(n_jobs=-1)]: Done   9 out of  33 | elapsed:    0.4s remaining:
1.2s
[Parallel(n_jobs=-1)]: Done  16 out of  33 | elapsed:    0.5s remaining:
0.5s

building tree 33 of 33

[Parallel(n_jobs=-1)]: Done  23 out of  33 | elapsed:    0.8s remaining:
0.3s
[Parallel(n_jobs=-1)]: Done  30 out of  33 | elapsed:    0.8s remaining:
0.1s
[Parallel(n_jobs=-1)]: Done  33 out of  33 | elapsed:    1.0s finished
```

In [31]:
```
# with open('bytetrigram_imp_features.pkl','wb') as f:
#     pickle.dump(byte_tri_names, f)
with open('bytetrigram_imp_features.pkl','rb') as f:
    byte_tri_names = pickle.load(f)
```

In [32]:
```
byte_tri_names
```

Out[32]:
```
array(['00 ff ff', '00 f1 04', '00 00 81', ..., '00 a5 11', '00 a5 10',
       '00 ?? ??'], dtype='<U8')
```

In [33]:
```
len(byte_tri_names)
```

Out[33]:
```
66049
```

In [34]:
```
byte_tri_names = list(byte_tri_names[:1000])
byte_tri_names.append('ID')
byte_tri_names.append('Class')
byte_tri_names.append('size')
len(byte_tri_names)
```

Out[34]:
```
1003
```

In [35]:
```
bytetrigram_df = bytetrigram_df[byte_tri_names]
```

In [36]:
```
len(bytetrigram_df.columns)
```

Out[36]:
```
1003
```

In [37]:
```
bytetrigram_df.head()
```

Out[37]:

	00 ff ff	00 f1 04	00 00 81	00 8d 8c	00 01 00	00 1e ff	00 00 66	00 00 75	00 33 c5	00 ff d6	...
0	0.000411	0.000000	0.000802	0.000000	0.004118	0.000000	0.000205	0.004714	0.0	0.0	...
1	0.001780	0.000000	0.000802	0.002364	0.001808	0.000000	0.000068	0.000589	0.0	0.0	...
2	0.000000	0.105263	0.003209	0.000000	0.002009	0.061538	0.000000	0.001179	0.0	0.0	...
3	0.011567	0.052632	0.146410	0.018913	0.125741	0.000000	0.098784	0.197407	0.0	0.0	...
4	0.000137	0.105263	0.000802	0.000000	0.002310	0.215385	0.000137	0.001179	0.0	0.0	...

5 rows × 1003 columns

In [1]:
```
import dill                           #pip install dill --user
# filename = 'globalsave.pkl'
# dill.dump_session('notebook_env2.db')

# and to load the session again:
dill.load_session('notebook_env2.db')
```

In [2]:
```
# bytetrigram_df.to_csv('bytetrigram_final_rf_reduced_df',index=False)
```

In [3]:
```
bytetrigram_df = pd.read_csv('bytetrigram_final_rf_reduced_df')
bytetrigram_df.head()
```

Out[3]:

	00 ff ff	00 f1 04	00 00 81	00 8d 8c	00 01 00	00 1e ff	00 00 66	00 00 75	00 33 c5	00 ff d6	...
0	0.000411	0.000000	0.000802	0.000000	0.004118	0.000000	0.000205	0.004714	0.0	0.0	...
1	0.001780	0.000000	0.000802	0.002364	0.001808	0.000000	0.000068	0.000589	0.0	0.0	...
2	0.000000	0.105263	0.003209	0.000000	0.002009	0.061538	0.000000	0.001179	0.0	0.0	...
3	0.011567	0.052632	0.146410	0.018913	0.125741	0.000000	0.098784	0.197407	0.0	0.0	...
4	0.000137	0.105263	0.000802	0.000000	0.002310	0.215385	0.000137	0.001179	0.0	0.0	...

5 rows × 1003 columns

Train Test split

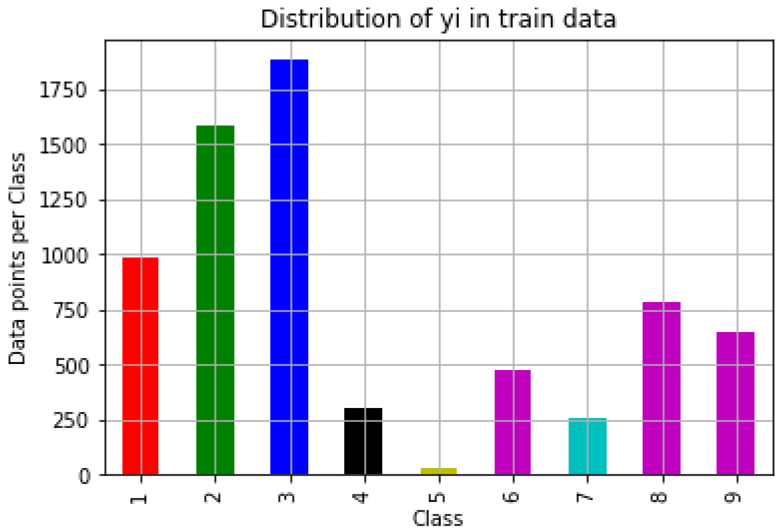
In [4]:
```
data_y = bytetrigram_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(bytetrigram_df.drop(['ID',
'Class'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [5]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

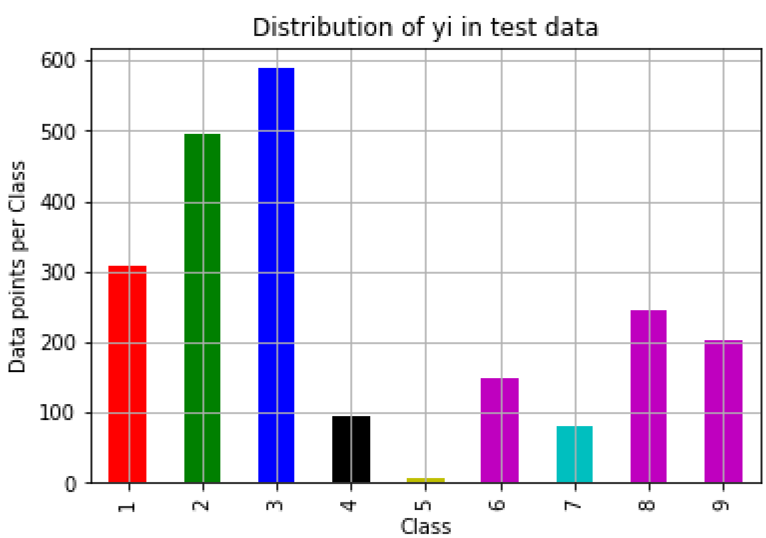
```
Number of data points in train data: (6955, 1001)
Number of data points in test data: (2174, 1001)
Number of data points in cross validation data: (1739, 1001)
```

In [6]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

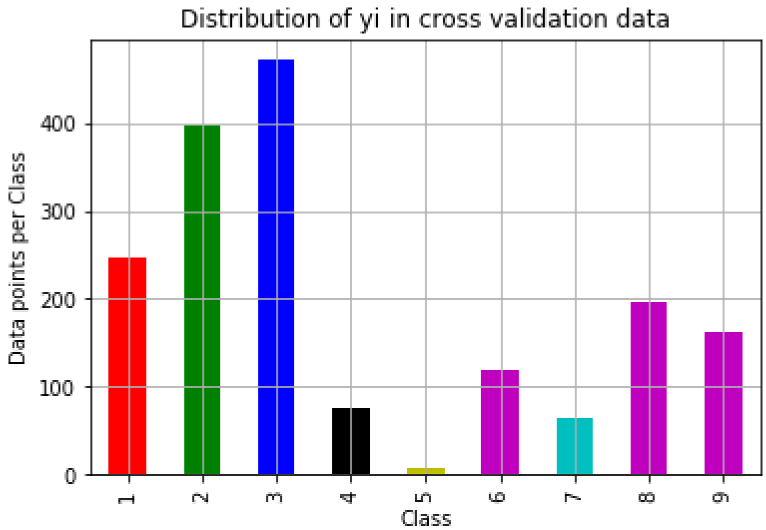
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
---------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
---------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [7]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes trigrams features

In [8]:

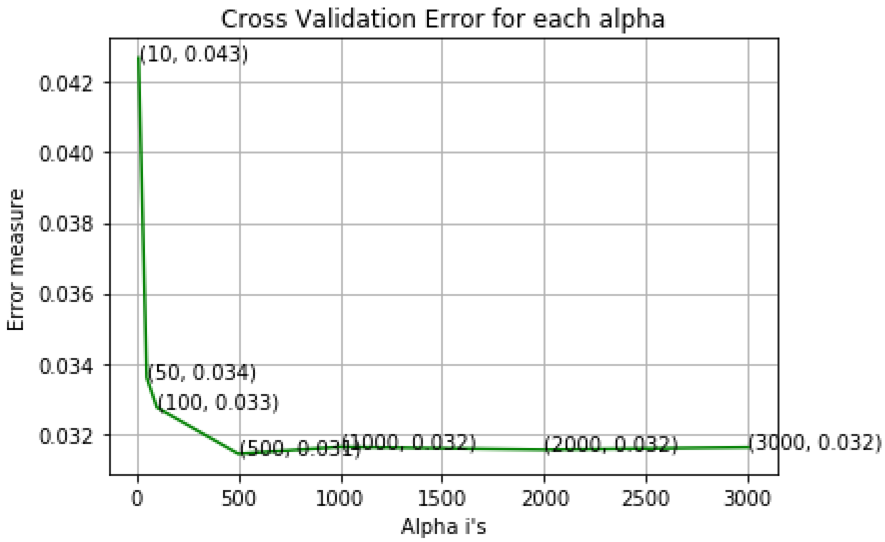
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.4. Random Forest Classifier

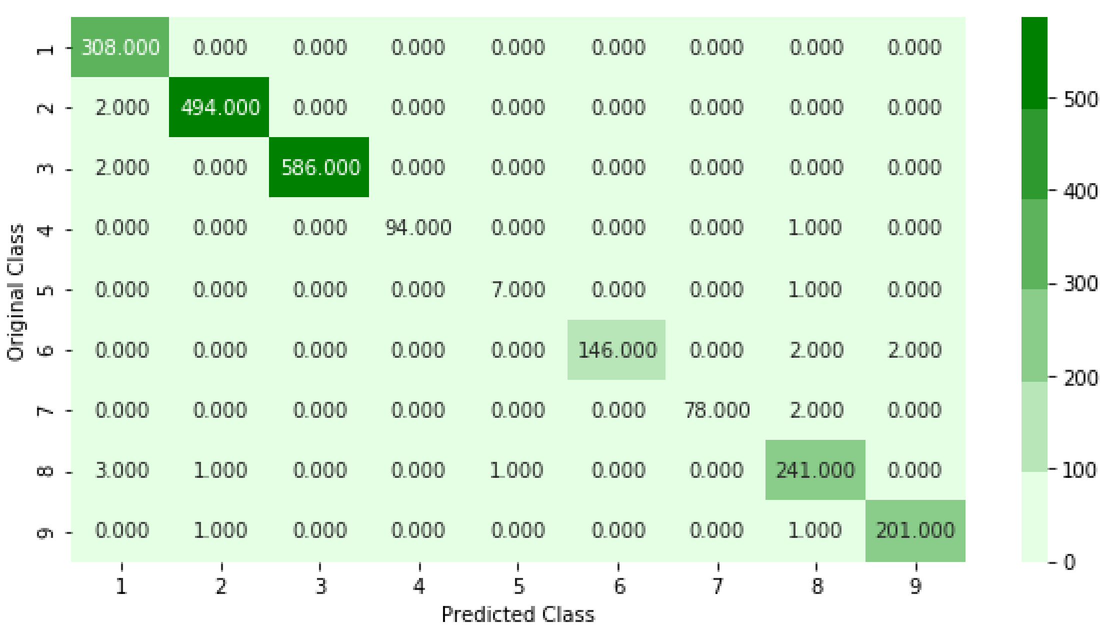
In [9]:
```
# -------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  10 is 0.042689967597717295
log_loss for c =  50 is 0.033598702744119975
log_loss for c =  100 is 0.032747906558161614
log_loss for c =  500 is 0.031426635880770305
log_loss for c =  1000 is 0.03162506912257781
log_loss for c =  2000 is 0.031545207192421945
log_loss for c =  3000 is 0.0316129867314329
```

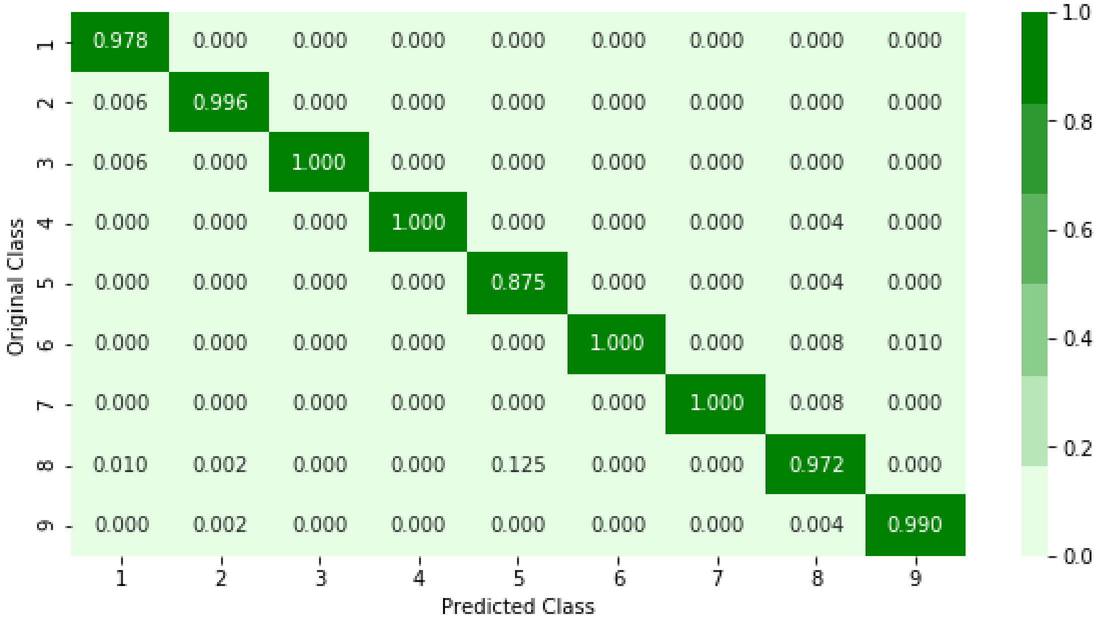



```
For values of best alpha =  500 The train log loss is: 0.014935436107096032
For values of best alpha =  500 The cross validation log loss is: 0.031426635
880770305
For values of best alpha =  500 The test log loss is: 0.04329348834861496
Number of misclassified points  0.8739650413983441
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```



	1	2	3	4	5	6	7	8	9
1	308.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	2.000	494.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	2.000	0.000	586.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	94.000	0.000	0.000	0.000	1.000	0.000
5	0.000	0.000	0.000	0.000	7.000	0.000	0.000	1.000	0.000
6	0.000	0.000	0.000	0.000	0.000	146.000	0.000	2.000	2.000
7	0.000	0.000	0.000	0.000	0.000	0.000	78.000	2.000	0.000
8	3.000	1.000	0.000	0.000	1.000	0.000	0.000	241.000	0.000
9	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	201.000

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




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


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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [10]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:  2.1min remaining: 19.2
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:  7.1min remaining: 23.5
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed: 10.1min remaining: 17.5
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed: 10.6min remaining: 10.6
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed: 11.4min remaining:  6.6
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 12.0min remaining:  3.7
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 12.9min remaining:  1.4
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 24.7min finished
```

Out[10]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

In [12]:
```
print (random_cfl1.best_params_)
```

```
{'n_estimators': 500, 'subsample': 0.5, 'colsample_bytree': 0.1, 'max_depth':
5, 'learning_rate': 0.03}
```

In [13]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.03, subsample= 0.5, n_estimators= 500, co
lsample_bytree= 0.1, max_depth= 5,n_jobs=-1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.012230363341002245
cv loss 0.027439246142274578
test loss 0.03738227661138209
Number of misclassified points  0.6439742410303588
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```


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


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


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

With Byte Bi and Tri-gram features

In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotlib inline
```

In [2]:
```
bytebigram_df = pd.read_csv('bytebigram_final_rf_reduced_df')
bytebigram_df.head()
```

Out[2]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1003 columns

In [3]:
```
bytetrigram_df = pd.read_csv('bytetrigram_final_rf_reduced_df')
bytetrigram_df.head()
```

Out[3]:

	00 ff ff	00 f1 04	00 00 81	00 8d 8c	00 01 00	00 1e ff	00 00 66	00 00 75	00 33 c5	00 ff d6	...
0	0.000411	0.000000	0.000802	0.000000	0.004118	0.000000	0.000205	0.004714	0.0	0.0	...
1	0.001780	0.000000	0.000802	0.002364	0.001808	0.000000	0.000068	0.000589	0.0	0.0	...
2	0.000000	0.105263	0.003209	0.000000	0.002009	0.061538	0.000000	0.001179	0.0	0.0	...
3	0.011567	0.052632	0.146410	0.018913	0.125741	0.000000	0.098784	0.197407	0.0	0.0	...
4	0.000137	0.105263	0.000802	0.000000	0.002310	0.215385	0.000137	0.001179	0.0	0.0	...

5 rows × 1003 columns

In [8]:
```
byte_bi_trigram_df = pd.merge(bytebigram_df, bytetrigram_df.drop(['size','Clas
s'],axis=1,inplace=False),on='ID', how='left')
# https://stackoverflow.com/a/50262269/8089731
df1 = byte_bi_trigram_df.pop('ID') # remove column ID and store it in df1
byte_bi_trigram_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = byte_bi_trigram_df.pop('Class') # remove column ID and store it in df1
byte_bi_trigram_df['Class']=df2 # add ID series as a 'new' column in the last.
df3 = byte_bi_trigram_df.pop('size') # remove column ID and store it in df1
byte_bi_trigram_df['size']=df3 # add ID series as a 'new' column in the last.
byte_bi_trigram_df.head()
```

Out[8]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 2003 columns

Train Test split

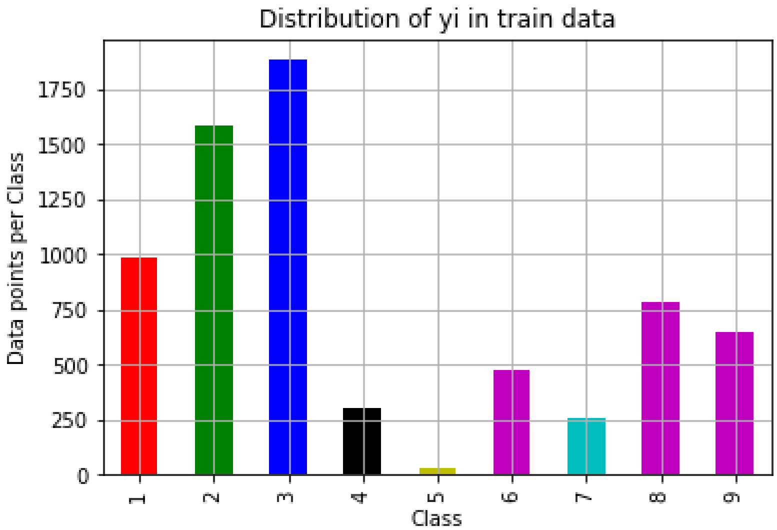
In [9]:
```
data_y = byte_bi_trigram_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(byte_bi_trigram_df.drop([
'ID','Class'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [10]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

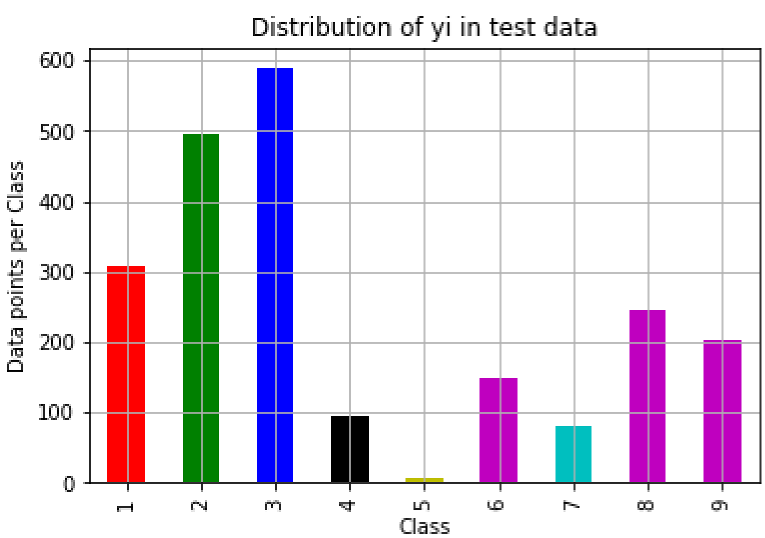
```
Number of data points in train data: (6955, 2001)
Number of data points in test data: (2174, 2001)
Number of data points in cross validation data: (1739, 2001)
```

In [11]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

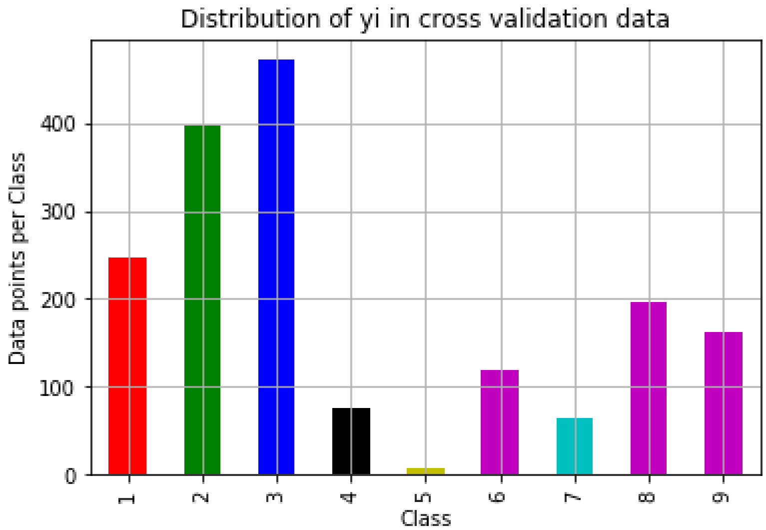
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [12]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes trigrams features

In [13]:

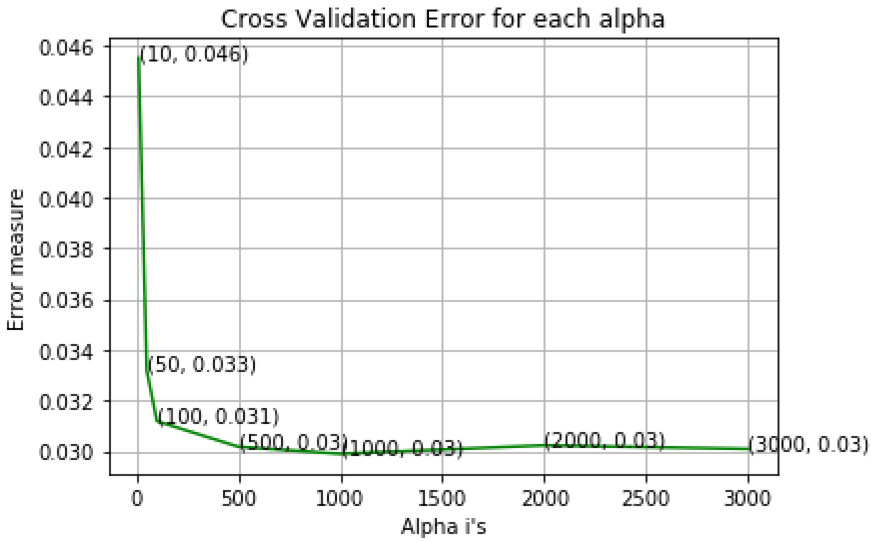
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.4. Random Forest Classifier

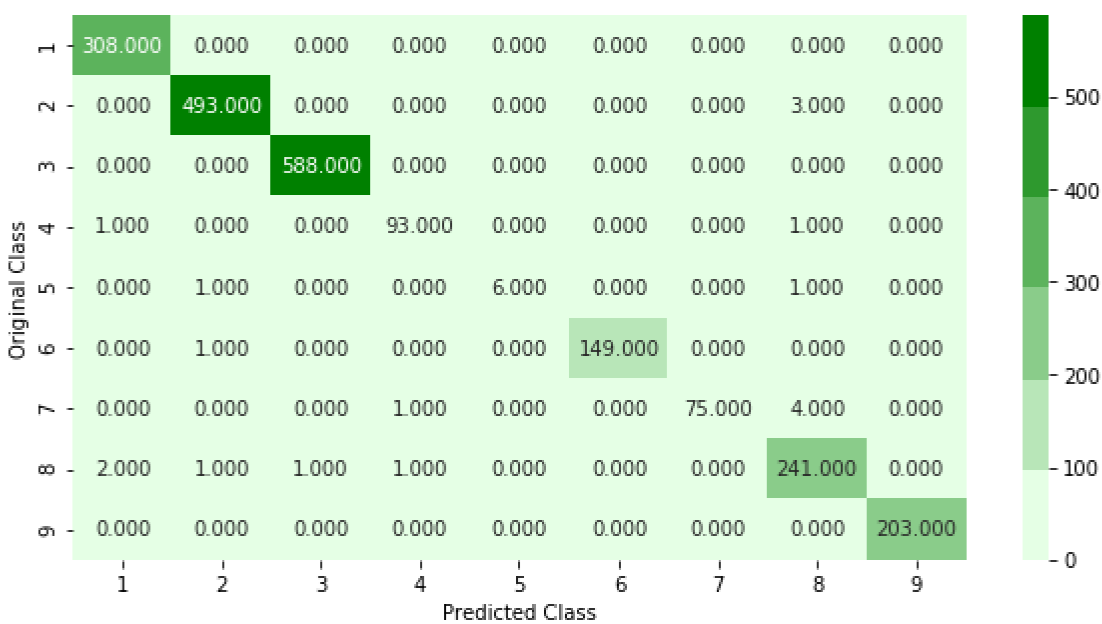
In [14]:
```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

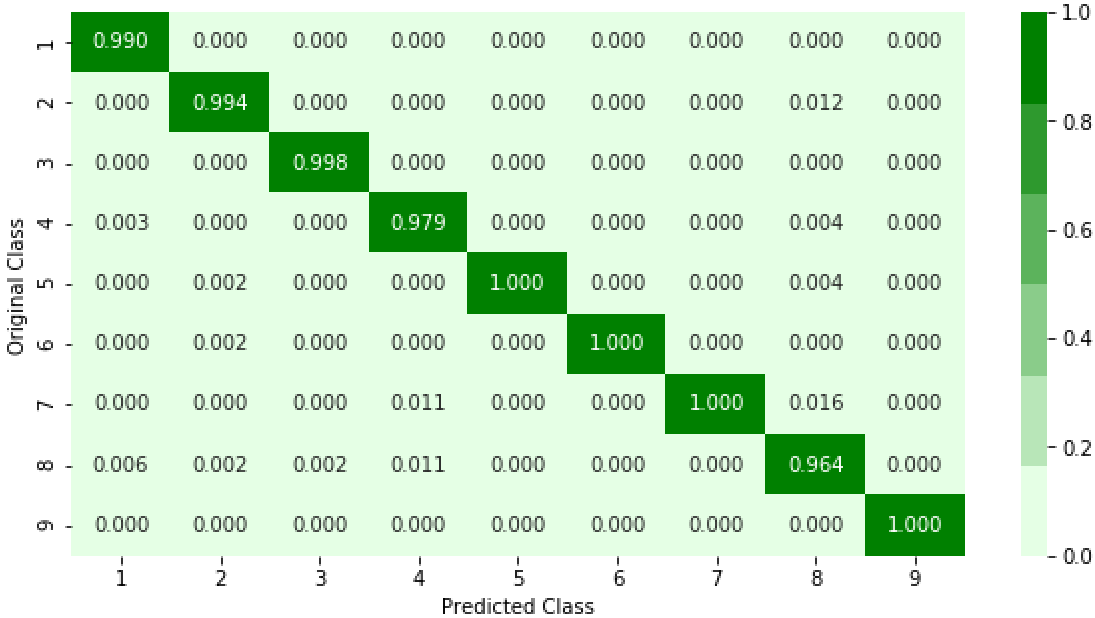
```
log_loss for c =  10 is 0.04551042020621661
log_loss for c =  50 is 0.033192139165734484
log_loss for c =  100 is 0.03118144320873043
log_loss for c =  500 is 0.030171499735335186
log_loss for c =  1000 is 0.029890840290377148
log_loss for c =  2000 is 0.030225913363936912
log_loss for c =  3000 is 0.030086873442090937
```




```
For values of best alpha =  1000 The train log loss is: 0.014702410007220173
For values of best alpha =  1000 The cross validation log loss is: 0.02989084
0290377148
For values of best alpha =  1000 The test log loss is: 0.03918666032311394
Number of misclassified points  0.8279668813247469
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```




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




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

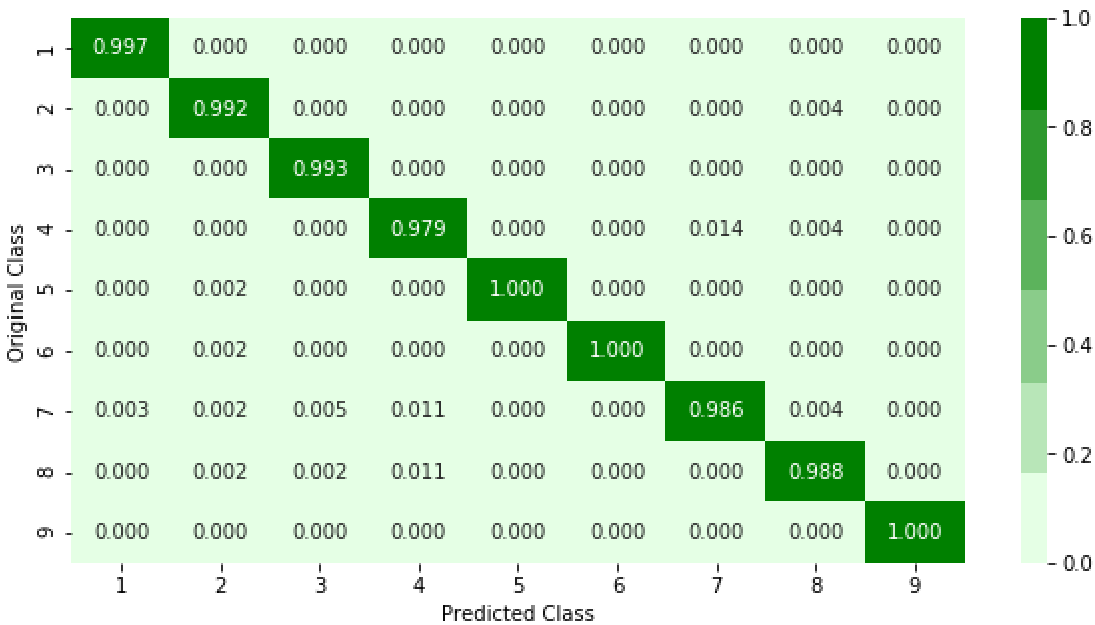

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

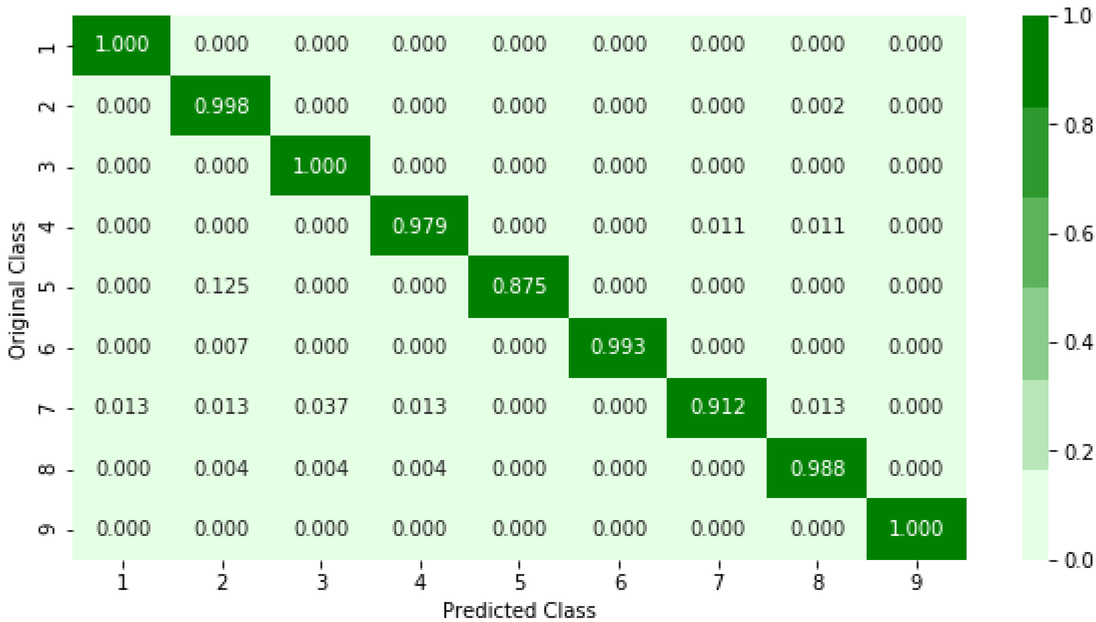
In [18]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 500, col
sample_bytree= 0.3, max_depth= 5,n_jobs=-1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.01287257759195633
cv loss 0.02359912934724191
test loss 0.0343506643185329
Number of misclassified points  0.6899724011039559
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```


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




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




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

In [ ]:

ASM Files:

In [18]:

```
#separating byte files and asm files

source = 'train'
destination = 'byteFiles'

# we will check if the folder 'byteFiles' exists if it not there we will creat
e a folder with the same name
if not os.path.isdir(destination):
    os.makedirs(destination)

# if we have folder called 'train' (train folder contains both .asm files and
 .bytes files) we will rename it 'asmFiles'
# for every file that we have in our 'asmFiles' directory we check if it is en
ding with .bytes, if yes we will move it to
# 'byteFiles' folder

# so by the end of this snippet we will separate all the .byte files and .asm
 files
if os.path.isdir(source):
    os.rename(source,'asmFiles')
    source='asmFiles'
    data_files = os.listdir(source)
    for file in data_files:
        if (file.endswith("bytes")):
            shutil.move(source+"/"+file,destination)
```

In [15]:
```
Y=pd.read_csv("trainLabels.csv")
```

In [16]:
```
# asmoutputfile.csv(output genarated from the above two cells) will contain al
l the extracted features from .asm files
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutputfile.csv")
Y.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, Y,on='ID', how='left')
result_asm.head()
```

Out[16]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 53 columns

4.2.1.1 Files sizes of each .asm file

In [19]:
```
#file sizes of byte files

files=os.listdir('asmFiles')
filenames=Y['ID'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=356157170
0, st_nlink=1, st_uid=0, st_gid=0,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519
638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_s
tat.htm
    statinfo=os.stat('asmFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file na
me
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
asm_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (asm_size_byte.head())
```

```
   Class                    ID       size
0      1  aMSX7lvrZeCBwE9kUnDf   1.011998
1      3  epj8anqLcrRxHGVWT1Bg  32.695071
2      3  3rt2gI9JVaZcTQGyjmbk  32.701280
3      3  aYRoe1Nvt4J8Bz6LbSZ5   0.163288
4      4  gIONM8E513LYstAjyzWl  11.216479
```

In [20]:
```
# add the file size feature to previous extracted features
print(result_asm.shape)
print(asm_size_byte.shape)
result_asm = pd.merge(result_asm, asm_size_byte.drop(['Class'], axis=1),on='I
D', how='left')
result_asm.head()
```

```
(10868, 53)
(10868, 3)
```

Out[20]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [23]:
```
# result_asm.to_csv('result_asm_with_size.csv',index=False)
result_asm = pd.read_csv('result_asm_with_size.csv')
result_asm.head()
```

Out[23]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [ ]:

Image Feature From ASM Files

In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [2]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
import scipy
```

In [3]:
```
len(os.listdir("asmFiles"))
```

Out[3]: 10868

In [24]:
```
import array
def img_asm():
    count=1
    for asmfile in os.listdir("asmFiles"):
        filename = asmfile.split('.')[0]
        file = codecs.open("asmFiles/" + asmfile, 'rb')
        filelen = os.path.getsize("asmFiles/" + asmfile)
        width = int(filelen ** 0.5)
        rem = int(filelen / width)
        arr = array.array('B')
        arr.frombytes(file.read())
        file.close()
        reshaped = np.reshape(arr[:width * width], (width, width))
        reshaped = np.uint8(reshaped)
        scipy.misc.imsave('asm_image/' + filename + '.png',reshaped)
        print('{} files -------- done'.format(count))
        count+=1
```

In [25]:
```
img_asm()
```

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Creating Image features:

In [29]:
```
import cv2
imagefeatures = np.zeros((10868, 500))
```

In [42]:
```
id_names = []
for i, asmfile in enumerate(os.listdir("asmFiles")):
    img = cv2.imread("asm_image/" + asmfile.split('.')[0] + '.png')
    img_arr = img.flatten()[:500]
    imagefeatures[i, :] += img_arr
    id_names.append(asmfile.split('.')[0])
    print('{} files -------- done'.format(i))
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10850 files -------- done
10851 files -------- done
10852 files -------- done
10853 files -------- done
10854 files -------- done
10855 files -------- done
10856 files -------- done
10857 files -------- done
10858 files -------- done
10859 files -------- done
10860 files -------- done
10861 files -------- done
10862 files -------- done
10863 files -------- done
10864 files -------- done
10865 files -------- done
10866 files -------- done
10867 files -------- done
```

In [4]:

```
# with open('imagefeatures.pkl','wb') as f:
#     pickle.dump(imagefeatures, f)
# with open('id_names.pkl','wb') as f:
#     pickle.dump(id_names, f)
with open('imagefeatures.pkl','rb') as f:
    imagefeatures = pickle.load(f)
with open('id_names.pkl','rb') as f:
    id_names = pickle.load(f)
```

In [5]:

```
len(id_names)
```

Out[5]:

```
10868
```

In [6]:

```
imagefeatures.shape
```

Out[6]:

```
(10868, 500)
```

In [7]:
```
imgfeatures_name = []
for i in range(500):
    imgfeatures_name.append('pixel' + str(i+1))
asm_df = pd.DataFrame(imagefeatures, columns = imgfeatures_name)
asm_df['ID'] = id_names
asm_df.to_csv('asm_df.csv',index=False)
asm_df = pd.read_csv('asm_df.csv')
asm_df.head()
```

Out[7]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10	...	pixel492	pixe
0	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	18.0	2
1	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	18.0	2
2	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	18.0	2
3	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	18.0	2
4	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	18.0	2

5 rows × 501 columns

In [8]:
```
result_asm = pd.read_csv('result_asm_with_size.csv')
result_asm = result_asm[['ID','Class','size']]
result_asm.head()
```

Out[8]:

	ID	Class	size
0	01kcPWA9K2BOxQeS5Rju	1	0.078190
1	1E93CpP60RHFNiT5Qfvn	1	0.063400
2	3ekVow2ajZHbTnBcsDfX	1	0.041695
3	3X2nY7iQaPBIWDrAZqJe	1	0.018757
4	46OZzdsSKDCFV8h7XWxf	1	0.037567

In [9]:
```
final_result_asm = pd.merge(asm_df, result_asm,on='ID', how='left')
final_result_asm.head()
```

Out[9]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10	...	pixel494	pixe
0	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	208.0	2
1	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	208.0	2
2	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	208.0	2
3	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	208.0	2
4	144.0	144.0	144.0	138.0	138.0	138.0	130.0	130.0	130.0	136.0	...	208.0	2

5 rows × 503 columns

In [10]:
```
# 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')
and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            if (max_value-min_value)!=0:
                result1[feature_name] = (df[feature_name] - min_value) / (max_
value - min_value)
    return result1
```

In [11]:
```
final_result_asm = normalize(final_result_asm)
final_result_asm.head()
```

Out[11]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 503 columns

In [3]:
```
import dill                           #pip install dill --user
# filename = 'globalsave.pkl'
# dill.dump_session('notebook_env3.db')

# and to load the session again:
dill.load_session('notebook_env3.db')
```

In [12]:
```
# final_result_asm.to_csv('asm_img_final_rf_reduced_df',index=False)
```

In [13]:
```
final_result_asm = pd.read_csv('asm_img_final_rf_reduced_df')
final_result_asm.head()
```

Out[13]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 503 columns

Train Test split

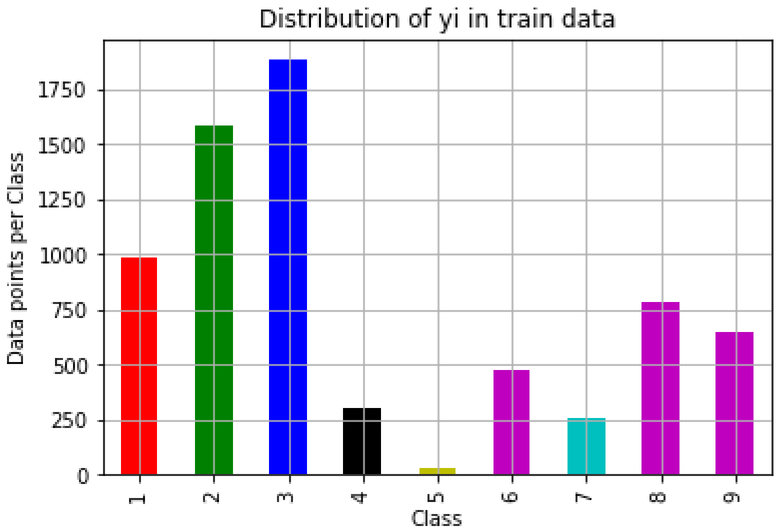
In [14]:
```
data_y = final_result_asm['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_result_asm.drop(['I
D','Class'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [15]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

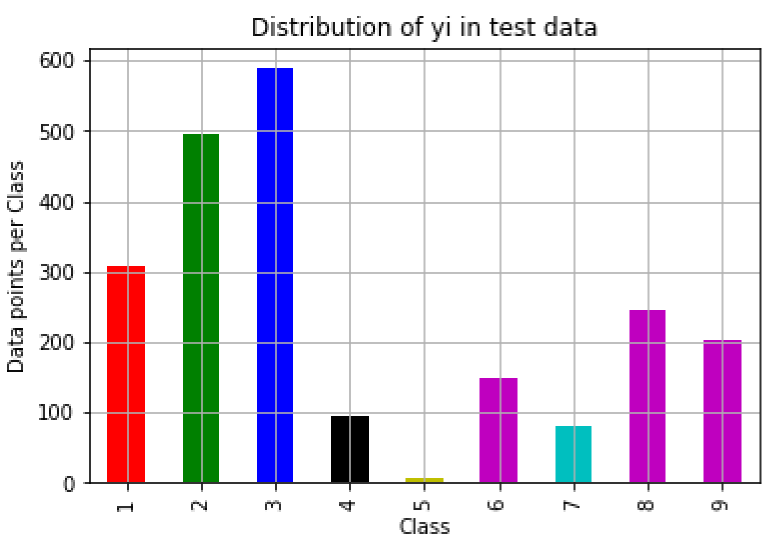
```
Number of data points in train data: (6955, 501)
Number of data points in test data: (2174, 501)
Number of data points in cross validation data: (1739, 501)
```

In [16]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

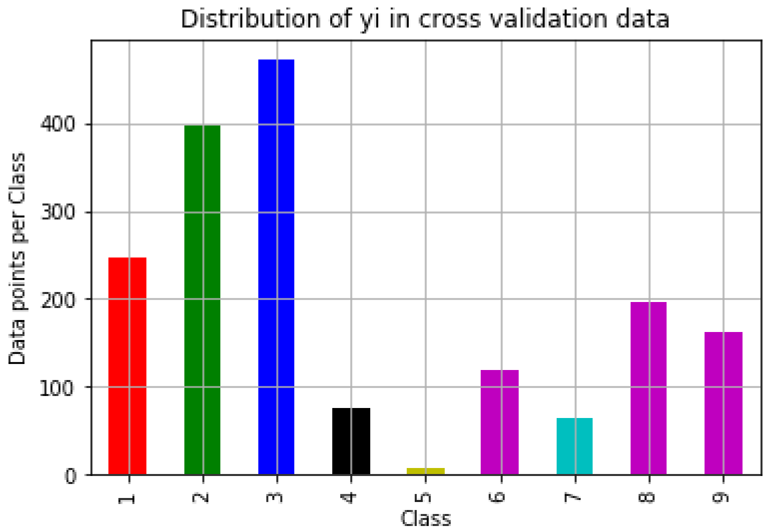
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [17]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes trigrams features

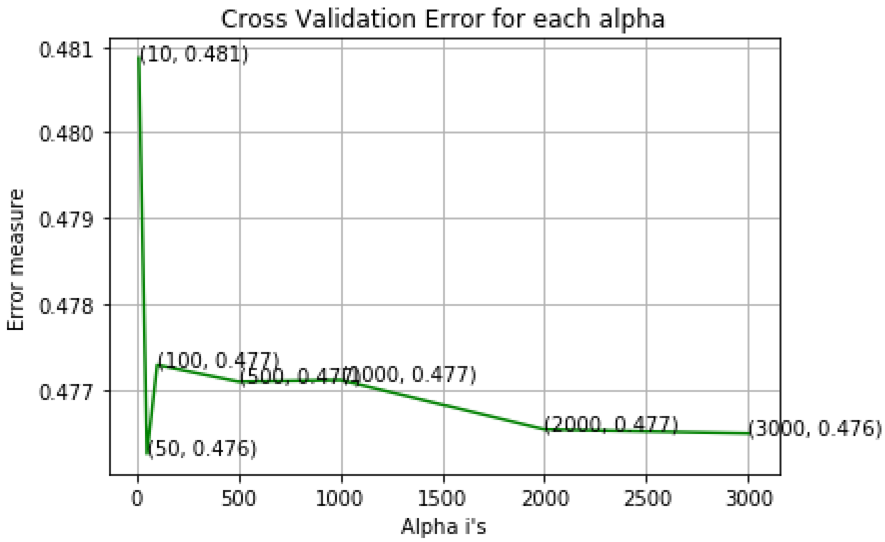
In [18]:
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.4. Random Forest Classifier

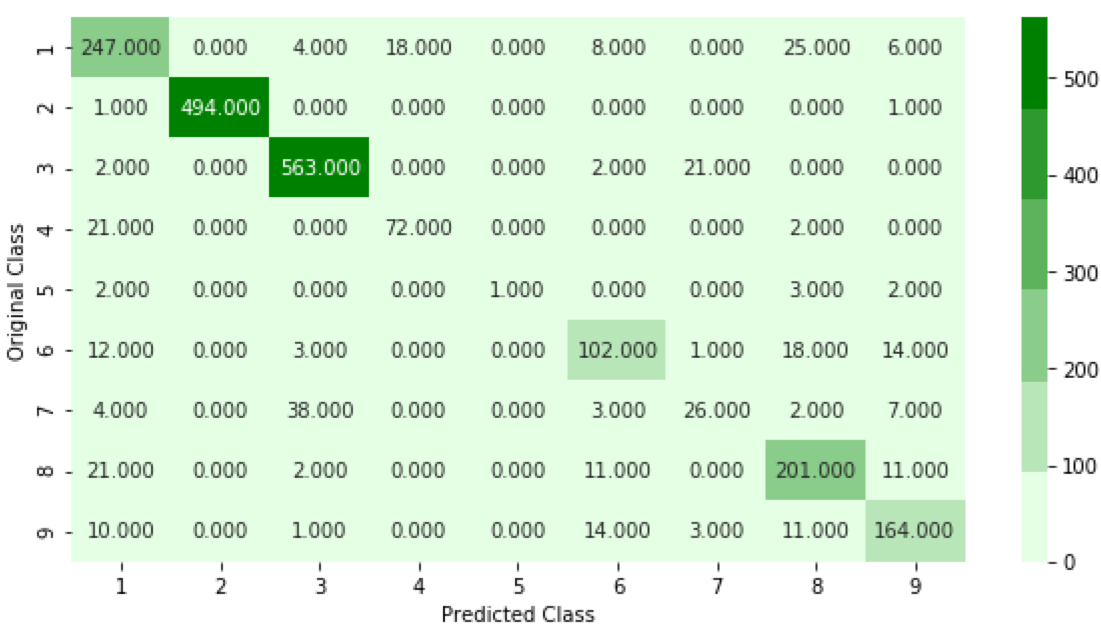
In [19]:
```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  10 is 0.48087198774280143
log_loss for c =  50 is 0.4762451178521051
log_loss for c =  100 is 0.4772857234827227
log_loss for c =  500 is 0.47709034025940206
log_loss for c =  1000 is 0.47710961327790663
log_loss for c =  2000 is 0.4765313971238696
log_loss for c =  3000 is 0.47648480894545464
```

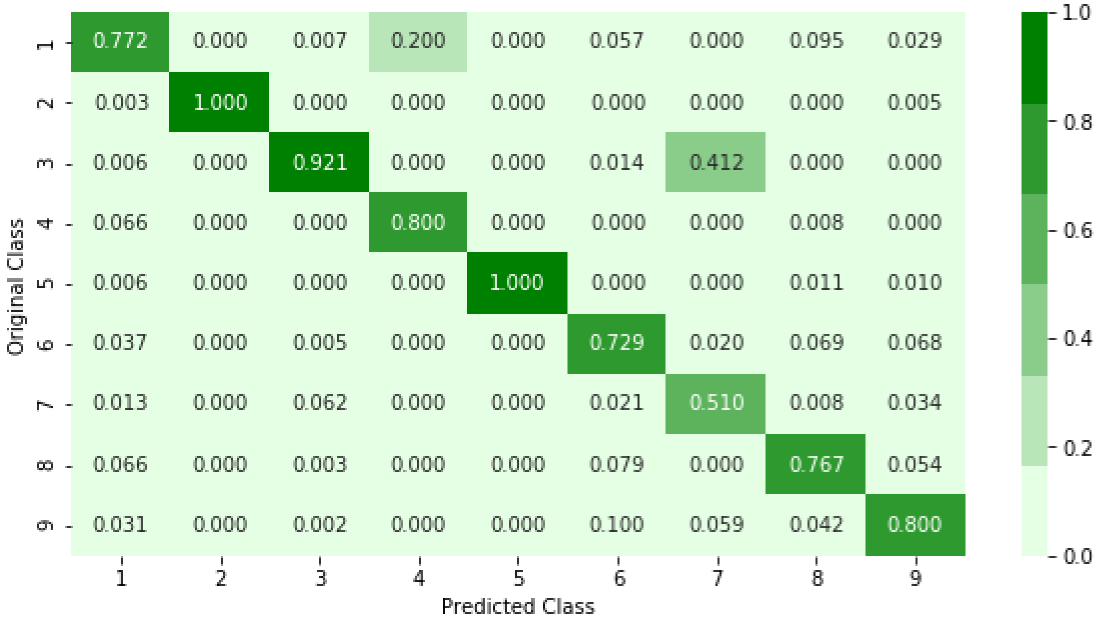



```
For values of best alpha =  50 The train log loss is: 0.20919627230790372
For values of best alpha =  50 The cross validation log loss is: 0.4762451178
521051
For values of best alpha =  50 The test log loss is: 0.4834634633772229
Number of misclassified points  13.983440662373505
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```

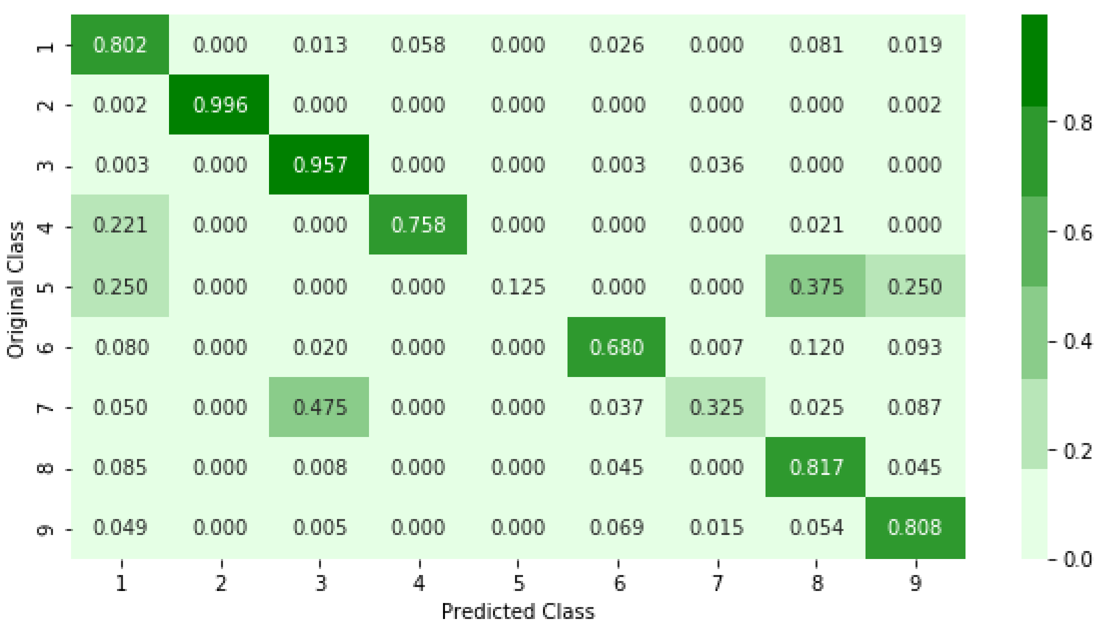


Original \ Predicted	1	2	3	4	5	6	7	8	9
1	247.000	0.000	4.000	18.000	0.000	8.000	0.000	25.000	6.000
2	1.000	494.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
3	2.000	0.000	563.000	0.000	0.000	2.000	21.000	0.000	0.000
4	21.000	0.000	0.000	72.000	0.000	0.000	0.000	2.000	0.000
5	2.000	0.000	0.000	0.000	1.000	0.000	0.000	3.000	2.000
6	12.000	0.000	3.000	0.000	0.000	102.000	1.000	18.000	14.000
7	4.000	0.000	38.000	0.000	0.000	3.000	26.000	2.000	7.000
8	21.000	0.000	2.000	0.000	0.000	11.000	0.000	201.000	11.000
9	10.000	0.000	1.000	0.000	0.000	14.000	3.000	11.000	164.000

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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [20]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:  1.2min remaining: 11.1
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:  1.5min remaining:  4.9
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  1.6min remaining:  2.7
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  2.6min remaining:  2.6
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  3.6min remaining:  2.1
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  4.4min remaining:  1.3
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  4.6min remaining:   3
0.5s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  5.3min finished
```

Out[20]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

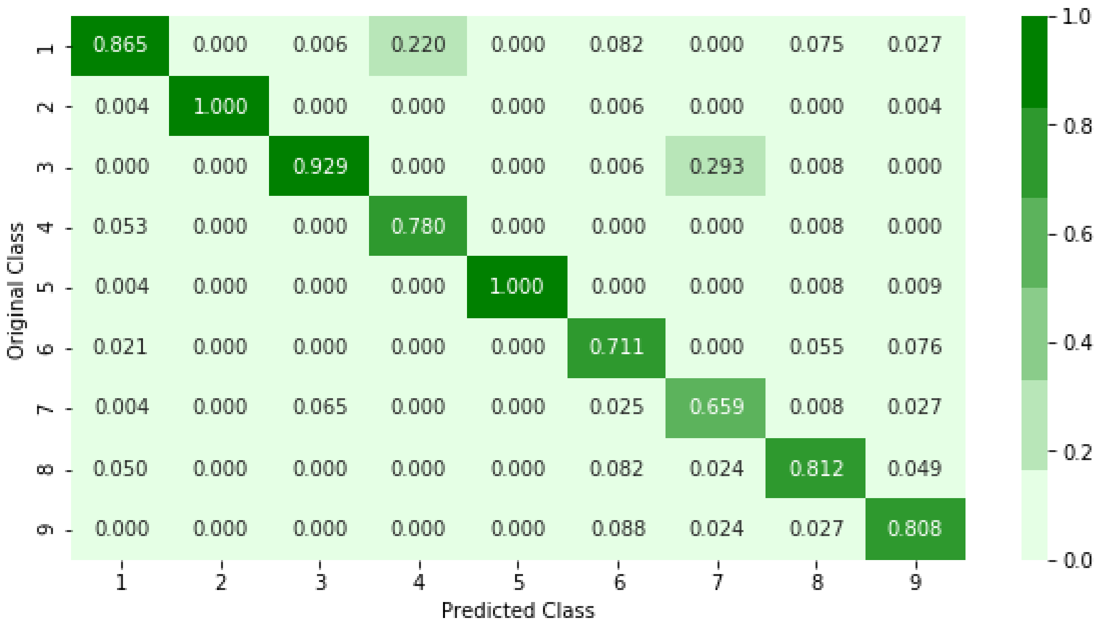
In [22]:
```python
print (random_cfl1.best_params_)
```

```
{'subsample': 0.3, 'max_depth': 5, 'n_estimators': 200, 'learning_rate': 0.1,
'colsample_bytree': 0.5}
```

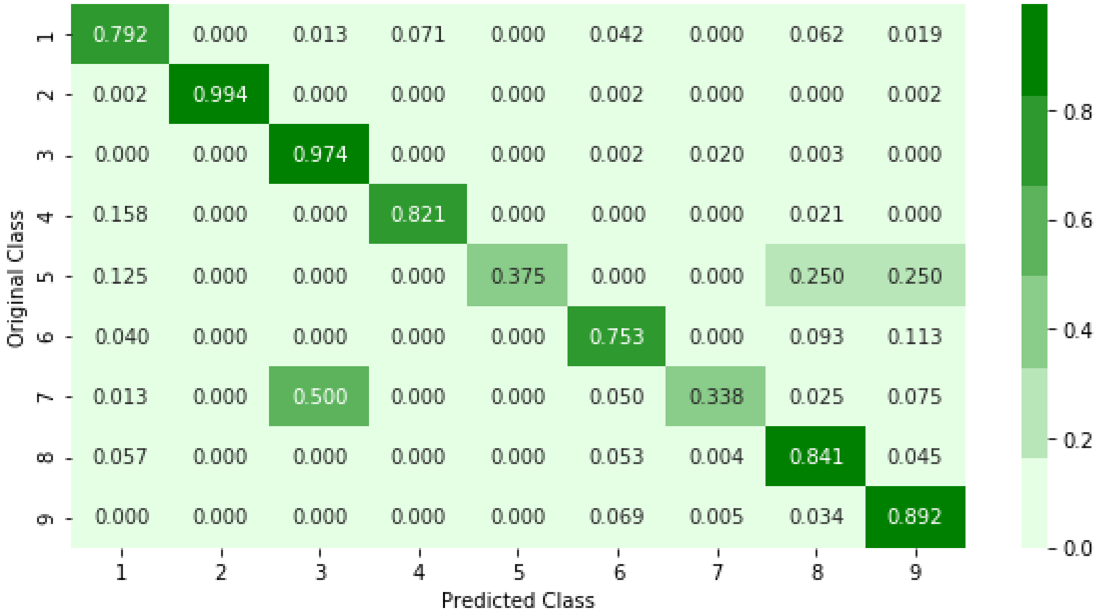
In [23]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 200, col
sample_bytree= 0.5, max_depth= 5,n_jobs=-1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.3348077042510442
cv loss 0.43008363543280925
test loss 0.4311127769330127
Number of misclassified points  11.729530818767248
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```


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




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




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

In [ ]:

With Asm image features(500), byte bigrams(1000), trigrams(1000)

In [2]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [13]:
```
bytebigram_df = pd.read_csv('bytebigram_final_rf_reduced_df')
bytebigram_df.head()
```

Out[13]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1003 columns

In [14]:
```
bytetrigram_df = pd.read_csv('bytetrigram_final_rf_reduced_df')
bytetrigram_df.head()
```

Out[14]:

	00 ff ff	00 f1 04	00 00 81	00 8d 8c	00 01 00	00 1e ff	00 00 66	00 00 75	00 33 c5	00 ff d6	...
0	0.000411	0.000000	0.000802	0.000000	0.004118	0.000000	0.000205	0.004714	0.0	0.0	...
1	0.001780	0.000000	0.000802	0.002364	0.001808	0.000000	0.000068	0.000589	0.0	0.0	...
2	0.000000	0.105263	0.003209	0.000000	0.002009	0.061538	0.000000	0.001179	0.0	0.0	...
3	0.011567	0.052632	0.146410	0.018913	0.125741	0.000000	0.098784	0.197407	0.0	0.0	...
4	0.000137	0.105263	0.000802	0.000000	0.002310	0.215385	0.000137	0.001179	0.0	0.0	...

5 rows × 1003 columns

In [15]:
```
final_result_asm = pd.read_csv('asm_img_final_rf_reduced_df')
final_result_asm.head()
```

Out[15]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 503 columns

In [18]:

```
byte_bi_trigram_df = pd.merge(bytebigram_df, bytetrigram_df.drop(['size','Clas
s'],axis=1,inplace=False),on='ID', how='left')
# https://stackoverflow.com/a/50262269/8089731
df1 = byte_bi_trigram_df.pop('ID') # remove column ID and store it in df1
byte_bi_trigram_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = byte_bi_trigram_df.pop('Class') # remove column ID and store it in df1
byte_bi_trigram_df['Class']=df2 # add ID series as a 'new' column in the last.
df3 = byte_bi_trigram_df.pop('size') # remove column ID and store it in df1
byte_bi_trigram_df['size']=df3 # add ID series as a 'new' column in the last.
byte_bi_trigram_df.head()
```

Out[18]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 2003 columns

In [16]:

```
final_result_asm = final_result_asm.rename(columns={"Class": "Class_y"})
final_result_asm.head()
```

Out[16]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 503 columns

In [19]:
```
asm_bi_trigram_df = pd.merge(final_result_asm.drop(['size'],axis=1,inplace=Fal
se), bytetrigram_df.drop(['size'],axis=1,inplace=False),on='ID', how='left')
asm_bi_trigram_df.head()
```

Out[19]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 1503 columns

In [21]:
```
# https://stackoverflow.com/a/50262269/8089731
df1 = asm_bi_trigram_df.pop('ID') # remove column ID and store it in df1
asm_bi_trigram_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = asm_bi_trigram_df.pop('Class_y') # remove column ID and store it in df1
asm_bi_trigram_df['Class_y']=df2 # add ID series as a 'new' column in the las
t.
asm_bi_trigram_df.drop(['Class_y'],axis=1,inplace=True)
asm_bi_trigram_df.head()
```

Out[21]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 1502 columns

Train Test split

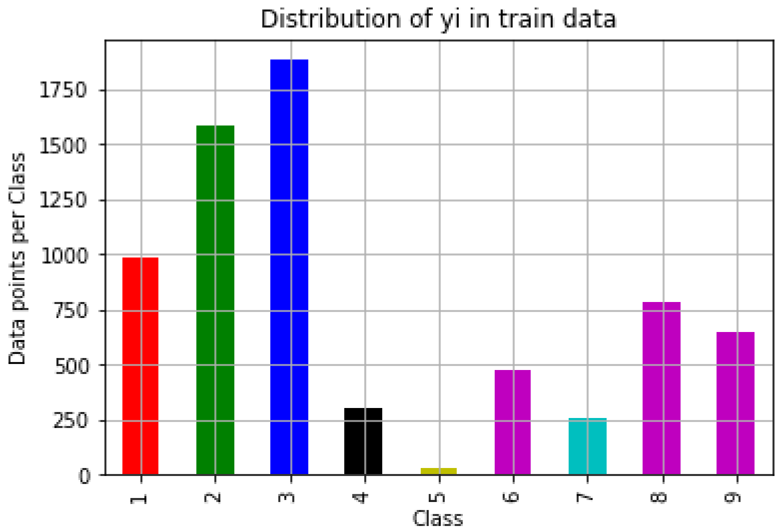
In [22]:
```
data_y = asm_bi_trigram_df['Class']
# split the data into test and train by maintaining same distribution of output varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(asm_bi_trigram_df.drop(['ID','Class'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same distribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_train,test_size=0.20)
```

In [23]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

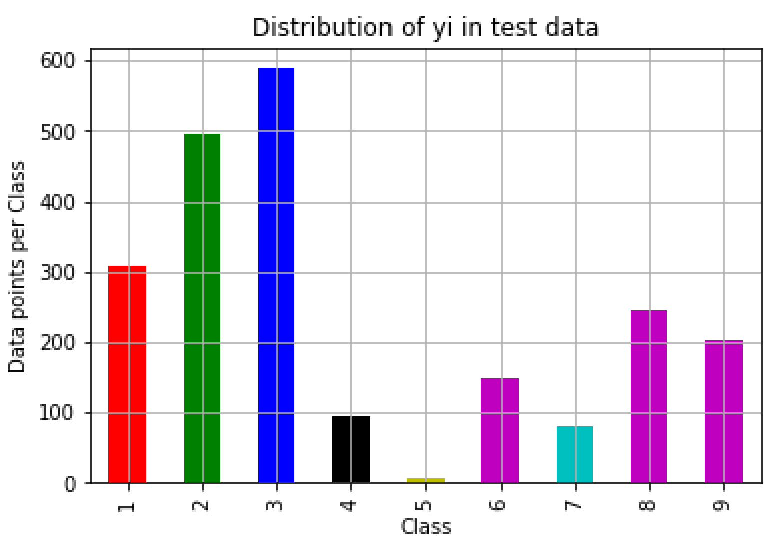
```
Number of data points in train data: (6955, 1500)
Number of data points in test data: (2174, 1500)
Number of data points in cross validation data: (1739, 1500)
```

In [25]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

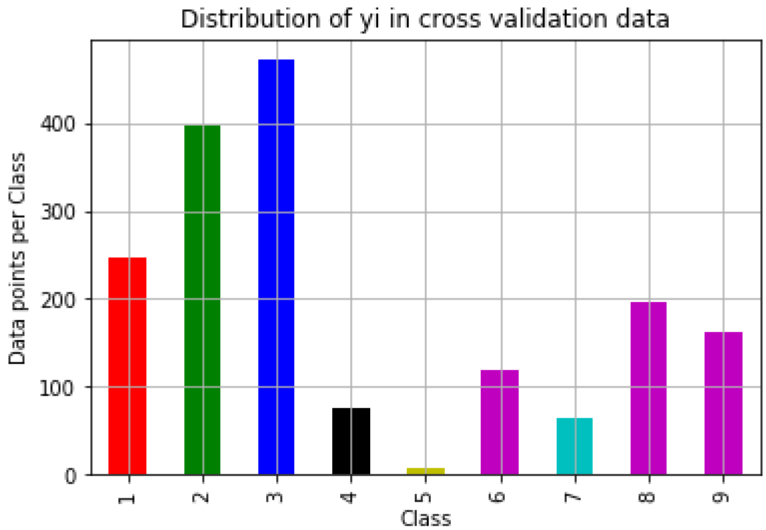
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [26]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes trigrams features

In [27]:
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

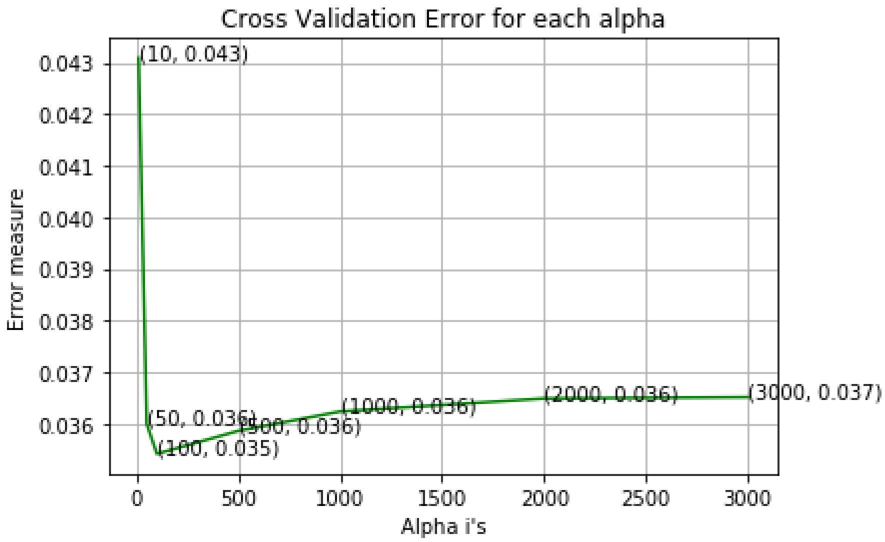
4.1.4. Random Forest Classifier

In [28]:

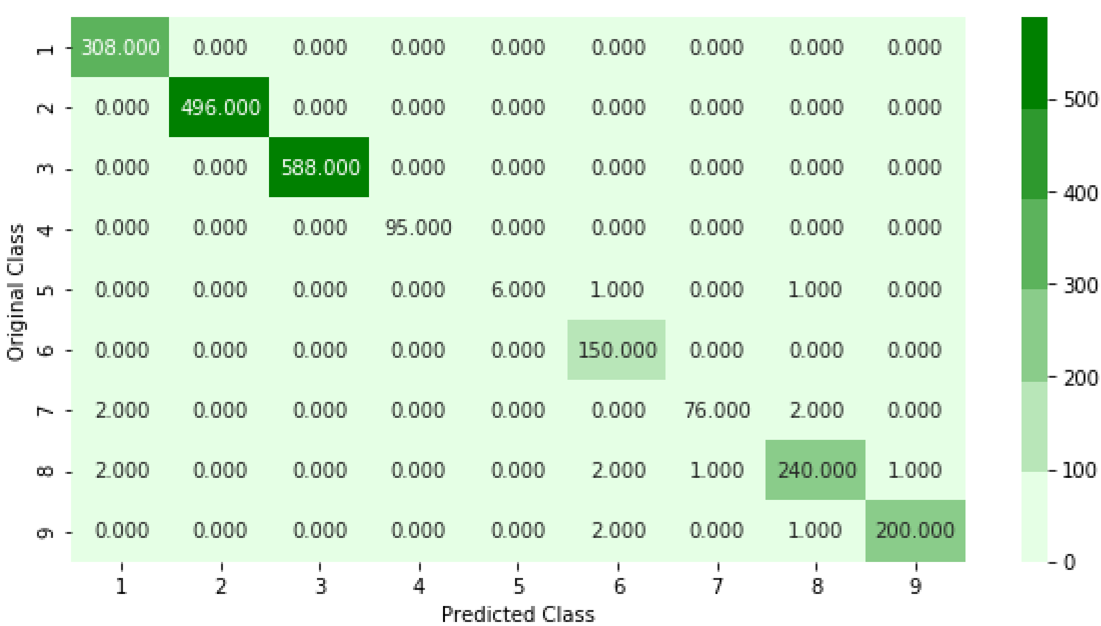
```
# ------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

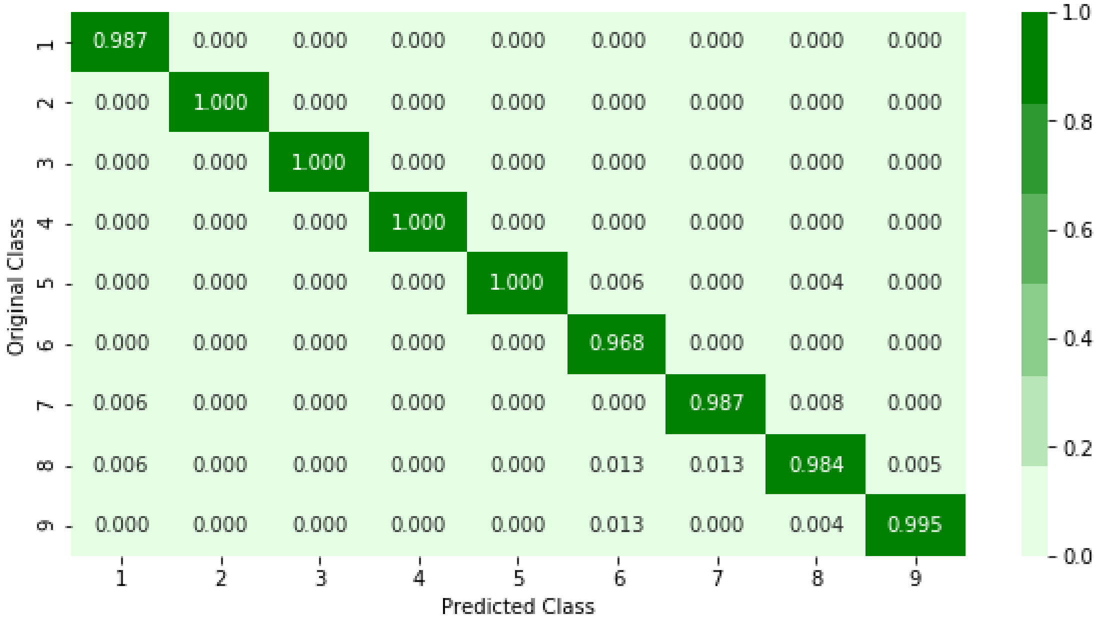
```
log_loss for c =  10 is 0.043092756976484466
log_loss for c =  50 is 0.03599125368463037
log_loss for c =  100 is 0.03540899557199856
log_loss for c =  500 is 0.03585517629249733
log_loss for c =  1000 is 0.036231891016034835
log_loss for c =  2000 is 0.03648524560120602
log_loss for c =  3000 is 0.03651085285189102
```



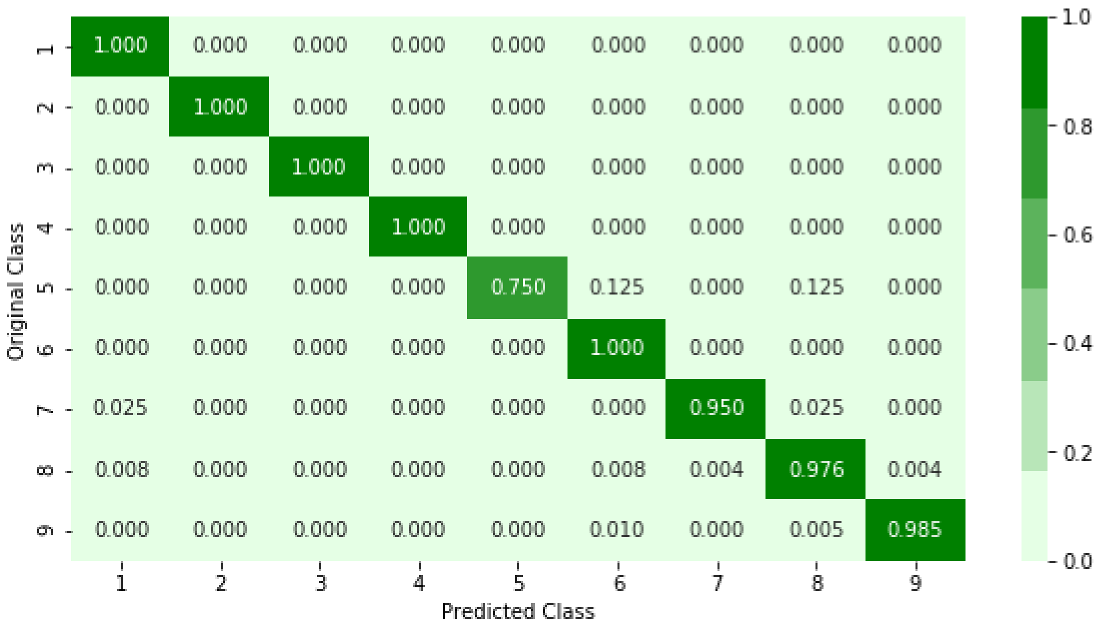

```
For values of best alpha =  100 The train log loss is: 0.012124677415981173
For values of best alpha =  100 The cross validation log loss is: 0.035408995
57199856
For values of best alpha =  100 The test log loss is: 0.034260776724482855
Number of misclassified points  0.6899724011039559
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [29]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jobs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:  2.6min remaining: 23.6
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:  3.1min remaining: 10.2
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  4.6min remaining:  7.9
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  6.5min remaining:  6.5
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  9.9min remaining:  5.7
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 10.3min remaining:  3.1
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 19.7min remaining:  2.2
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 42.5min finished
```

Out[29]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

In [31]:

```python
print (random_cfl1.best_params_)
```

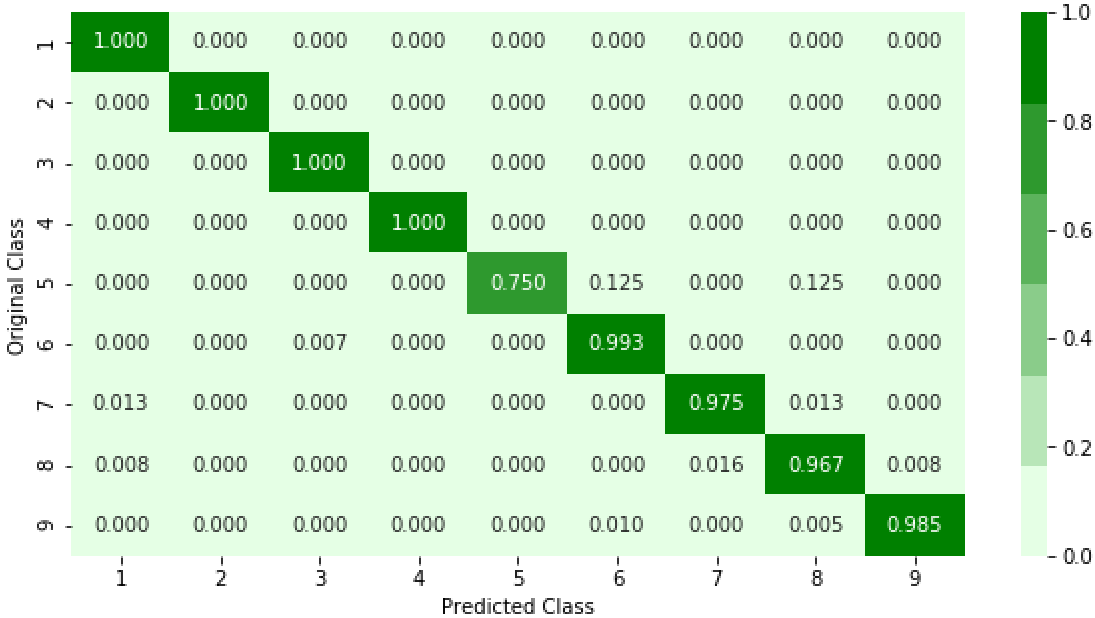
```
{'subsample': 0.5, 'colsample_bytree': 0.1, 'learning_rate': 0.01, 'max_dept
h': 10, 'n_estimators': 1000}
```

In [32]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.01, subsample= 0.5, n_estimators= 1000, c
olsample_bytree= 0.1, max_depth= 10,n_jobs=-1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.011437101388726102
cv loss 0.03412791942023307
test loss 0.03762675975742778
Number of misclassified points  0.7359705611775529
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```


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


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




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

Creating advanced features:

Byte unigrams

In [1]:

```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [2]:

```
#
byte_unigram_df = pd.read_csv("result_with_size.csv")
byte_unigram_df.head()
```

Out[2]:

	Unnamed: 0	ID	0	1	2	3	4	5	6	7	...
0	0	01azqd4InC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	...
1	1	01IsoiSMh5gxyDYTl4CB	39755	8337	7249	7186	8663	6844	8420	7589	...
2	2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	...
3	3	01kcPWA9K2BOxQeS5Rju	21091	1213	726	817	1257	625	550	523	...
4	4	01SuzwMJEIXsK7A8dQbl	19764	710	302	433	559	410	262	249	...

5 rows × 261 columns

In [3]:

```
#
# 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_valu
e - min_value)
    return result1
byte_unigram_df = normalize(byte_unigram_df)
```

In [5]:

```
byte_unigram_df.to_csv('byte_unigram_df.csv',index=False)
byte_unigram_df.head()
```

Out[5]:

	Unnamed: 0	ID	0	1	2	3	4	
0	0.000000	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001
1	0.000092	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003
2	0.000184	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005
3	0.000276	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000

5 rows × 261 columns

Asm unigrams

In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [3]:
```
# asmoutputfile.csv(output genarated from the above two cells) will contain al
l the extracted features from .asm files
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutputfile.csv")
Y=pd.read_csv("trainLabels.csv")
Y.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, Y,on='ID', how='left')
result_asm.head()
```

Out[3]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 53 columns

4.2.1.1 Files sizes of each .asm file

In [4]:
```
#file sizes of byte files

files=os.listdir('asmFiles')
filenames=Y['ID'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=356157170
0, st_nlink=1, st_uid=0, st_gid=0,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519
638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_s
tat.htm
    statinfo=os.stat('asmFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file na
me
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
asm_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (asm_size_byte.head())
```

```
   Class                    ID       size
0      1  aMSX7lvrZeCBwE9kUnDf   1.011998
1      3  epj8anqLcrRxHGVWT1Bg  32.695071
2      3  3rt2gI9JVaZcTQGyjmbk  32.701280
3      3  aYRoe1Nvt4J8Bz6LbSZ5   0.163288
4      4  gIONM8E513LYstAjyzWl  11.216479
```

In [5]:
```
# add the file size feature to previous extracted features
print(result_asm.shape)
print(asm_size_byte.shape)
asm_unigram_df = pd.merge(result_asm, asm_size_byte.drop(['Class'], axis=1),on
='ID', how='left')
asm_unigram_df.head()
```

```
(10868, 53)
(10868, 3)
```

Out[5]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [9]:
```
#
# 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_valu
e - min_value)
    return result1
```

In [10]:
```
# we normalize the data each column
asm_unigram_df = normalize(asm_unigram_df)
asm_unigram_df.head()
```

Out[10]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 54 columns

In [11]:
```
asm_unigram_df.to_csv('asm_unigram_df.csv',index=False)
asm_unigram_df.head()
```

Out[11]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 54 columns

Byte bigrams 1000 features

In [13]:
```
bytebigram1000_df = pd.read_csv('bytebigram_final_rf_reduced_df')
bytebigram1000_df.head()
```

Out[13]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1003 columns

Asm image 500 features

In [ ]:

In [14]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [15]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
import scipy
```

In [12]:
```
# final_result_asm.to_csv('asm_img_final_rf_reduced_df',index=False)
```

In [20]:
```
asm500_df = pd.read_csv('asm_img_final_rf_reduced_df')
asm500_df.head()
```

Out[20]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 503 columns

Entropy

In [29]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import math
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [30]:
```
# Calculate Shannon's Entropy, https://en.wikipedia.org/wiki/Entropy_(informat
ion_theory)
# https://github.com/dchad/malware-detection/blob/master/mmcc/feature-extracti
on.ipynb
def calculate_entropy(byte_counts, total):
    entropy = 0.0
    for count in byte_counts:
        # If no bytes of this value were seen in the value, it doesn't affect
        # the entropy of the file.
        if count == 0:
            continue
        # p is the probability of seeing this byte in the file, as a floating-
point number
        p = 1.0 * count / total
        entropy -= p * math.log(p, 256)
    return entropy
```

In [53]:
```
def entropy_counter(byte_code):
    byte_counts = [0] * 256
    total = 0
  #code_length = len(byte_code)
    for row in byte_code:
        nrow = row.rstrip('\r\n')
        bytes = nrow.split(' ')
        # skip first token as it is the relative memory address
        # print(bytes)
        for i in range(1, len(bytes)):
            #   print(bytes[i])
            if bytes[i] != '??':
                byte_counts[int(bytes[i], 16)] += 1
            else:
                byte_counts[0] += 1
            total += 1

    entropy = calculate_entropy(byte_counts, total)

    return entropy
```

In [58]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [100]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    ext_drive = 'first/'
    tfiles = os.listdir('first/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('first_entropy.csv',index=False)

#same as above
def secondprocess():

    ext_drive = 'second/'
    tfiles = os.listdir('second/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('second_entropy.csv',index=False)

# same as smallprocess() functions
def thirdprocess():

    ext_drive = 'third/'
    tfiles = os.listdir('third/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('third_entropy.csv',index=False)
```

```
def fourthprocess():

    ext_drive = 'fourth/'
    tfiles = os.listdir('fourth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('fourth_entropy.csv',index=False)


def fifthprocess():

    ext_drive = 'fifth/'
    tfiles = os.listdir('fifth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('fifth_entropy.csv',index=False)

def sixthprocess():

    ext_drive = 'sixth/'
    tfiles = os.listdir('sixth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('sixth_entropy.csv',index=False)

def seventhprocess():

    ext_drive = 'seventh/'
    tfiles = os.listdir('seventh/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
```

```
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('seventh_entropy.csv',index=False)

def eigthprocess():

    ext_drive = 'eigth/'
    tfiles = os.listdir('eigth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('eigth_entropy.csv',index=False)

def ningthprocess():

    ext_drive = 'ningth/'
    tfiles = os.listdir('ningth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('ningth_entropy.csv',index=False)

def tenthprocess():

    ext_drive = 'tenth/'
    tfiles = os.listdir('tenth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('tenth_entropy.csv',index=False)
```

```
def eleventhprocess():

    ext_drive = 'eleventh/'
    tfiles = os.listdir('eleventh/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('eleventh_entropy.csv',index=False)


def twelvethprocess():

    ext_drive = 'twelveth/'
    tfiles = os.listdir('twelveth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('twelveth_entropy.csv',index=False)

def thirteenthprocess():

    ext_drive = 'thirteenth/'
    tfiles = os.listdir('thirteenth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('thirteenth_entropy.csv',index=False)

def fourteenthprocess():

    ext_drive = 'fourteenth/'
    tfiles = os.listdir('fourteenth/')
    final_lst = []
    byte_files = [i for i in tfiles if '.bytes' in i]
    for fname in byte_files:
        f = open(ext_drive + fname, 'r')
```

```
        filesize = os.path.getsize(ext_drive + fname)
        lines = f.readlines()
        entropy = entropy_counter(lines)
        lst = [fname.split('.')[0],round(entropy, 6)]
        final_lst.append(lst)
    df = pd.DataFrame(final_lst, columns=["ID","entropy"])
    df.to_csv('fourteenth_entropy.csv',index=False)


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
    p12.join()
    p13.join()
```

```
    p14.join()

if __name__=="__main__":
    main()
```

In [101]:
```
import pandas as pd
from pebble import concurrent
# https://stackoverflow.com/a/56676389/8089731

@concurrent.process
def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment
    first_entropy_df = pd.read_csv('first_entropy.csv')
    return first_entropy_df

#same as above
@concurrent.process
def secondprocess():

    second_entropy_df = pd.read_csv('second_entropy.csv')
    return second_entropy_df

@concurrent.process
def thirdprocess():

    third_entropy_df = pd.read_csv('third_entropy.csv')
    return third_entropy_df

@concurrent.process
def fourthprocess():

    fourth_entropy_df = pd.read_csv('fourth_entropy.csv')
    return fourth_entropy_df

@concurrent.process
def fifthprocess():

    fifth_entropy_df = pd.read_csv('fifth_entropy.csv')
    return fifth_entropy_df

@concurrent.process
def sixthprocess():

    sixth_entropy_df = pd.read_csv('sixth_entropy.csv')
    return sixth_entropy_df

@concurrent.process
def seventhprocess():

    seventh_entropy_df = pd.read_csv('seventh_entropy.csv')
    return seventh_entropy_df

@concurrent.process
def eigthprocess():

    eigth_entropy_df = pd.read_csv('eigth_entropy.csv')
    return eigth_entropy_df
```

```
@concurrent.process
def ningthprocess():

    ningth_entropy_df = pd.read_csv('ningth_entropy.csv')
    return ningth_entropy_df

@concurrent.process
def tenthprocess():

    tenth_entropy_df = pd.read_csv('tenth_entropy.csv')
    return tenth_entropy_df

@concurrent.process
def eleventhprocess():

    eleventh_entropy_df = pd.read_csv('eleventh_entropy.csv')
    return eleventh_entropy_df

@concurrent.process
def twelvethprocess():

    twelveth_entropy_df = pd.read_csv('twelveth_entropy.csv')
    return twelveth_entropy_df

@concurrent.process
def thirteenthprocess():

    thirteenth_entropy_df = pd.read_csv('thirteenth_entropy.csv')
    return thirteenth_entropy_df

@concurrent.process
def fourteenthprocess():

    fourteenth_entropy_df = pd.read_csv('fourteenth_entropy.csv')
    return fourteenth_entropy_df

# def
first_entropy_df = firstprocess()
second_entropy_df = secondprocess()
third_entropy_df = thirdprocess()
fourth_entropy_df = fourthprocess()
fifth_entropy_df = fifthprocess()
sixth_entropy_df = sixthprocess()
seventh_entropy_df = seventhprocess()
eigth_entropy_df = eigthprocess()
ningth_entropy_df = ningthprocess()
tenth_entropy_df = tenthprocess()
eleventh_entropy_df = eleventhprocess()
twelveth_entropy_df = twelvethprocess()
thirteenth_entropy_df = thirteenthprocess()
fourteenth_entropy_df = fourteenthprocess()
```

In [102]:
```
first_entropy_df = (first_entropy_df.result())
second_entropy_df = (second_entropy_df.result())
third_entropy_df = (third_entropy_df.result())
fourth_entropy_df = (fourth_entropy_df.result())
fifth_entropy_df = (fifth_entropy_df.result())
sixth_entropy_df = (sixth_entropy_df.result())
seventh_entropy_df = (seventh_entropy_df.result())
eigth_entropy_df = (eigth_entropy_df.result())
ningth_entropy_df = (ningth_entropy_df.result())
tenth_entropy_df = (tenth_entropy_df.result())
eleventh_entropy_df = (eleventh_entropy_df.result())
twelveth_entropy_df = (twelveth_entropy_df.result())
thirteenth_entropy_df = (thirteenth_entropy_df.result())
fourteenth_entropy_df = (fourteenth_entropy_df.result())
```

In [103]:
```
fourteenth_entropy_df.head()
```

Out[103]:

	ID	entropy
0	18SQsaz6IMJlZCknYpgL	0.746360
1	3hfRptP5gUEqDHICkMYX	0.218112
2	invl0ZhpcKaBLtyMTsfx	0.450236
3	9gL8j0XVyEOe5sSmlpv2	0.475397
4	GCUmV5ly1LpqM70ZYoKR	0.802355

In [104]:
```
final_entropy_df = pd.concat([first_entropy_df,second_entropy_df,third_entropy_df,fourth_entropy_df,fifth_entropy_df,sixth_entropy_df,seventh_entropy_df,eigth_entropy_df,ningth_entropy_df,tenth_entropy_df,eleventh_entropy_df,twelveth_entropy_df,thirteenth_entropy_df,fourteenth_entropy_df])
```

In [105]:
```
final_entropy_df
```

Out[105]:

	ID	entropy
0	GhHS0zL9cgNXFK6j1dlJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	lHiArX1xcBZgv69o4s0a	0.633535
...	...	...
771	5CiGOStRIX3ayFUrAeoQ	0.473972
772	ANsbQFrM0cvZoxHjS5y9	0.989155
773	hGJZKoMdcW9s6SEqNnOg	0.008913
774	BIHLcoqT27fn5bgJsGvr	0.857762
775	3MbT7ePSqZuEWgXpiKDm	0.842998

10868 rows × 2 columns

In [106]:
```
# final_entropy_df.to_csv('final_entropy_df.csv',index=False)
```

In [110]:
```
final_entropy_df = pd.read_csv('final_entropy_df.csv')
```

In [111]:
```
final_entropy_df
```

Out[111]:

	ID	entropy
0	GhHS0zL9cgNXFK6j1dlJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	lHiArX1xcBZgv69o4s0a	0.633535
...	...	...
10863	5CiGOStRIX3ayFUrAeoQ	0.473972
10864	ANsbQFrM0cvZoxHjS5y9	0.989155
10865	hGJZKoMdcW9s6SEqNnOg	0.008913
10866	BIHLcoqT27fn5bgJsGvr	0.857762
10867	3MbT7ePSqZuEWgXpiKDm	0.842998

10868 rows × 2 columns

Opcode Bigrams

In [6]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import math
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [15]:
```
len(os.listdir('asmFiles'))
```

Out[15]: 10868

In [16]:
```
#intially create five folders
#first
#second
#thrid
#fourth
#fifth
#this code tells us about random split of files into five folders
folder_1 ='first_'
folder_2 ='second_'
folder_3 ='third_'
folder_4 ='fourth_'
folder_5 ='fifth_'
folder_6 ='sixth_'
folder_7 ='seventh_'
folder_8 ='eigth_'
folder_9 ='ningth_'
folder_10 ='tenth_'
folder_11='eleventh_'
folder_12 ='twelveth_'
folder_13 ='thirteenth_'
folder_14 ='fourteenth_'
folder_15 = 'output_'
for i in [folder_1,folder_2,folder_3,folder_4,folder_5,folder_6,folder_7,folde
r_8,folder_9,folder_10,folder_11,folder_12,folder_13,folder_14,folder_15]:
    if not os.path.isdir(i):
        os.makedirs(i)

source='asmFiles/'
files = os.listdir('asmFiles')
# ID=df['Id'].tolist()
data=list(range(0,10868))
# r.shuffle(data)
count=0
for i in range(0,10868):
    if i>=0 and i<=776:
        shutil.move(source+files[data[i]],'first_')
    elif i>=777 and i<=1553:
        shutil.move(source+files[data[i]],'second_')
    elif i>=1554 and i<=2330:
        shutil.move(source+files[data[i]],'third_')
    elif i>=2331 and i<=3107:
        shutil.move(source+files[data[i]],'fourth_')
    elif i>=3108 and i<=3883:
        shutil.move(source+files[data[i]],'fifth_')
    elif i>=3884 and i<=4659:
        shutil.move(source+files[data[i]],'sixth_')
    elif i>=4660 and i<=5435:
        shutil.move(source+files[data[i]],'seventh_')
    elif i>=5436 and i<=6211:
        shutil.move(source+files[data[i]],'eigth_')
    elif i>=6212 and i<=6987:
        shutil.move(source+files[data[i]],'ningth_')
    elif i>=6988 and i<=7763:
        shutil.move(source+files[data[i]],'tenth_')
    elif i>=7764 and i<=8539:
        shutil.move(source+files[data[i]],'eleventh_')
```

```
    elif i>=8540 and i<=9315:
        shutil.move(source+files[data[i]],'twelveth_')
    elif i>=9316 and i<=10091:
        shutil.move(source+files[data[i]],'thirteenth_')
    elif i>=10092 and i<=10867:
        shutil.move(source+files[data[i]],'fourteenth_')
```

In [17]:
```
len(os.listdir('first_')) + \
len(os.listdir('second_')) + \
len(os.listdir('third_')) + \
len(os.listdir('fourth_')) + \
len(os.listdir('fifth_')) + \
len(os.listdir('sixth_')) + \
len(os.listdir('seventh_')) + \
len(os.listdir('eigth_')) + \
len(os.listdir('ningth_')) + \
len(os.listdir('tenth_')) + \
len(os.listdir('eleventh_')) + \
len(os.listdir('twelveth_')) + \
len(os.listdir('thirteenth_')) + \
len(os.listdir('fourteenth_'))
```

Out[17]:
```
10868
```

In [18]:
```
print(len(os.listdir('first_')),
len(os.listdir('second_')),
len(os.listdir('third_')),
len(os.listdir('fourth_')),
len(os.listdir('fifth_')),
len(os.listdir('sixth_')),
len(os.listdir('seventh_')),
len(os.listdir('eigth_')),
len(os.listdir('ningth_')),
len(os.listdir('tenth_')),
len(os.listdir('eleventh_')),
len(os.listdir('twelveth_')),
len(os.listdir('thirteenth_')),
len(os.listdir('fourteenth_')))
```

```
777 777 777 777 776 776 776 776 776 776 776 776 776 776
```

In [3]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [5]:
```
opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub',
'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ror',
'rol', 'jnb','jz','rtn','lea','movzx']
```

In [6]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    op_file = open("opcode_file1.txt", "w+")
    for asmfile in os.listdir('first_'):
        opcode_str = ""
        with codecs.open('first_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

#same as above
def secondprocess():

    op_file = open("opcode_file2.txt", "w+")
    for asmfile in os.listdir('second_'):
        opcode_str = ""
        with codecs.open('second_/' + asmfile, encoding='cp1252', errors ='rep
lace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

# same as smallprocess() functions
def thirdprocess():

    op_file = open("opcode_file3.txt", "w+")
    for asmfile in os.listdir('third_'):
        opcode_str = ""
        with codecs.open('third_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()


def fourthprocess():
```

```
    op_file = open("opcode_file4.txt", "w+")
    for asmfile in os.listdir('fourth_'):
        opcode_str = ""
        with codecs.open('fourth_/' + asmfile, encoding='cp1252', errors ='rep
lace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()


def fifthprocess():

    op_file = open("opcode_file5.txt", "w+")
    for asmfile in os.listdir('fifth_'):
        opcode_str = ""
        with codecs.open('fifth_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def sixthprocess():

    op_file = open("opcode_file6.txt", "w+")
    for asmfile in os.listdir('sixth_'):
        opcode_str = ""
        with codecs.open('sixth_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def seventhprocess():

    op_file = open("opcode_file7.txt", "w+")
    for asmfile in os.listdir('seventh_'):
        opcode_str = ""
        with codecs.open('seventh_/' + asmfile, encoding='cp1252', errors ='re
place') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
```

```
    op_file.close()

def eigthprocess():

    op_file = open("opcode_file8.txt", "w+")
    for asmfile in os.listdir('eigth_'):
        opcode_str = ""
        with codecs.open('eigth_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def ningthprocess():

    op_file = open("opcode_file9.txt", "w+")
    for asmfile in os.listdir('ningth_'):
        opcode_str = ""
        with codecs.open('ningth_/' + asmfile, encoding='cp1252', errors ='rep
lace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def tenthprocess():

    op_file = open("opcode_file10.txt", "w+")
    for asmfile in os.listdir('tenth_'):
        opcode_str = ""
        with codecs.open('tenth_/' + asmfile, encoding='cp1252', errors ='repl
ace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def eleventhprocess():

    op_file = open("opcode_file11.txt", "w+")
    for asmfile in os.listdir('eleventh_'):
        opcode_str = ""
        with codecs.open('eleventh_/' + asmfile, encoding='cp1252', errors ='r
eplace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
```

```
                    if li in opcodes:
                        opcode_str += li + ' '
            op_file.write(opcode_str + "\n")
        op_file.close()


def twelvethprocess():

    op_file = open("opcode_file12.txt", "w+")
    for asmfile in os.listdir('twelveth_'):
        opcode_str = ""
        with codecs.open('twelveth_/' + asmfile, encoding='cp1252', errors ='r
eplace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def thirteenthprocess():

    op_file = open("opcode_file13.txt", "w+")
    for asmfile in os.listdir('thirteenth_'):
        opcode_str = ""
        with codecs.open('thirteenth_/' + asmfile, encoding='cp1252', errors =
'replace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()

def fourteenthprocess():

    op_file = open("opcode_file14.txt", "w+")
    for asmfile in os.listdir('fourteenth_'):
        opcode_str = ""
        with codecs.open('fourteenth_/' + asmfile, encoding='cp1252', errors =
'replace') as fli:
            for lines in fli:
                line = lines.rstrip().split()
                for li in line:
                    if li in opcodes:
                        opcode_str += li + ' '
        op_file.write(opcode_str + "\n")
    op_file.close()


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
```

```
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
    p12.join()
    p13.join()
    p14.join()

if __name__=="__main__":
    main()
```

In [7]:

```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [8]:
```
opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub',
'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ror',
'rol', 'jnb','jz','rtn','lea','movzx']
```

In [3]:
```
asmopcodebigram = []
def asmopcodebigramm():
    for i, v in enumerate(opcodes):
        for j in range(0, len(opcodes)):
            asmopcodebigram.append(v + ' ' + opcodes[j])
asmopcodebigramm()
```

In [4]:
```
len(asmopcodebigram)
```

Out[4]: 676

In [10]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((777, len(asmopcodebigram)))
    raw_opcode = open('opcode_file1.txt').read().split('\n')

    for indx in range(777):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df1 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df1['ID'] = os.listdir('first_')
    opcodebigram_df1.to_csv('opcodebigram_df1.csv',index=False)

#same as above
def secondprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((777, len(asmopcodebigram)))
    raw_opcode = open('opcode_file2.txt').read().split('\n')

    for indx in range(777):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df2 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df2['ID'] = os.listdir('second_')
    opcodebigram_df2.to_csv('opcodebigram_df2.csv',index=False)

# same as smallprocess() functions
def thirdprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((777, len(asmopcodebigram)))
    raw_opcode = open('opcode_file3.txt').read().split('\n')

    for indx in range(777):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df3 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df3['ID'] = os.listdir('third_')
    opcodebigram_df3.to_csv('opcodebigram_df3.csv',index=False)


def fourthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((777, len(asmopcodebigram)))
    raw_opcode = open('opcode_file4.txt').read().split('\n')
```

```
    for indx in range(777):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df4 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df4['ID'] = os.listdir('fourth_')
    opcodebigram_df4.to_csv('opcodebigram_df4.csv',index=False)


def fifthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file5.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df5 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df5['ID'] = os.listdir('fifth_')
    opcodebigram_df5.to_csv('opcodebigram_df5.csv',index=False)

def sixthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file6.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df6 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df6['ID'] = os.listdir('sixth_')
    opcodebigram_df6.to_csv('opcodebigram_df6.csv',index=False)

def seventhprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file7.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df7 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df7['ID'] = os.listdir('seventh_')
    opcodebigram_df7.to_csv('opcodebigram_df7.csv',index=False)

def eigthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file8.txt').read().split('\n')
```

```
    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df8 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df8['ID'] = os.listdir('eigth_')
    opcodebigram_df8.to_csv('opcodebigram_df8.csv',index=False)

def ningthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file9.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df9 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df9['ID'] = os.listdir('ningth_')
    opcodebigram_df9.to_csv('opcodebigram_df9.csv',index=False)

def tenthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file10.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df10 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df10['ID'] = os.listdir('tenth_')
    opcodebigram_df10.to_csv('opcodebigram_df10.csv',index=False)

def eleventhprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file11.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df11 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df11['ID'] = os.listdir('eleventh_')
    opcodebigram_df11.to_csv('opcodebigram_df11.csv',index=False)


def twelvethprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file12.txt').read().split('\n')
```

```
    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df12 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df12['ID'] = os.listdir('twelveth_')
    opcodebigram_df12.to_csv('opcodebigram_df12.csv',index=False)

def thirteenthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file13.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df13 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df13['ID'] = os.listdir('thirteenth_')
    opcodebigram_df13.to_csv('opcodebigram_df13.csv',index=False)

def fourteenthprocess():

    vect = CountVectorizer(ngram_range=(2, 2), vocabulary = asmopcodebigram)
    opcodebivect = scipy.sparse.csr_matrix((776, len(asmopcodebigram)))
    raw_opcode = open('opcode_file14.txt').read().split('\n')

    for indx in range(776):
        opcodebivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_o
pcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df14 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df14['ID'] = os.listdir('fourteenth_')
    opcodebigram_df14.to_csv('opcodebigram_df14.csv',index=False)


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
```

```
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
    p12.join()
    p13.join()
    p14.join()

if __name__=="__main__":
    main()
```

In [11]:

```
opcodebigram_df1 = pd.read_csv('opcodebigram_df1.csv')
opcodebigram_df2 = pd.read_csv('opcodebigram_df2.csv')
opcodebigram_df3 = pd.read_csv('opcodebigram_df3.csv')
opcodebigram_df4 = pd.read_csv('opcodebigram_df4.csv')
opcodebigram_df5 = pd.read_csv('opcodebigram_df5.csv')
opcodebigram_df6 = pd.read_csv('opcodebigram_df6.csv')
opcodebigram_df7 = pd.read_csv('opcodebigram_df7.csv')
opcodebigram_df8 = pd.read_csv('opcodebigram_df8.csv')
opcodebigram_df9 = pd.read_csv('opcodebigram_df9.csv')
opcodebigram_df10 = pd.read_csv('opcodebigram_df10.csv')
opcodebigram_df11 = pd.read_csv('opcodebigram_df11.csv')
opcodebigram_df12 = pd.read_csv('opcodebigram_df12.csv')
opcodebigram_df13 = pd.read_csv('opcodebigram_df13.csv')
opcodebigram_df14 = pd.read_csv('opcodebigram_df14.csv')
```

In [12]:

```
opcodebigram_df = pd.concat([opcodebigram_df1,opcodebigram_df2,opcodebigram_df
3,opcodebigram_df4,opcodebigram_df5,opcodebigram_df6,opcodebigram_df7,opcodebi
gram_df8,opcodebigram_df9,opcodebigram_df10,opcodebigram_df11,opcodebigram_df1
2,opcodebigram_df13,opcodebigram_df14])
```

In [17]:
```
opcodebigram_df['ID'] = opcodebigram_df['ID'].str[:-4]
opcodebigram_df.head()
```

Out[17]:

	jmp jmp	jmp mov	jmp retf	jmp push	jmp pop	jmp xor	jmp retn	jmp nop	jmp sub	jmp inc	...	movzx call	movzx shl	movzx ror	movzx rol	r
0	8.0	95.0	0.0	43.0	2.0	22.0	0.0	0.0	0.0	3.0	...	0.0	0.0	0.0	0.0	
1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	

5 rows × 677 columns

In [ ]:

In [18]:
```
result_asm = pd.read_csv('result_asm_with_size.csv')
result_asm = result_asm[['ID','Class','size']]
result_asm.head()
```

Out[18]:

	ID	Class	size
0	01kcPWA9K2BOxQeS5Rju	1	0.078190
1	1E93CpP60RHFNiT5Qfvn	1	0.063400
2	3ekVow2ajZHbTnBcsDfX	1	0.041695
3	3X2nY7iQaPBIWDrAZqJe	1	0.018757
4	46OZzdsSKDCFV8h7XWxf	1	0.037567

In [19]:
```
final_opcodebigram_df = pd.merge(opcodebigram_df, result_asm,on='ID', how='lef
t')
final_opcodebigram_df.head()
```

Out[19]:

	jmp jmp	jmp mov	jmp retf	jmp push	jmp pop	jmp xor	jmp retn	jmp nop	jmp sub	jmp inc	...	movzx ror	movzx rol	movzx jnb	movzx jz	r
0	8.0	95.0	0.0	43.0	2.0	22.0	0.0	0.0	0.0	3.0	...	0.0	0.0	0.0	3.0	
1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	

5 rows × 679 columns

In [20]:
```
# 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')
and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            if (max_value-min_value)!=0:
                result1[feature_name] = (df[feature_name] - min_value) / (max_
value - min_value)
    return result1
```

In [21]:
```
final_opcodebigram_df = normalize(final_opcodebigram_df)
final_opcodebigram_df.head()
```

Out[21]:

	jmp jmp	jmp mov	jmp retf	jmp push	jmp pop	jmp xor	jmp retn	jmp nop	jmp sub	jmp inc	...	movzx ror	n
0	0.002604	0.005519	0.0	0.020254	0.002759	0.0162	0.0	0.0	0.0	0.015228	...	0.0	
1	0.000000	0.000058	0.0	0.000000	0.000000	0.0000	0.0	0.0	0.0	0.000000	...	0.0	
2	0.000000	0.000000	0.0	0.000000	0.000000	0.0000	0.0	0.0	0.0	0.000000	...	0.0	
3	0.000000	0.000000	0.0	0.000471	0.000000	0.0000	0.0	0.0	0.0	0.000000	...	0.0	
4	0.000000	0.000000	0.0	0.000471	0.000000	0.0000	0.0	0.0	0.0	0.000000	...	0.0	

5 rows × 679 columns

Selecting important features

In [23]:
```
#'Unnamed: 0'
data_y = final_opcodebigram_df['Class']
```

In [24]:
```
def imp_features(data, features):
    rf = RandomForestClassifier(n_estimators = 35, n_jobs = -1,verbose=5)
    rf.fit(data, data_y)
    imp_feature_indx = np.argsort(rf.feature_importances_)[::-1]
    print(len(features),  len(imp_feature_indx))
    imp_feature_name = np.take(features, imp_feature_indx)
    return imp_feature_name
```

In [25]:
```
opcode_bi_names = imp_features(final_opcodebigram_df.drop(['ID','Class','size'
],axis=1,inplace=False), asmopcodebigram)
```

```
[Parallel(n_jobs=-1)]: Using backend ThreadingBackend with 16 concurrent work
ers.
[Parallel(n_jobs=-1)]: Done  12 out of  35 | elapsed:    0.2s remaining:
0.4s

building tree 1 of 35building tree 2 of 35
building tree 3 of 35
building tree 4 of 35
building tree 5 of 35
building tree 6 of 35
building tree 7 of 35
building tree 8 of 35
building tree 9 of 35
building tree 10 of 35
building tree 11 of 35
building tree 12 of 35

building tree 13 of 35
building tree 14 of 35
building tree 15 of 35
building tree 16 of 35
building tree 17 of 35
building tree 18 of 35
building tree 19 of 35building tree 20 of 35
building tree 21 of 35
building tree 22 of 35

building tree 23 of 35
building tree 24 of 35
building tree 25 of 35
building tree 26 of 35
building tree 27 of 35
building tree 28 of 35
building tree 29 of 35
building tree 30 of 35
building tree 31 of 35
building tree 32 of 35
building tree 33 of 35building tree 34 of 35

building tree 35 of 35
676 676

[Parallel(n_jobs=-1)]: Done  20 out of  35 | elapsed:    0.3s remaining:
0.2s
[Parallel(n_jobs=-1)]: Done  28 out of  35 | elapsed:    0.3s remaining:
0.1s
[Parallel(n_jobs=-1)]: Done  35 out of  35 | elapsed:    0.3s finished
```

In [26]:
```
# with open('asmopcodebigram_imp_features.pkl','wb') as f:
#     pickle.dump(opcode_bi_names, f)
with open('asmopcodebigram_imp_features.pkl','rb') as f:
    opcode_bi_names = pickle.load(f)
```

In [28]:
```
len(opcode_bi_names)
```

Out[28]: 676

In [29]:
```
opcode_bi_names = list(opcode_bi_names[:300])
opcode_bi_names.append('ID')
opcode_bi_names.append('Class')
opcode_bi_names.append('size')
len(opcode_bi_names)
```

Out[29]: 303

In [30]:
```
final_opcodebigram_df = final_opcodebigram_df[opcode_bi_names]
```

In [31]:
```
len(final_opcodebigram_df.columns)
```

Out[31]: 303

In [32]:
```
final_opcodebigram_df.head()
```

Out[32]:

	retn push	lea mov	add pop	mov lea	dec sub	call cmp	call add	jz mov	cmp mov	
0	0.018566	0.008112	0.003616	0.005119	0.001795	0.009737	0.005154	0.011867	0.017688	0.(
1	0.000000	0.000484	0.033143	0.000091	0.000000	0.000000	0.005545	0.000000	0.000126	0.(
2	0.000000	0.000605	0.033143	0.000000	0.000000	0.000000	0.005480	0.000000	0.000253	0.(
3	0.000151	0.000363	0.026815	0.000091	0.000000	0.000000	0.004632	0.000089	0.000126	0.(
4	0.000000	0.000121	0.002410	0.000000	0.000000	0.000348	0.000065	0.000000	0.000126	0.(

5 rows × 303 columns

In [34]:
```
# final_opcodebigram_df.to_csv('opcodebigram_final_rf_reduced_df.csv',index=Fa
lse)
```

In [35]:
```
final_opcodebigram_df = pd.read_csv('opcodebigram_final_rf_reduced_df.csv')
final_opcodebigram_df.head()
```

Out[35]:

	retn push	lea mov	add pop	mov lea	dec sub	call cmp	call add	jz mov	cmp mov	
0	0.018566	0.008112	0.003616	0.005119	0.001795	0.009737	0.005154	0.011867	0.017688	0.(
1	0.000000	0.000484	0.033143	0.000091	0.000000	0.000000	0.005545	0.000000	0.000126	0.(
2	0.000000	0.000605	0.033143	0.000000	0.000000	0.000000	0.005480	0.000000	0.000253	0.(
3	0.000151	0.000363	0.026815	0.000091	0.000000	0.000000	0.004632	0.000089	0.000126	0.(
4	0.000000	0.000121	0.002410	0.000000	0.000000	0.000348	0.000065	0.000000	0.000126	0.(

5 rows × 303 columns

Train Test split

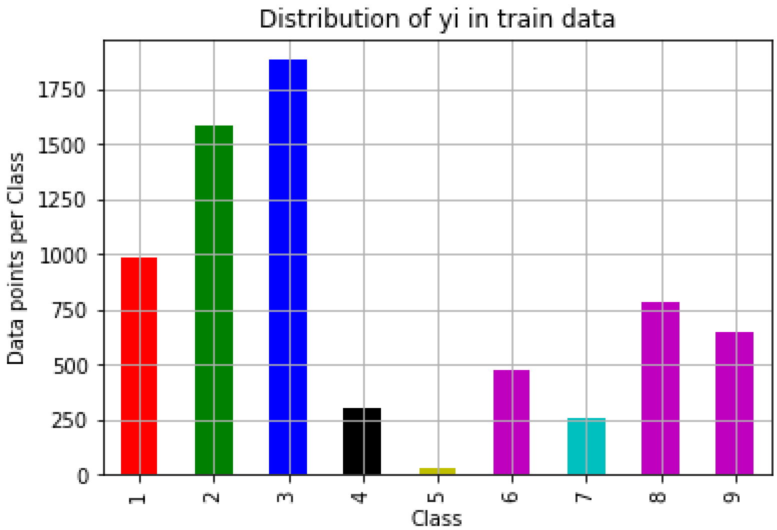
In [36]:
```
data_y = final_opcodebigram_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_opcodebigram_df.drop
(['ID','Class','size'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [37]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

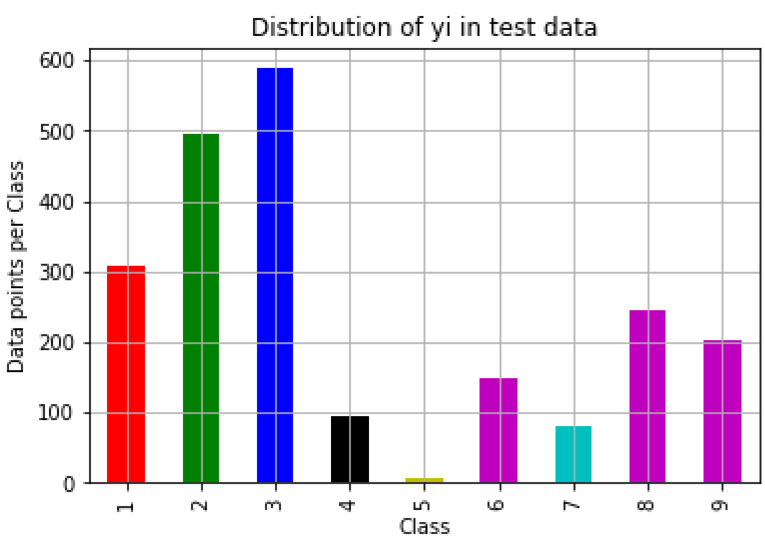
```
Number of data points in train data: (6955, 300)
Number of data points in test data: (2174, 300)
Number of data points in cross validation data: (1739, 300)
```

In [38]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

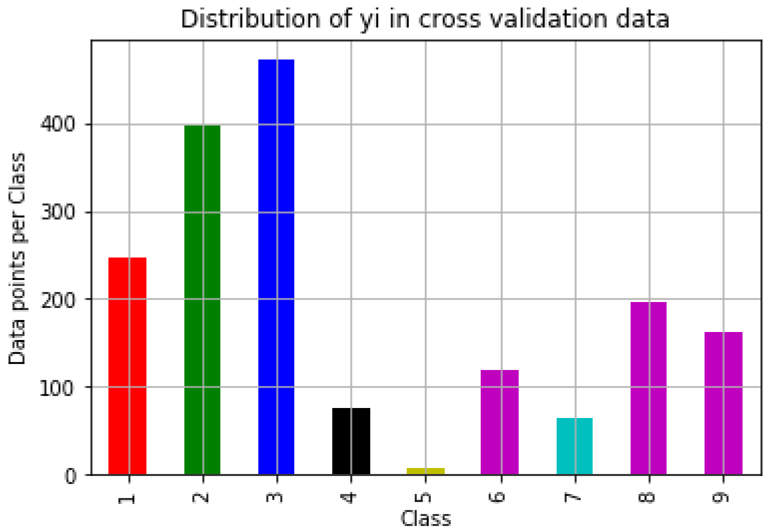
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
---------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
---------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [39]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes bigrams features

In [40]:

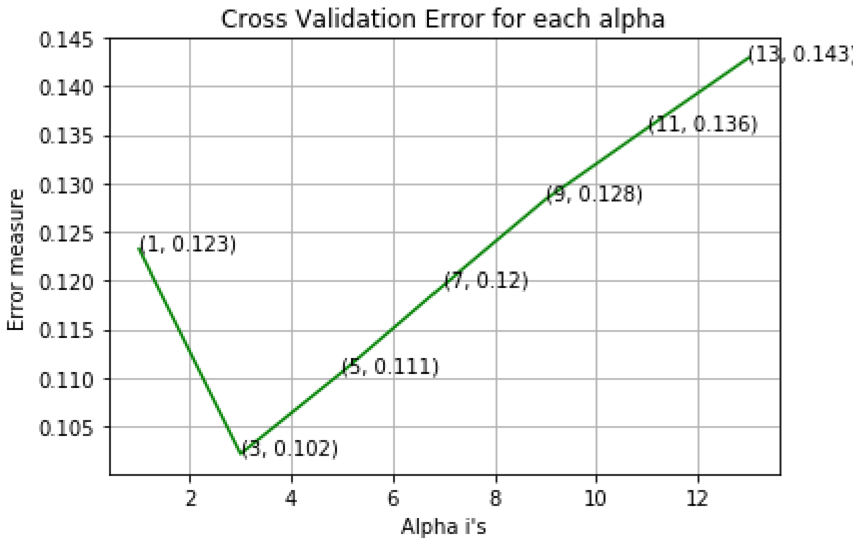
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.2. K Nearest Neighbour Classification

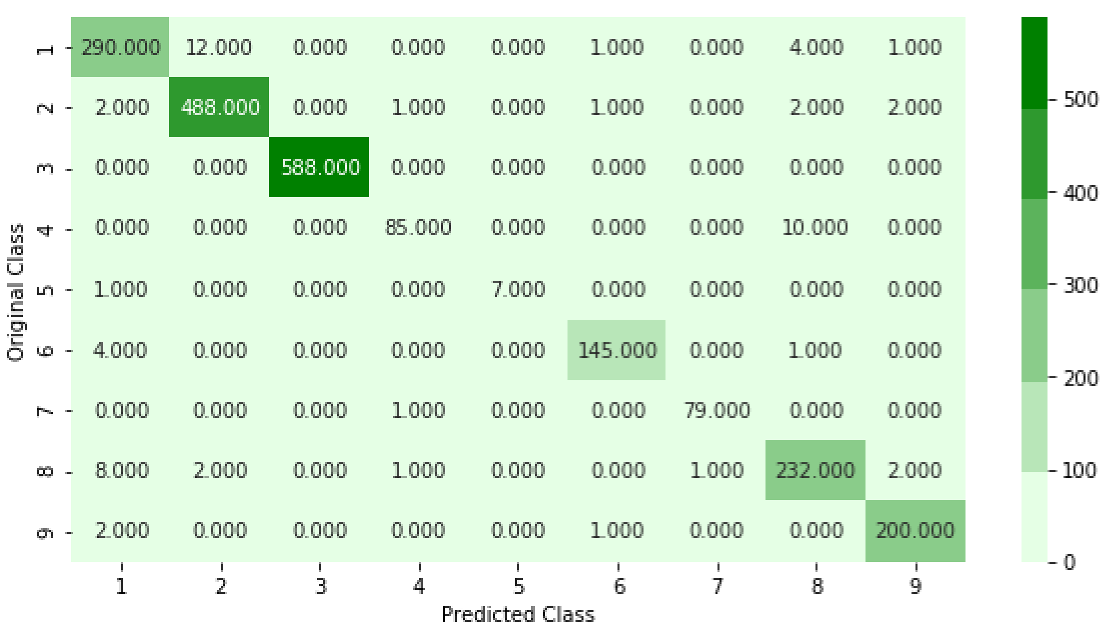
In [41]:
```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/m
odules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', lea
f_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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


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

alpha = [x for x in range(1, 15, 2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
    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=k_cfl.classes_,
eps=1e-15))

for i in range(len(cv_log_error_array)):
    print ('log_loss for k = ',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()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for k =  1 is 0.12322902249120343
log_loss for k =  3 is 0.10214532275881437
log_loss for k =  5 is 0.1105684613524605
log_loss for k =  7 is 0.11955191278771904
log_loss for k =  9 is 0.12832970327736956
log_loss for k =  11 is 0.13566466635988322
log_loss for k =  13 is 0.1429209953631547
```

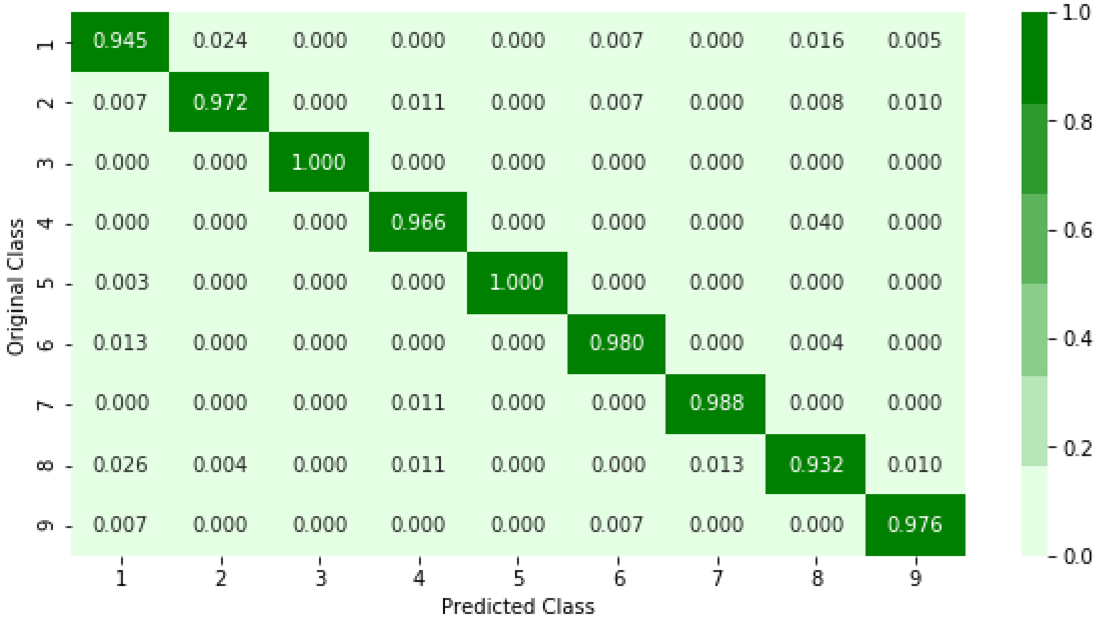



```
For values of best alpha =  3 The train log loss is: 0.06577087460438581
For values of best alpha =  3 The cross validation log loss is: 0.10214532275
881437
For values of best alpha =  3 The test log loss is: 0.112712223177701
Number of misclassified points  2.7598896044158234
------------------------------------------------- Confusion matrix ---------
----------------------------------------
```

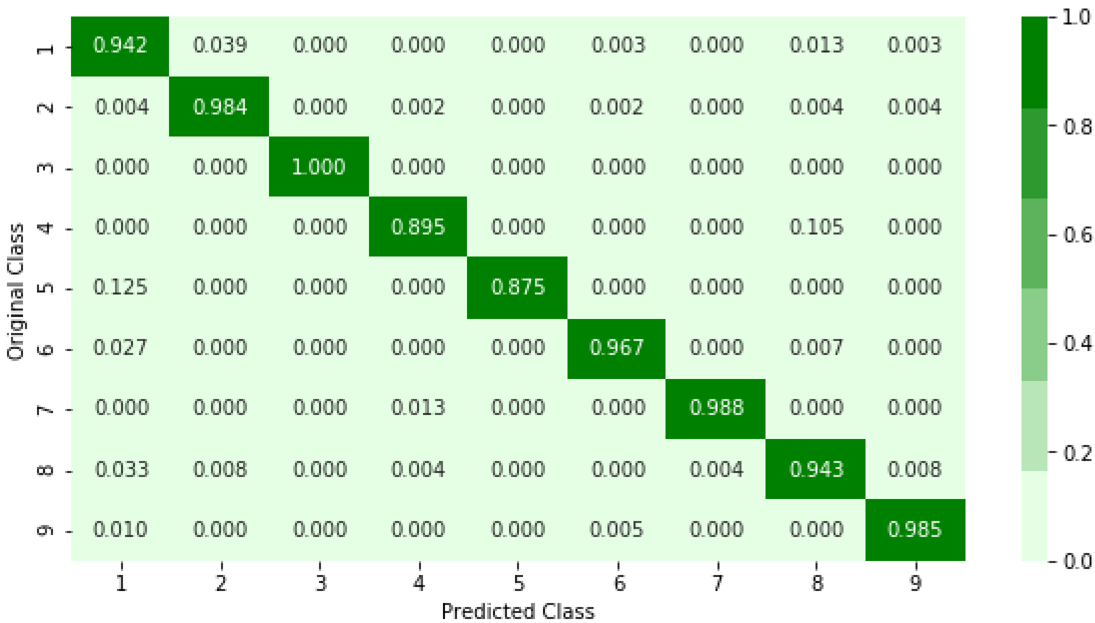


	1	2	3	4	5	6	7	8	9
1	290.000	12.000	0.000	0.000	0.000	1.000	0.000	4.000	1.000
2	2.000	488.000	0.000	1.000	0.000	1.000	0.000	2.000	2.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	85.000	0.000	0.000	0.000	10.000	0.000
5	1.000	0.000	0.000	0.000	7.000	0.000	0.000	0.000	0.000
6	4.000	0.000	0.000	0.000	0.000	145.000	0.000	1.000	0.000
7	0.000	0.000	0.000	1.000	0.000	0.000	79.000	0.000	0.000
8	8.000	2.000	0.000	1.000	0.000	0.000	1.000	232.000	2.000
9	2.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	200.000

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



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



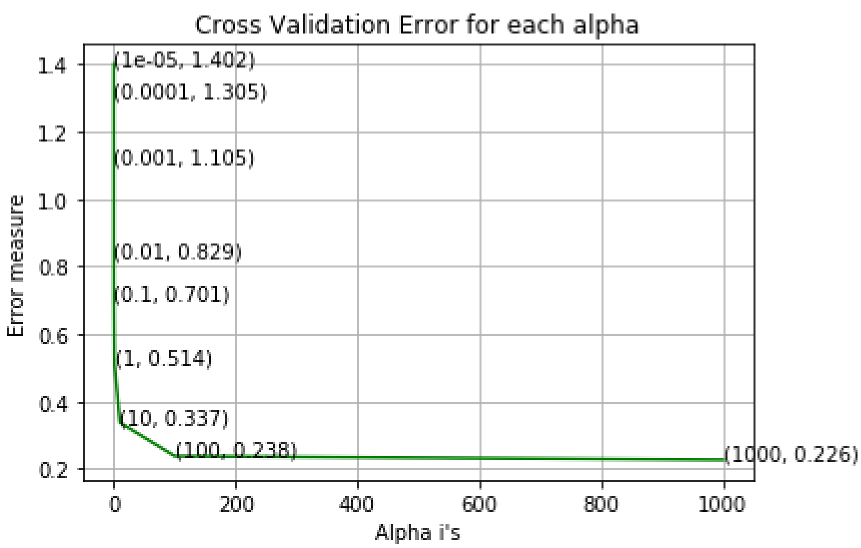
```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.3. Logistic Regression

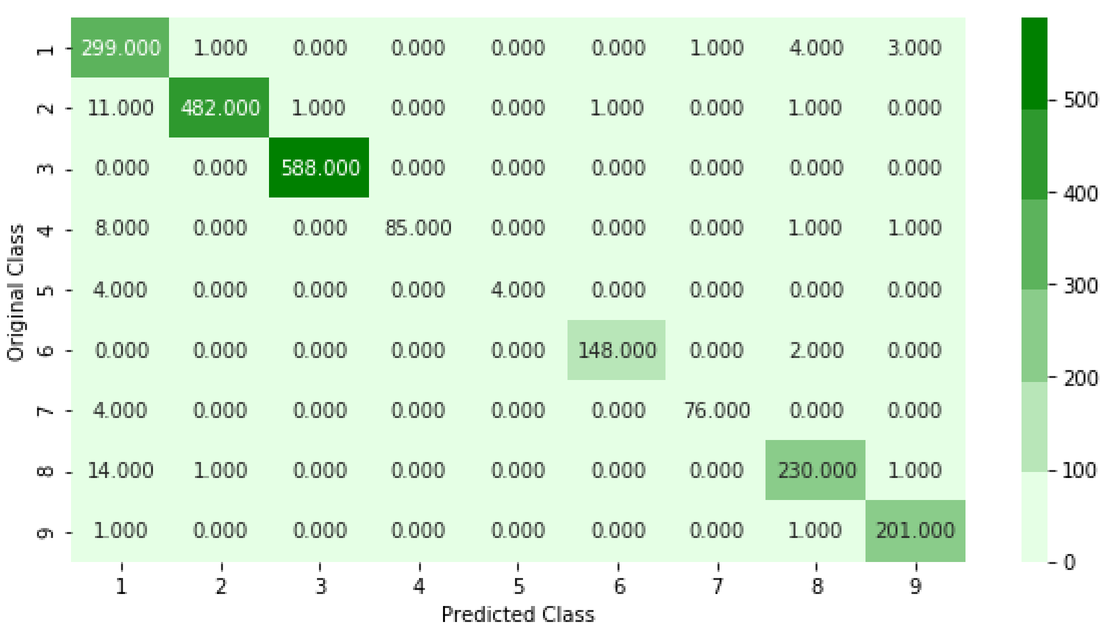
In [42]:
```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_iter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

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

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

alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
    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=logisticR.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()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='balanced')
logisticR.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
sig_clf.fit(X_train, y_train)
pred_y=sig_clf.predict(X_test)

predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, eps=1e-15))
```

```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.class
es_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.c
lasses_, eps=1e-15))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  1e-05 is 1.4015223878079384
log_loss for c =  0.0001 is 1.304556838873391
log_loss for c =  0.001 is 1.1048080836993546
log_loss for c =  0.01 is 0.8291328950550755
log_loss for c =  0.1 is 0.7011053414955715
log_loss for c =  1 is 0.5143230626115443
log_loss for c =  10 is 0.337179022742621
log_loss for c =  100 is 0.23754426361216452
log_loss for c =  1000 is 0.2263287264119156
```

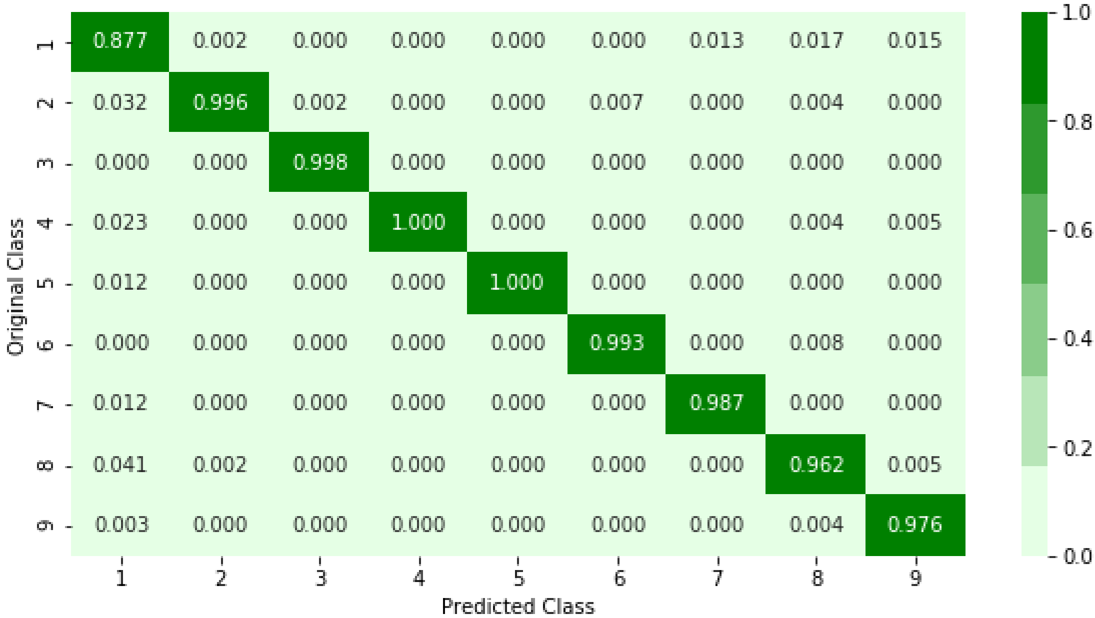



```
log loss for train data 0.1987070999049597
log loss for cv data 0.2263287264119156
log loss for test data 0.2276627687629669
Number of misclassified points  2.8058877644894205
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```

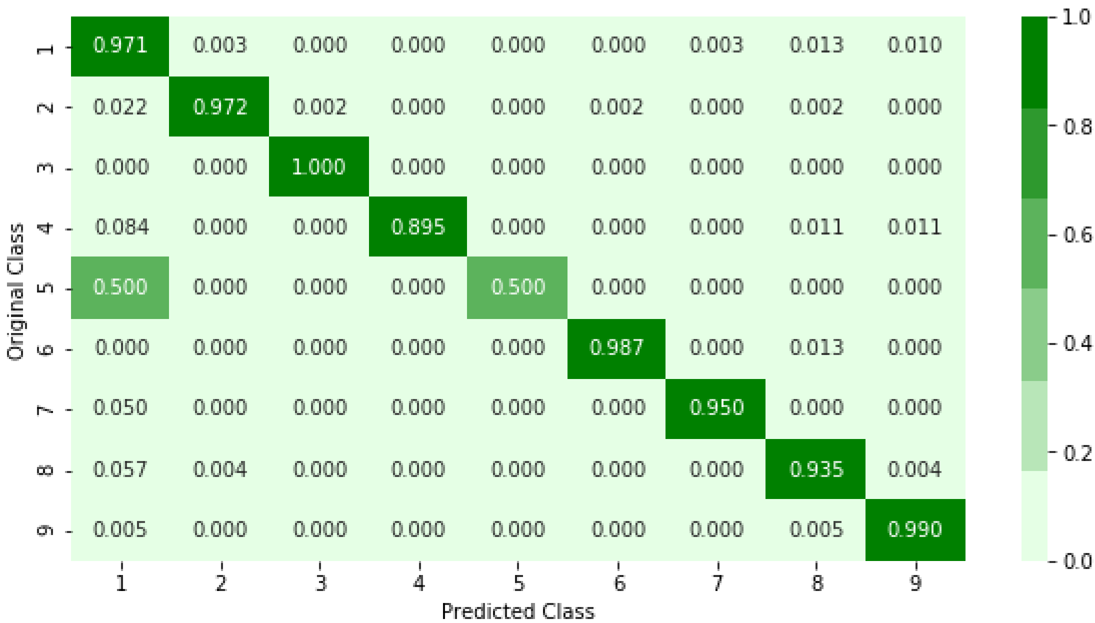


	1	2	3	4	5	6	7	8	9
1	299.000	1.000	0.000	0.000	0.000	0.000	1.000	4.000	3.000
2	11.000	482.000	1.000	0.000	0.000	1.000	0.000	1.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	8.000	0.000	0.000	85.000	0.000	0.000	0.000	1.000	1.000
5	4.000	0.000	0.000	0.000	4.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	148.000	0.000	2.000	0.000
7	4.000	0.000	0.000	0.000	0.000	0.000	76.000	0.000	0.000
8	14.000	1.000	0.000	0.000	0.000	0.000	0.000	230.000	1.000
9	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	201.000

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




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




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

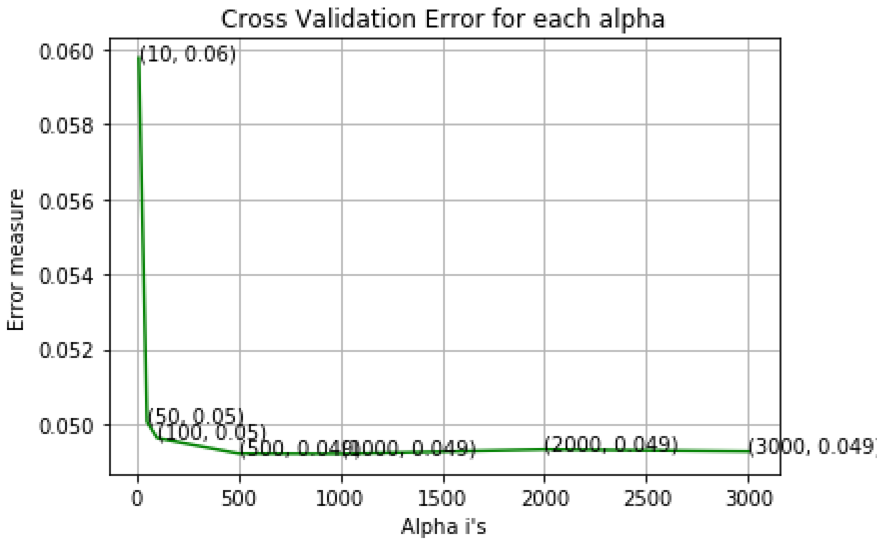
4.1.4. Random Forest Classifier

In [43]:

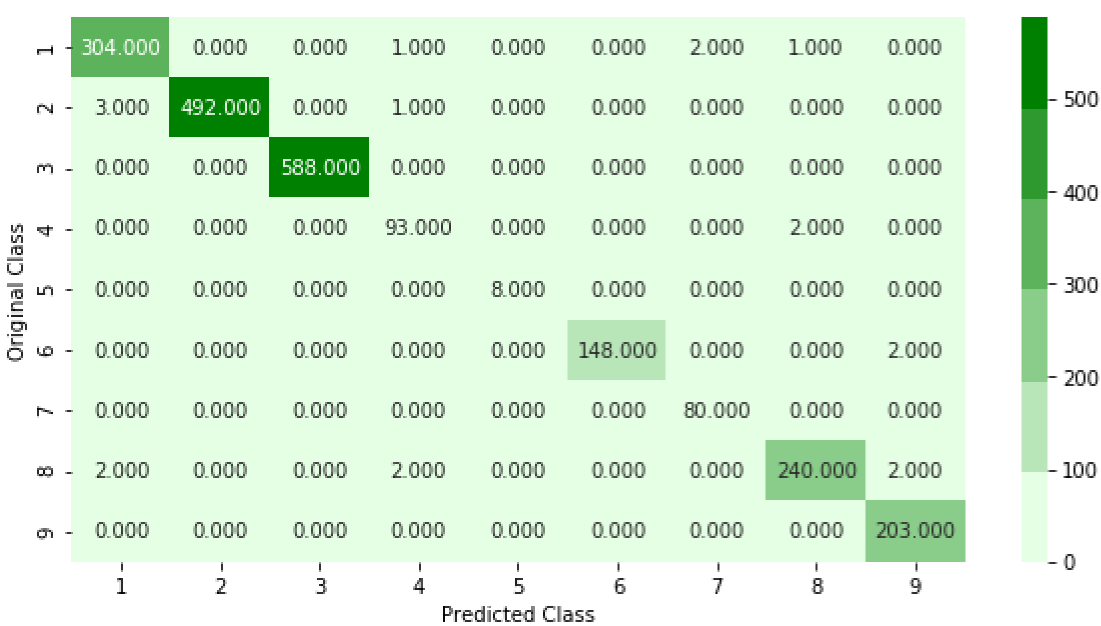
```
# ----------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  10 is 0.05976414860469076
log_loss for c =  50 is 0.05006561285899124
log_loss for c =  100 is 0.04962752219138262
log_loss for c =  500 is 0.04921544368913552
log_loss for c =  1000 is 0.04920569035331009
log_loss for c =  2000 is 0.049324919956923556
log_loss for c =  3000 is 0.049273187475216286
```

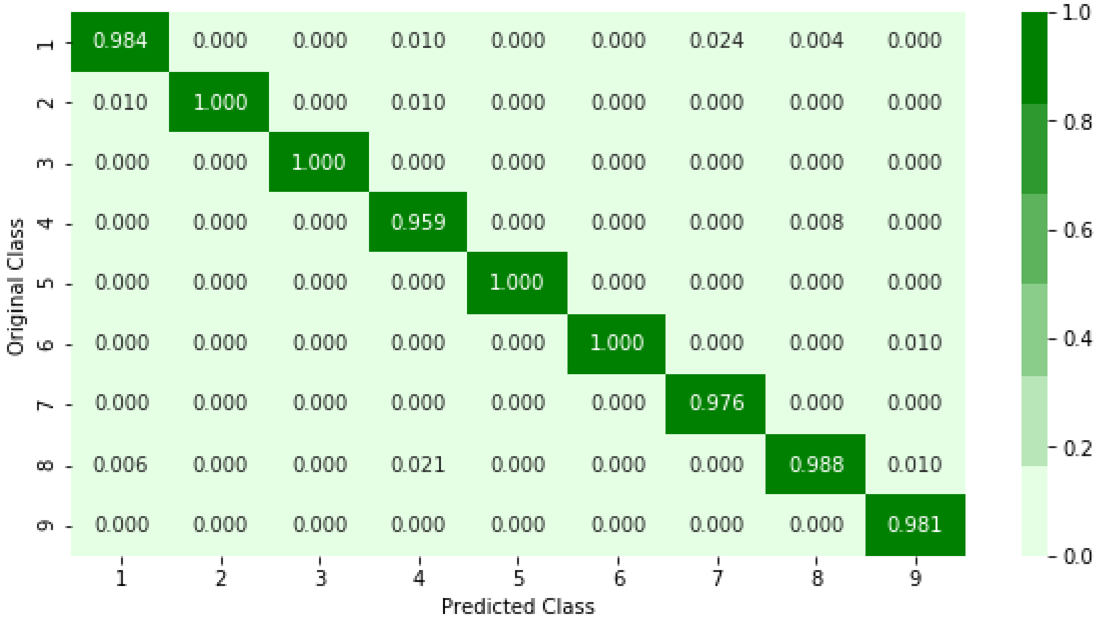



```
For values of best alpha =  1000 The train log loss is: 0.02729217419796757
For values of best alpha =  1000 The cross validation log loss is: 0.04920568
486568558
For values of best alpha =  1000 The test log loss is: 0.04403411243756223
Number of misclassified points  0.8279668813247469
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```

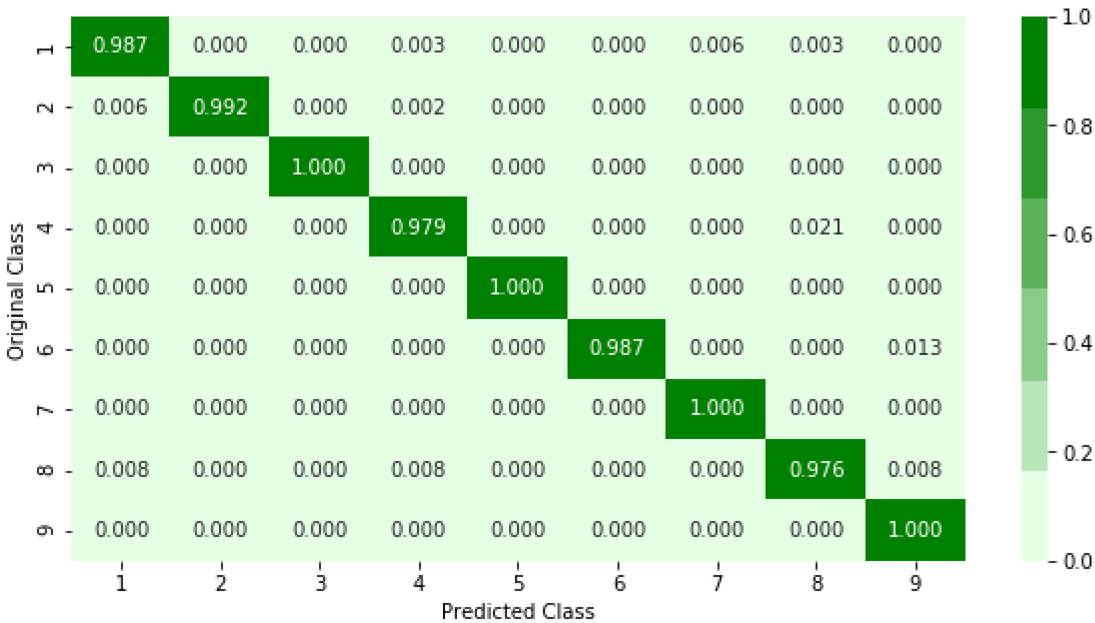


	1	2	3	4	5	6	7	8	9
1	304.000	0.000	0.000	1.000	0.000	0.000	2.000	1.000	0.000
2	3.000	492.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	93.000	0.000	0.000	0.000	2.000	0.000
5	0.000	0.000	0.000	0.000	8.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	148.000	0.000	0.000	2.000
7	0.000	0.000	0.000	0.000	0.000	0.000	80.000	0.000	0.000
8	2.000	0.000	0.000	2.000	0.000	0.000	0.000	240.000	2.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	203.000

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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [45]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:   28.3s remaining:  4.2
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:   51.0s remaining:  2.8
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  1.2min remaining:  2.0
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  1.4min remaining:  1.4
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  2.9min remaining:  1.7
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  3.2min remaining:   5
9.0s
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  3.8min remaining:   2
5.2s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  6.6min finished
```

Out[45]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

In [47]:
```python
print (random_cfl1.best_params_)
```

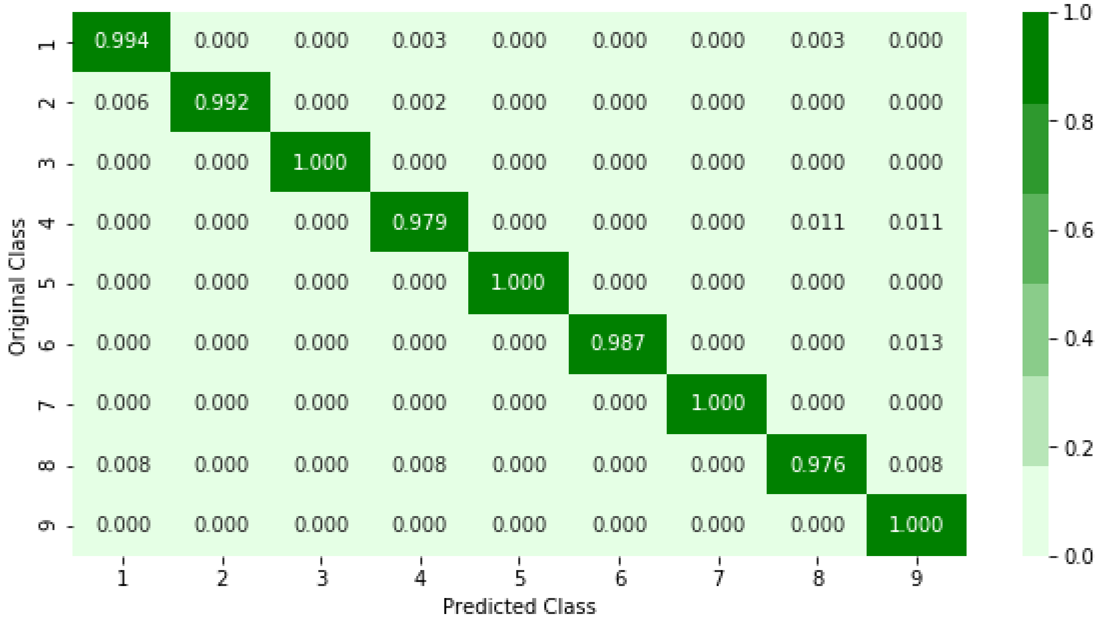
```
{'max_depth': 3, 'learning_rate': 0.05, 'subsample': 0.5, 'n_estimators': 200
0, 'colsample_bytree': 0.1}
```

In [48]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.05, subsample= 0.5, n_estimators= 2000, c
olsample_bytree= 0.1, max_depth= 3,n_jobs=-1,verbose=1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.026166591194686922
cv loss 0.046756140278601296
test loss 0.04462516950196891
Number of misclassified points  0.7359705611775529
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```


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


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




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

In [ ]:

Opcode Trigrams

In [49]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import math
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [15]:
```
len(os.listdir('asmFiles'))
```

Out[15]:
```
10868
```

In [16]:
```
#intially create five folders
#first
#second
#thrid
#fourth
#fifth
#this code tells us about random split of files into five folders
folder_1 ='first_'
folder_2 ='second_'
folder_3 ='third_'
folder_4 ='fourth_'
folder_5 ='fifth_'
folder_6 ='sixth_'
folder_7 ='seventh_'
folder_8 ='eigth_'
folder_9 ='ningth_'
folder_10 ='tenth_'
folder_11='eleventh_'
folder_12 ='twelveth_'
folder_13 ='thirteenth_'
folder_14 ='fourteenth_'
folder_15 = 'output_'
for i in [folder_1,folder_2,folder_3,folder_4,folder_5,folder_6,folder_7,folde
r_8,folder_9,folder_10,folder_11,folder_12,folder_13,folder_14,folder_15]:
    if not os.path.isdir(i):
        os.makedirs(i)

source='asmFiles/'
files = os.listdir('asmFiles')
# ID=df['Id'].tolist()
data=list(range(0,10868))
# r.shuffle(data)
count=0
for i in range(0,10868):
    if i>=0 and i<=776:
        shutil.move(source+files[data[i]],'first_')
    elif i>=777 and i<=1553:
        shutil.move(source+files[data[i]],'second_')
    elif i>=1554 and i<=2330:
        shutil.move(source+files[data[i]],'third_')
    elif i>=2331 and i<=3107:
        shutil.move(source+files[data[i]],'fourth_')
    elif i>=3108 and i<=3883:
        shutil.move(source+files[data[i]],'fifth_')
    elif i>=3884 and i<=4659:
        shutil.move(source+files[data[i]],'sixth_')
    elif i>=4660 and i<=5435:
        shutil.move(source+files[data[i]],'seventh_')
    elif i>=5436 and i<=6211:
        shutil.move(source+files[data[i]],'eigth_')
    elif i>=6212 and i<=6987:
        shutil.move(source+files[data[i]],'ningth_')
    elif i>=6988 and i<=7763:
        shutil.move(source+files[data[i]],'tenth_')
    elif i>=7764 and i<=8539:
        shutil.move(source+files[data[i]],'eleventh_')
```

```
    elif i>=8540 and i<=9315:
        shutil.move(source+files[data[i]],'twelveth_')
    elif i>=9316 and i<=10091:
        shutil.move(source+files[data[i]],'thirteenth_')
    elif i>=10092 and i<=10867:
        shutil.move(source+files[data[i]],'fourteenth_')
```

In [17]:

```
len(os.listdir('first_')) + \
len(os.listdir('second_')) + \
len(os.listdir('third_')) + \
len(os.listdir('fourth_')) + \
len(os.listdir('fifth_')) + \
len(os.listdir('sixth_')) + \
len(os.listdir('seventh_')) + \
len(os.listdir('eigth_')) + \
len(os.listdir('ningth_')) + \
len(os.listdir('tenth_')) + \
len(os.listdir('eleventh_')) + \
len(os.listdir('twelveth_')) + \
len(os.listdir('thirteenth_')) + \
len(os.listdir('fourteenth_'))
```

Out[17]: 10868

In [18]:

```
print(len(os.listdir('first_')),
len(os.listdir('second_')),
len(os.listdir('third_')),
len(os.listdir('fourth_')),
len(os.listdir('fifth_')),
len(os.listdir('sixth_')),
len(os.listdir('seventh_')),
len(os.listdir('eigth_')),
len(os.listdir('ningth_')),
len(os.listdir('tenth_')),
len(os.listdir('eleventh_')),
len(os.listdir('twelveth_')),
len(os.listdir('thirteenth_')),
len(os.listdir('fourteenth_')))
```

```
777 777 777 777 776 776 776 776 776 776 776 776 776 776
```

In [50]:

```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
from sklearn.feature_extraction.text import CountVectorizer
import scipy
```

In [51]:

```
opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub',
'inc', 'dec', 'add','imul', 'xchg', 'or', 'shr', 'cmp', 'call', 'shl', 'ror',
'rol', 'jnb','jz','rtn','lea','movzx']
```

In [52]:
```
asmopcodetrigram = []
def asmopcodetrigramm():
    for i, v in enumerate(opcodes):
        for j in range(0, len(opcodes)):
            for k in range(0, len(opcodes)):
                asmopcodetrigram.append(v + ' ' + opcodes[j] + ' ' + opcodes[k
])
asmopcodetrigramm()
```

In [54]:
```
len(asmopcodetrigram)
```

Out[54]: 17576

In [56]:
```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((777, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file1.txt').read().split('\n')

    for indx in range(777):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df1 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df1['ID'] = os.listdir('first_')
    opcodetrigram_df1.to_csv('opcodetrigram_df1.csv',index=False)

#same as above
def secondprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((777, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file2.txt').read().split('\n')

    for indx in range(777):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df2 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df2['ID'] = os.listdir('second_')
    opcodetrigram_df2.to_csv('opcodetrigram_df2.csv',index=False)

# same as smallprocess() functions
def thirdprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((777, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file3.txt').read().split('\n')

    for indx in range(777):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df3 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df3['ID'] = os.listdir('third_')
    opcodetrigram_df3.to_csv('opcodetrigram_df3.csv',index=False)


def fourthprocess():
```

```
    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((777, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file4.txt').read().split('\n')

    for indx in range(777):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df4 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df4['ID'] = os.listdir('fourth_')
    opcodetrigram_df4.to_csv('opcodetrigram_df4.csv',index=False)


def fifthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file5.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df5 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df5['ID'] = os.listdir('fifth_')
    opcodetrigram_df5.to_csv('opcodetrigram_df5.csv',index=False)

def sixthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file6.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df6 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df6['ID'] = os.listdir('sixth_')
    opcodetrigram_df6.to_csv('opcodetrigram_df6.csv',index=False)

def seventhprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file7.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df7 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df7['ID'] = os.listdir('seventh_')
```

```
    opcodetrigram_df7.to_csv('opcodetrigram_df7.csv',index=False)

def eigthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file8.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df8 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df8['ID'] = os.listdir('eigth_')
    opcodetrigram_df8.to_csv('opcodetrigram_df8.csv',index=False)

def ningthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file9.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df9 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigram
)
    opcodetrigram_df9['ID'] = os.listdir('ningth_')
    opcodetrigram_df9.to_csv('opcodetrigram_df9.csv',index=False)

def tenthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file10.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df10 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigra
m)
    opcodetrigram_df10['ID'] = os.listdir('tenth_')
    opcodetrigram_df10.to_csv('opcodetrigram_df10.csv',index=False)

def eleventhprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file11.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
```

```
    opcodetrigram_df11 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigra
m)
    opcodetrigram_df11['ID'] = os.listdir('eleventh_')
    opcodetrigram_df11.to_csv('opcodetrigram_df11.csv',index=False)


def twelvethprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file12.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df12 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigra
m)
    opcodetrigram_df12['ID'] = os.listdir('twelveth_')
    opcodetrigram_df12.to_csv('opcodetrigram_df12.csv',index=False)

def thirteenthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file13.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df13 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigra
m)
    opcodetrigram_df13['ID'] = os.listdir('thirteenth_')
    opcodetrigram_df13.to_csv('opcodetrigram_df13.csv',index=False)

def fourteenthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodetrigram)
    opcodetrivect = scipy.sparse.csr_matrix((776, len(asmopcodetrigram)))
    raw_opcode = open('opcode_file14.txt').read().split('\n')

    for indx in range(776):
        opcodetrivect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_
opcode[indx]]))
    opcodetrivect = opcodetrivect.todense()
    opcodetrigram_df14 = pd.DataFrame(opcodetrivect, columns = asmopcodetrigra
m)
    opcodetrigram_df14['ID'] = os.listdir('fourteenth_')
    opcodetrigram_df14.to_csv('opcodetrigram_df14.csv',index=False)


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
```

```
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    p6=Process(target=sixthprocess)
    p7=Process(target=seventhprocess)
    p8=Process(target=eigthprocess)
    p9=Process(target=ningthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelvethprocess)
    p13=Process(target=thirteenthprocess)
    p14=Process(target=fourteenthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    p6.start()
    p7.start()
    p8.start()
    p9.start()
    p10.start()
    p11.start()
    p12.start()
    p13.start()
    p14.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()
    p6.join()
    p7.join()
    p8.join()
    p9.join()
    p10.join()
    p11.join()
    p12.join()
    p13.join()
    p14.join()

if __name__=="__main__":
    main()
```

In [59]:
```
opcodetrigram_df14 = pd.read_csv('opcodetrigram_df14.csv')
opcodetrigram_df14.head()
```

Out[59]:

	jmp jmp jmp	jmp jmp mov	jmp jmp retf	jmp jmp push	jmp jmp pop	jmp jmp xor	jmp jmp retn	jmp jmp nop	jmp jmp sub	jmp jmp inc	...	movzx movzx call	movzx movzx shl	movzx movzx ror	movzx movzx rol	r r
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
2	2.0	6.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
3	8.0	4.0	0.0	2.0	0.0	0.0	2.0	0.0	3.0	1.0	...	0.0	0.0	0.0	0.0	
4	21.0	11.0	0.0	11.0	0.0	1.0	0.0	0.0	2.0	0.0	...	0.0	1.0	0.0	0.0	

5 rows × 17577 columns

In [60]:
```
opcodetrigram_df1 = pd.read_csv('opcodetrigram_df1.csv')
opcodetrigram_df2 = pd.read_csv('opcodetrigram_df2.csv')
opcodetrigram_df3 = pd.read_csv('opcodetrigram_df3.csv')
opcodetrigram_df4 = pd.read_csv('opcodetrigram_df4.csv')
opcodetrigram_df5 = pd.read_csv('opcodetrigram_df5.csv')
opcodetrigram_df6 = pd.read_csv('opcodetrigram_df6.csv')
opcodetrigram_df7 = pd.read_csv('opcodetrigram_df7.csv')
opcodetrigram_df8 = pd.read_csv('opcodetrigram_df8.csv')
opcodetrigram_df9 = pd.read_csv('opcodetrigram_df9.csv')
opcodetrigram_df10 = pd.read_csv('opcodetrigram_df10.csv')
opcodetrigram_df11 = pd.read_csv('opcodetrigram_df11.csv')
opcodetrigram_df12 = pd.read_csv('opcodetrigram_df12.csv')
opcodetrigram_df13 = pd.read_csv('opcodetrigram_df13.csv')
opcodetrigram_df14 = pd.read_csv('opcodetrigram_df14.csv')
```

In [61]:
```
opcodetrigram_df = pd.concat([opcodetrigram_df1,opcodetrigram_df2,opcodetrigra
m_df3,opcodetrigram_df4,opcodetrigram_df5,opcodetrigram_df6,opcodetrigram_df7,
opcodetrigram_df8,opcodetrigram_df9,opcodetrigram_df10,opcodetrigram_df11,opco
detrigram_df12,opcodetrigram_df13,opcodetrigram_df14])
```

In [62]:
```
opcodetrigram_df['ID'] = opcodetrigram_df['ID'].str[:-4]
opcodetrigram_df.head()
```

Out[62]:

	jmp jmp jmp	jmp jmp mov	jmp jmp retf	jmp jmp push	jmp jmp pop	jmp jmp xor	jmp jmp retn	jmp jmp nop	jmp jmp sub	jmp jmp inc	...	movzx movzx call	movzx movzx shl	movzx movzx ror	movzx movzx rol	n n
0	2.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	

5 rows × 17577 columns

In [ ]:

In [63]:
```
result_asm = pd.read_csv('result_asm_with_size.csv')
result_asm = result_asm[['ID','Class','size']]
result_asm.head()
```

Out[63]:

	ID	Class	size
0	01kcPWA9K2BOxQeS5Rju	1	0.078190
1	1E93CpP60RHFNiT5Qfvn	1	0.063400
2	3ekVow2ajZHbTnBcsDfX	1	0.041695
3	3X2nY7iQaPBIWDrAZqJe	1	0.018757
4	46OZzdsSKDCFV8h7XWxf	1	0.037567

In [64]:
```
final_opcodetrigram_df = pd.merge(opcodetrigram_df, result_asm,on='ID', how='l
eft')
final_opcodetrigram_df.head()
```

Out[64]:

	jmp jmp jmp	jmp jmp mov	jmp jmp retf	jmp jmp push	jmp jmp pop	jmp jmp xor	jmp jmp retn	jmp jmp nop	jmp jmp sub	jmp jmp inc	...	movzx movzx ror	movzx movzx rol	movzx movzx jnb	movzx movzx jz	n n
0	2.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	2.0	
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	0.0	

5 rows × 17579 columns

In [65]:
```
# 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')
and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            if (max_value-min_value)!=0:
                result1[feature_name] = (df[feature_name] - min_value) / (max_
value - min_value)
    return result1
```

In [66]:
```
final_opcodetrigram_df = normalize(final_opcodetrigram_df)
final_opcodetrigram_df.head()
```

Out[66]:

	jmp jmp jmp	jmp jmp mov	jmp jmp retf	jmp jmp push	jmp jmp pop	jmp jmp xor	jmp jmp retn	jmp jmp nop	jmp jmp sub	jmp jmp inc	...	movzx movzx ror	movzx movzx rol	movzx movzx jnb
0	0.000656	0.005671	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0
1	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0
2	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0
3	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0
4	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0

5 rows × 17579 columns

Selecting important features

In [67]:
```
#'Unnamed: 0'
data_y = final_opcodetrigram_df['Class']
```

In [68]:
```
def imp_features(data, features):
    rf = RandomForestClassifier(n_estimators = 35, n_jobs = -1,verbose=5)
    rf.fit(data, data_y)
    imp_feature_indx = np.argsort(rf.feature_importances_)[::-1]
    print(len(features),  len(imp_feature_indx))
    imp_feature_name = np.take(features, imp_feature_indx)
    return imp_feature_name
```

In [69]:
```
opcode_tri_names = imp_features(final_opcodetrigram_df.drop(['ID','Class','siz
e'],axis=1,inplace=False), asmopcodetrigram)
```

```
[Parallel(n_jobs=-1)]: Using backend ThreadingBackend with 16 concurrent work
ers.

building tree 1 of 35building tree 2 of 35
building tree 3 of 35
building tree 4 of 35
building tree 5 of 35
building tree 6 of 35
building tree 7 of 35
building tree 8 of 35
building tree 9 of 35
building tree 10 of 35
building tree 11 of 35
building tree 12 of 35
building tree 13 of 35
building tree 14 of 35
building tree 15 of 35
building tree 16 of 35

building tree 17 of 35building tree 18 of 35

building tree 19 of 35
building tree 20 of 35
building tree 21 of 35
building tree 22 of 35
building tree 23 of 35
building tree 24 of 35building tree 25 of 35

building tree 26 of 35
building tree 27 of 35
building tree 28 of 35
building tree 29 of 35

[Parallel(n_jobs=-1)]: Done  12 out of  35 | elapsed:    0.2s remaining:
0.4s
[Parallel(n_jobs=-1)]: Done  20 out of  35 | elapsed:    0.4s remaining:
0.3s
[Parallel(n_jobs=-1)]: Done  28 out of  35 | elapsed:    0.4s remaining:
0.1s

building tree 30 of 35
building tree 31 of 35
building tree 32 of 35
building tree 33 of 35
building tree 34 of 35
building tree 35 of 35

[Parallel(n_jobs=-1)]: Done  35 out of  35 | elapsed:    0.5s finished

17576 17576
```

In [70]:
```
# with open('asmopcodetrigram_imp_features.pkl','wb') as f:
#     pickle.dump(opcode_tri_names, f)
with open('asmopcodetrigram_imp_features.pkl','rb') as f:
    opcode_tri_names = pickle.load(f)
```

In [71]:
```
len(opcode_tri_names)
```

Out[71]: 17576

In [72]:
```
opcode_tri_names = list(opcode_tri_names[:700])
opcode_tri_names.append('ID')
opcode_tri_names.append('Class')
opcode_tri_names.append('size')
len(opcode_tri_names)
```

Out[72]: 703

In [73]:
```
final_opcodetrigram_df = final_opcodetrigram_df[opcode_tri_names]
```

In [74]:
```
len(final_opcodetrigram_df.columns)
```

Out[74]: 703

In [75]:
```
final_opcodetrigram_df.head()
```

Out[75]:

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	mov mov mov	pop lea sub	mov jmp mov	mov pop pop	.
0	0.012821	0.002126	0.002772	0.0	0.017045	0.004888	0.005571	0.0	0.004736	0.009377	.
1	0.307692	0.030120	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
2	0.320513	0.029766	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
3	0.230769	0.025159	0.000000	0.0	0.000000	0.031425	0.000028	0.0	0.000000	0.000000	.
4	0.000000	0.000000	0.000308	0.0	0.000000	0.000000	0.000014	0.0	0.000000	0.000000	.

5 rows × 703 columns

In [76]:
```
# final_opcodetrigram_df.to_csv('opcodetrigram_final_rf_reduced_df.csv',index=False)
```

In [77]:
```
final_opcodetrigram_df = pd.read_csv('opcodetrigram_final_rf_reduced_df.csv')
final_opcodetrigram_df.head()
```

Out[77]:

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	mov mov mov	pop lea sub	mov jmp mov	mov pop pop	.
0	0.012821	0.002126	0.002772	0.0	0.017045	0.004888	0.005571	0.0	0.004736	0.009377	.
1	0.307692	0.030120	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
2	0.320513	0.029766	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
3	0.230769	0.025159	0.000000	0.0	0.000000	0.031425	0.000028	0.0	0.000000	0.000000	.
4	0.000000	0.000000	0.000308	0.0	0.000000	0.000000	0.000014	0.0	0.000000	0.000000	.

5 rows × 703 columns

Train Test split

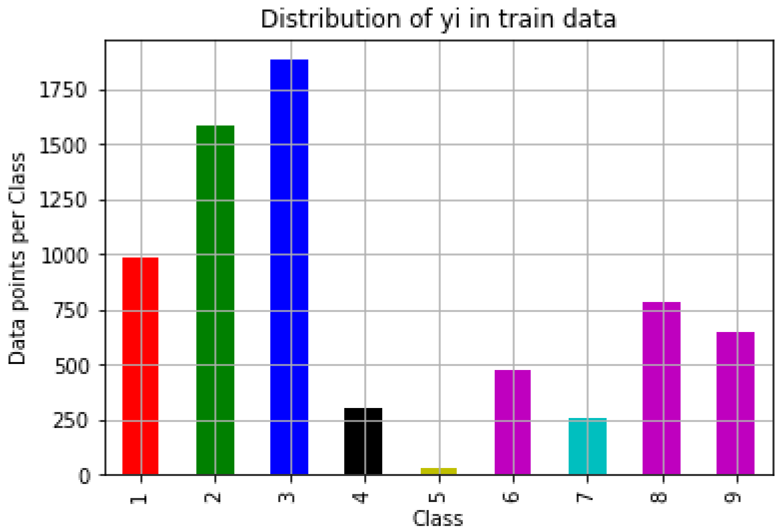
In [78]:
```
data_y = final_opcodetrigram_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_opcodetrigram_df.dro
p(['ID','Class','size'], axis=1), data_y,stratify=data_y,test_size=0.20)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.20)
```

In [79]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

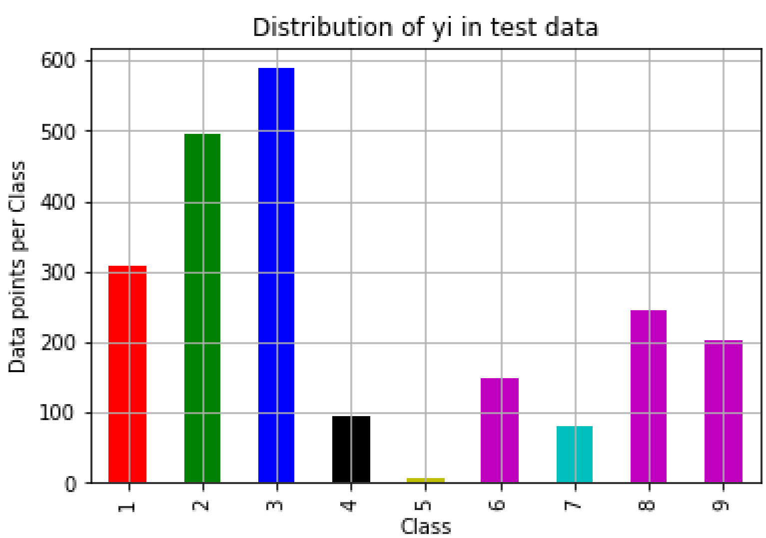
```
Number of data points in train data: (6955, 700)
Number of data points in test data: (2174, 700)
Number of data points in cross validation data: (1739, 700)
```

In [80]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

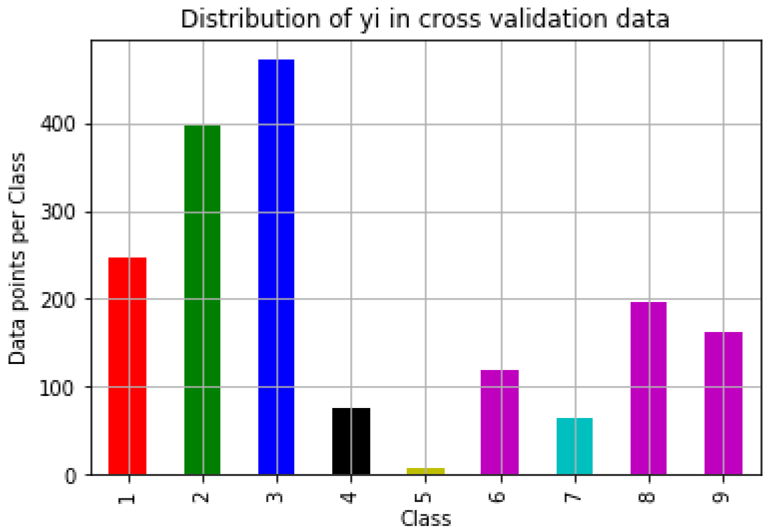
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 1883 ( 27.074 %)
Number of data points in class 2 : 1586 ( 22.804 %)
Number of data points in class 1 : 986 ( 14.177 %)
Number of data points in class 8 : 786 ( 11.301 %)
Number of data points in class 9 : 648 ( 9.317 %)
Number of data points in class 6 : 481 ( 6.916 %)
Number of data points in class 4 : 304 ( 4.371 %)
Number of data points in class 7 : 254 ( 3.652 %)
Number of data points in class 5 : 27 ( 0.388 %)
----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 588 ( 27.047 %)
Number of data points in class 2 : 496 ( 22.815 %)
Number of data points in class 1 : 308 ( 14.167 %)
Number of data points in class 8 : 246 ( 11.316 %)
Number of data points in class 9 : 203 ( 9.338 %)
Number of data points in class 6 : 150 ( 6.9 %)
Number of data points in class 4 : 95 ( 4.37 %)
Number of data points in class 7 : 80 ( 3.68 %)
Number of data points in class 5 : 8 ( 0.368 %)
----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 471 ( 27.085 %)
Number of data points in class 2 : 396 ( 22.772 %)
Number of data points in class 1 : 247 ( 14.204 %)
Number of data points in class 8 : 196 ( 11.271 %)
Number of data points in class 9 : 162 ( 9.316 %)
Number of data points in class 6 : 120 ( 6.901 %)
Number of data points in class 4 : 76 ( 4.37 %)
Number of data points in class 7 : 64 ( 3.68 %)
Number of data points in class 5 : 7 ( 0.403 %)
```

In [81]:
```
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 a
re predicted class j
    
    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes bigrams features

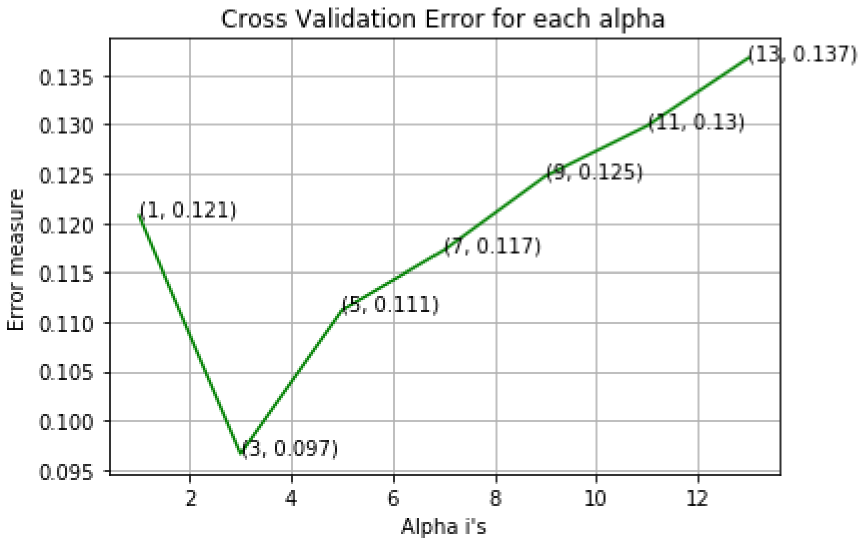
In [82]:
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.2. K Nearest Neighbour Classification

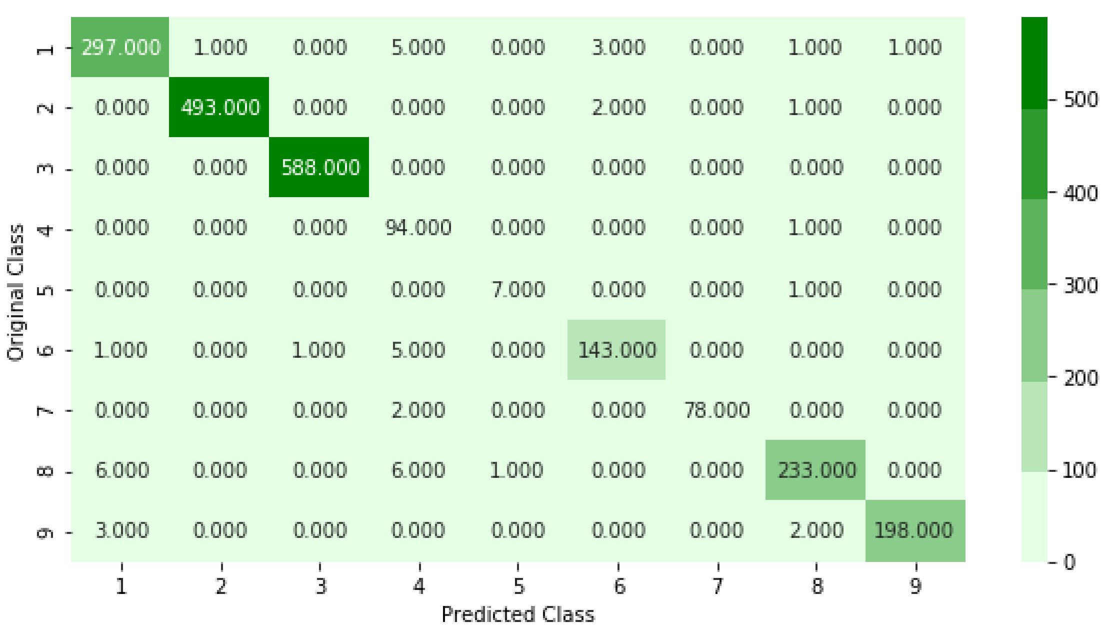
In [83]:
```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/m
odules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', lea
f_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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


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

alpha = [x for x in range(1, 15, 2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
    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=k_cfl.classes_,
eps=1e-15))

for i in range(len(cv_log_error_array)):
    print ('log_loss for k = ',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()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid",cv=3)
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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for k =  1 is 0.12073689596391325
log_loss for k =  3 is 0.09662362520423909
log_loss for k =  5 is 0.11120107885498673
log_loss for k =  7 is 0.11723525177886919
log_loss for k =  9 is 0.12475569016696969
log_loss for k =  11 is 0.12984708445983975
log_loss for k =  13 is 0.1367357606748941
```

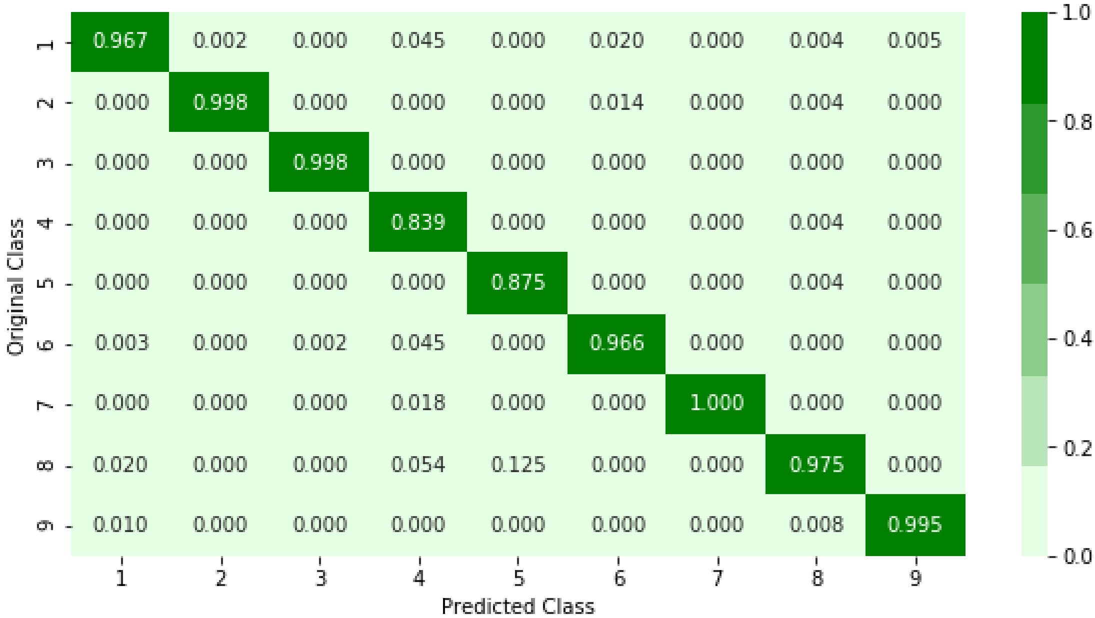



```
For values of best alpha =  3 The train log loss is: 0.06300788568888706
For values of best alpha =  3 The cross validation log loss is: 0.09662362520
423909
For values of best alpha =  3 The test log loss is: 0.10060749393460935
Number of misclassified points  1.9779208831646733
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```

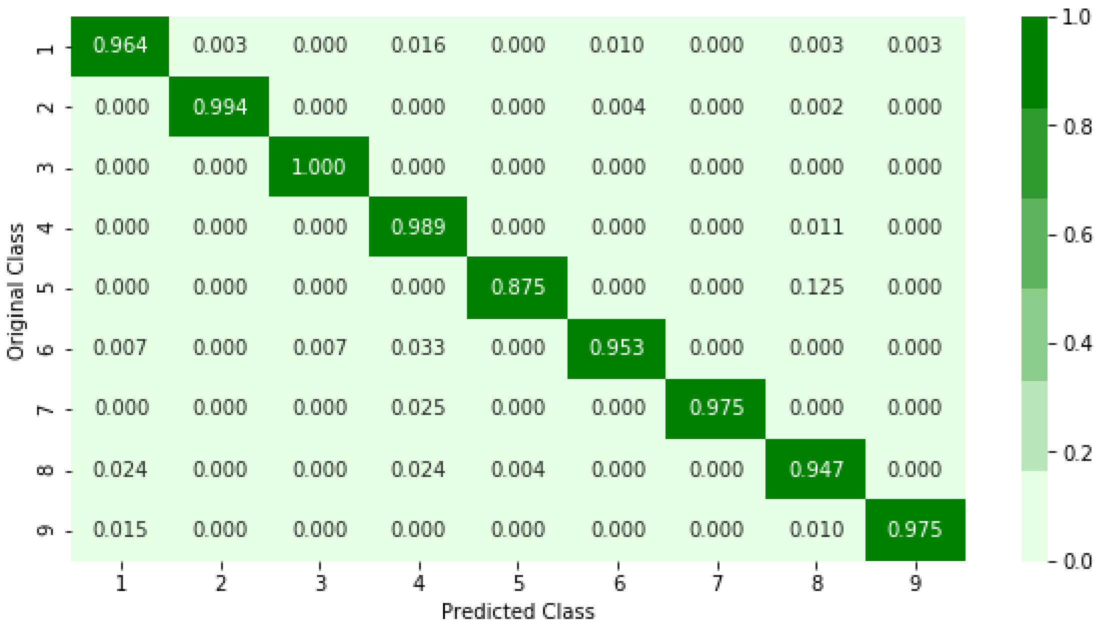


	1	2	3	4	5	6	7	8	9
1	297.000	1.000	0.000	5.000	0.000	3.000	0.000	1.000	1.000
2	0.000	493.000	0.000	0.000	0.000	2.000	0.000	1.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	94.000	0.000	0.000	0.000	1.000	0.000
5	0.000	0.000	0.000	0.000	7.000	0.000	0.000	1.000	0.000
6	1.000	0.000	1.000	5.000	0.000	143.000	0.000	0.000	0.000
7	0.000	0.000	0.000	2.000	0.000	0.000	78.000	0.000	0.000
8	6.000	0.000	0.000	6.000	1.000	0.000	0.000	233.000	0.000
9	3.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000	198.000

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




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



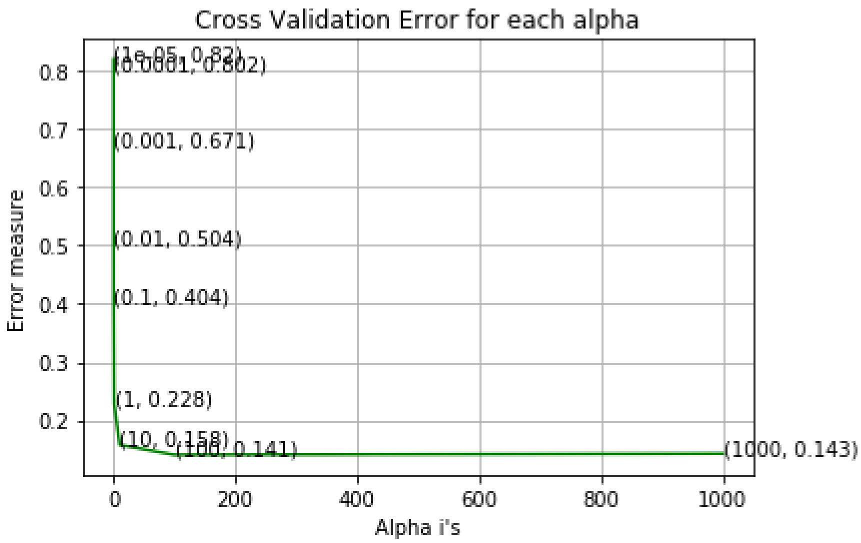

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.3. Logistic Regression

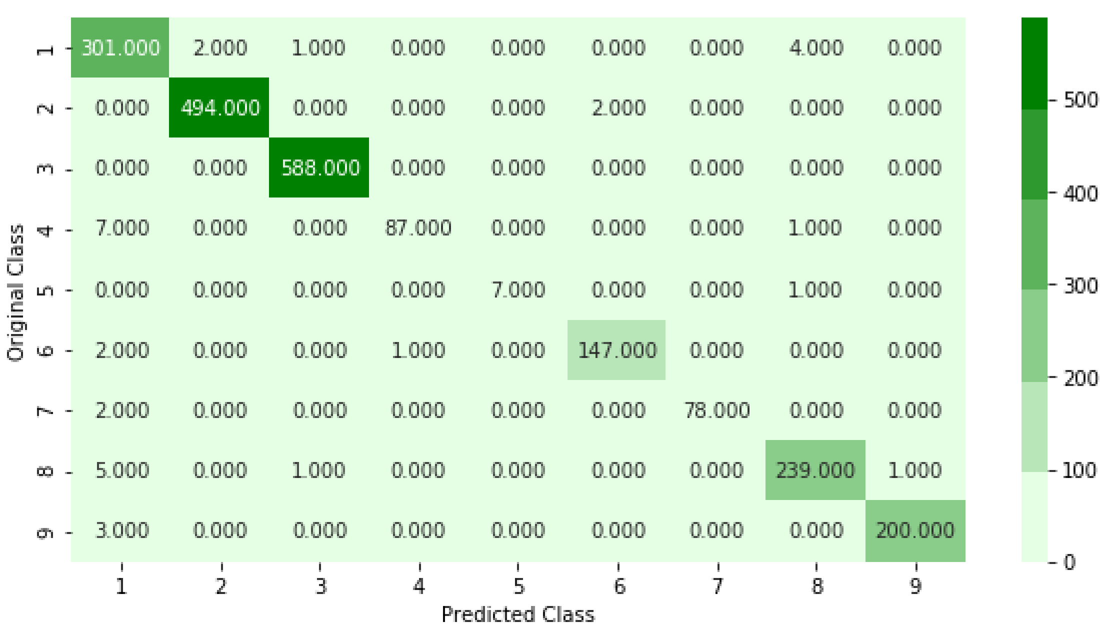
In [84]:
```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_iter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

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

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

alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
    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=logisticR.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()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='balanced')
logisticR.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid",cv=3)
sig_clf.fit(X_train, y_train)
pred_y=sig_clf.predict(X_test)

predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, eps=1e-15))
```

```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.class
es_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.c
lasses_, eps=1e-15))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  1e-05 is 0.8196899363900952
log_loss for c =  0.0001 is 0.8020264925412575
log_loss for c =  0.001 is 0.6713181766563318
log_loss for c =  0.01 is 0.503761635232317
log_loss for c =  0.1 is 0.4035232845725124
log_loss for c =  1 is 0.2281691266442353
log_loss for c =  10 is 0.157771342004538
log_loss for c =  100 is 0.1405495639371003
log_loss for c =  1000 is 0.14268905814004948
```

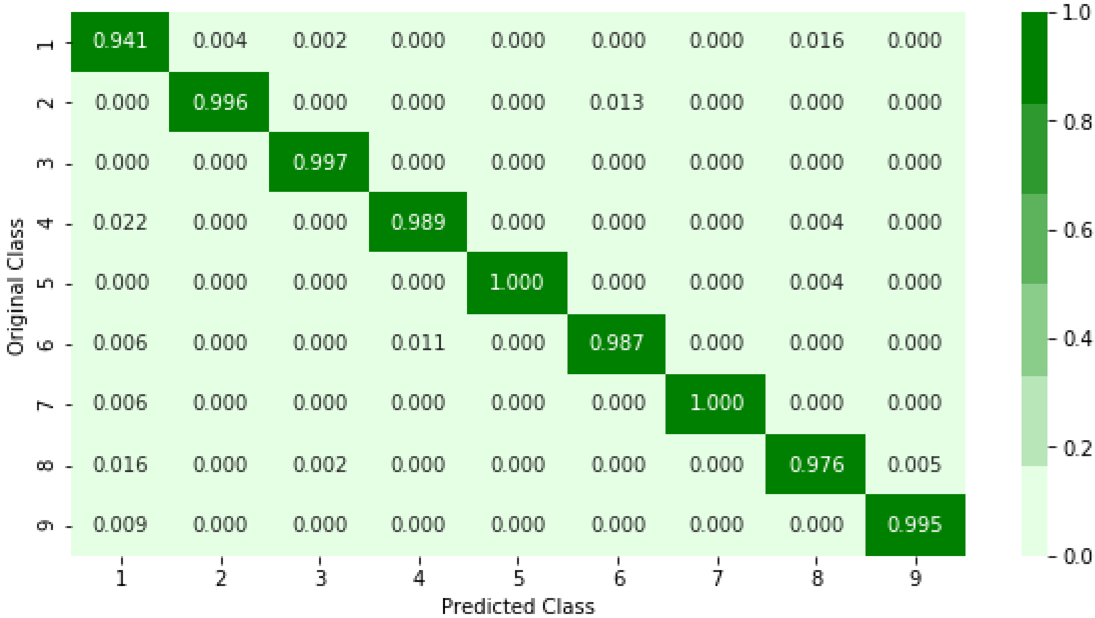



```
log loss for train data 0.11284165997114552
log loss for cv data 0.1405495639371003
log loss for test data 0.12969790479813978
Number of misclassified points  1.517939282428703
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```

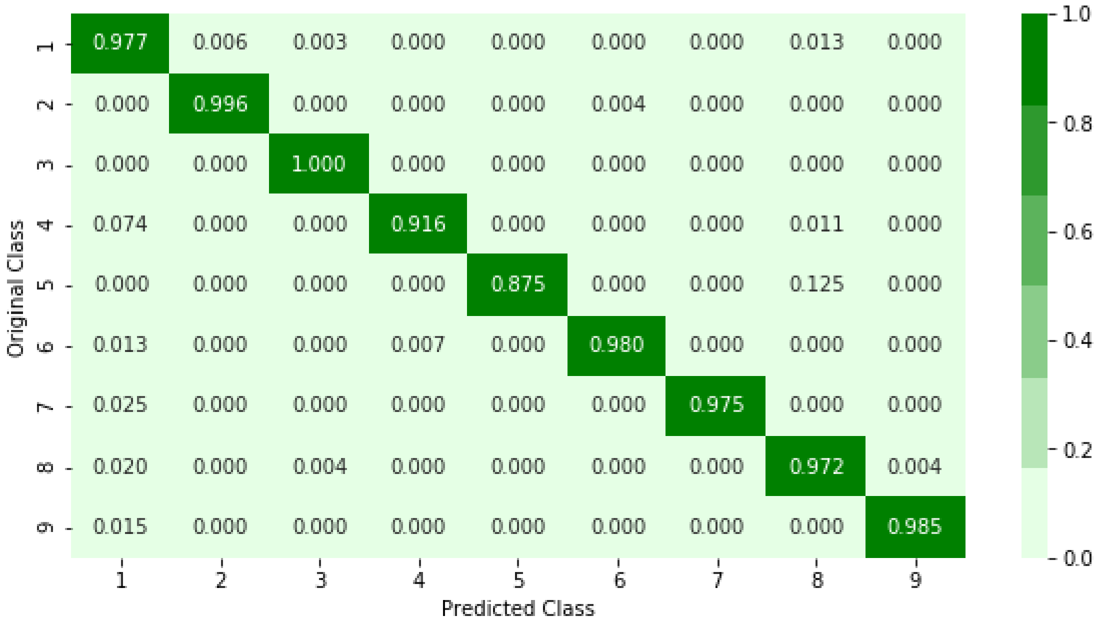


Original \ Predicted	1	2	3	4	5	6	7	8	9
1	301.000	2.000	1.000	0.000	0.000	0.000	0.000	4.000	0.000
2	0.000	494.000	0.000	0.000	0.000	2.000	0.000	0.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	7.000	0.000	0.000	87.000	0.000	0.000	0.000	1.000	0.000
5	0.000	0.000	0.000	0.000	7.000	0.000	0.000	1.000	0.000
6	2.000	0.000	0.000	1.000	0.000	147.000	0.000	0.000	0.000
7	2.000	0.000	0.000	0.000	0.000	0.000	78.000	0.000	0.000
8	5.000	0.000	1.000	0.000	0.000	0.000	0.000	239.000	1.000
9	3.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	200.000

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




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



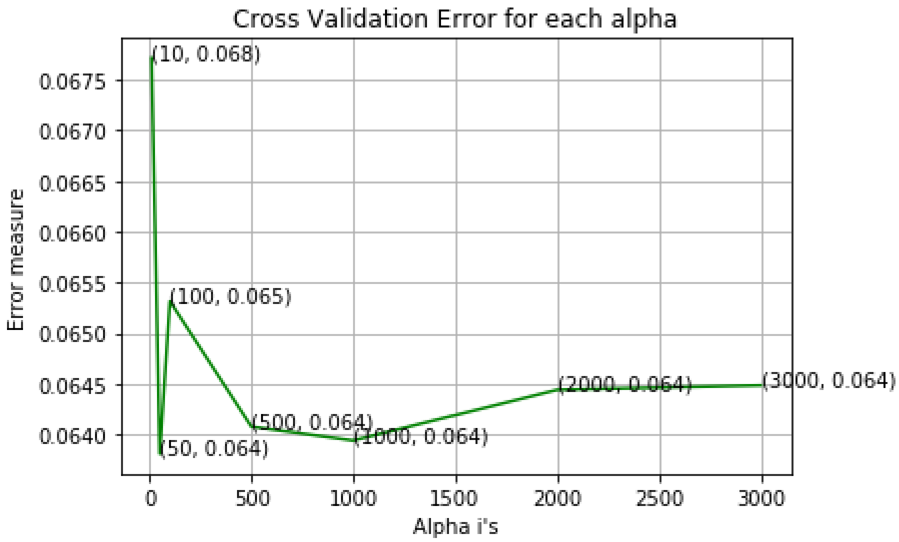

```
Sum of rows in precision matrix [1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

4.1.4. Random Forest Classifier

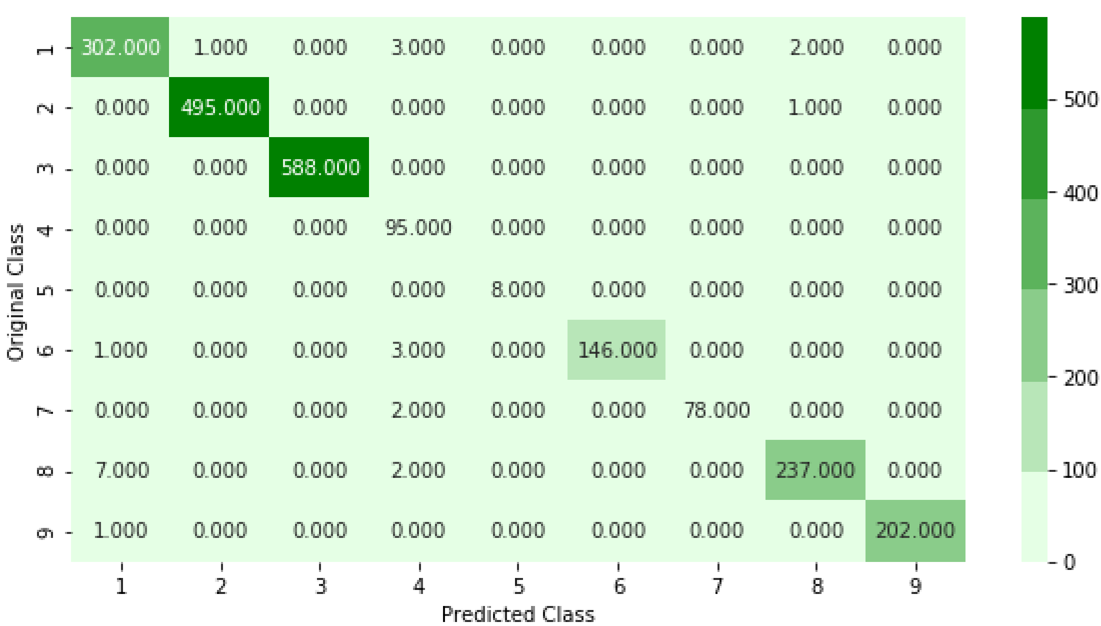
In [85]:
```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', m
ax_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_l
eaf_nodes=None, min_impurity_decrease=0.0,
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_s
tate=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 train
ing 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

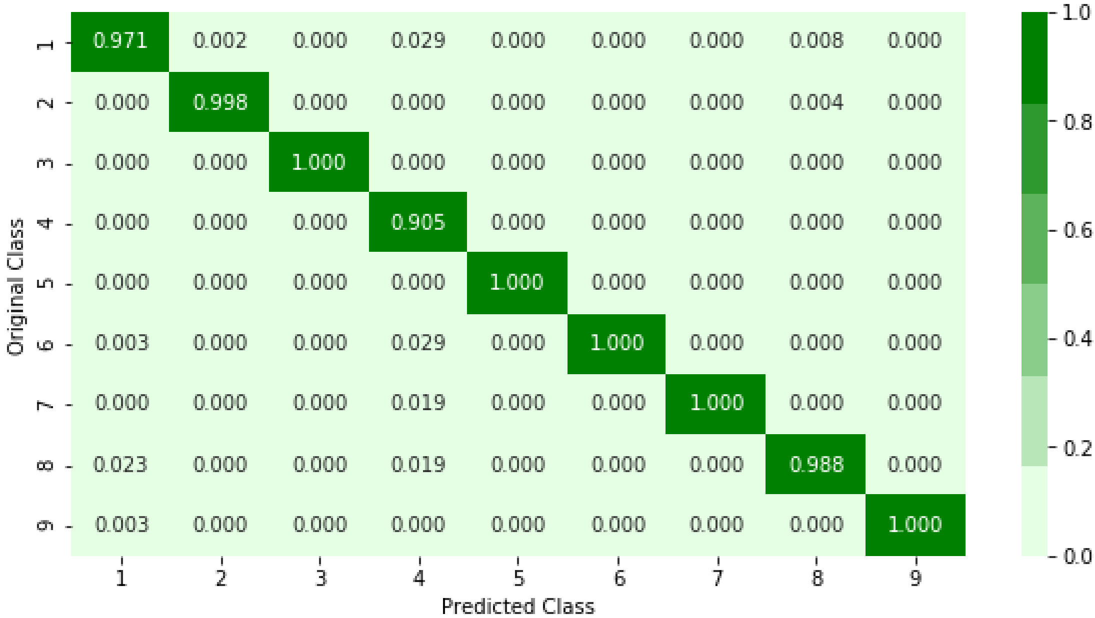
```
log_loss for c =  10 is 0.06771726879837035
log_loss for c =  50 is 0.06380559237406035
log_loss for c =  100 is 0.06531590546650978
log_loss for c =  500 is 0.06407506666674595
log_loss for c =  1000 is 0.06393791946780773
log_loss for c =  2000 is 0.06443916266165282
log_loss for c =  3000 is 0.06448353860059373
```



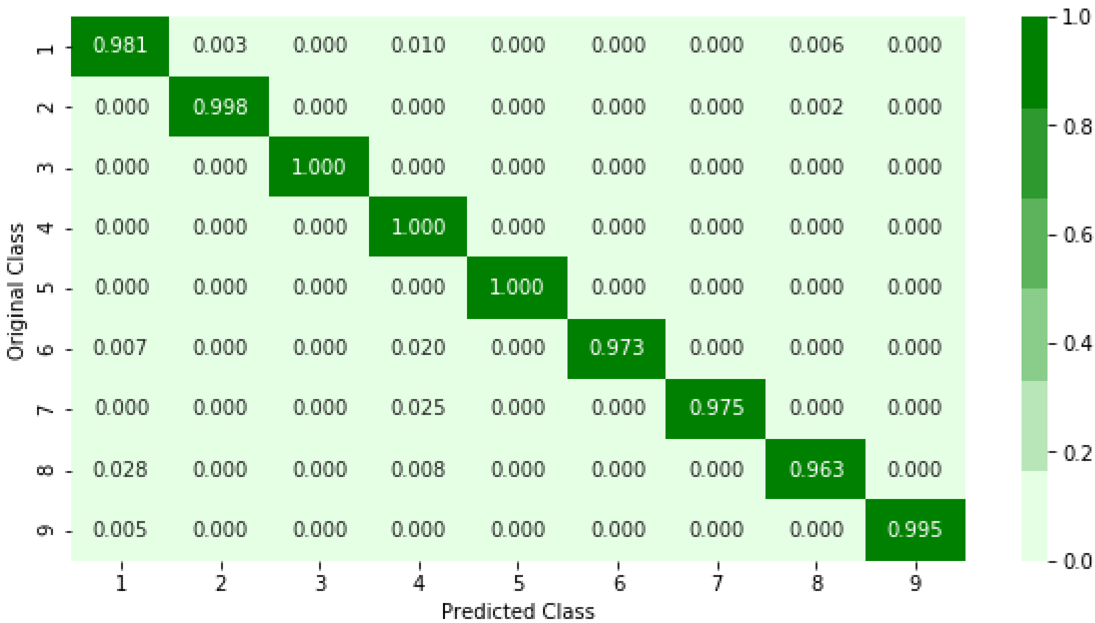

```
For values of best alpha =  50 The train log loss is: 0.0283935796383184
For values of best alpha =  50 The cross validation log loss is: 0.0638055923
7406035
For values of best alpha =  50 The test log loss is: 0.0509767311310544
Number of misclassified points  1.0579576816927323
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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




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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [86]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:  1.4min remaining: 12.2
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed:  2.0min remaining:  6.6
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  3.6min remaining:  6.2
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  7.0min remaining:  7.0
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  9.7min remaining:  5.6
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 10.0min remaining:  3.1
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 15.9min remaining:  1.8
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 17.5min finished
```

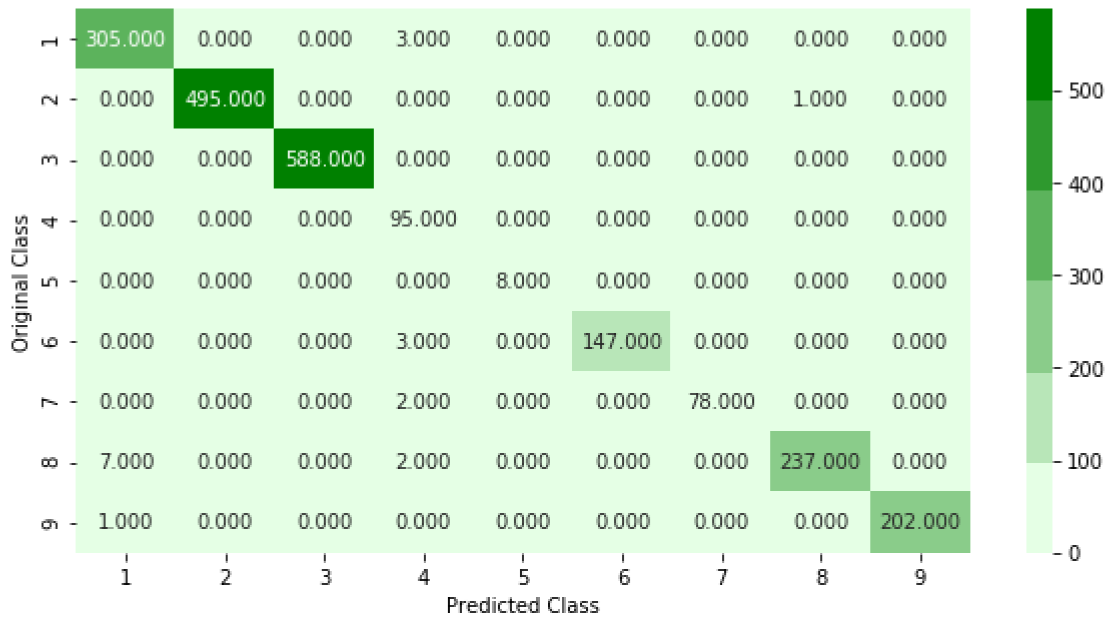
Out[86]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

In [88]:
```
print (random_cfl1.best_params_)
```

```
{'max_depth': 5, 'learning_rate': 0.1, 'subsample': 0.3, 'n_estimators': 100
0, 'colsample_bytree': 0.1}
```

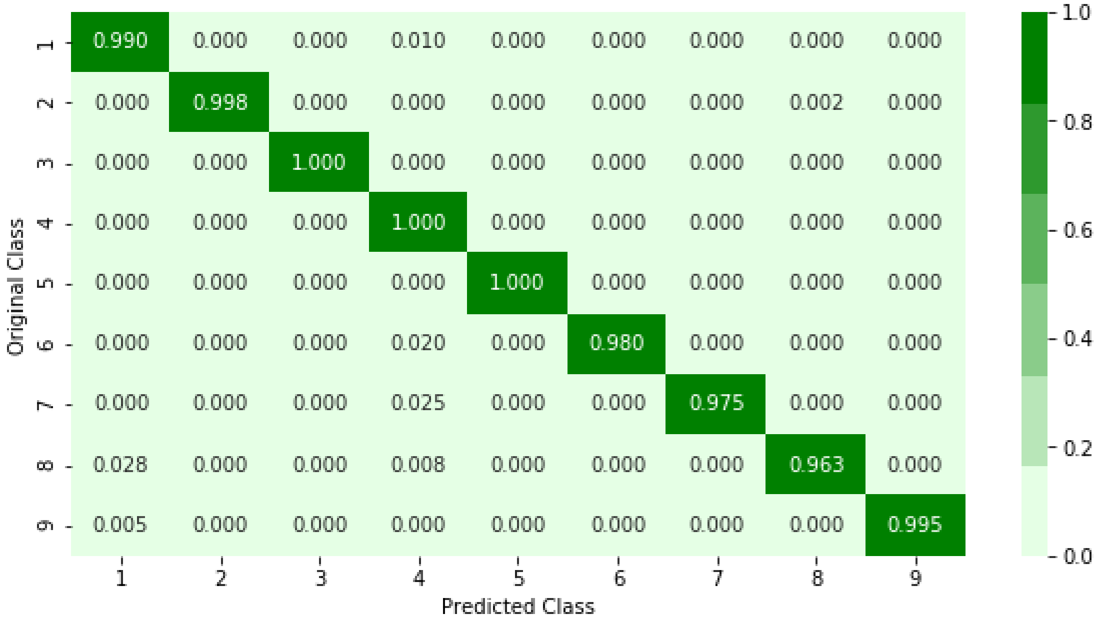
In [89]:
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 1000, co
lsample_bytree= 0.1, max_depth= 5,n_jobs=-1,verbose=1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.026067096568778484
cv loss 0.0617486470212045
test loss 0.04639167793516503
Number of misclassified points  0.8739650413983441
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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


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




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

In [ ]:

With asm and byte unigrams, byte bigrams(1000), image features(500), entropy, opcode bigrams(300), opcode trigrams(700)

Byte unigrams

In [1]:
```
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
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 random as r
from xgboost import XGBClassifier
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
# matplotlib.use(u'nbAgg')
# %matplotib inline
```

In [2]:
```
from tqdm import tqdm
from tqdm import tqdm_notebook as tqdm1
import scipy
```

In [3]:
```
# byte_unigram_df.to_csv('byte_unigram_df.csv',index=False)
byte_unigram_df = pd.read_csv('byte_unigram_df.csv')
byte_unigram_df.drop(['size'],axis=1,inplace=True)
byte_unigram_df.head()
```

Out[3]:

	Unnamed: 0	ID	0	1	2	3	4	
0	0.000000	01azqd4InC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048	0.001
1	0.000092	01IsoiSMh5gxyDYTl4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003
2	0.000184	01jsnpXSAlgw6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005
3	0.000276	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000

5 rows × 260 columns

Asm unigrams

In [4]:
```
# asm_unigram_df.to_csv('asm_unigram_df.csv',index=False)
asm_unigram_df = pd.read_csv('asm_unigram_df.csv')
asm_unigram_df.drop(['size'],axis=1,inplace=True)
asm_unigram_df.head()
```

Out[4]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

5 rows × 53 columns

Byte bigrams 1000 features

In [5]:
```
bytebigram1000_df = pd.read_csv('bytebigram_final_rf_reduced_df')
bytebigram1000_df.drop(['size'],axis=1,inplace=True)
bytebigram1000_df.head()
```

Out[5]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1002 columns

Asm image 500 features

In [6]:
```
# final_result_asm.to_csv('asm_img_final_rf_reduced_df',index=False)
```

In [7]:
```
asm500_df = pd.read_csv('asm_img_final_rf_reduced_df')
asm500_df.drop(['size'],axis=1,inplace=True)
asm500_df.head()
```

Out[7]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10
0	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
1	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
2	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
3	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778
4	0.481928	0.481928	0.481928	0.302632	0.302632	0.302632	0.0	0.0	0.0	0.277778

5 rows × 502 columns

Entropy

In [8]:
```
# final_entropy_df.to_csv('final_entropy_df.csv',index=False)
```

In [9]:
```
final_entropy_df = pd.read_csv('final_entropy_df.csv')
```

In [10]:
```
final_entropy_df.head()
```

Out[10]:

	ID	entropy
0	GhHS0zL9cgNXFK6j1dlJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	lHiArX1xcBZgv69o4s0a	0.633535

Opcode Bigrams

In [11]:
```
# final_opcodebigram_df.to_csv('opcodebigram_final_rf_reduced_df.csv',index=Fa
lse)
```

In [12]:
```
final_opcodebigram_df = pd.read_csv('opcodebigram_final_rf_reduced_df.csv')
final_opcodebigram_df.drop(['size'],axis=1,inplace=True)
final_opcodebigram_df.head()
```

Out[12]:

	retn push	lea mov	add pop	mov lea	dec sub	call cmp	call add	jz mov	cmp mov	
0	0.018566	0.008112	0.003616	0.005119	0.001795	0.009737	0.005154	0.011867	0.017688	0.(
1	0.000000	0.000484	0.033143	0.000091	0.000000	0.000000	0.005545	0.000000	0.000126	0.(
2	0.000000	0.000605	0.033143	0.000000	0.000000	0.000000	0.005480	0.000000	0.000253	0.(
3	0.000151	0.000363	0.026815	0.000091	0.000000	0.000000	0.004632	0.000089	0.000126	0.(
4	0.000000	0.000121	0.002410	0.000000	0.000000	0.000348	0.000065	0.000000	0.000126	0.(

5 rows × 302 columns

Opcode Trigrams

In [13]:
```
# final_opcodetrigram_df.to_csv('opcodetrigram_final_rf_reduced_df.csv',index=
False)
```

In [14]:
```
final_opcodetrigram_df = pd.read_csv('opcodetrigram_final_rf_reduced_df.csv')
final_opcodetrigram_df.drop(['size'],axis=1,inplace=True)
final_opcodetrigram_df.head()
```

Out[14]:

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	mov mov mov	pop lea sub	mov jmp mov	mov pop pop	.
0	0.012821	0.002126	0.002772	0.0	0.017045	0.004888	0.005571	0.0	0.004736	0.009377	.
1	0.307692	0.030120	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
2	0.320513	0.029766	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
3	0.230769	0.025159	0.000000	0.0	0.000000	0.031425	0.000028	0.0	0.000000	0.000000	.
4	0.000000	0.000000	0.000308	0.0	0.000000	0.000000	0.000014	0.0	0.000000	0.000000	.

5 rows × 702 columns

First we'll merge Byte unigrams and asm unigrams

In [26]:
```
asm_unigram_df.rename(columns={'Class':'Class_y'}, inplace=True)
unigrams_combined_df = pd.merge(byte_unigram_df, asm_unigram_df,on='ID', how=
'left')
df1 = unigrams_combined_df.pop('ID') # remove column ID and store it in df1
unigrams_combined_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = unigrams_combined_df.pop('Class') # remove column ID and store it in df1
unigrams_combined_df['Class']=df2 # add ID series as a 'new' column in the las
t.
unigrams_combined_df.drop(['Class_y'],axis=1,inplace=True)
unigrams_combined_df.head()
```

Out[26]:

	Unnamed: 0	0	1	2	3	4	5	6	7	
0	0.000000	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.002058	0.002946	(
1	0.000092	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984	(
2	0.000184	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155	(
3	0.000276	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481	(
4	0.000368	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229	(

5 rows × 311 columns

Now we'll combine Byte bigrams 1000 features and image 500 features

In [27]:
```
asm500_df.rename(columns={'Class':'Class_y'}, inplace=True)
bigrams_image_combined_df = pd.merge(bytebigram1000_df, asm500_df,on='ID', how
='left')
df1 = bigrams_image_combined_df.pop('ID') # remove column ID and store it in d
f1
bigrams_image_combined_df['ID']=df1 # add ID series as a 'new' column in the l
ast.
df2 = bigrams_image_combined_df.pop('Class') # remove column ID and store it i
n df1
bigrams_image_combined_df['Class']=df2 # add ID series as a 'new' column in th
e last.
bigrams_image_combined_df.drop(['Class_y'],axis=1,inplace=True)
bigrams_image_combined_df.head()
```

Out[27]:

	98 87	f1 b3	ae ef	19 ce	fb 9e	a7 16	d5 e1	87 f5	f5 bb	
0	0.000000	0.000000	0.002976	0.000000	0.002577	0.000000	0.000000	0.000000	0.000000	0.(
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000	0.(
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393	0.(
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000	0.(
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577	0.(

5 rows × 1502 columns

Now we'll combine Entropy , Opcode bygrams , Opcode trigrams

In [28]:

```
entropy_opcodebigram_combined_df = pd.merge(final_entropy_df, final_opcodebigr
am_df,on='ID', how='left')
df1 = entropy_opcodebigram_combined_df.pop('ID') # remove column ID and store
 it in df1
entropy_opcodebigram_combined_df['ID']=df1 # add ID series as a 'new' column i
n the last.
df2 = entropy_opcodebigram_combined_df.pop('Class') # remove column ID and sto
re it in df1
entropy_opcodebigram_combined_df['Class']=df2 # add ID series as a 'new' colum
n in the last.
df3 = entropy_opcodebigram_combined_df.pop('entropy') # remove column ID and s
tore it in df1
entropy_opcodebigram_combined_df['entropy']=df3 # add ID series as a 'new' col
umn in the last.
entropy_opcodebigram_combined_df.head()
```

Out[28]:

	retn push	lea mov	add pop	mov lea	dec sub	call cmp	call add	jz mov	cmp mov	
0	0.002868	0.000121	0.000301	0.000457	0.000000	0.000174	0.001435	0.005756	0.008844	0.(
1	0.000755	0.000605	0.000301	0.001280	0.000000	0.001391	0.001370	0.000974	0.004422	0.(
2	0.000151	0.000484	0.045194	0.000091	0.000000	0.000000	0.008742	0.000000	0.000000	0.(
3	0.125132	0.367841	0.124435	0.293811	0.017953	0.047644	0.158077	0.185618	0.609097	0.:
4	0.000151	0.000848	0.020789	0.000000	0.000000	0.000000	0.003523	0.000000	0.000000	0.(

5 rows × 303 columns

In [29]:
```
entropy_opcodebigram_combined_df.rename(columns={'Class':'Class_y'}, inplace=T
rue)
entropy_opbi_optri_combined_df = pd.merge(final_opcodetrigram_df, entropy_opco
debigram_combined_df,on='ID', how='left')
df1 = entropy_opbi_optri_combined_df.pop('ID') # remove column ID and store it
in df1
entropy_opbi_optri_combined_df['ID']=df1 # add ID series as a 'new' column in
 the last.
df2 = entropy_opbi_optri_combined_df.pop('Class') # remove column ID and store
it in df1
entropy_opbi_optri_combined_df['Class']=df2 # add ID series as a 'new' column
 in the last.
entropy_opbi_optri_combined_df.drop(['Class_y'],axis=1,inplace=True)
entropy_opbi_optri_combined_df.head()
```

Out[29]:

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	mov mov mov	pop lea sub	mov jmp mov	mov pop pop	.
0	0.012821	0.002126	0.002772	0.0	0.017045	0.004888	0.005571	0.0	0.004736	0.009377	.
1	0.307692	0.030120	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
2	0.320513	0.029766	0.000154	0.0	0.000000	0.038408	0.000000	0.0	0.000000	0.000000	.
3	0.230769	0.025159	0.000000	0.0	0.000000	0.031425	0.000028	0.0	0.000000	0.000000	.
4	0.000000	0.000000	0.000308	0.0	0.000000	0.000000	0.000014	0.0	0.000000	0.000000	.

5 rows × 1003 columns

Now we'll merge unigrams_combined_df, bigrams_image_combined_df

In [31]:
```
unigrams_combined_df.rename(columns={'Class':'Class_y'}, inplace=True)
unigrams_bigrams_image_combined_df = pd.merge(unigrams_combined_df, bigrams_im
age_combined_df,on='ID', how='left')
df1 = unigrams_bigrams_image_combined_df.pop('ID') # remove column ID and stor
e it in df1
unigrams_bigrams_image_combined_df['ID']=df1 # add ID series as a 'new' column
in the last.
df2 = unigrams_bigrams_image_combined_df.pop('Class_y') # remove column ID and
store it in df1
unigrams_bigrams_image_combined_df['Class_y']=df2 # add ID series as a 'new' c
olumn in the last.
df3 = unigrams_bigrams_image_combined_df.pop('Class') # remove column ID and s
tore it in df1
unigrams_bigrams_image_combined_df['Class']=df3 # add ID series as a 'new' col
umn in the last.
unigrams_bigrams_image_combined_df.drop(['Class_y'],axis=1,inplace=True)
unigrams_bigrams_image_combined_df.head()
```

Out[31]:

	Unnamed: 0	0	1	2	3	4	5	6	7	
0	0.000000	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.002058	0.002946	0
1	0.000092	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984	0
2	0.000184	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155	0
3	0.000276	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481	0
4	0.000368	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229	0

5 rows × 1811 columns

Now finally we merge the remaining df's to get the final df i.e unigrams_bigrams_image_combined_df and entropy_opbi_optri_combined_df

In [33]:

```
unigrams_bigrams_image_combined_df.rename(columns={'Class':'Class_y'}, inplace
=True)
final_all_combined_df = pd.merge(unigrams_bigrams_image_combined_df, entropy_o
pbi_optri_combined_df,on='ID', how='left')
df1 = final_all_combined_df.pop('ID') # remove column ID and store it in df1
final_all_combined_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = final_all_combined_df.pop('Class_y') # remove column ID and store it in
 df1
final_all_combined_df['Class_y']=df2 # add ID series as a 'new' column in the
 last.
df3 = final_all_combined_df.pop('Class') # remove column ID and store it in df
1
final_all_combined_df['Class']=df3 # add ID series as a 'new' column in the la
st.
df4 = final_all_combined_df.pop('entropy') # remove column ID and store it in
 df1
final_all_combined_df['entropy']=df4 # add ID series as a 'new' column in the
 last.
final_all_combined_df.drop(['Class_y'],axis=1,inplace=True)
final_all_combined_df.head()
```

Out[33]:

	Unnamed: 0	0	1	2	3	4	5	6	7
0	0.000000	0.262806	0.005498	0.001567	0.002067	0.002048	0.001835	0.002058	0.002946
1	0.000092	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984
2	0.000184	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155
3	0.000276	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481
4	0.000368	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229

5 rows × 2812 columns

In [34]:

```
# final_all_combined_df.to_csv('final_all_combined_df.csv',index=False)
```

In [3]:

```
final_all_combined_df = pd.read_csv('final_all_combined_df.csv')
```

In [4]:

```
final_all_combined_df.columns[final_all_combined_df.isna().any()].tolist()
```

Out[4]:

```
['.BSS:', '.CODE', 'rtn']
```

In [5]:

```
final_all_combined_df.drop(['.BSS:','.CODE','rtn'],axis=1,inplace=True)
```

In [6]:

```
final_all_combined_df.columns[final_all_combined_df.isna().any()].tolist()
```

Out[6]:

```
[]
```

In [7]:

```
final_all_combined_df.isnull().values.any()
```

Out[7]:

```
False
```

Train Test split

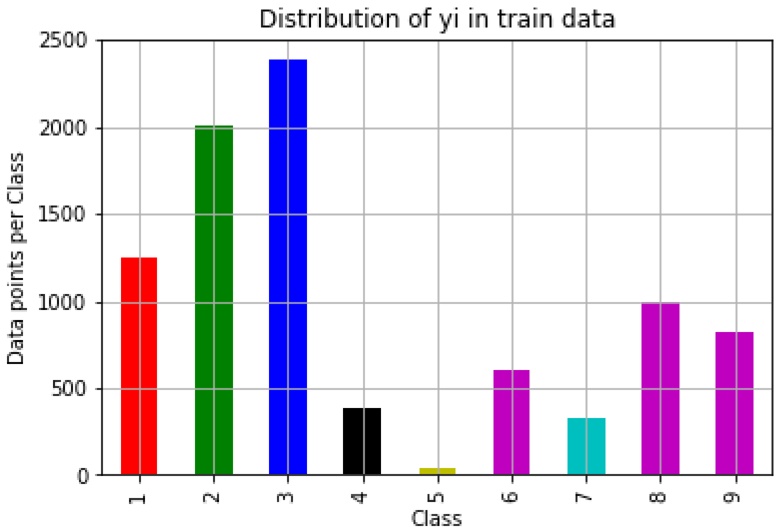
In [45]:
```
data_y = final_all_combined_df['Class']
# split the data into test and train by maintaining same distribution of outpu
t varaible 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_all_combined_df.drop
(['ID','Class'], axis=1), data_y,stratify=data_y,test_size=0.10)
# split the train data into train and cross validation by maintaining same dis
tribution of output varaible 'y_train' [stratify=y_train]
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_tr
ain,test_size=0.10)
```

In [46]:
```
print('Number of data points in train data:', X_train.shape)
print('Number of data points in test data:', X_test.shape)
print('Number of data points in cross validation data:', X_cv.shape)
```

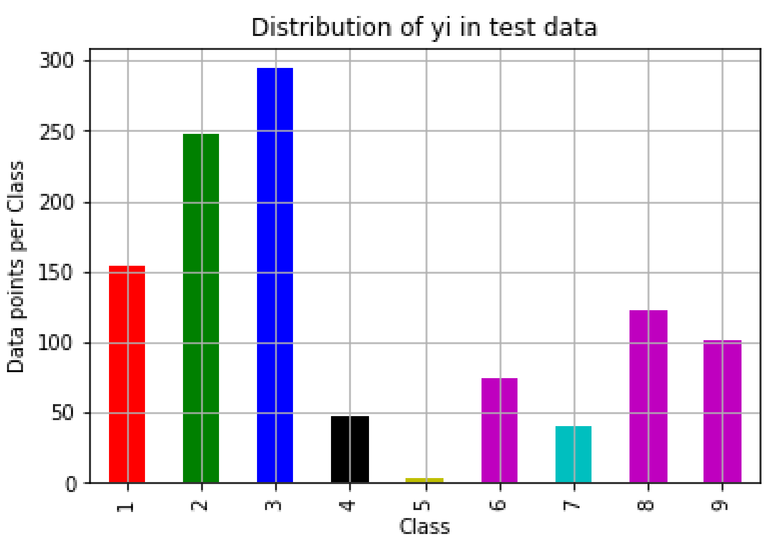
```
Number of data points in train data: (8802, 2807)
Number of data points in test data: (1087, 2807)
Number of data points in cross validation data: (979, 2807)
```

In [47]:
```
# it returns a dict, keys as class labels and values as the number of data poi
nts in that class
train_class_distribution = y_train.value_counts().sort_index()
test_class_distribution = y_test.value_counts().sort_index()
cv_class_distribution = y_cv.value_counts().sort_index()

# my_colors = 'rgbkymc'
my_colors = ['r','g','b','k','y','m','c','m','m']
train_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in train data')
plt.grid()
plt.show()

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


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

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

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

# ref: argsort https://docs.scipy.org/doc/numpy/reference/generated/numpy.args
ort.html
```

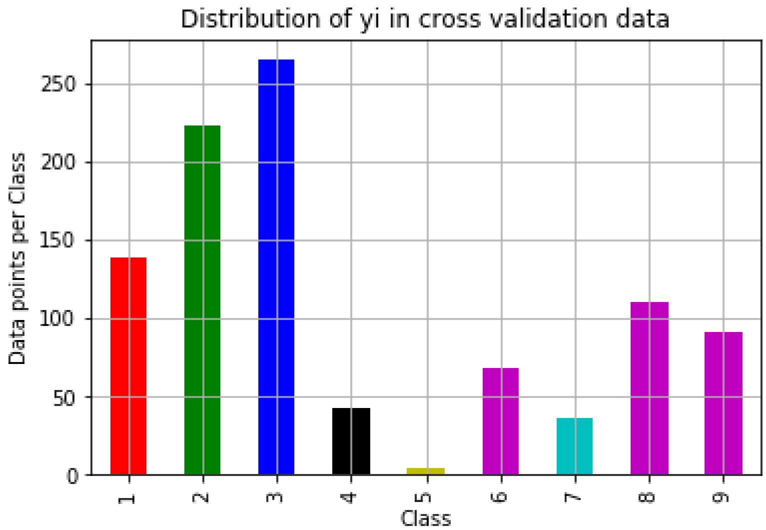
```
# -(train_class_distribution.values): the minus sign will give us in decreasin
g order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':',cv_class_distribution.val
ues[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0]*100), 3),
'%)')
```




```
Number of data points in class 3 : 2383 ( 27.073 %)
Number of data points in class 2 : 2007 ( 22.802 %)
Number of data points in class 1 : 1248 ( 14.179 %)
Number of data points in class 8 : 995 ( 11.304 %)
Number of data points in class 9 : 821 ( 9.327 %)
Number of data points in class 6 : 608 ( 6.908 %)
Number of data points in class 4 : 384 ( 4.363 %)
Number of data points in class 7 : 322 ( 3.658 %)
Number of data points in class 5 : 34 ( 0.386 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 294 ( 27.047 %)
Number of data points in class 2 : 248 ( 22.815 %)
Number of data points in class 1 : 154 ( 14.167 %)
Number of data points in class 8 : 123 ( 11.316 %)
Number of data points in class 9 : 101 ( 9.292 %)
Number of data points in class 6 : 75 ( 6.9 %)
Number of data points in class 4 : 48 ( 4.416 %)
Number of data points in class 7 : 40 ( 3.68 %)
Number of data points in class 5 : 4 ( 0.368 %)
-----------------------------------------------------------------------------
---
```




```
Number of data points in class 3 : 265 ( 27.068 %)
Number of data points in class 2 : 223 ( 22.778 %)
Number of data points in class 1 : 139 ( 14.198 %)
Number of data points in class 8 : 110 ( 11.236 %)
Number of data points in class 9 : 91 ( 9.295 %)
Number of data points in class 6 : 68 ( 6.946 %)
Number of data points in class 4 : 43 ( 4.392 %)
Number of data points in class 7 : 36 ( 3.677 %)
Number of data points in class 5 : 4 ( 0.409 %)
```

In [48]:
```
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 a
re predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in th
at 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 th
at 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, ytick
labels=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, ytick
labels=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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

4. Machine Learning Models

4.1. Machine Leaning Models on bytes bigrams features

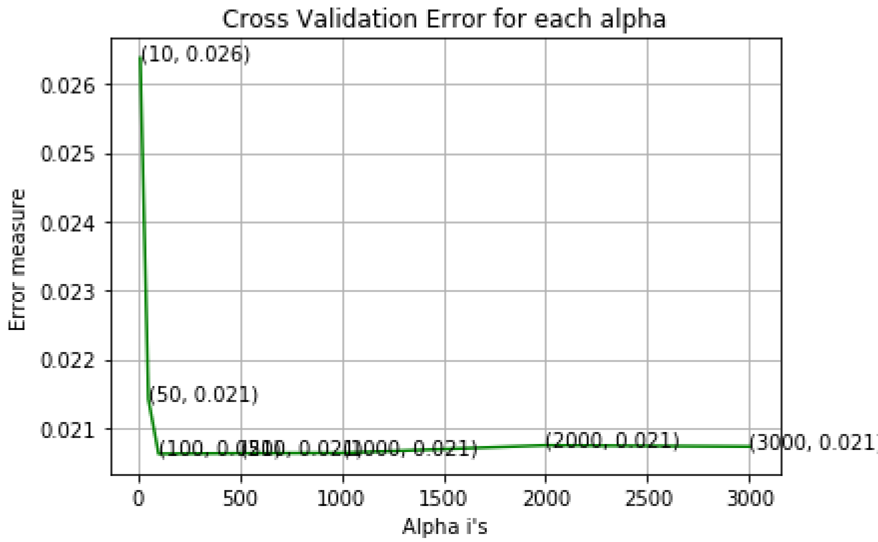
In [49]:
```
# # import warnings filter
# from warnings import simplefilter
# # ignore all future warnings
# simplefilter(action='ignore', category=FutureWarning)

# import warnings filter
from warnings import simplefilter
# ignore all future warnings
simplefilter(action='ignore', category=FutureWarning)
```

4.1.4. Random Forest Classifier

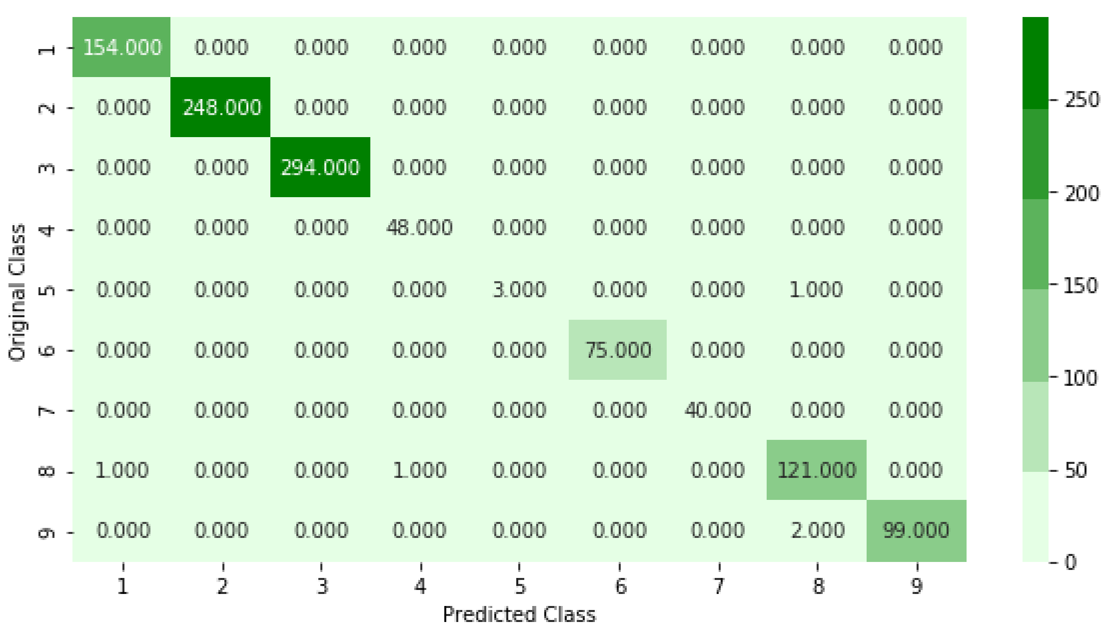
In [50]:
```
# ----------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None, min_samples_split=2,
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0,
# 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=[]
from sklearn.ensemble import RandomForestClassifier
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))

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 i
s:",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 i
s:",log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

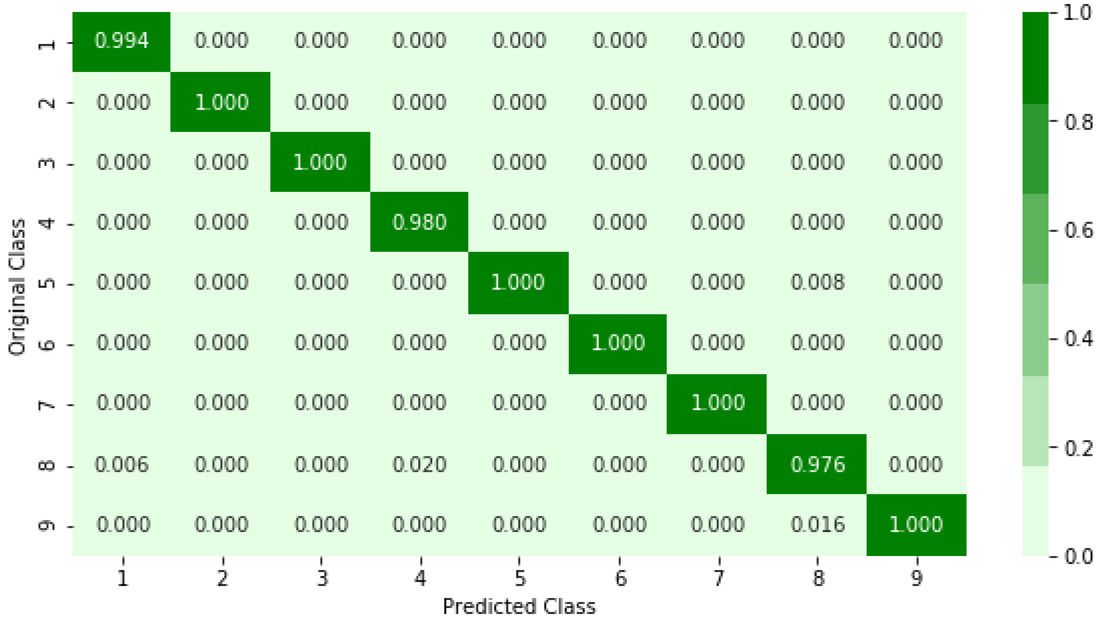
```
log_loss for c =  10 is 0.026381106113884268
log_loss for c =  50 is 0.021414120408190428
log_loss for c =  100 is 0.020619472025640306
log_loss for c =  500 is 0.020627750337120363
log_loss for c =  1000 is 0.0206319812610034
log_loss for c =  2000 is 0.020743919102657035
log_loss for c =  3000 is 0.0207256949640951
```




```
For values of best alpha =  100 The train log loss is: 0.011049375927013985
For values of best alpha =  100 The cross validation log loss is: 0.020619472
025640306
For values of best alpha =  100 The test log loss is: 0.019597358899095856
Number of misclassified points  0.45998160073597055
-------------------------------------------------- Confusion matrix ---------
-----------------------------------------
```




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




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


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

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [73]:
```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning
-xgboost-with-codes-python/
x_cfl=XGBClassifier()

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],
    '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,n_jo
bs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 16 concurrent workers.
[Parallel(n_jobs=-1)]: Done   3 out of  30 | elapsed:  2.0min remaining: 18.1
min
[Parallel(n_jobs=-1)]: Done   7 out of  30 | elapsed: 12.6min remaining: 41.5
min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed: 17.9min remaining: 31.0
min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed: 21.5min remaining: 21.5
min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed: 23.1min remaining: 13.4
min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 25.4min remaining:  7.7
min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 35.3min remaining:  3.9
min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 64.5min finished
```

Out[73]:
```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=0, reg_al...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=10, n_jobs=-1,
                   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, 1000,
                                                         2000],
                                        'subsample': [0.1, 0.3, 0.5, 1]},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring=None, verbose=10)
```

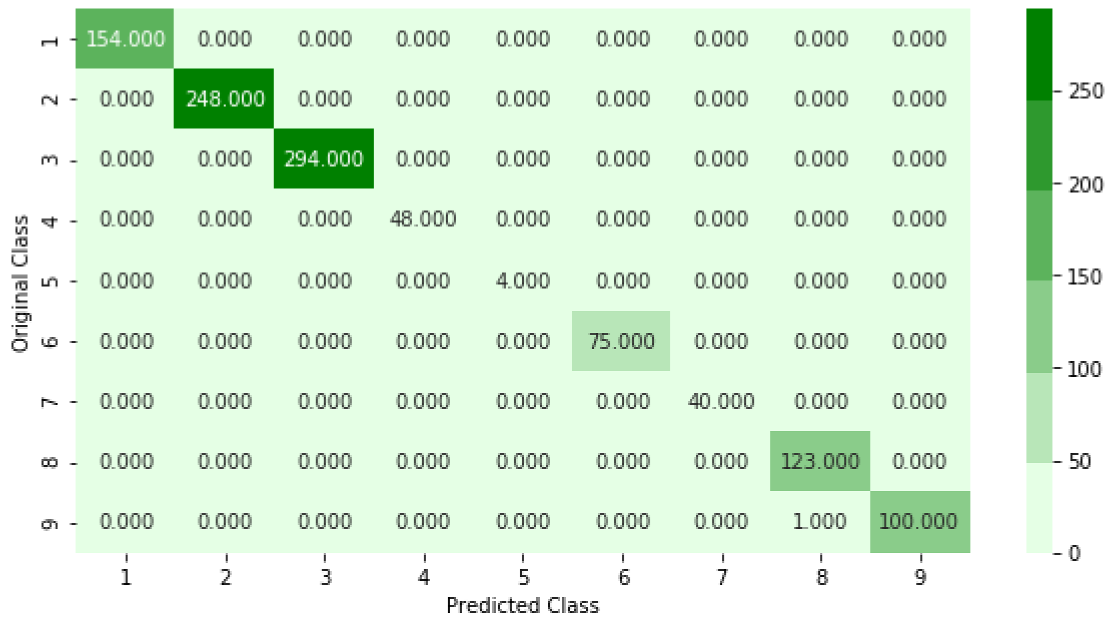
In [75]:
```
print (random_cfl1.best_params_)
```

```
{'learning_rate': 0.2, 'max_depth': 10, 'colsample_bytree': 0.5, 'subsample':
1, 'n_estimators': 2000}
```

In [51]:

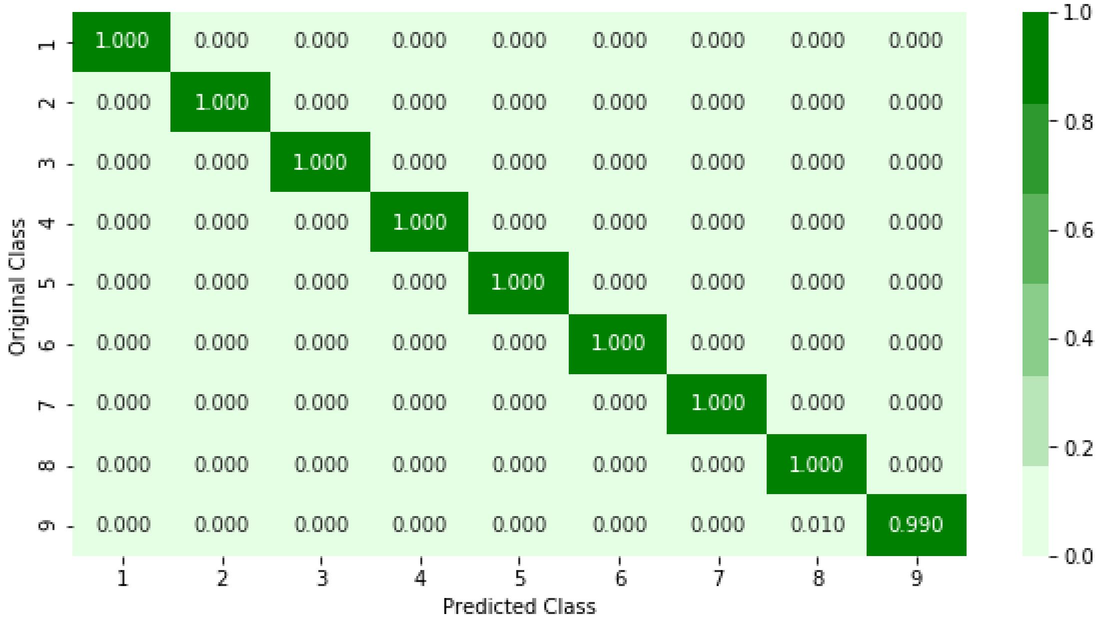
```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/e
n/latest/python/python_api.html?#xgboost.XGBClassifier
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=10
0, 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_stoppin
g_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-onlin
e/lessons/what-are-ensembles/
# -----------------------

x_cfl=XGBClassifier(learning_rate= 0.2, subsample= 1, n_estimators= 2000, cols
ample_bytree= 0.5, max_depth= 10,n_jobs=-1,verbose=1)
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))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

```
train loss 0.009010185109170987
cv loss 0.018041522950192696
test loss 0.012365238971620807
Number of misclassified points  0.09199632014719411
-------------------------------------------------- Confusion matrix ---------
----------------------------------------
```




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


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




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

Results(Pretty Table)

In [3]:
```
from prettytable import PrettyTable
x = PrettyTable()
x.field_names = [ "Model", "Features" , "Test log-loss"]
x.add_row([ "Knn","{Byte bigrams(1000)}", 0.187])
x.add_row([ "LR", "{Byte bigrams(1000)}", 0.200])
x.add_row([ "RF", "{Byte bigrams(1000)}", 0.036])
x.add_row([ "XGBoost", "{Byte bigrams(1000)}", 0.071])
x.add_row([ "XGBoost(Hypertuned)", "{Byte bigrams(1000)}", 0.041])
x.add_row([ "", "", ""])
x.add_row([ "RF", "{Byte trigrams(1000)}", 0.043])
x.add_row([ "XGBoost(Hypertuned)", "{Byte trigrams(1000)}", 0.037])
x.add_row([ "", "", ""])
x.add_row([ "RF", "{Byte bigrams(1000) and trigrams(1000)}", 0.039])
x.add_row([ "XGBoost(Hypertuned)", "{Byte bigrams(1000) and trigrams(1000)}",
0.034])
x.add_row([ "", "", ""])
x.add_row([ "RF", "{ASM image features(500)}", 0.483])
x.add_row([ "XGBoost(Hypertuned)", "{ASM image features(500)}", 0.431])
x.add_row([ "", "", ""])
x.add_row([ "RF", "{ASM image features(500)+byte bigrams(1000)+byte trigrams(1
000)}", 0.034])
x.add_row([ "XGBoost(Hypertuned)", "{ASM image features(500)+byte bigrams(100
0)+byte trigrams(1000)}", 0.037])
x.add_row([ "", "", ""])
x.add_row([ "Knn","{Opcode bigrams(300)}", 0.112])
x.add_row([ "LR", "{Opcode bigrams(300)}", 0.227])
x.add_row([ "RF", "{Opcode bigrams(300)}", 0.044])
x.add_row([ "XGBoost(Hypertuned)", "{Opcode bigrams(300)}", 0.044])
x.add_row([ "", "", ""])
x.add_row([ "Knn","{Opcode trigrams(700)}", 0.100])
x.add_row([ "LR", "{Opcode trigrams(700)}", 0.129])
x.add_row([ "RF", "{Opcode trigrams(700)}", 0.050])
x.add_row([ "XGBoost(Hypertuned)", "{Opcode trigrams(700)}", 0.046])
x.add_row([ "", "", ""])
x.add_row([ "RF", "{asm and byte unigrams + byte bigrams(1000) + image  featur
es(500) + entropy + opcode bigrams(300) + opcode trigrams(700)}", 0.019])
x.add_row([ "XGBoost(Hypertuned)", "{asm and byte unigrams + byte bigrams(100
0) + image  features(500) + entropy + opcode bigrams(300) + opcode trigrams(70
0)}", 0.012])
print(x)
```

```
+---------------------+------------------------------------------------------
----------------------------------------------------------------------+------
---------+
|        Model        |
Features                                                              | Test log-
loss |
+---------------------+------------------------------------------------------
----------------------------------------------------------------------+------
---------+
|         Knn         |                                                    {B
yte bigrams(1000)}                                                    |
0.187     |
|          LR         |                                                    {B
yte bigrams(1000)}                                                    |
0.2       |
|          RF         |                                                    {B
yte bigrams(1000)}                                                    |
0.036     |
|       XGBoost       |                                                    {B
yte bigrams(1000)}                                                    |
0.071     |
| XGBoost(Hypertuned) |                                                    {B
yte bigrams(1000)}                                                    |
0.041     |
|                     |
|                 |
|          RF         |                                                   {By
te trigrams(1000)}                                                    |
0.043     |
| XGBoost(Hypertuned) |                                                   {By
te trigrams(1000)}                                                    |
0.037     |
|                     |
|                 |
|          RF         |                                          {Byte bigram
s(1000) and trigrams(1000)}                                           |
0.039     |
| XGBoost(Hypertuned) |                                          {Byte bigram
s(1000) and trigrams(1000)}                                           |
0.034     |
|                     |
|                 |
|          RF         |                                                  {ASM
image features(500)}                                                  |
0.483     |
| XGBoost(Hypertuned) |                                                  {ASM
image features(500)}                                                  |
0.431     |
|                     |
|                 |
|          RF         |                            {ASM image features(500)
+byte bigrams(1000)+byte trigrams(1000)}                              |
0.034     |
| XGBoost(Hypertuned) |                            {ASM image features(500)
+byte bigrams(1000)+byte trigrams(1000)}                              |
0.037     |
|                     |
```

```
|               |
|         Knn        |                                                   {Op
code bigrams(300)}                                                 |
0.112     |
|          LR        |                                                   {Op
code bigrams(300)}                                                 |
0.227     |
|          RF        |                                                   {Op
code bigrams(300)}                                                 |
0.044     |
| XGBoost(Hypertuned) |                                                  {Op
code bigrams(300)}                                                 |
0.044     |
|                    |
|               |
|         Knn        |                                                   {Op
code trigrams(700)}                                                |
0.1      |
|          LR        |                                                   {Op
code trigrams(700)}                                                |
0.129     |
|          RF        |                                                   {Op
code trigrams(700)}                                                |
0.05     |
| XGBoost(Hypertuned) |                                                  {Op
code trigrams(700)}                                                |
0.046     |
|                    |
|               |
|          RF        | {asm and byte unigrams + byte bigrams(1000) + image
features(500) + entropy + opcode bigrams(300) + opcode trigrams(700)} |
0.019     |
| XGBoost(Hypertuned) | {asm and byte unigrams + byte bigrams(1000) + image
features(500) + entropy + opcode bigrams(300) + opcode trigrams(700)} |
0.012     |
+---------------------+-----------------------------------------------------
---------------------------------------------------------------------+------
---------+
```

Conclusions:

1. First i tried with Byte bigrams and got the best score of 0.041 for XGBoost
2. Then i tried Byte trigrams and got the best score of 0.037 for XGBoost
3. Next i tried with Byte bigrams(1000) and trigrams(1000) and got 0.034 for XGB
4. Then ASM image 500 features and got 0.431 for XGboost
5. Next for ASM image features(500)+byte bigrams(1000)+byte trigrams(1000) i got 0.034 for Random Forest
6. Then for Opcode bigrams(300) i got the best score of 0.044 for both RF and XGBoost
7. Then for Opcode trigrams(700) i got the best score of 0.046 for XGBoost
8. Next, finally for asm and byte unigrams + byte bigrams(1000) + image features(500) + entropy + opcode bigrams(300) + opcode trigrams(700) , i got the best of all models for XGBoost i.e 0.012

In [ ]:

```

```