

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 its 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 finish 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
.text:00401001 8D 44 24 08
.text:00401005 50
.text:00401006 8B F1
.text:00401008 E8 1C 1B 00 00
@@QAE@ABQBD@Z ; std::exception::exception(char const * const &)
.text:0040100D C7 06 08 BB 42 00
offset off_42BB08
.text:00401013 8B C6
.text:00401015 5E
.text:00401016 C2 04 00
.text:00401016
; -----



.text:00401019 CC CC CC CC CC CC CC CC align 10h
.text:00401020 C7 01 08 BB 42 00
offset off_42BB08
.text:00401026 E9 26 1C 00 00
.text:00401026
; -----



.text:0040102B CC CC CC CC CC CC align 10h
.text:00401030 56
.push    esi
.text:00401031 8B F1
.text:00401033 C7 06 08 BB 42 00
offset off_42BB08
.text:00401039 E8 13 1C 00 00
.text:0040103E F6 44 24 08 01
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
loc_40104E:          ; CODE XREF:
.jz      short loc_40104E
.text:00401043
.text:0040104E 8B C6
.mov    eax, esi
.text:00401050 5E
.pop    esi
.text:00401051 C2 04 00
.ret    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 Learning 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 probabilities => 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/AAB6EeInEjvvuQg2nu_pIB6ua?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-packages (1.5.5)
Requirement already satisfied: requests in /usr/local/lib/python3.6/dist-packages (from kaggle) (2.21.0)
Requirement already satisfied: python-slugify in /usr/local/lib/python3.6/dist-packages (from kaggle) (3.0.3)
Requirement already satisfied: urllib3<1.25,>=1.21.1 in /usr/local/lib/python3.6/dist-packages (from kaggle) (1.24.3)
Requirement already satisfied: certifi in /usr/local/lib/python3.6/dist-packages (from kaggle) (2019.6.16)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.6/dist-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-packages (from kaggle) (1.12.0)
Requirement already satisfied: chardet<3.1.0,>=3.0.2 in /usr/local/lib/python3.6/dist-packages (from requests->kaggle) (3.0.4)
Requirement already satisfied: idna<2.9,>=2.5 in /usr/local/lib/python3.6/dist-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": "dileepeteja3", "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 updating (server 1.5.6 / client 1.5.4)
Downloading sampleSubmission.csv to {/content}/competitions/malware-classification
 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/49/7e10686647f741bd9c8918b0decdb94135b542fe372ca1100739b8529503/xgboost-0.82-py2.py3-none-manylinux1_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/b1/3367ea1f372957f97a6752ec725b87886e12af1415216feec9067e31df70/numpy-1.16.5-cp27-cp27mu-manylinux1_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/f6/7c16d60aeb3694e5611976cb4f1eaf1c6b7f1e7c55771d691013405a02ea/scipy-1.2.2-cp27-cp27mu-manylinux1_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')
%matplotlib inline
```

UsageError: Line magic function `%matplotlib` 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 create 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 ending with .bytes, if yes we will move it to # 'byteFiles' folder

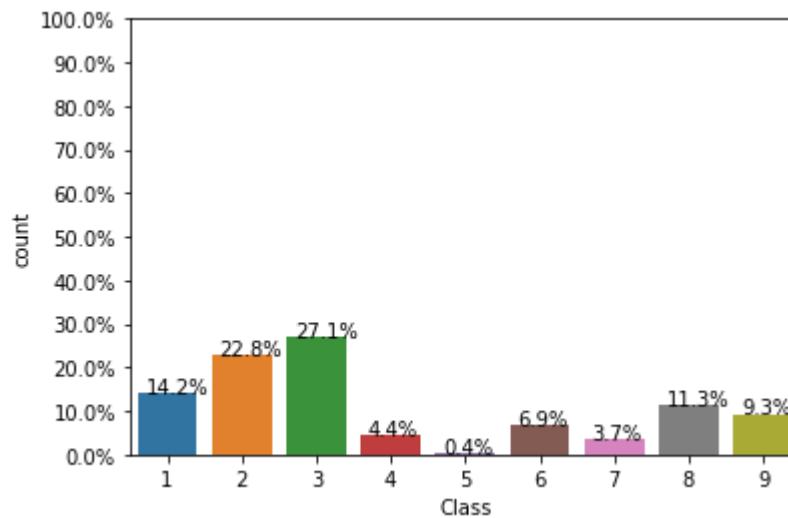
# so by the end of this snippet we will separate all the .byte files and .asm files
if os.path.isdir(source):
    os.rename(source, 'asmFiles')
    source='asmFiles'
    data_files = os.listdir(source)
    for file in data_files:
        if (file.endswith("bytes")):
            shutil.move(source+"/"+file,destination)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

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()/total))
plt.show()
```



In [4]:

Y

Out[4]:

		Id	Class
0	01kcPWA9K2B0xQeS5Rju	1	
1	04EjldbPV5e1XroFOpiN	1	
2	05EeG39MTRrl6VY21DPd	1	
3	05rJTUWYAKNegBk2wE8X	1	
4	0AnoOZDNbPXlr2MRBSCJ	1	
...
10863	KFrZ0Lop1WDGwUtkusCi	9	
10864	kg24YRJTB8DNdKMxpOH	9	
10865	kG29BLiFYPgWtpb350sO	9	
10866	kGITL4OJxYMWEQ1bKBiP	9	
10867	KGorN9J6XAC4bOEkmuyup	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\_stat.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())

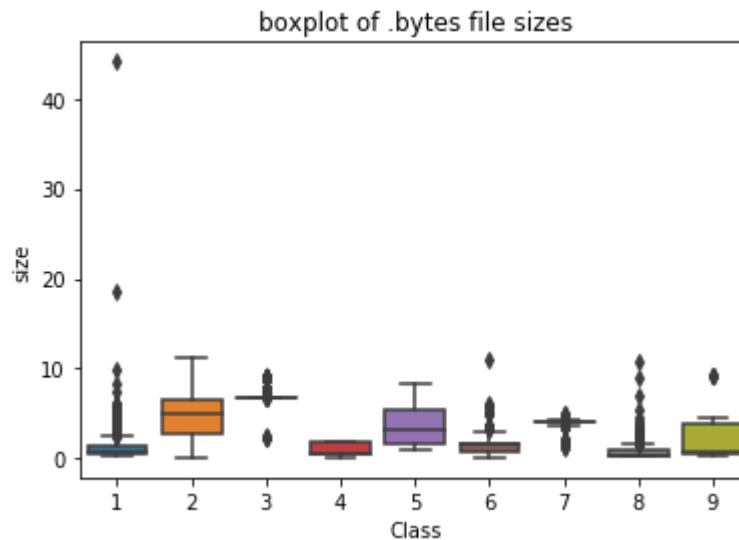
```

	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	81jMeyEZiOpJkCuB1DYg	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 address 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_file:
            for lines in byte_file:
                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_file.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	01lsoiSMh5gxyDYTI4CB	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	LoqA6FX02GWguYrl1Zbe	5671	221	270	323	313	155	248	147	261	...
10866	LoWgaidpb2IUM5ACcSGO	3637	437	453	506	511	390	431	407	405	...
10867	IS0IVqXeJrN6Dzi9Pap1	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	

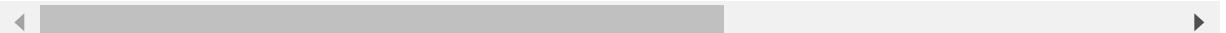
10868 rows × 3 columns

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	01lsoiSMh5gxyDYTi4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlg6aPeDxrU	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	01lsoiSMh5gxyDYTI4CB	39755	8337	7249	7186	8663	6844	8420	7589	...
2	2	01jsnpXSAlg6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	...
3	3	01kcPWA9K2B0xQeS5Rju	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_value - 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
1	0.000092	01lsoiSMh5gxyDYTI4CB	0.017358	0.011737	0.004033	0.003876	0.005303
2	0.000184	01jsnpXSAlg6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464
3	0.000276	01kcPWA9K2B0xQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342

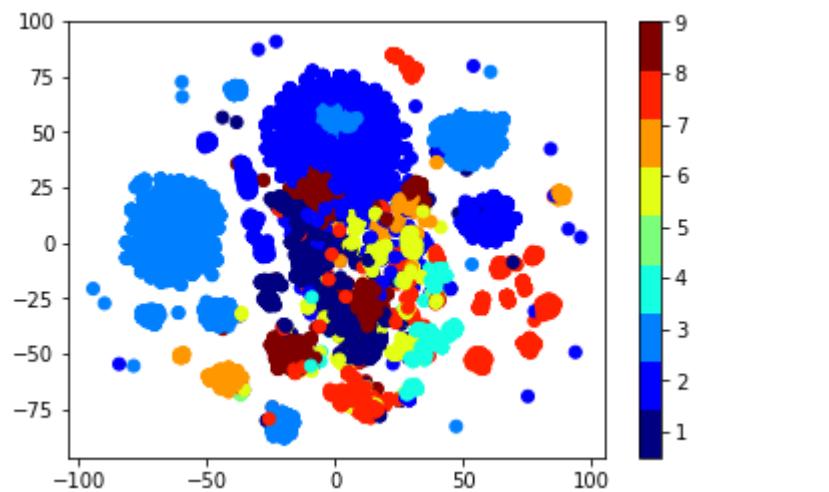
5 rows × 261 columns

3.2.4 Multivariate Analysis

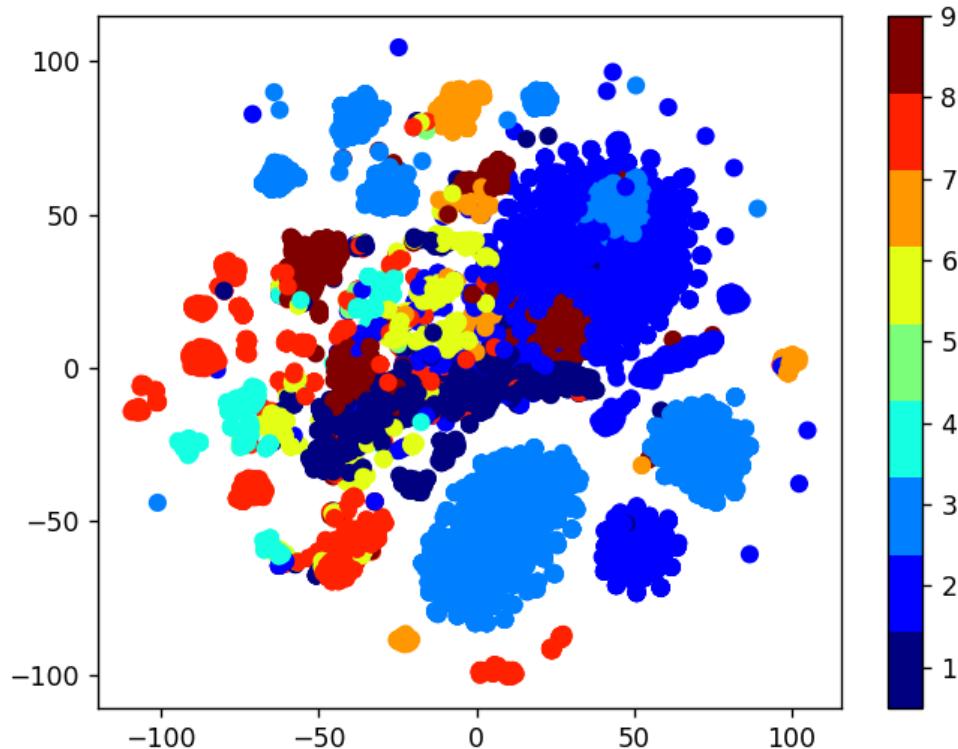
```
In [32]: results[:,].shape
```

```
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.ylim(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 output variable '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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

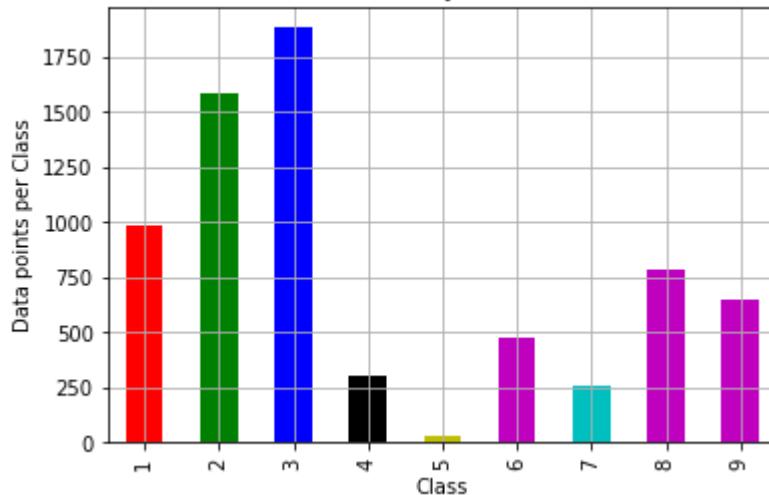
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

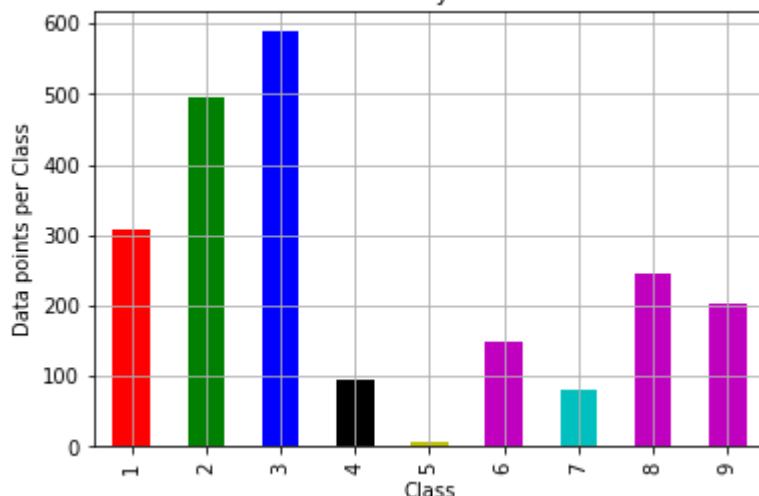
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

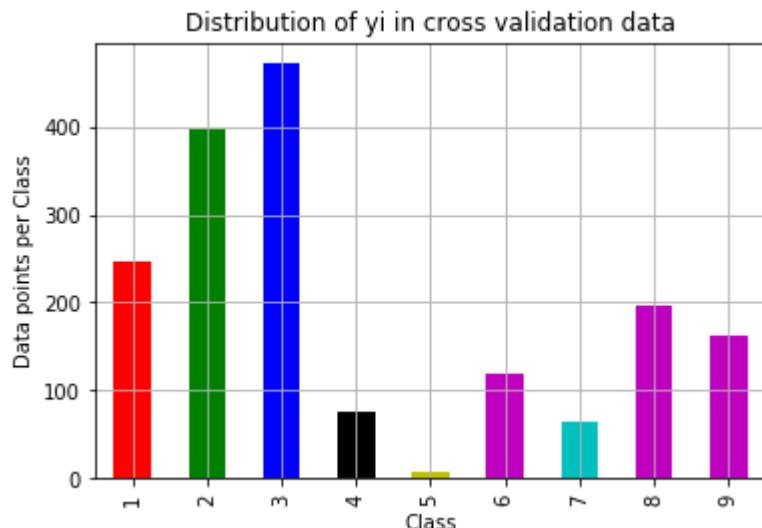
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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 generate 9 numbers and divide each of the numbers by their 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_predicted_y, eps=1e-15))

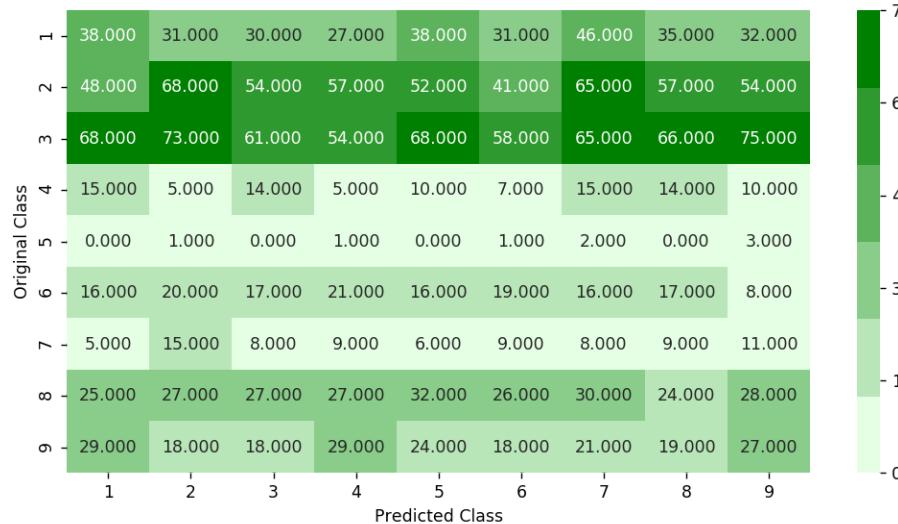
predicted_y = np.argmax(test_predicted_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

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/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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

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

alpha = [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)

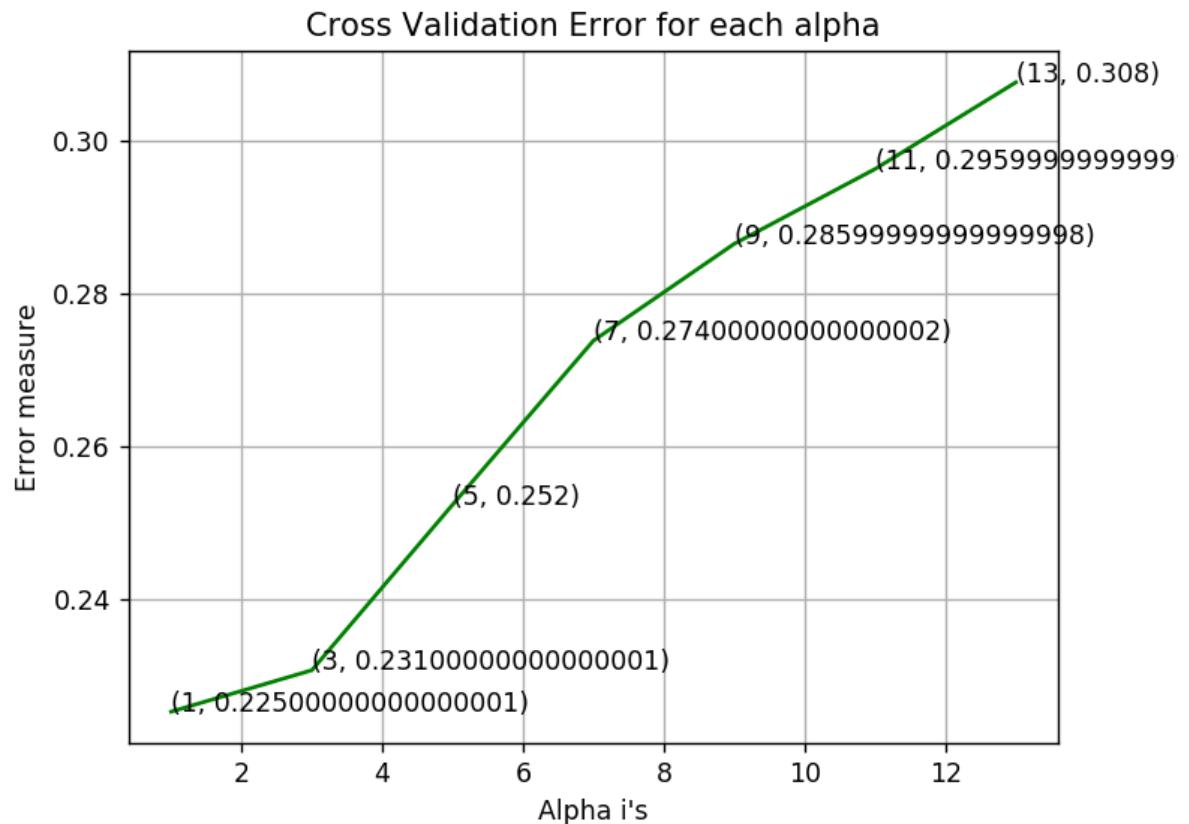
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

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

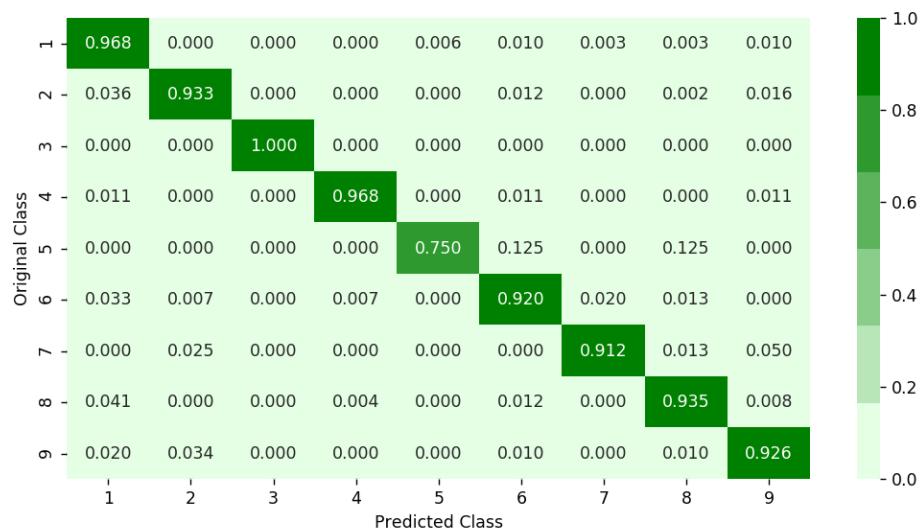


For values of best alpha = 1 The train log loss is: 0.0782947669247
 For values of best alpha = 1 The cross validation log loss is: 0.225386237304

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/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")
    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)

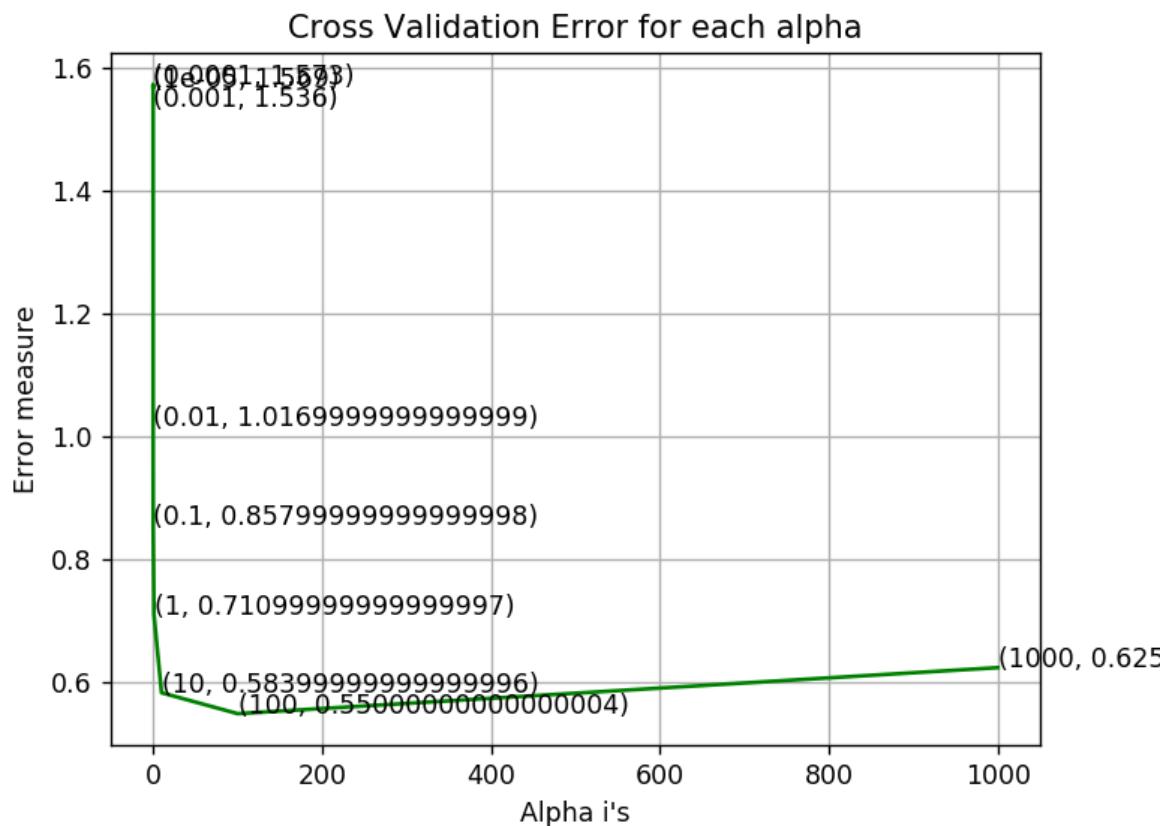
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

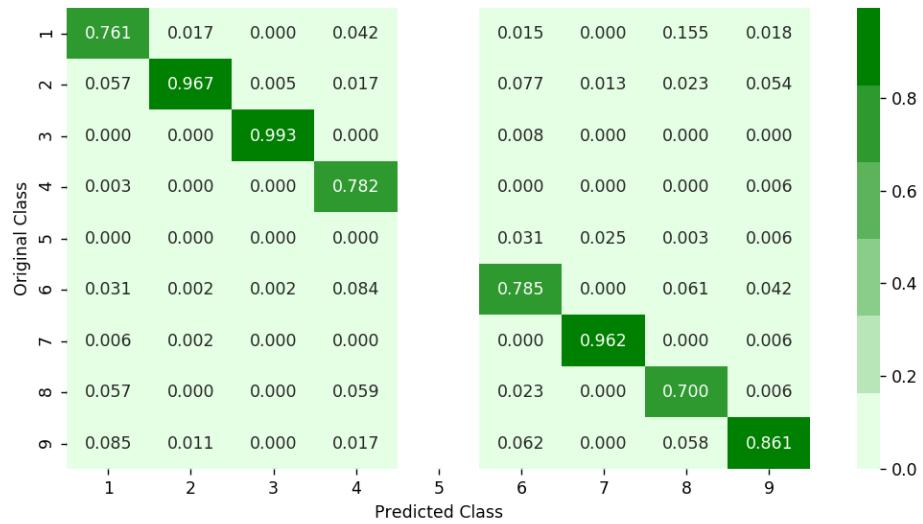
```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.classes_, eps=1e-15))
plot_confusion_matrix(y_test,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



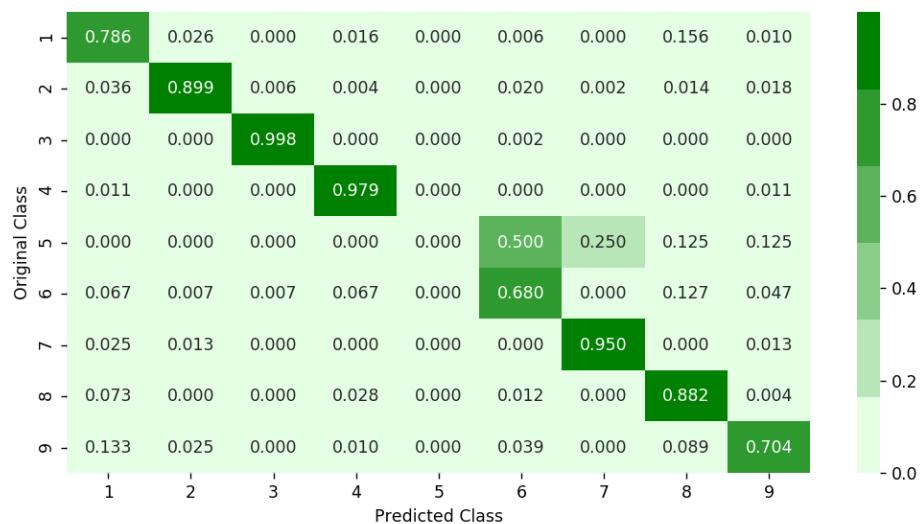
```
log loss for train data 0.498923428696
log loss for cv data 0.549929846589
log loss for test data 0.528347316704
Number of misclassified points 12.3275068997
```

----- 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', 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()

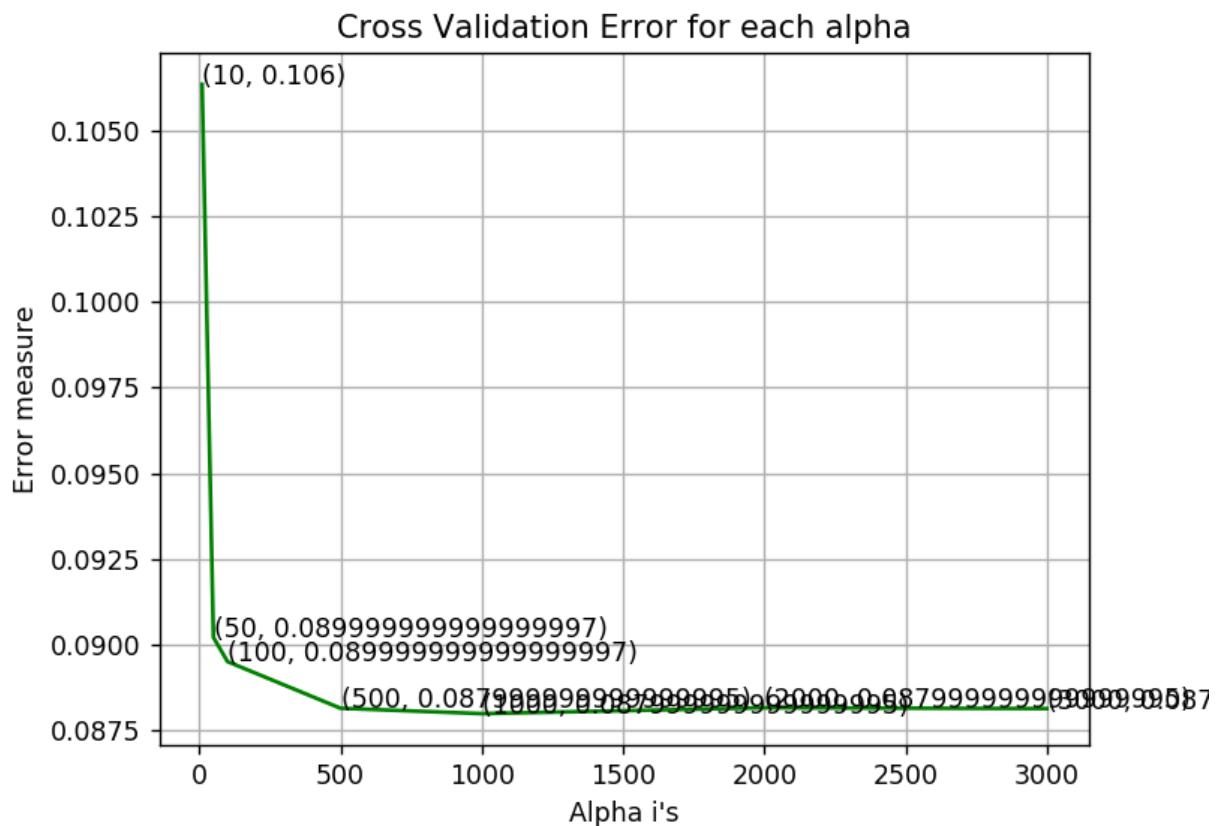
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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



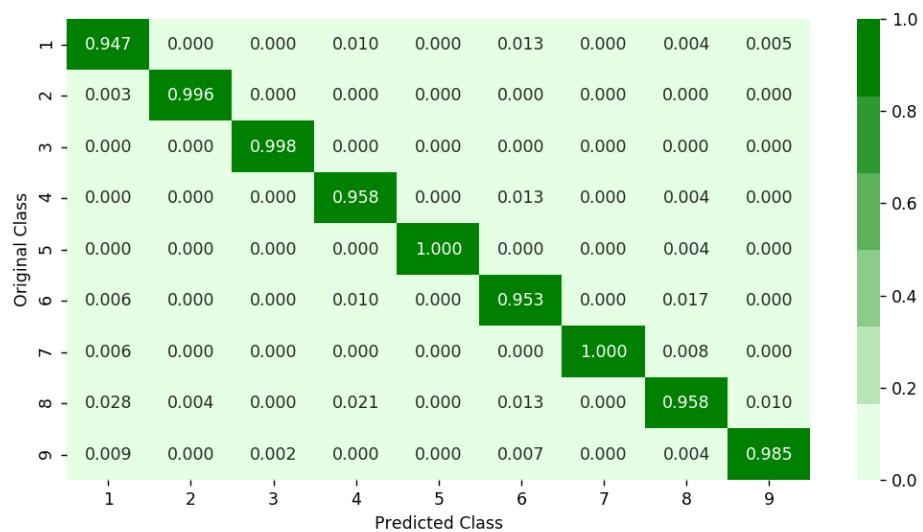
For values of best alpha = 1000 The train log loss is: 0.0266476291801

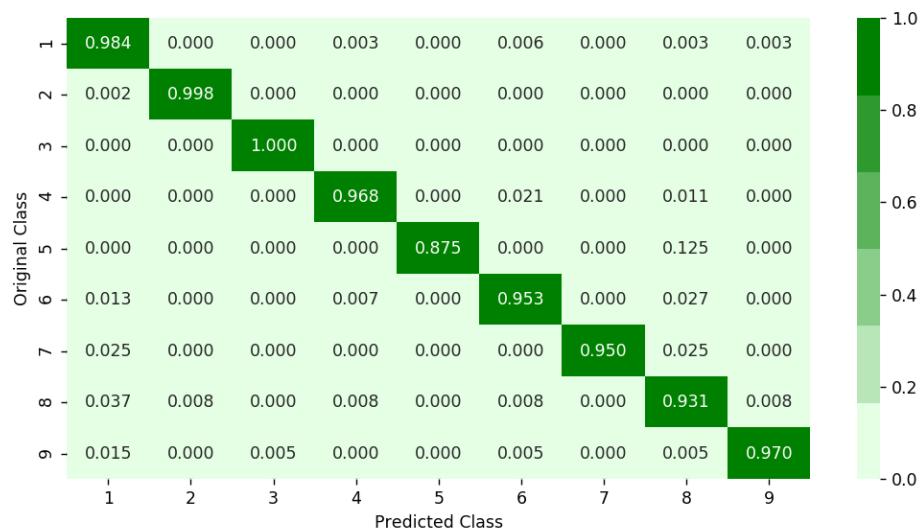
For values of best alpha = 1000 The cross validation log loss is: 0.0879849524621

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

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

alpha=[10,50,100,500,1000,2000]
cv_log_error_array=[]
for i in alpha:
 x_cfl=XGBClassifier(n_estimators=i,nthread=-1)
 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])

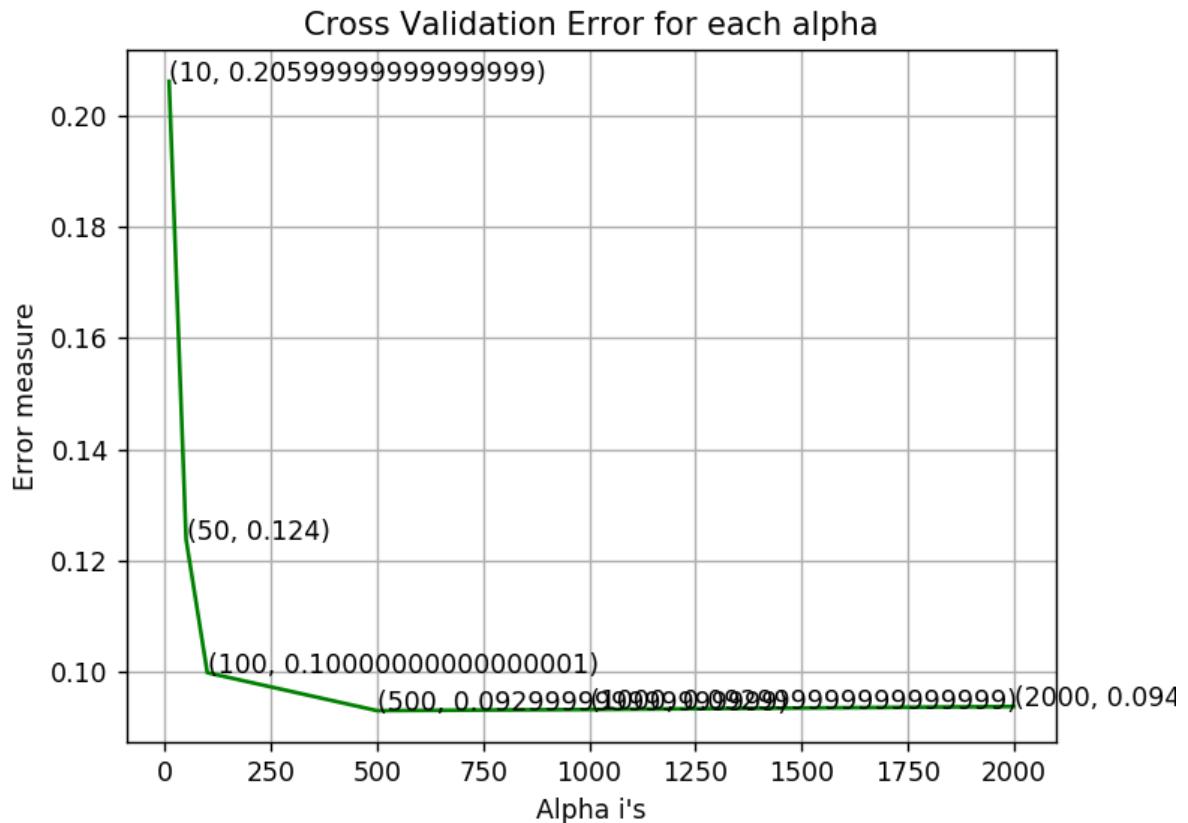
best_alpha = np.argmin(cv_log_error_array)

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



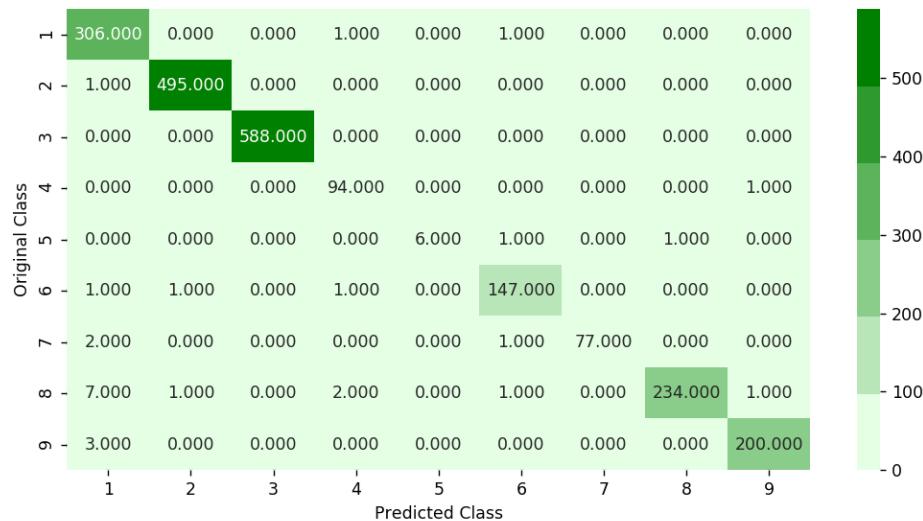
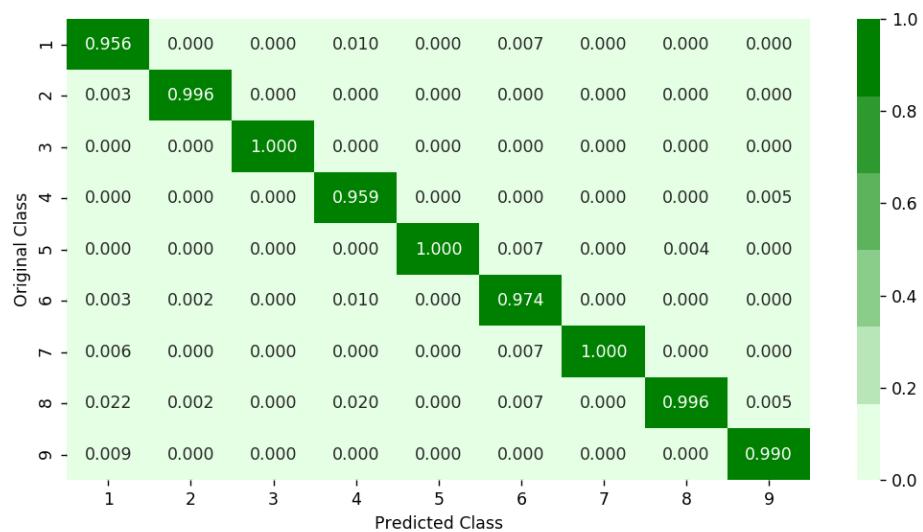
For values of best alpha = 500 The train log loss is: 0.0225231805824

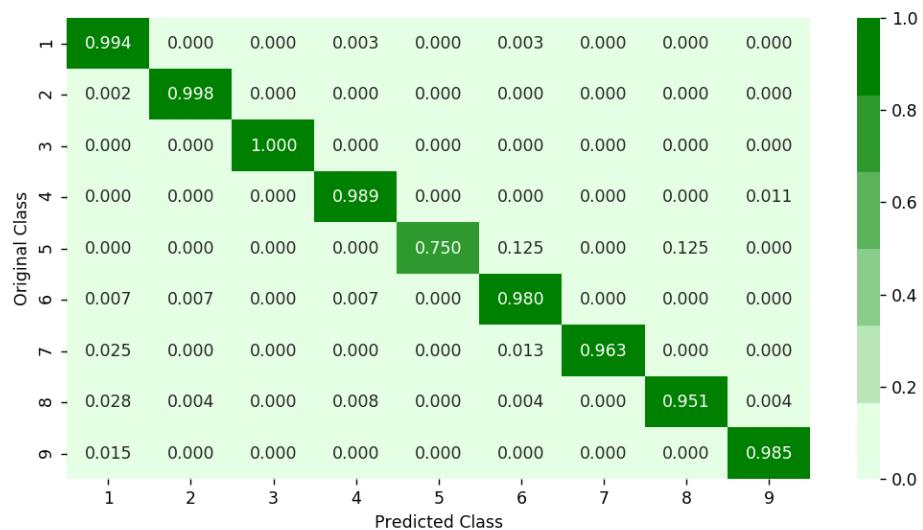
For values of best alpha = 500 The cross validation log loss is: 0.093103568
1289

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_jobs=-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:  5.4min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 10.1min remaining:  3.1min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 14.0min remaining:  1.6min
[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, 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, 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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

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

x_cfl=XGBClassifier(n_estimators=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 can 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 prefixes 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 generated from the above two cells) will contain all 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
1	1E93CpP60RHFNiT5Qfvn		17	838	0	103	49	0	0	3
2	3ekVow2ajZHbTnBcsDfX		17	427	0	50	43	0	145	0
3	3X2nY7iQaPBIWDrAZqJe		17	227	0	43	19	0	0	3
4	46OZzdsSKDCFV8h7XWxf		17	402	0	59	170	0	0	3

5 rows × 53 columns

4.2.1.1 Files sizes of each .asm file

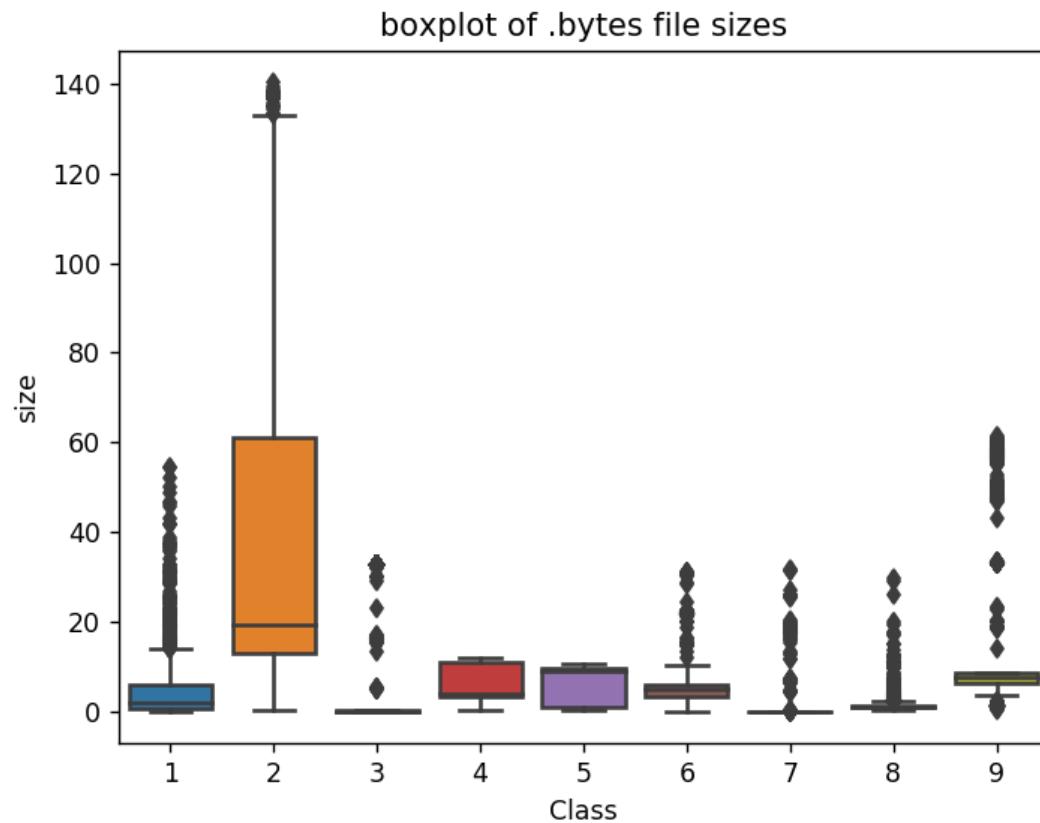
```
In [0]: #file sizes of byte files

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/0A32eTdBKayjCWhZqD0Q.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\_stat.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	01IsoiSMh5gxyDYT14CB	13.999378
2	9	01jsnpXSAlg6aPeDxrU	8.507785
3	1	01kcPWA9K2B0xQeS5Rju	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='ID', 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
1	1E93CpP60RHFNiT5Qfvn		17	838	0	103	49	0	0	3
2	3ekVow2ajZHbTnBcsDfX		17	427	0	50	43	0	145	0
3	3X2nY7iQaPBIVDrAZqJe		17	227	0	43	19	0	0	3
4	46OZzdsSKDCFV8h7XWxf		17	402	0	59	170	0	0	3

5 rows × 54 columns

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

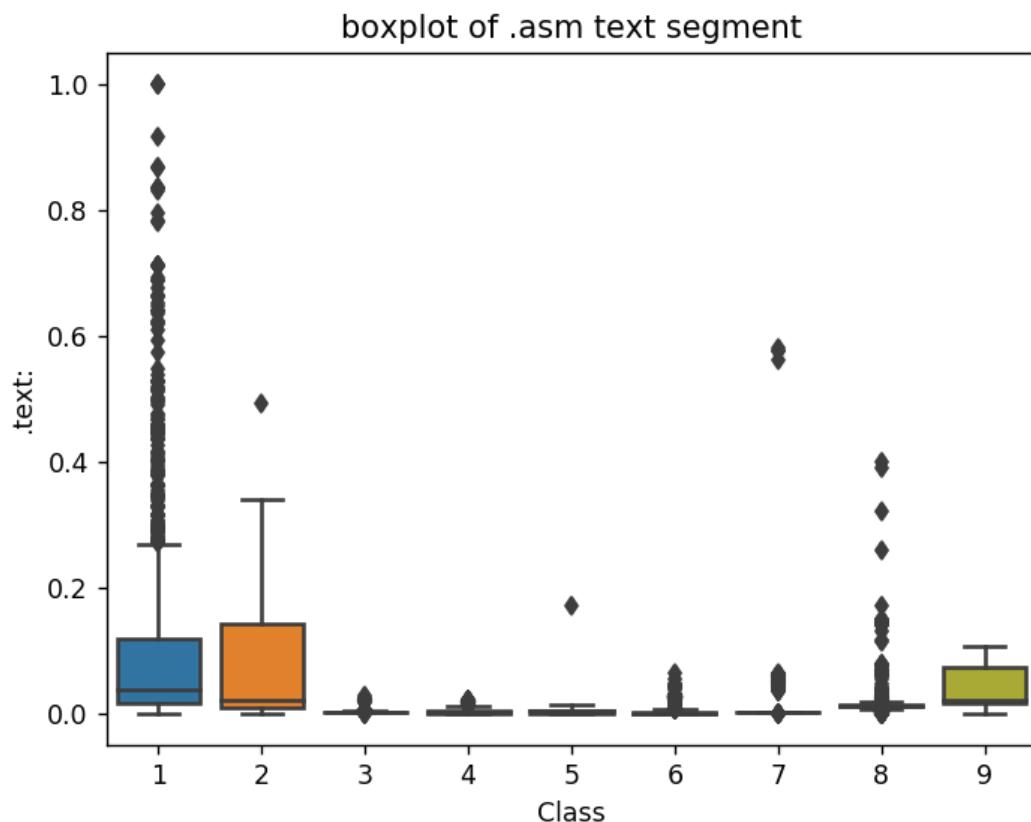
Out[0]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.ed
0	01kcPWA9K2B0xQeS5Rju	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

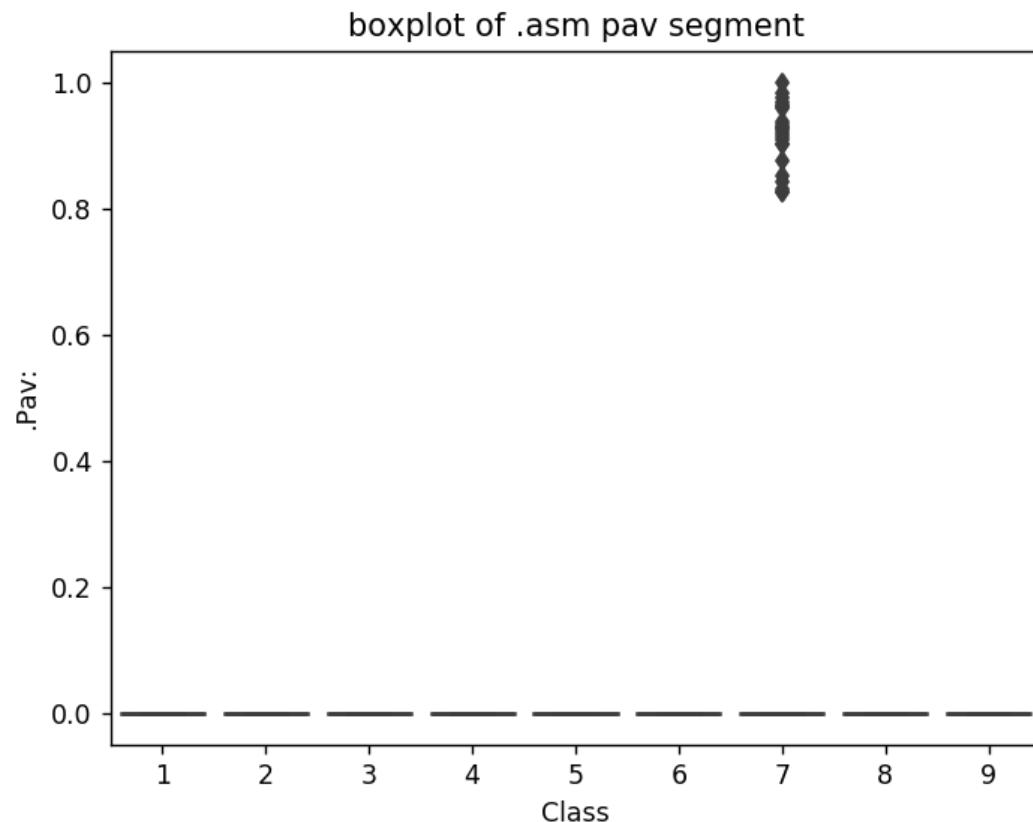
4.2.2 Univariate analysis on asm file features

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

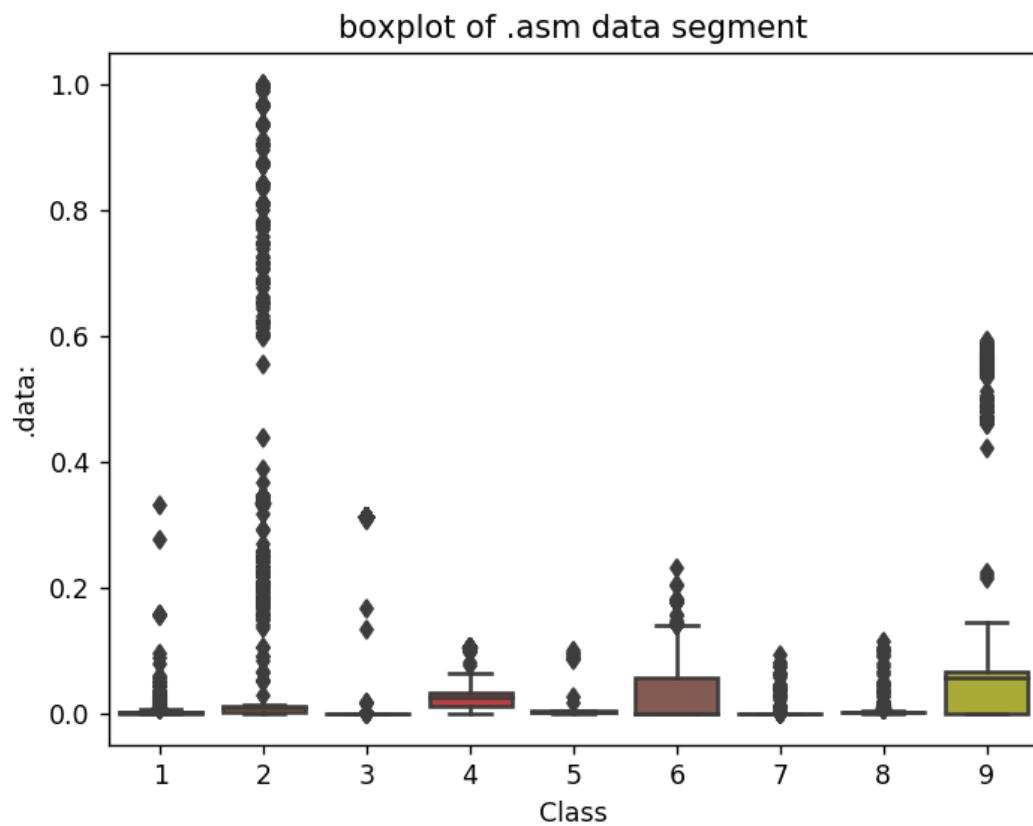


The plot is between Text and class
Class 1,2 and 9 can be easily separated

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

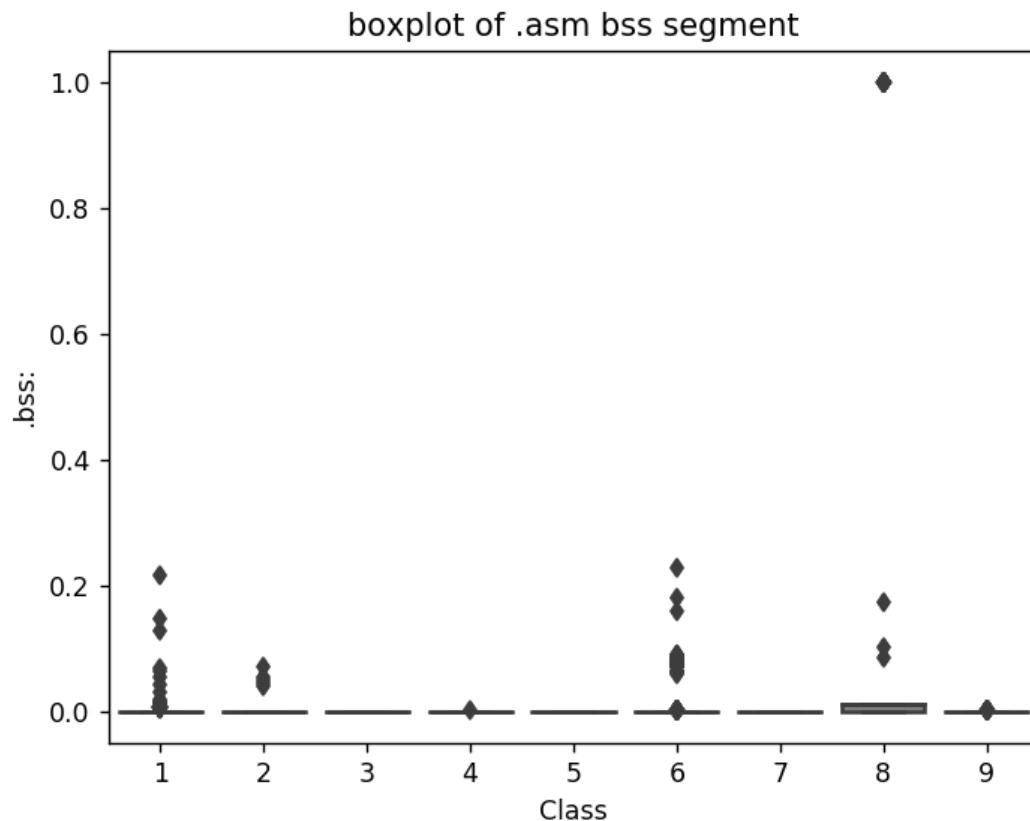


```
In [0]: ax = sns.boxplot(x="Class", y=".data:", data=result_asm)
plt.title("boxplot of .asm data segment")
plt.show()
```



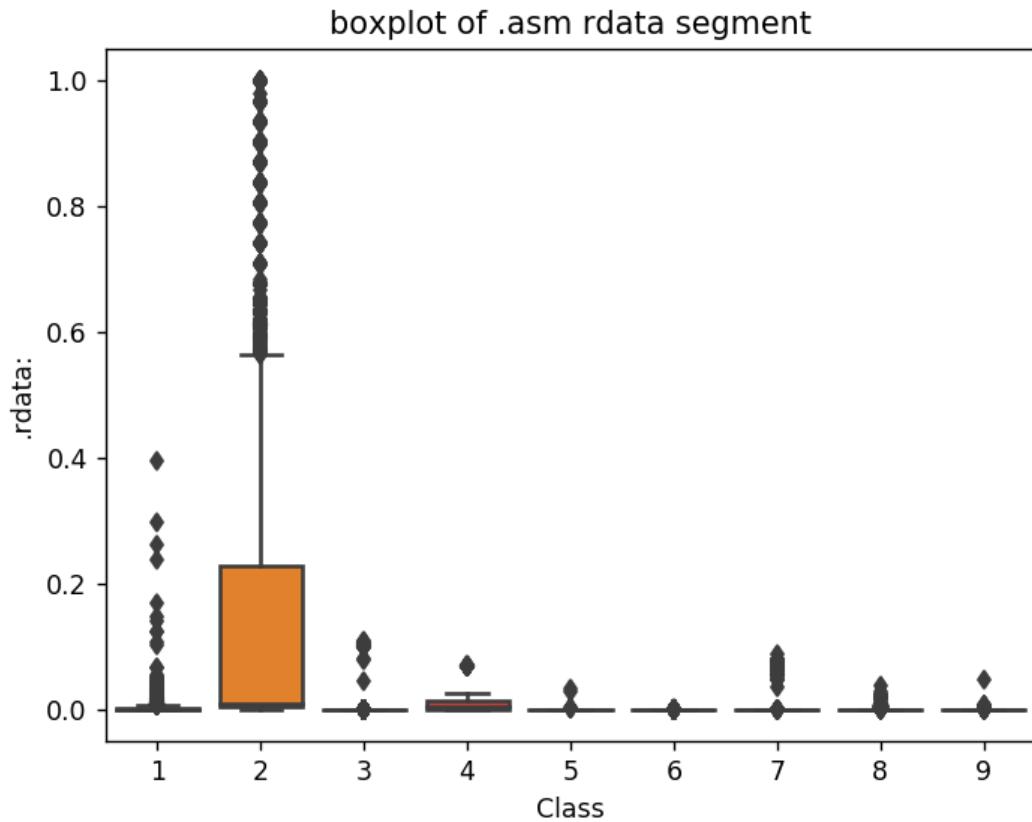
The plot is between data segment and class label
class 6 and class 9 can be easily separated from given points

```
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

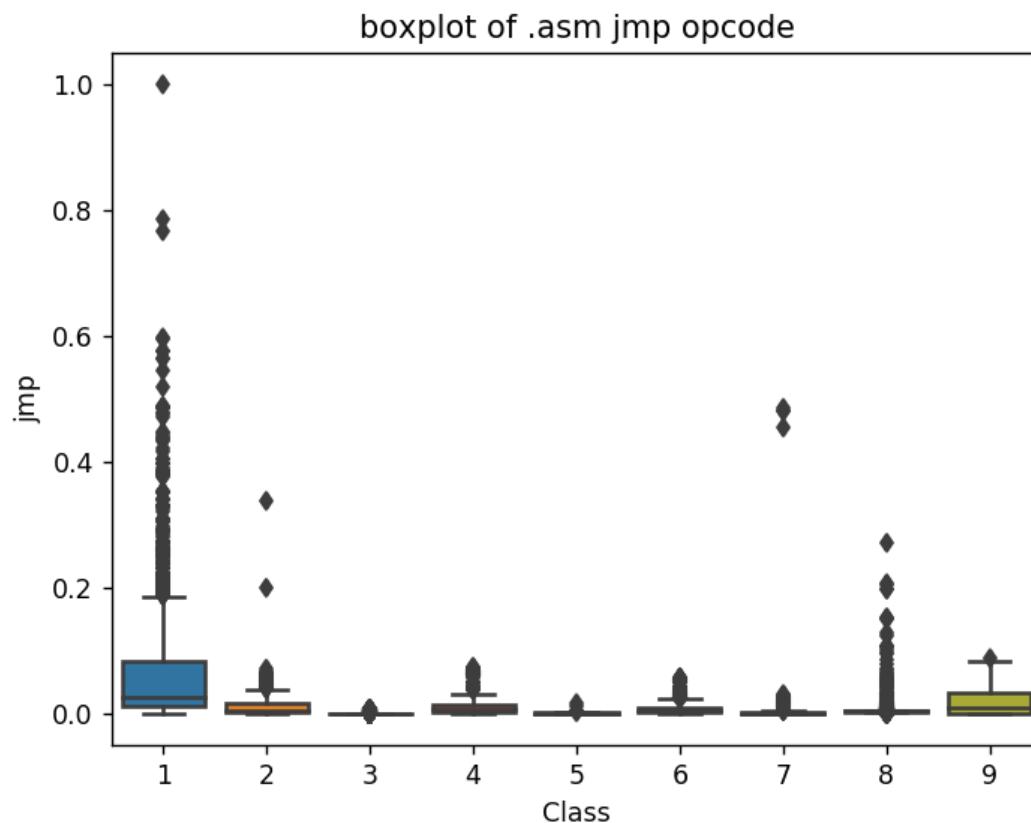
```
In [0]: ax = sns.boxplot(x="Class", y=".rdata:", data=result_asm)
plt.title("boxplot of .asm rdata segment")
plt.show()
```



Plot between rdata segment and Class segment

Class 2 can be easily separated 75 percentile files are having 1M rdata lines

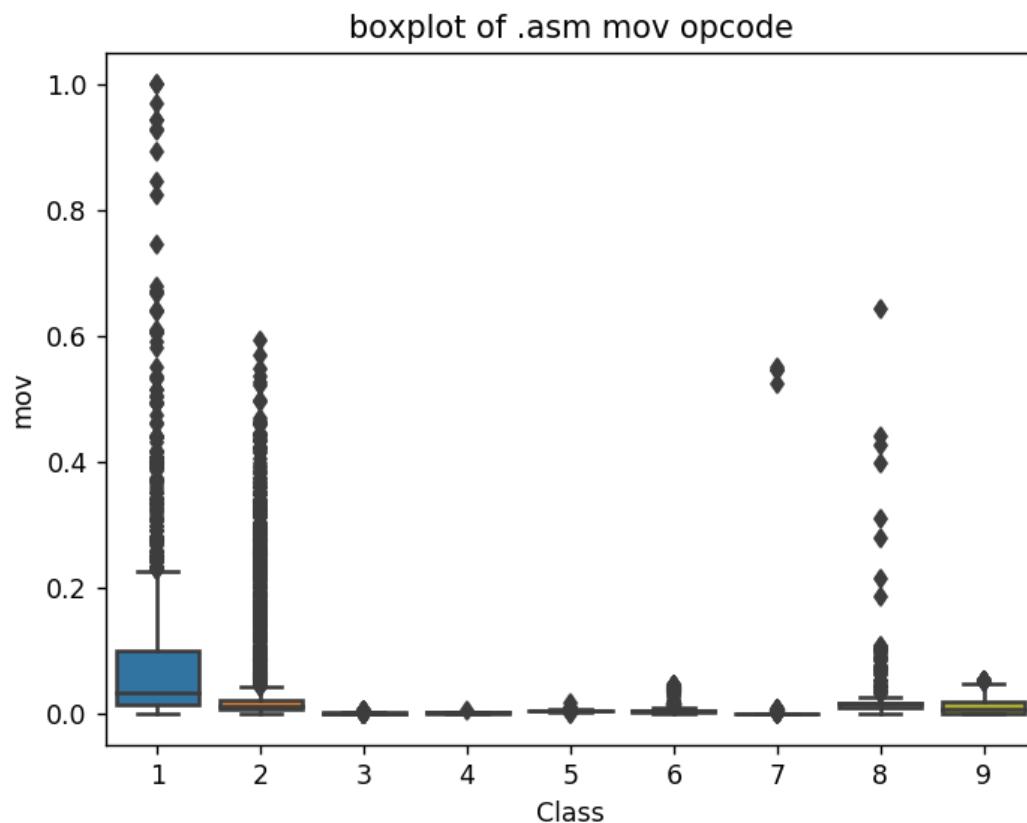
```
In [0]: ax = sns.boxplot(x="Class", y="jmp", data=result_asm)
plt.title("boxplot of .asm jmp opcode")
plt.show()
```



plot between jmp and Class label

Class 1 is having frequency of 2000 approx in 75 percentile of files

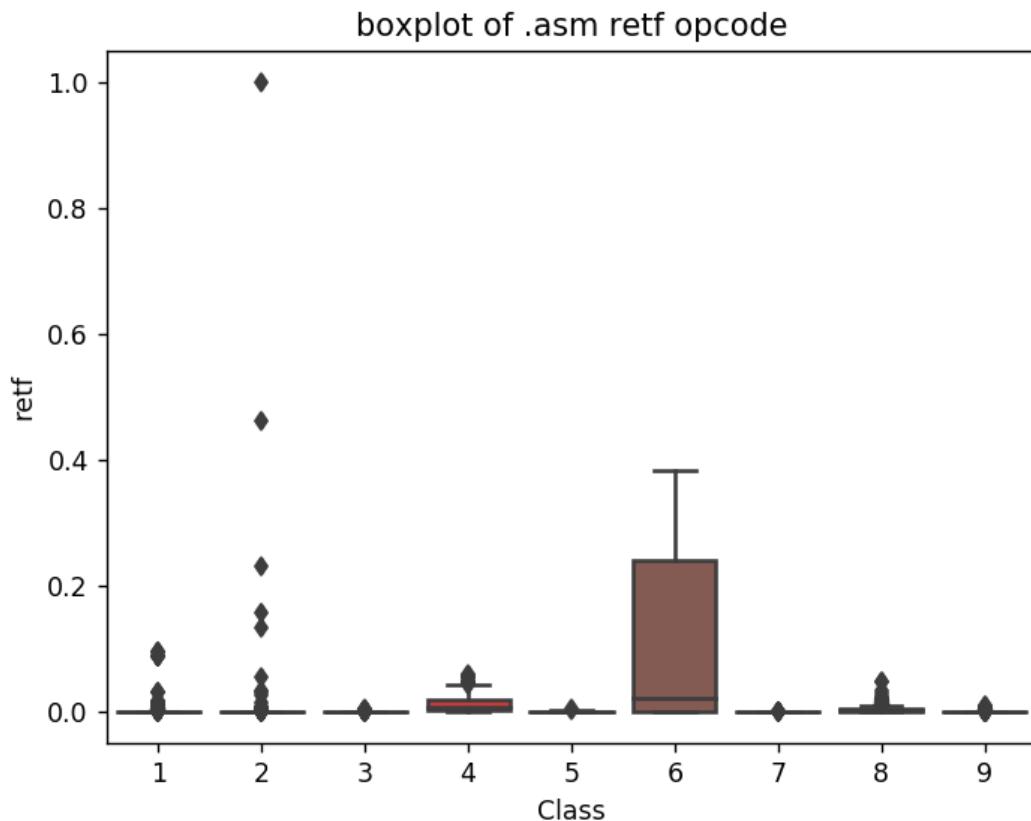
```
In [0]: ax = sns.boxplot(x="Class", y="mov", data=result_asm)
plt.title("boxplot of .asm mov opcode")
plt.show()
```



plot between Class label and mov opcode

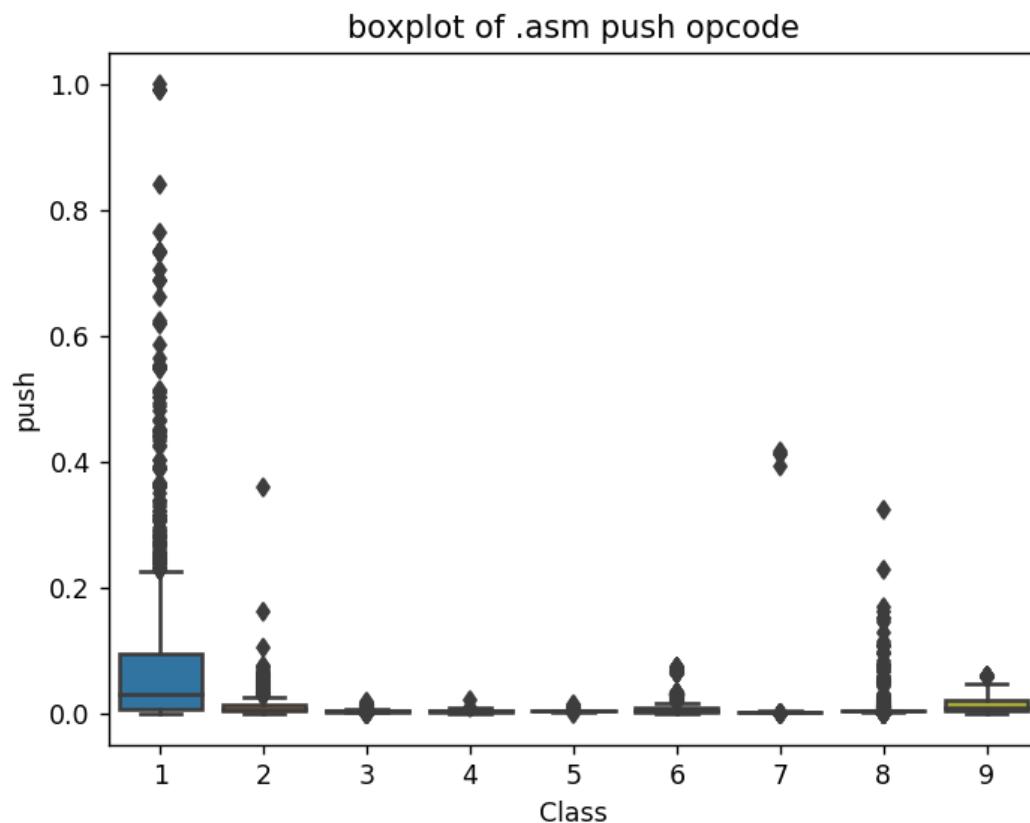
Class 1 is having frequency of 2000 approx in 75 percentile of files

```
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()
```



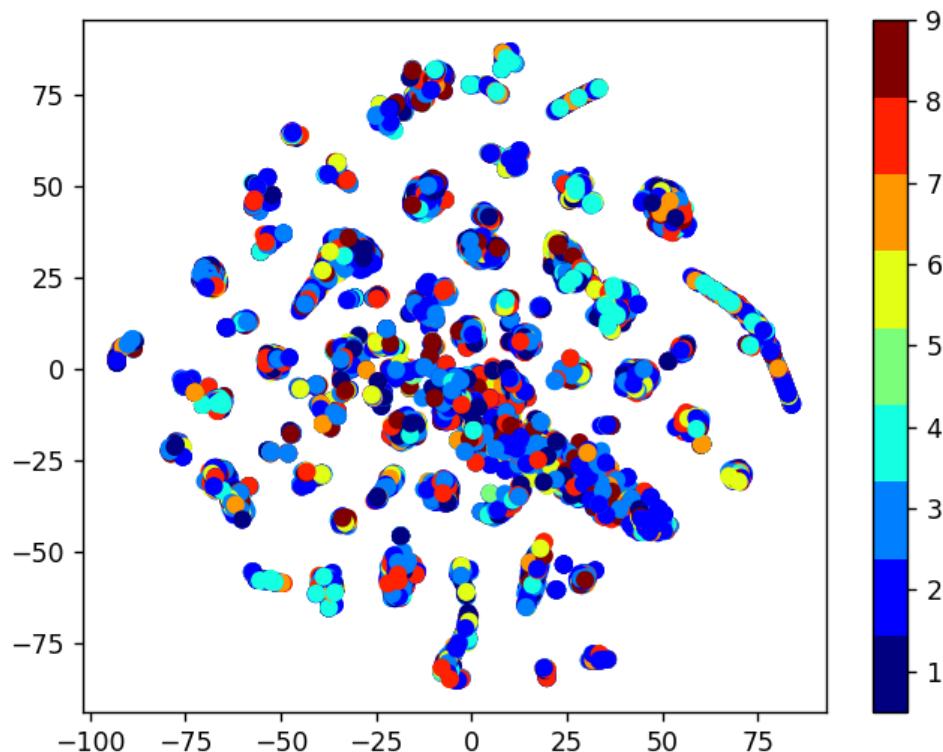
plot between push opcode and Class label

Class 1 is having 75 precentile files with push opcodes of frequency 1000

4.2.2 Multivariate Analysis on .asm file features

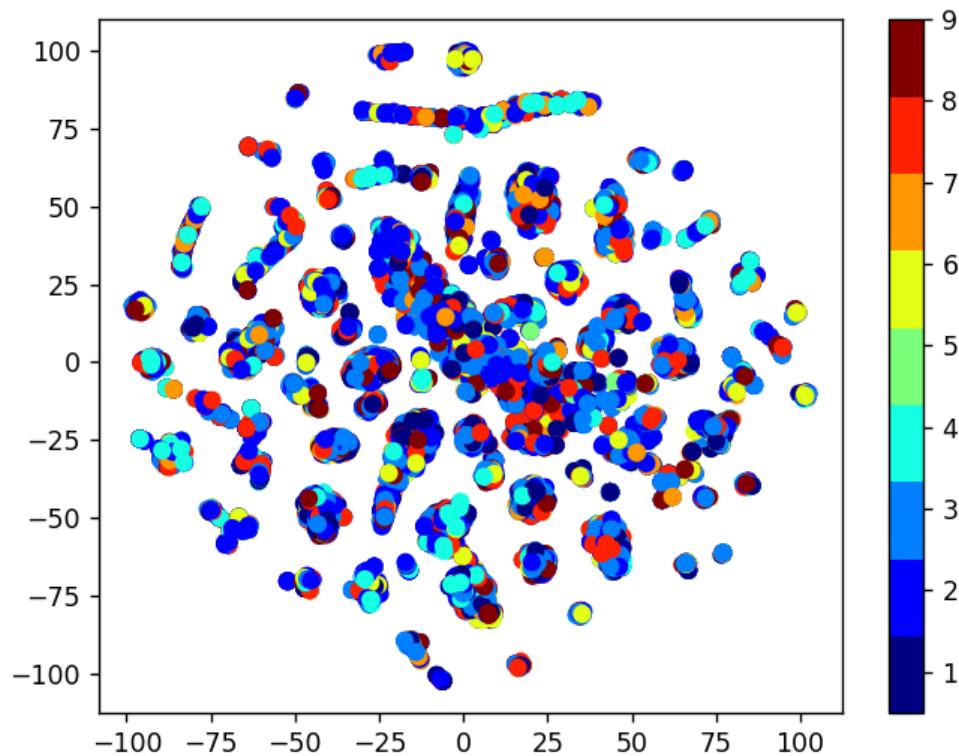
```
In [0]: # check out the course content for more explantion on tsne algorithm
# https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/t-distributed-stochastic-neighbourhood-embeddingt-sne-part-1/

#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 negligible information from
# 'rtn', '.BSS:' '.CODE' features, so heare we are trying multivariate analysis after removing those features
# the plot Looks very messy

xtsne=TSNE(perplexity=30)
results=xtsne.fit_transform(result_asm.drop(['ID','Class', 'rtn', '.BSS:', '.CODE', '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 Neighbors

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

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

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

alpha = [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.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)

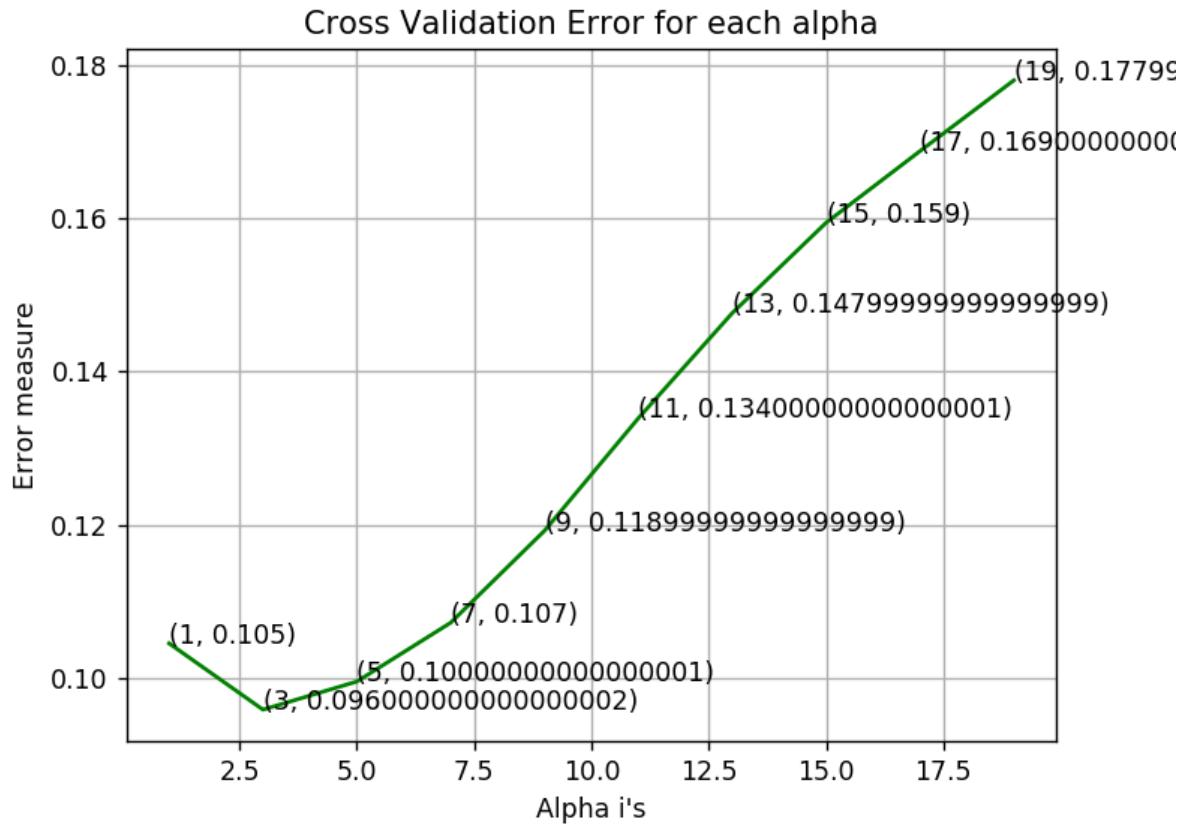
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

```
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train_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)

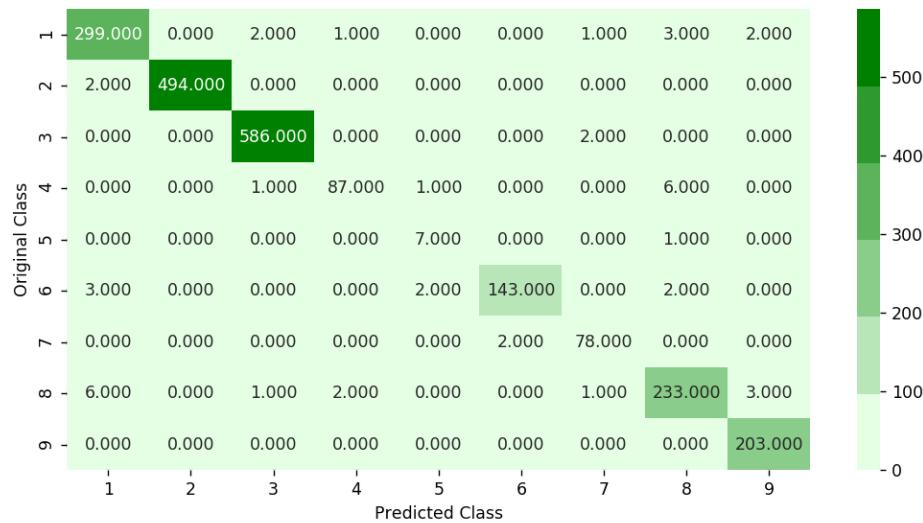
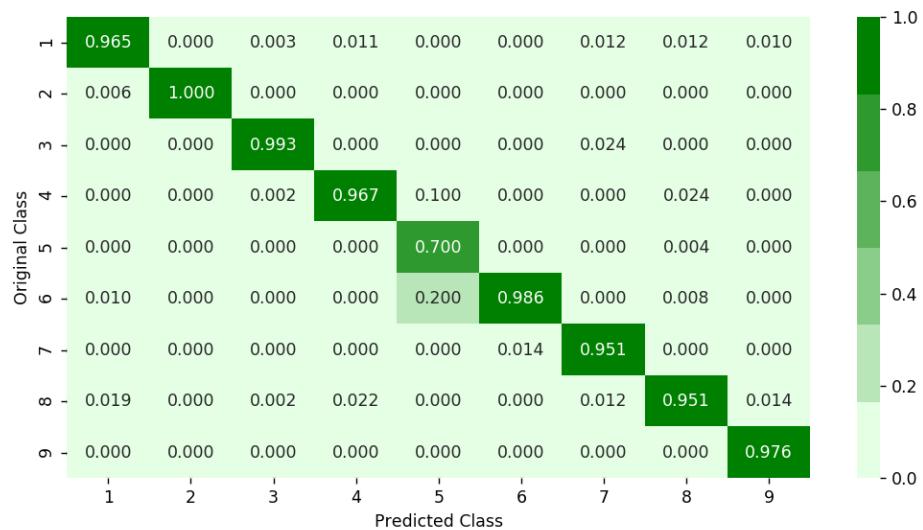
predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',log_loss(y_train_asm, predict_y))
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',log_loss(y_cv_asm, predict_y))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',log_loss(y_test_asm,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

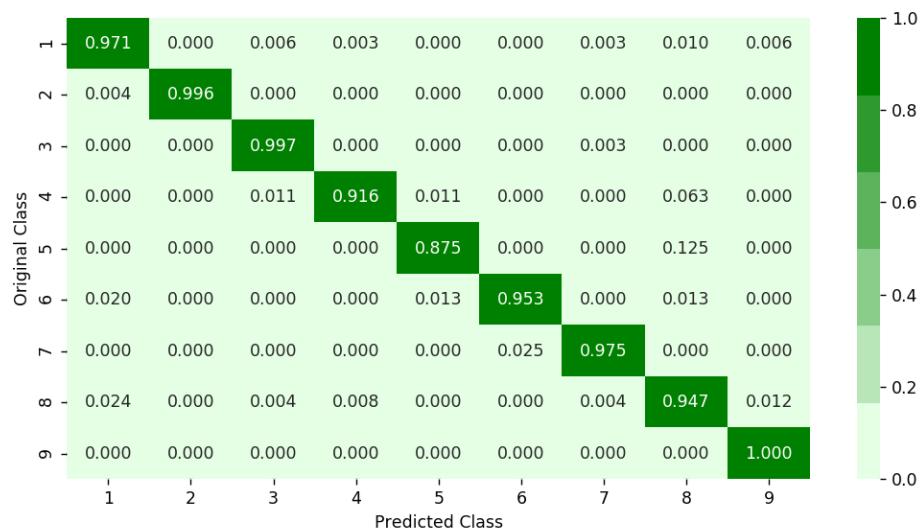
```
log_loss for k = 1 is 0.104531321344
log_loss for k = 3 is 0.0958800580948
log_loss for k = 5 is 0.0995466557335
log_loss for k = 7 is 0.107227274345
log_loss for k = 9 is 0.119239543547
log_loss for k = 11 is 0.133926642781
log_loss for k = 13 is 0.147643793967
log_loss for k = 15 is 0.159439699615
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/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_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.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)

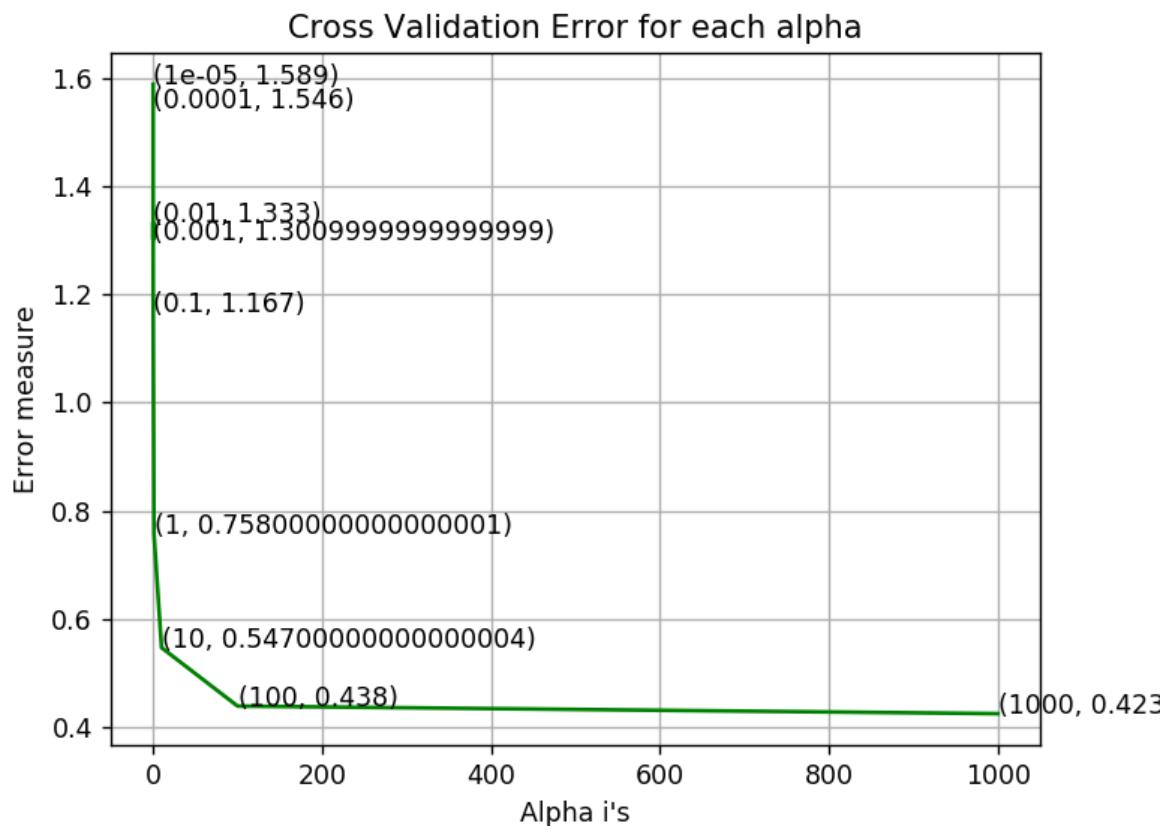
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='balanced')
logisticR.fit(X_train_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=logisticR.classes_, eps=1e-15)))
```

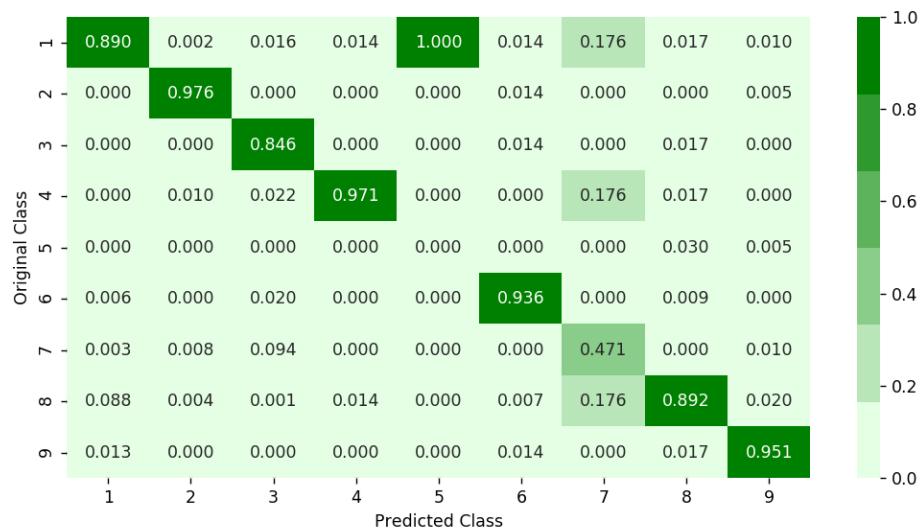
```
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=logisticR.
classes_, eps=1e-15)))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',(log_loss(y_test_asm, predict_y, labels=logist
icR.classes_, eps=1e-15)))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



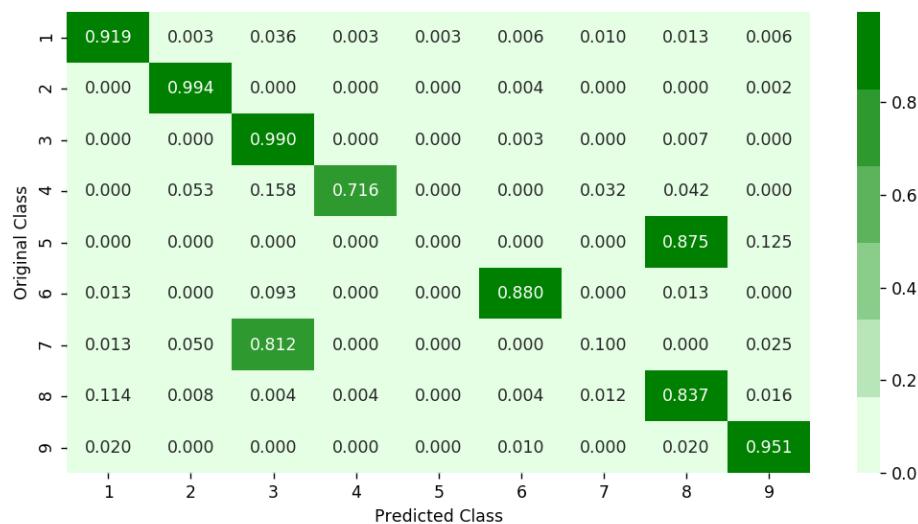
```
log loss for train data 0.396219394701
log loss for cv data 0.424423536526
log loss for test data 0.415685592517
Number of misclassified points 9.61361545538
```

----- 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', 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=[]
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.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)

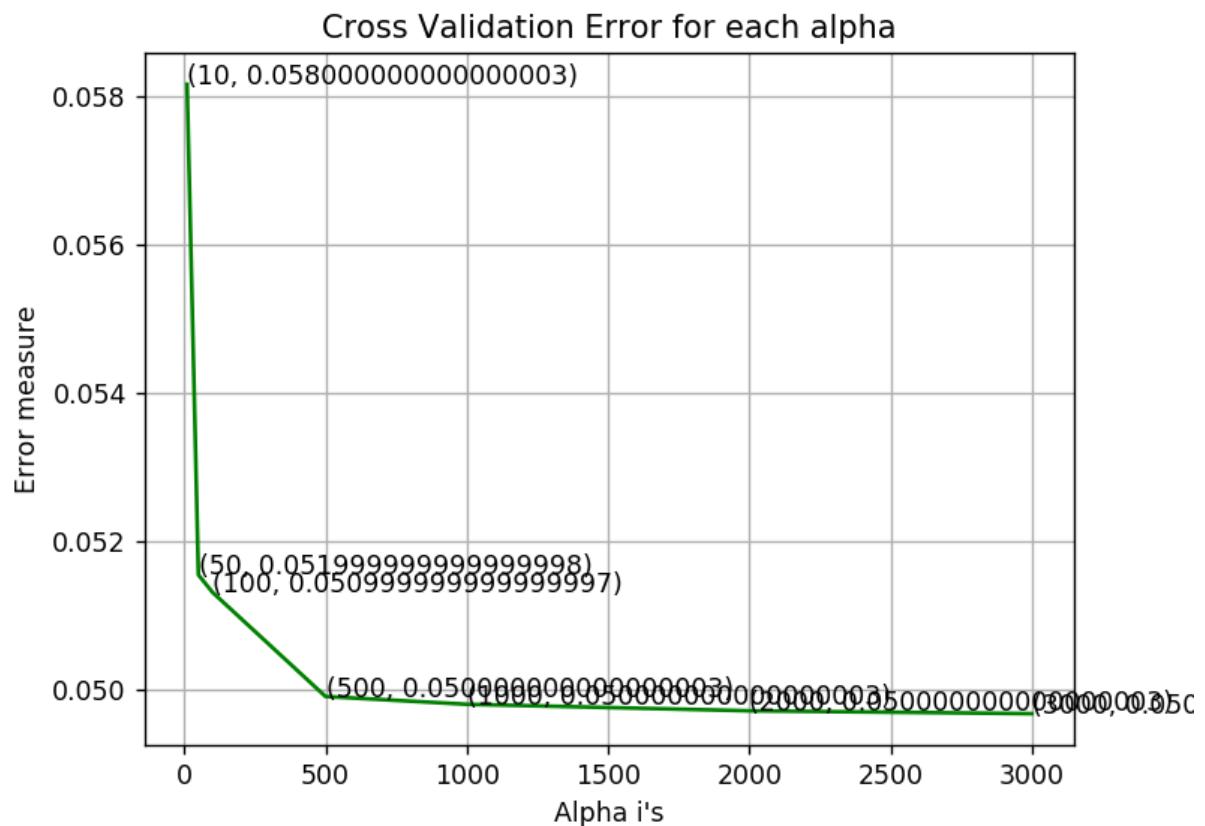
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

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

```

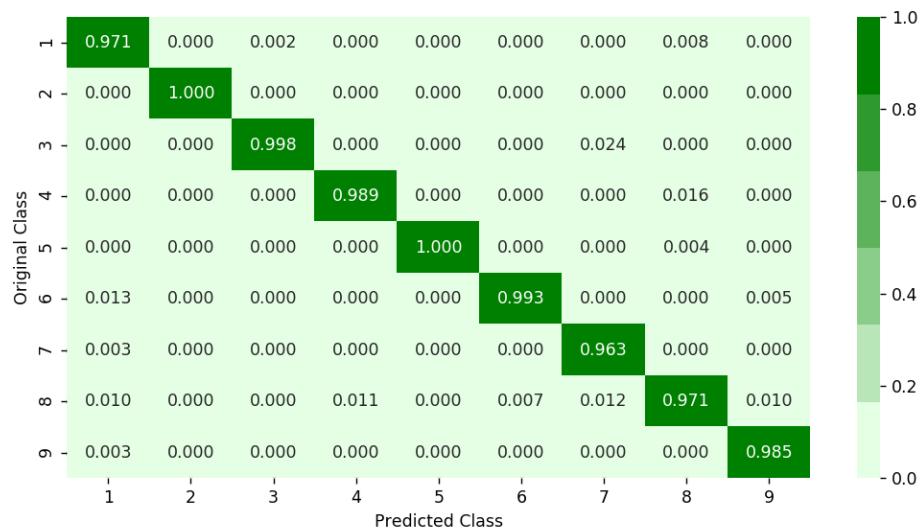
```
sig_clf.fit(X_train_asm, y_train_asm)
predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',(log_loss(y_train_asm, predict_y, labels=sig_
clf.classes_, eps=1e-15)))
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=sig_clf.cl_
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))
```

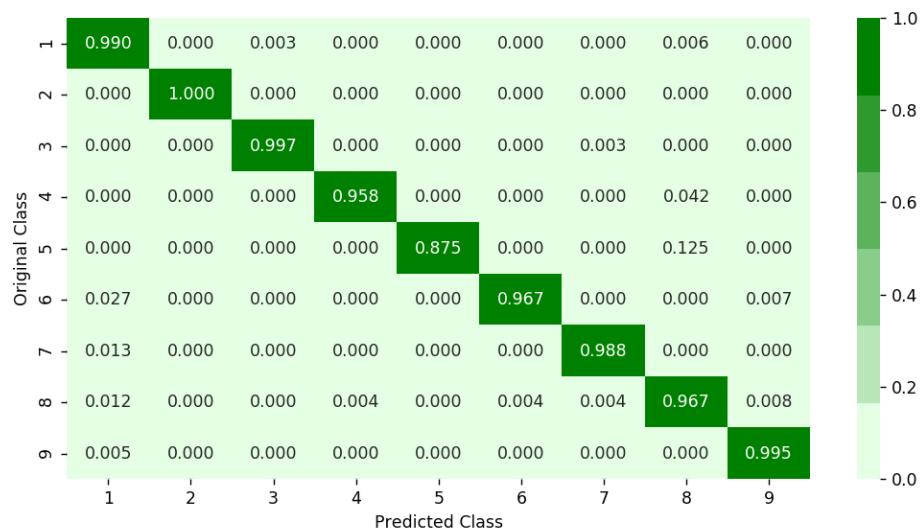
```
log_loss for c = 10 is 0.0581657906023
log_loss for c = 50 is 0.0515443148419
log_loss for c = 100 is 0.0513084973231
log_loss for c = 500 is 0.0499021761479
log_loss for c = 1000 is 0.0497972474298
log_loss for c = 2000 is 0.0497091690815
log_loss for c = 3000 is 0.0496706817633
```



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

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


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.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()

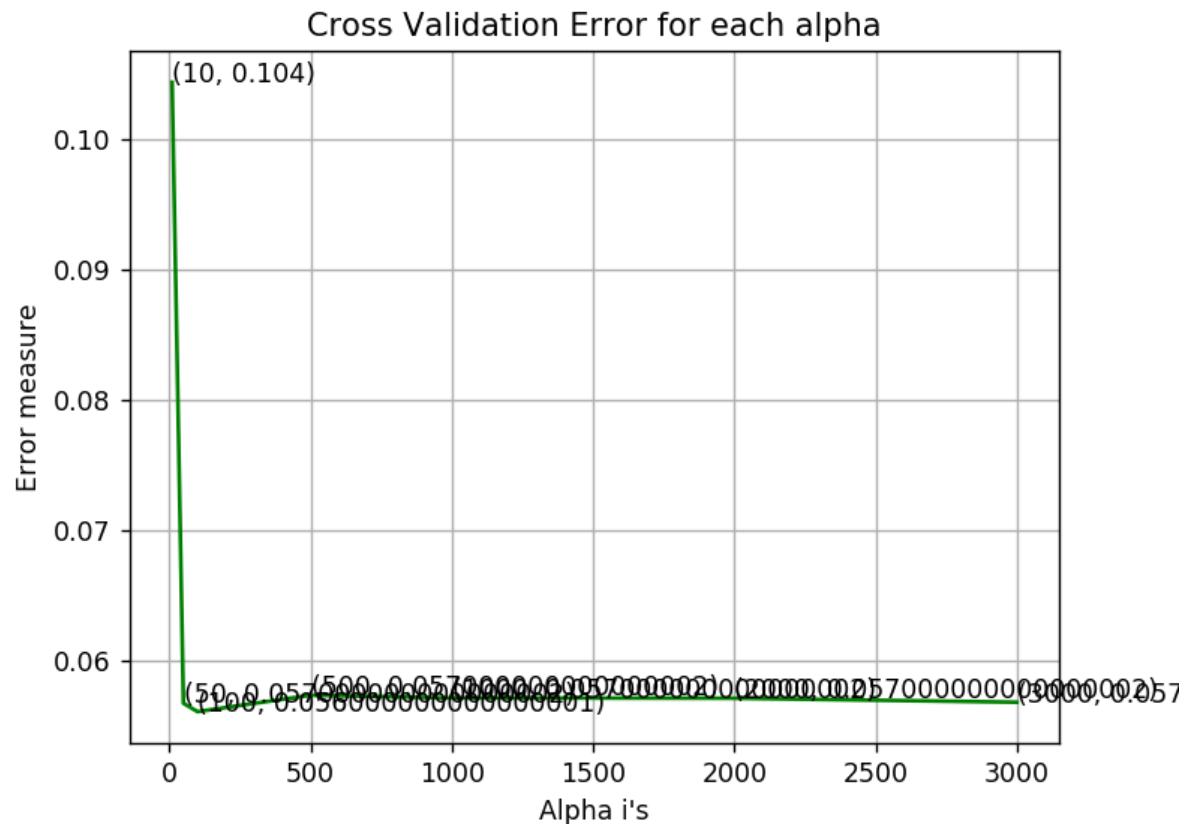
x_cfl=XGBClassifier(n_estimators=alpha[best_alpha],nthread=-1)
x_cfl.fit(X_train_asm,y_train_asm)
```

```
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)

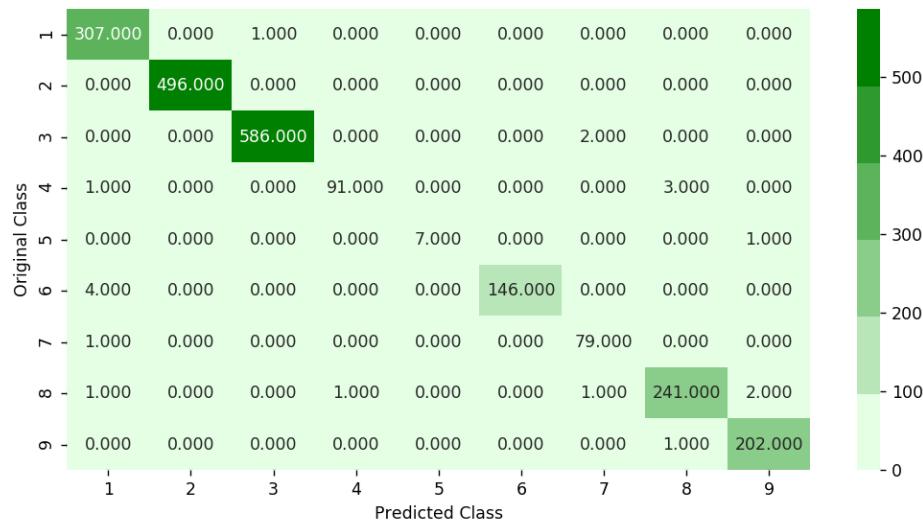
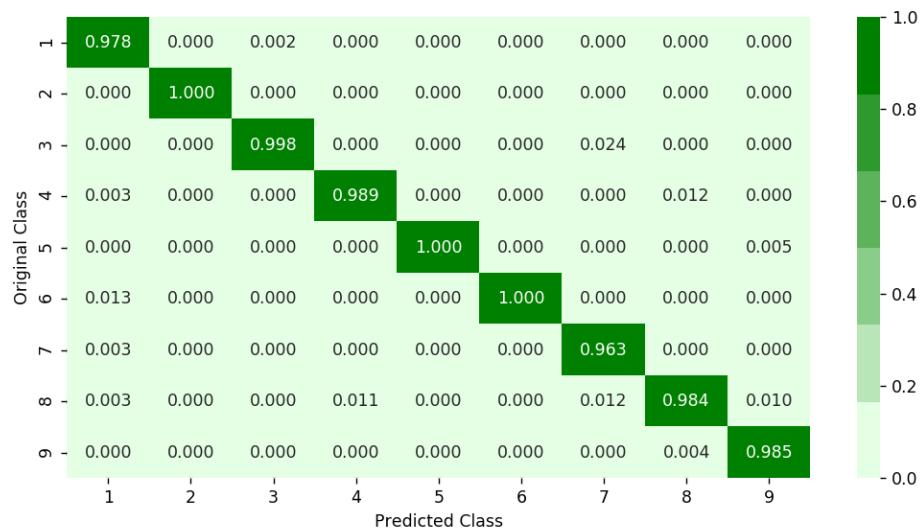
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train_asm, predict_y))
predict_y = sig_clf.predict_proba(X_cv_asm)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv_asm, predict_y))
predict_y = sig_clf.predict_proba(X_test_asm)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

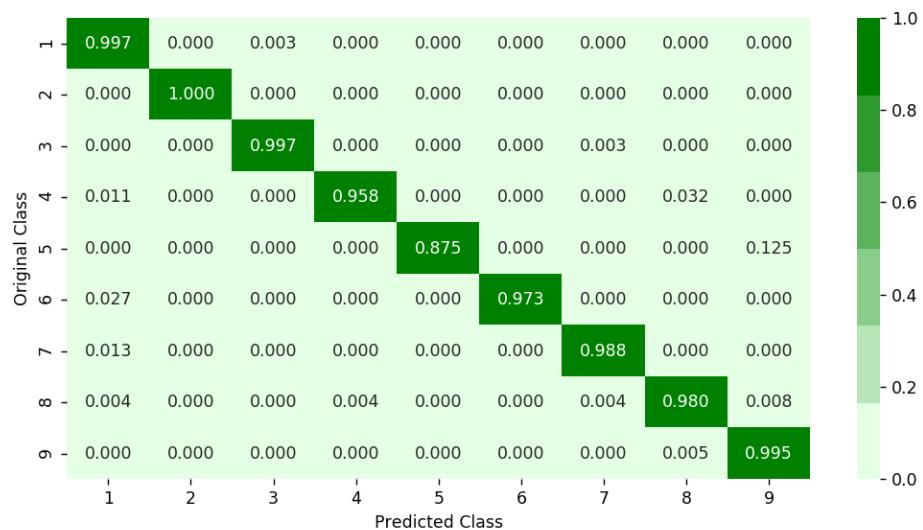
```
log_loss for c = 10 is 0.104344888454
log_loss for c = 50 is 0.0567190635611
log_loss for c = 100 is 0.056075038646
log_loss for c = 500 is 0.057336051683
log_loss for c = 1000 is 0.0571265109903
log_loss for c = 2000 is 0.057103406781
log_loss for c = 3000 is 0.0567993215778
```



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: 0.056075038646
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_jobs=-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:  2
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, 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, 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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1, max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

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

```
x_cfl=XGBClassifier(n_estimators=200,subsample=0.5,learning_rate=0.15,colsample_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

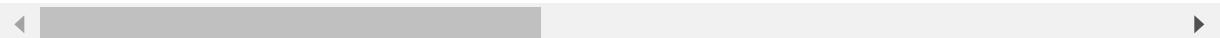
4.5.1. Merging both asm and byte file features

```
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
1	01IsoiSMh5gxyDYTI4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873
2	01jsnpXSAlg6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280
3	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354
4	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232

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()
```

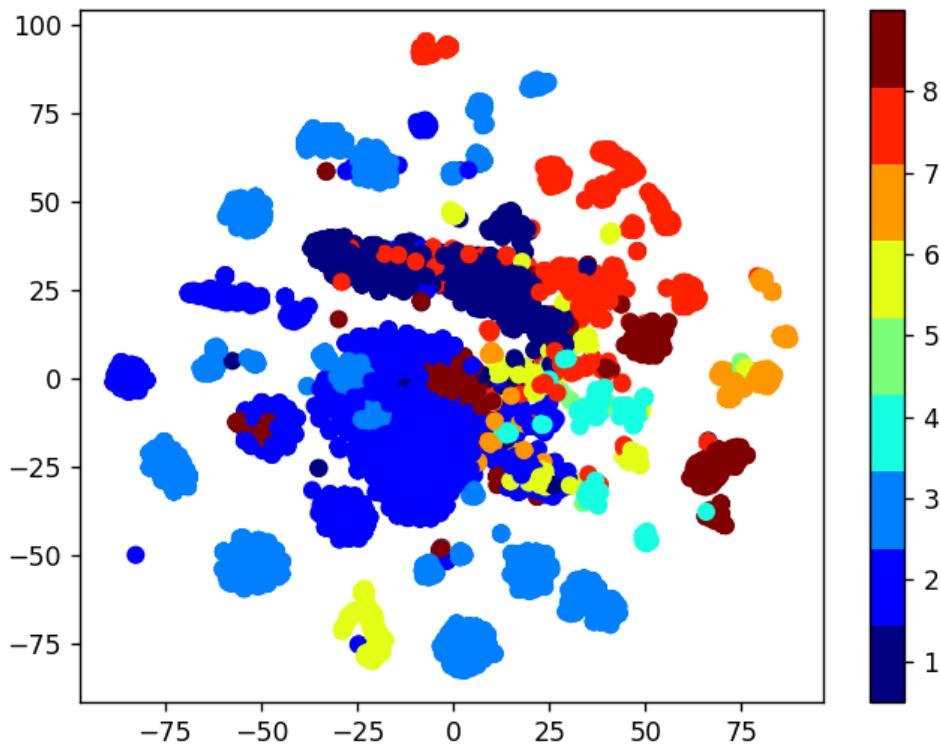
Out[0]:

	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
1	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873	0.004747	0.006984	0.008267
2	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280	0.005078	0.002155	0.008104
3	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354	0.000310	0.000481	0.000959
4	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232	0.000148	0.000229	0.000376

5 rows × 307 columns

4.5.2. Multivariate Analysis on final features

```
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, result_y,stratify=result_y,test_size=0.20)
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, 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', 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=[]
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.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)

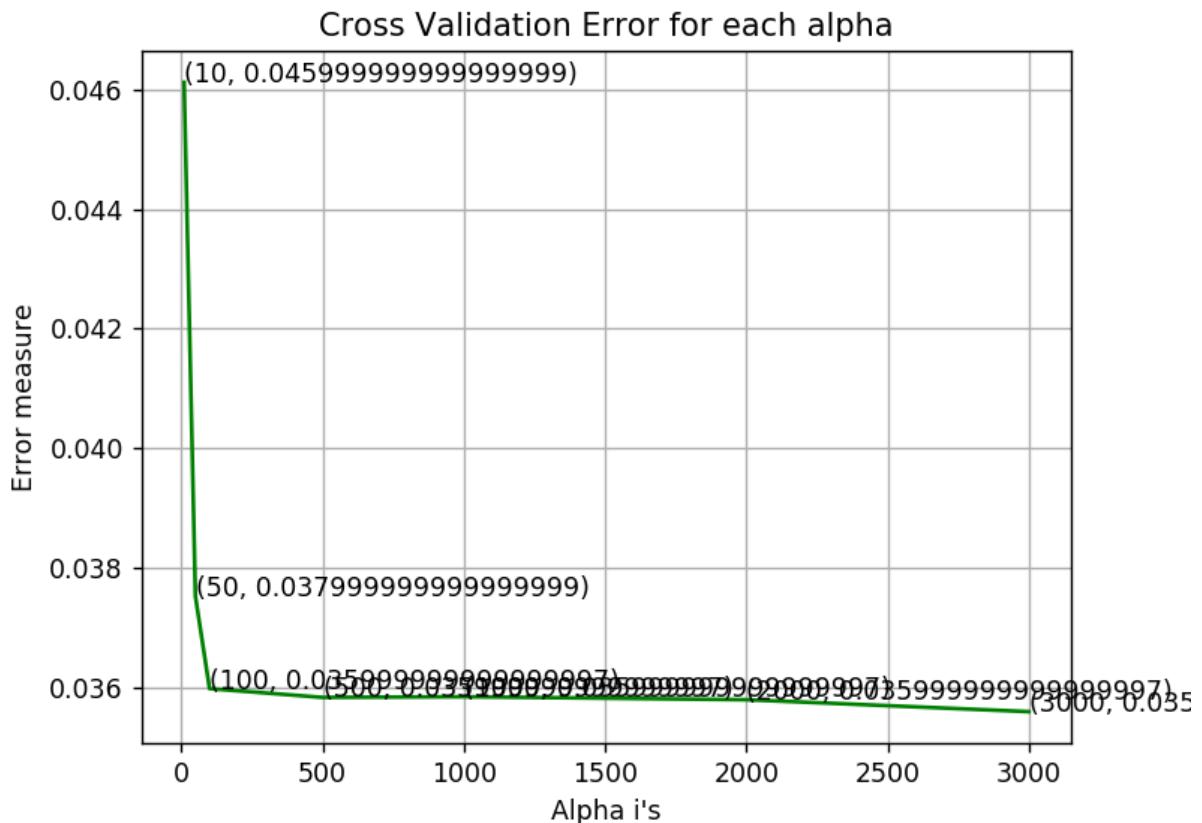
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
```

```
r_cfl.fit(X_train_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 is:",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 is:",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: 0.0355909487962
 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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1,
#                             max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None,
#                             **kwargs)

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


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.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=3000,nthread=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
```

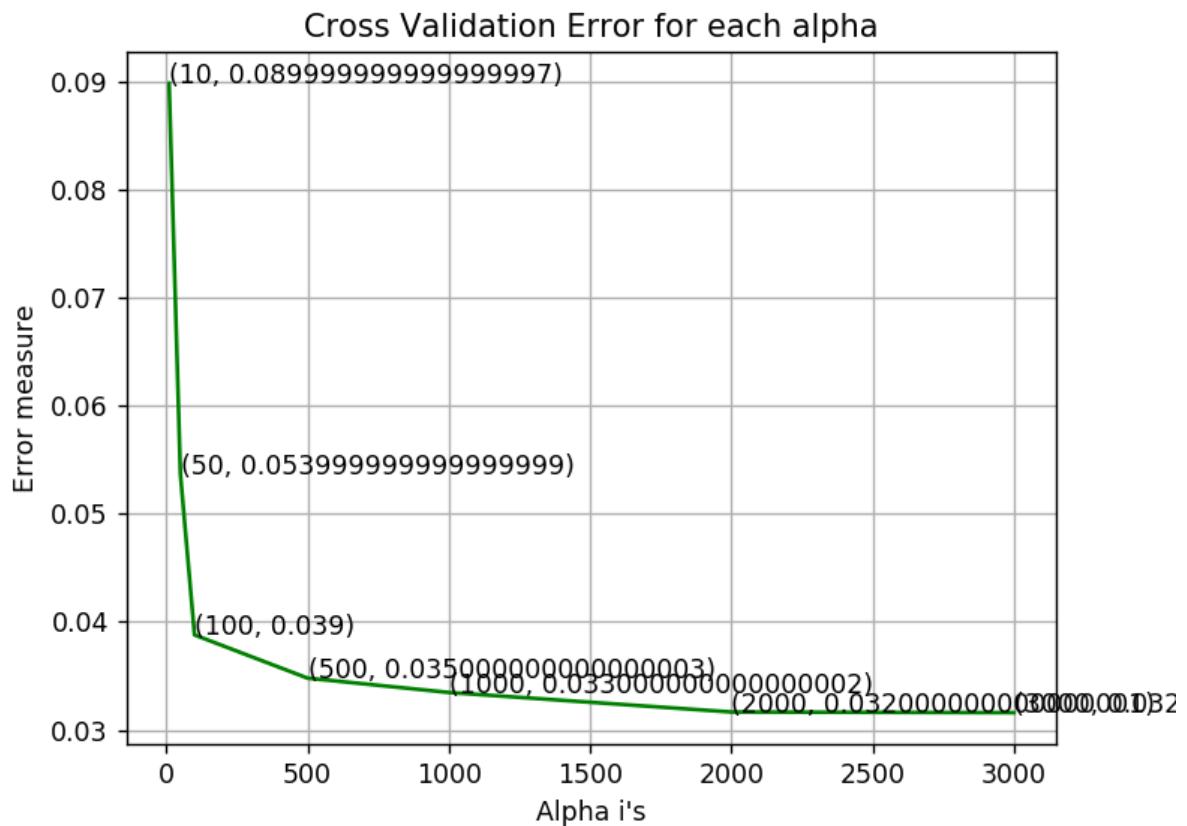
```

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 is:",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 is:",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: 0.0315972694477
 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_jobs=-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/en/latest/python/python_api.html#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child_weight=1,
#                             max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

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

x_cfl=XGBClassifier(n_estimators=1000,max_depth=10,learning_rate=0.15,colsample_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 is:",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 is:",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

Some Improvements

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 create 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 ending with .bytes, if yes we will move it to
# # 'byteFiles' folder

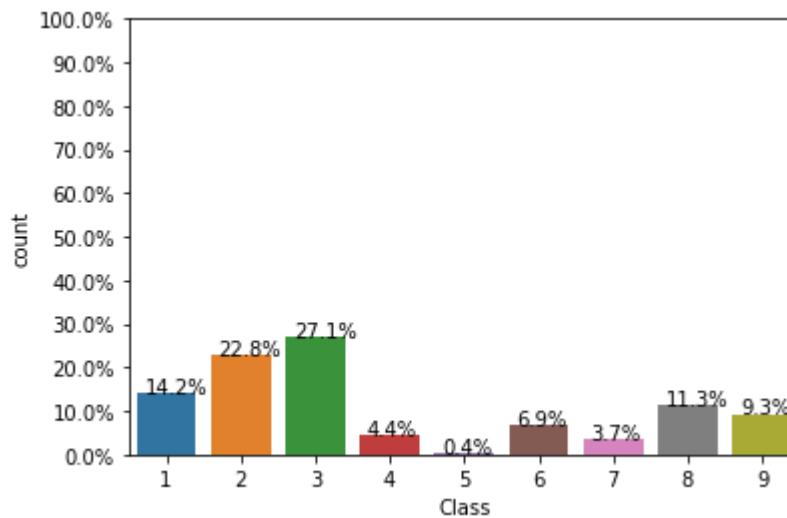
# # so by the end of this snippet we will separate all the .byte files and .asm files
# if os.path.isdir(source):
#     os.rename(source, 'asmFiles')
#     source='asmFiles'
#     data_files = os.listdir(source)
#     for file in data_files:
#         if (file.endswith("bytes")):
#             shutil.move(source+"/"+file,destination)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

3.1. Distribution of malware classes in whole data set

```
In [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()/total))
plt.show()
```



In [3]: Y

Out[3]:

		Id	Class
0	01kcPWA9K2B0xQeS5Rju	1	
1	04EjldbPV5e1XroFOpiN	1	
2	05EeG39MTRrl6VY21DPd	1	
3	05rJTUWYAKNegBk2wE8X	1	
4	0AnoOZDNbPXlr2MRBSCJ	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	01azqd4lnC7m9JpocGv5	601905	3905	2816	3832	3345	3242	3650	3201	2965	...	3101
1	01lsoiSMh5gxyDYTI4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlgw6aPeDxrU	93506	9542	2568	2438	8925	9330	9007	2342	9107	...	2242
3	01kcPWA9K2B0xQeS5Rju	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)
```

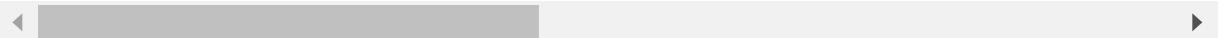
```
In [6]: #
# https://stackoverflow.com/a/29651514
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - 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
1	01lsoiSMh5gxyDYTI4CB	0.017358	0.011737	0.004033	0.003876	0.005303	0.003873
2	01jsnpXSAlg6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464	0.005280
3	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770	0.000354
4	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342	0.000232

5 rows × 260 columns



In []:

```
In [9]: # asmoutputfile.csv(output generated from the above two cells) will contain all 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	01kcPWA9K2B0xQeS5Rju	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\_stat.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='ID', 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

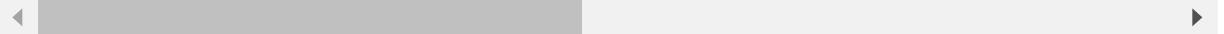


```
In [31]: # we normalize the data each column
result_asm = normalize(result_asm)
result_asm.head()
```

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	01IsoiSMh5gxyDYTI4CB	39755	8337	7249	7186	8663	6844	8420	7589	9291	...	439
2	01jsnpXSAlg6aPeDxrU	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
1	39755	8337	7249	7186	8663	6844	8420	7589	9291	358	...	260	1090	391	905	4
2	93506	9542	2568	2438	8925	9330	9007	2342	9107	2457	...	5	547	5	451	1
3	21091	1213	726	817	1257	625	550	523	1078	473	...	18	66	15	43	1
4	19764	710	302	433	559	410	262	249	422	223	...	18	1228	24	1546	1

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 = 'eighth'
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]], 'eighth')
    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('eighth')) + \  
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('eighth')),  
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](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('eighth'))):
        f = open('eighth/' + 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('eighth')
    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=eighthprocess)
p9=Process(target=ninthprocess)
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
    bytebigramp1_df = pd.read_csv('bytebigramp1.csv')
    return bytebigramp1_df

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

    bytebigramp2_df = pd.read_csv('bytebigramp2.csv')
    return bytebigramp2_df

@concurrent.process
def thirdprocess():

    bytebigramp3_df = pd.read_csv('bytebigramp3.csv')
    return bytebigramp3_df

@concurrent.process
def fourthprocess():

    bytebigramp4_df = pd.read_csv('bytebigramp4.csv')
    return bytebigramp4_df

@concurrent.process
def fifthprocess():

    bytebigramp5_df = pd.read_csv('bytebigramp5.csv')
    return bytebigramp5_df

@concurrent.process
def sixthprocess():

    bytebigramp6_df = pd.read_csv('bytebigramp6.csv')
    return bytebigramp6_df

@concurrent.process
def seventhprocess():

    bytebigramp7_df = pd.read_csv('bytebigramp7.csv')
    return bytebigramp7_df

@concurrent.process
def eigthprocess():

    bytebigramp8_df = pd.read_csv('bytebigramp8.csv')
    return bytebigramp8_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]: bytebigr1_df = (bytebigr1_df.result())
bytebigr2_df = (bytebigr2_df.result())
bytebigr3_df = (bytebigr3_df.result())
bytebigr4_df = (bytebigr4_df.result())
bytebigr5_df = (bytebigr5_df.result())
bytebigr6_df = (bytebigr6_df.result())
bytebigr7_df = (bytebigr7_df.result())
bytebigr8_df = (bytebigr8_df.result())
bytebigr9_df = (bytebigr9_df.result())
bytebigr10_df = (bytebigr10_df.result())
bytebigr11_df = (bytebigr11_df.result())
bytebigr12_df = (bytebigr12_df.result())
bytebigr13_df = (bytebigr13_df.result())
bytebigr14_df = (bytebigr14_df.result())
```

```
In [10]: bytebigr1_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	?? ft
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



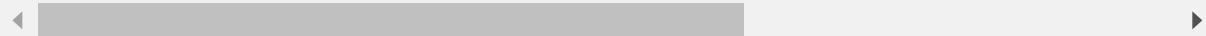
```
In [11]: bytebigr_df = pd.concat([bytebigr1_df,bytebigr2_df,bytebigr3_df,bytebigr4_df,bytebigr5_df,bytebigr6_df,bytebigr7_df,bytebigr8_df,bytebigr9_df,bytebigr10_df,bytebigr11_df,bytebigr12_df,bytebigr13_df,bytebigr14_df])
```

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

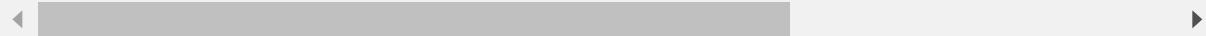


In [13]: bytebigram_df['ID'] = bytebigram_df['ID'].str[:-6]
bytebigram_df.head()

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	?? ft
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	00 09	...	?? fa	?? fb	?? fc	?? fc
0	0.009458	0.007180	0.001356	0.007605	0.000758	0.001183	0.000486	0.002309	0.000470	0.0	...	0.0	0.0	0.0	0.0
1	0.004489	0.002234	0.000339	0.000076	0.000344	0.000645	0.000388	0.000486	0.000336	0.0	...	0.0	0.0	0.0	0.0
2	0.002845	0.003271	0.001831	0.005552	0.001240	0.005805	0.002331	0.005469	0.001276	0.0	...	0.0	0.0	0.0	0.0
3	0.063507	0.137307	0.049508	0.073922	0.039272	0.043969	0.034088	0.050924	0.038627	0.0	...	0.0	0.0	0.0	0.0
4	0.002611	0.003830	0.002170	0.006084	0.001722	0.008170	0.002913	0.005834	0.002351	0.0	...	0.0	0.0	0.0	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_idx = np.argsort(rf.feature_importances_)[::-1]  
    print(len(features), len(imp_feature_idx))  
    imp_feature_name = np.take(features, imp_feature_idx)  
    return imp_feature_name
```

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

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

```
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)
```

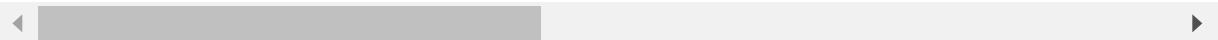
```
Out[21]: 1003
```

```
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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

5 rows × 1003 columns



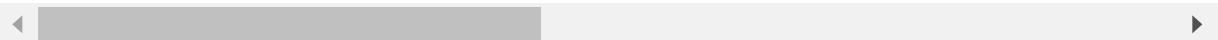
```
In [23]: # bytebigram_df.to_csv('bytebigram_final_rf_reduced_df', index=False)
```

```
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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

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 output variable '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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

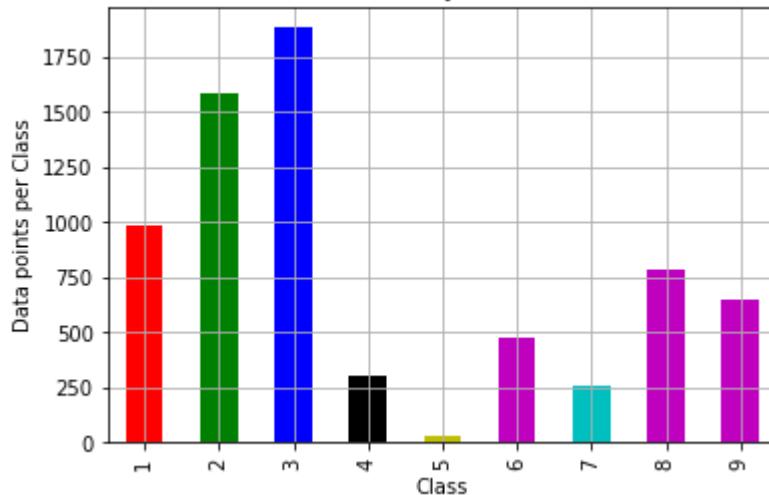
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

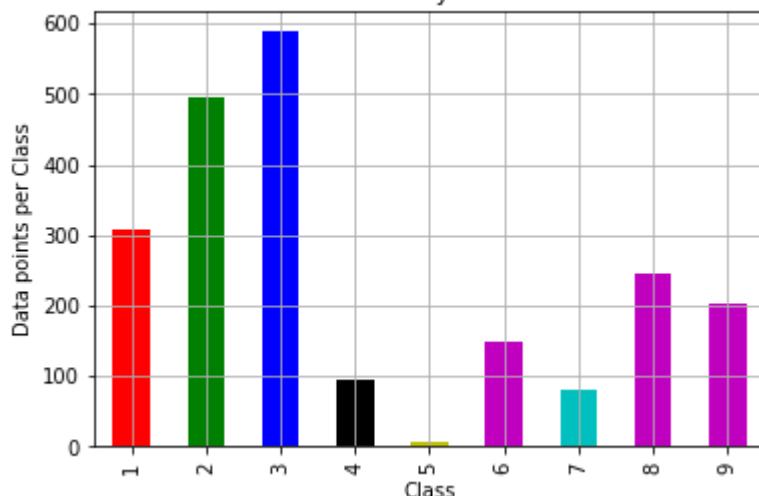
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

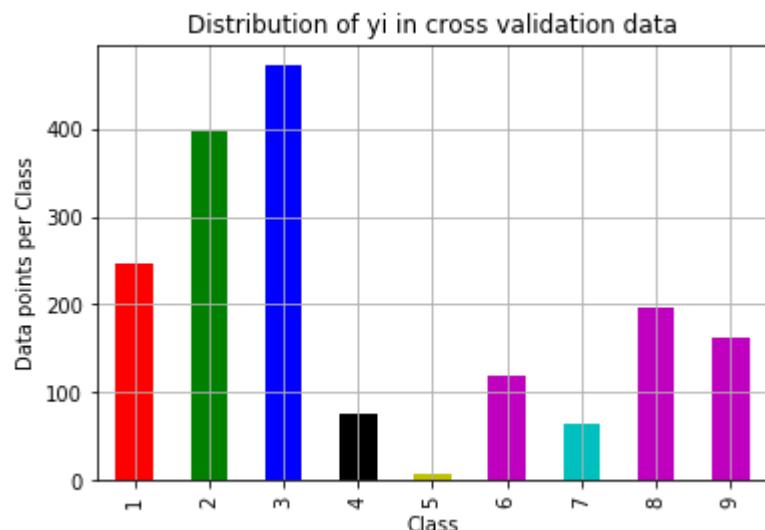
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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

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

alpha = [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)

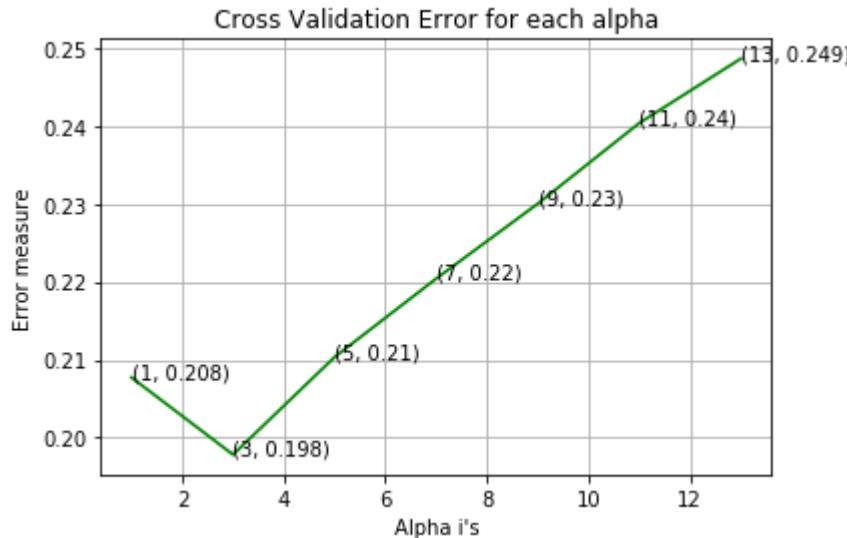
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

```
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 is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
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: 0.1978249822431406

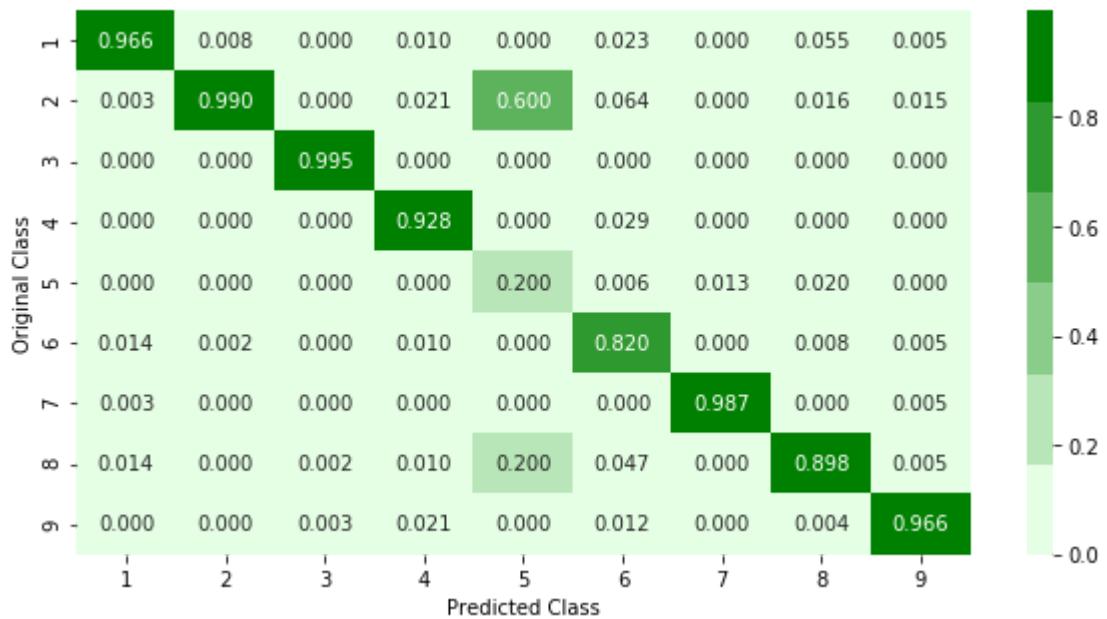
For values of best alpha = 3 The test log loss is: 0.18726276834434555

Number of misclassified points 4.323827046918123

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

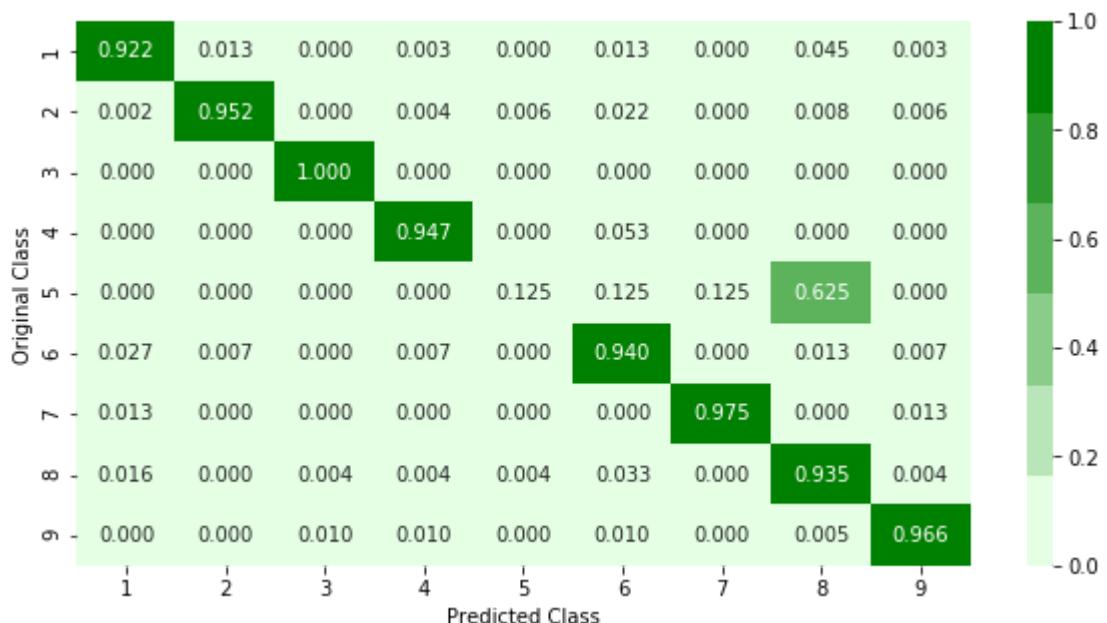
Original Class	1	2	3	4	5	6	7	8	9
	1	2	3	4	5	6	7	8	9
1	284.000	4.000	0.000	1.000	0.000	4.000	0.000	14.000	1.000
2	1.000	472.000	0.000	2.000	3.000	11.000	0.000	4.000	3.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	90.000	0.000	5.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	1.000	1.000	1.000	5.000	0.000
6	4.000	1.000	0.000	1.000	0.000	141.000	0.000	2.000	1.000
7	1.000	0.000	0.000	0.000	0.000	0.000	78.000	0.000	1.000
8	4.000	0.000	1.000	1.000	1.000	8.000	0.000	230.000	1.000
9	0.000	0.000	2.000	2.000	0.000	2.000	0.000	1.000	196.000

----- 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 [15]: # 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)

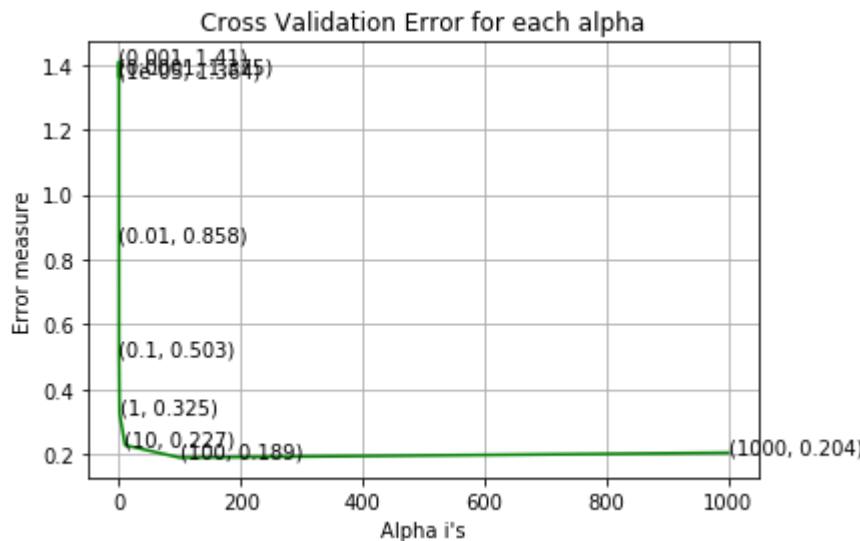
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

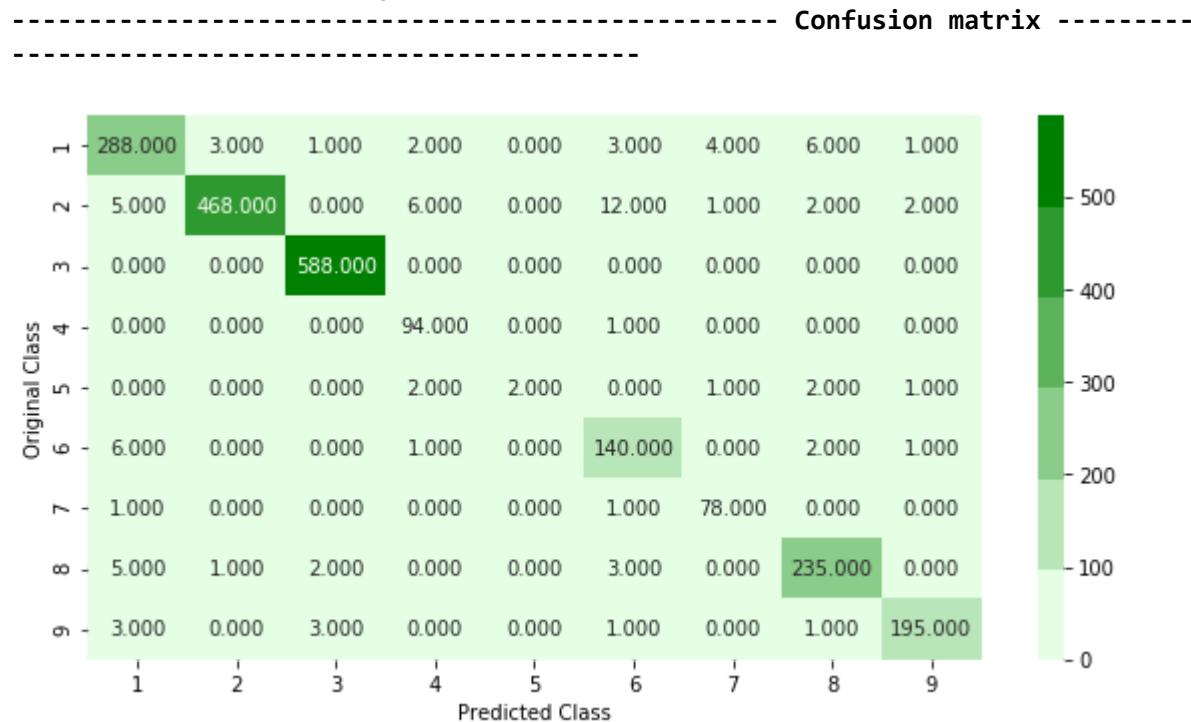
predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, eps=1e-15))
```

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

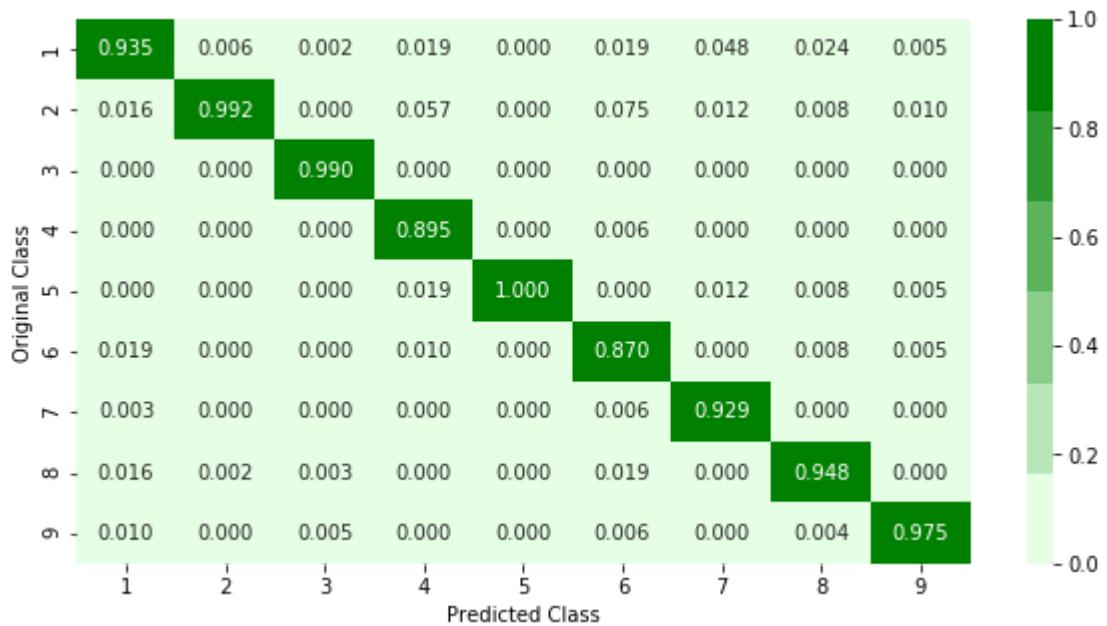
```
log_loss for c = 1e-05 is 1.3643575716090401
log_loss for c = 0.0001 is 1.3745366745151122
log_loss for c = 0.001 is 1.409786683014128
log_loss for c = 0.01 is 0.8575757630061275
log_loss for c = 0.1 is 0.5033783854842001
log_loss for c = 1 is 0.32459063858093135
log_loss for c = 10 is 0.22703952361235605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

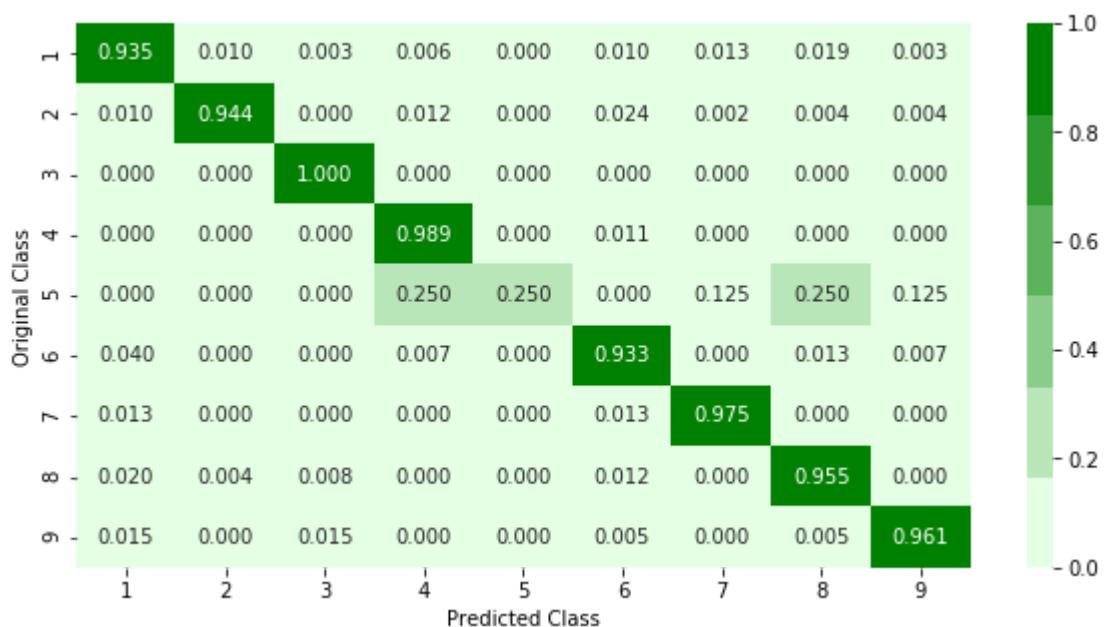


----- Precision matrix -----



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', 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()

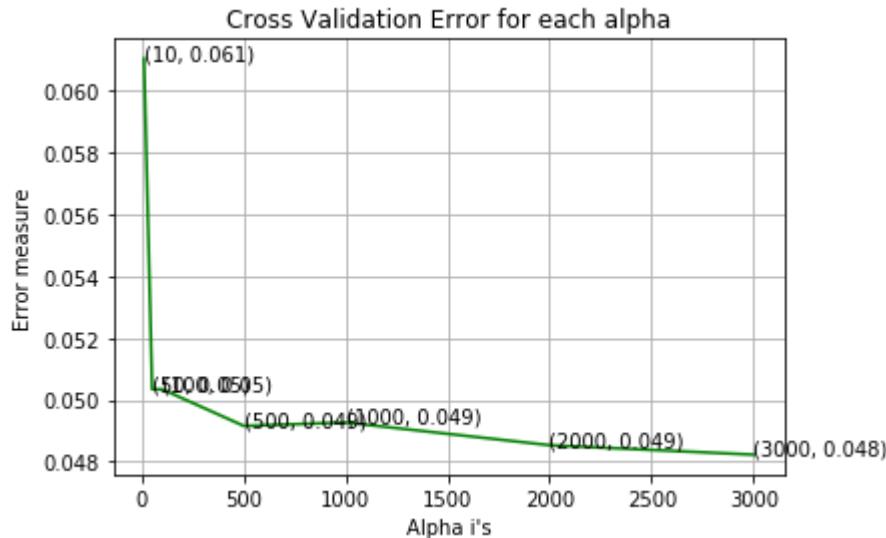
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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



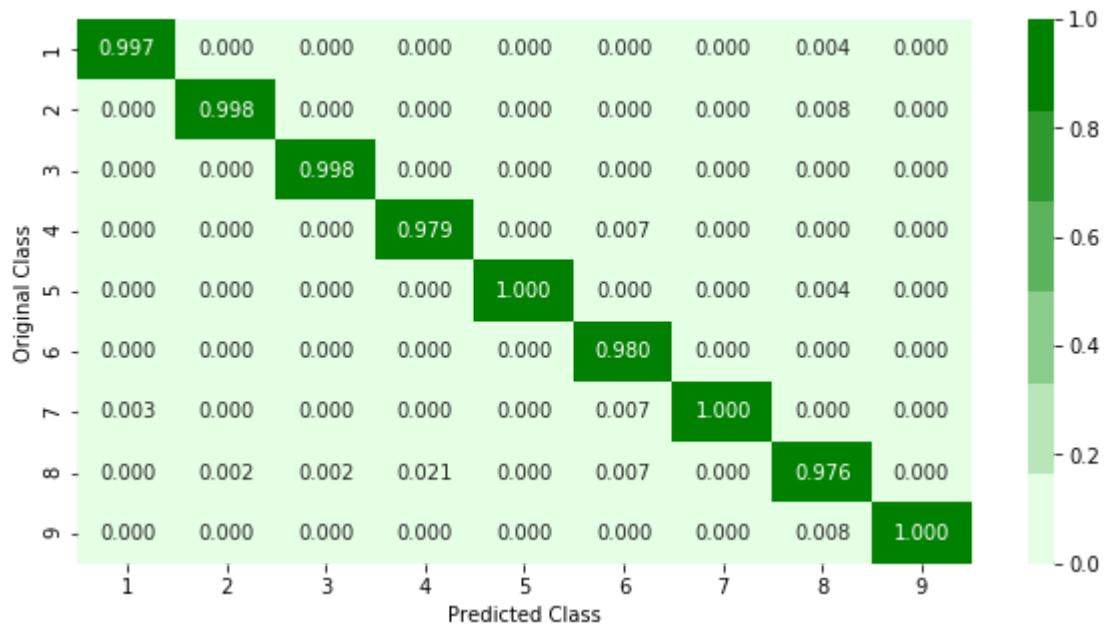
For values of best alpha = 3000 The train log loss is: 0.016007472330591885
 For values of best alpha = 3000 The cross validation log loss is: 0.04823060068036552

For values of best alpha = 3000 The test log loss is: 0.03671922339651359
 Number of misclassified points 0.6439742410303588

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

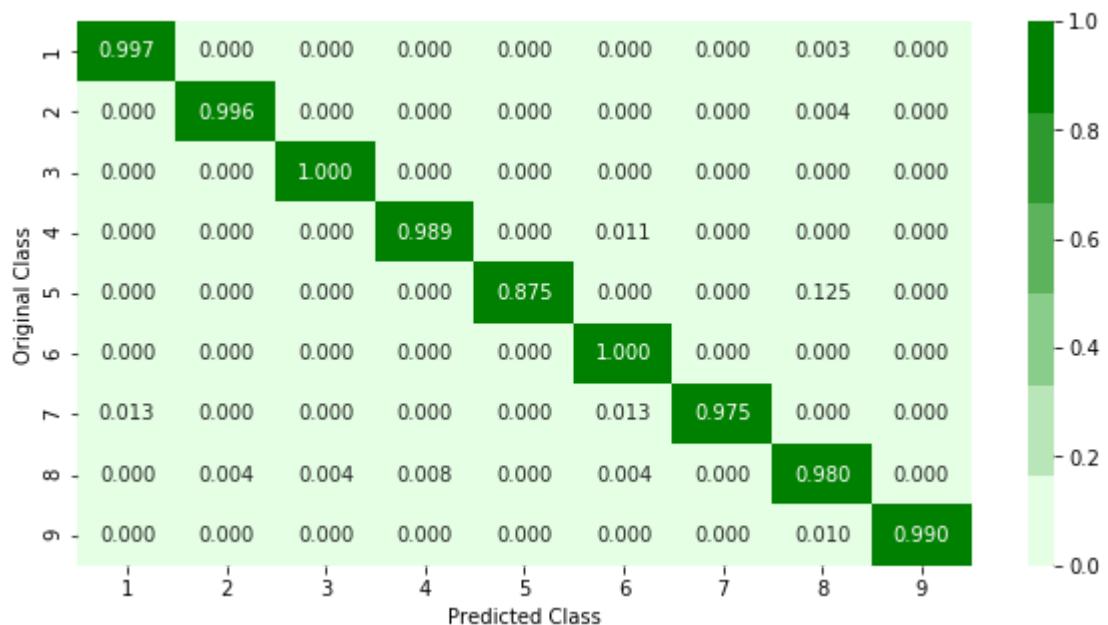
Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	Others
1	307.000	0.000	0.000	0.000	0.000	0.000	0.000	1000	0.000	-
2	0.000	494.000	0.000	0.000	0.000	0.000	0.000	2.000	0.000	-
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000	-
4	0.000	0.000	0.000	94.000	0.000	1.000	0.000	0.000	0.000	-
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	150.000	0.000	0.000	0.000	-
7	1.000	0.000	0.000	0.000	0.000	1.000	78.000	0.000	0.000	-
8	0.000	1.000	1.000	2.000	0.000	1.000	0.000	241.000	0.000	-
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000	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

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

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

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

```
alpha=[10,50,100,500,1000,2000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,nthread=-1)
    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])
```



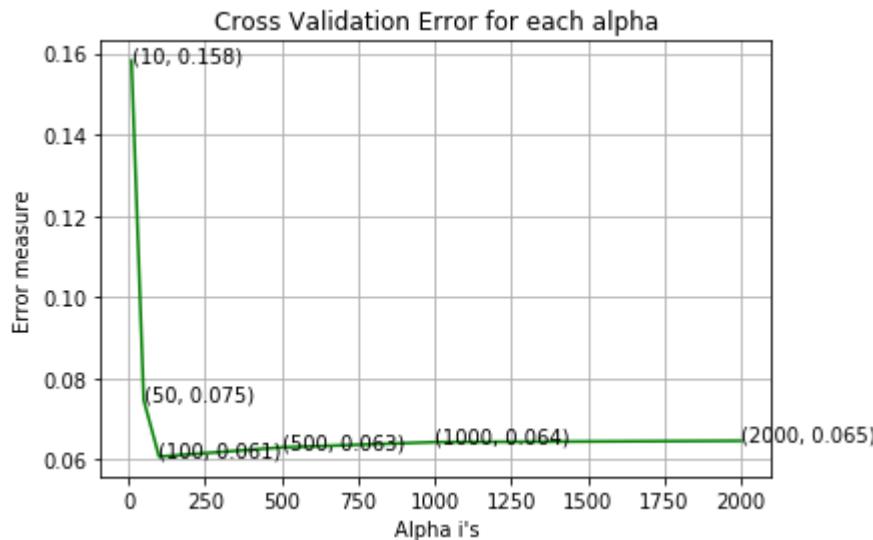
```
best_alpha = np.argmin(cv_log_error_array)

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)

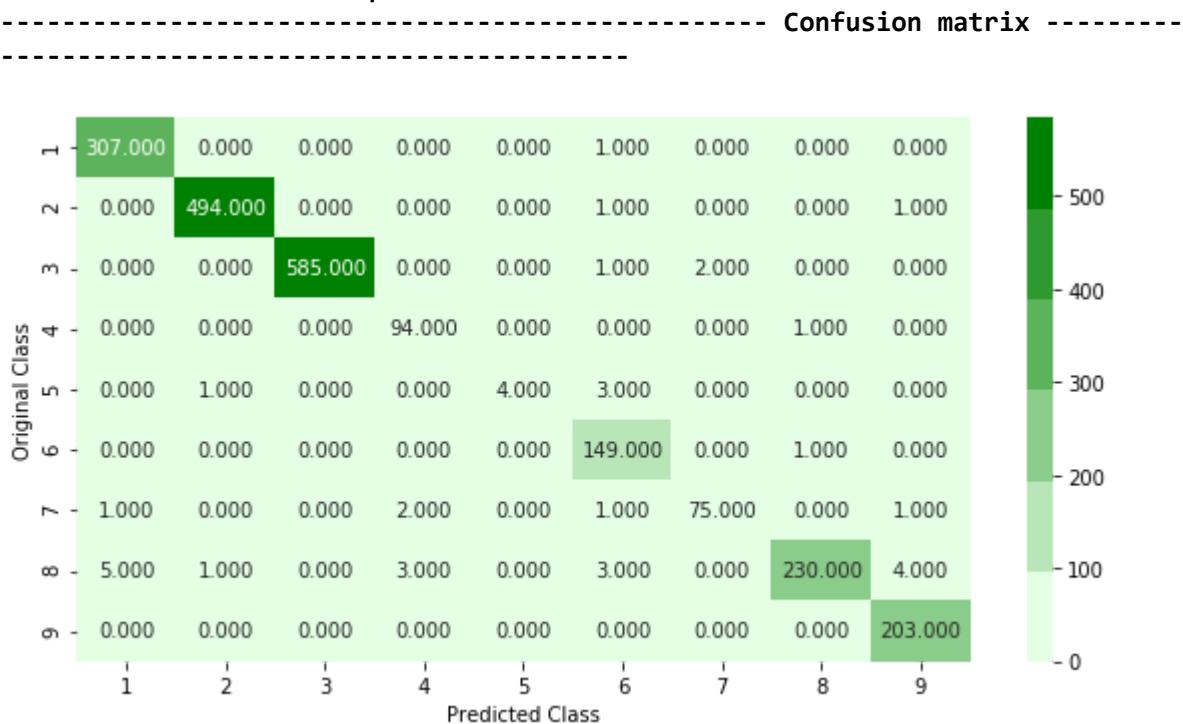
predict_y = sig_clf.predict_proba(X_train)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv,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

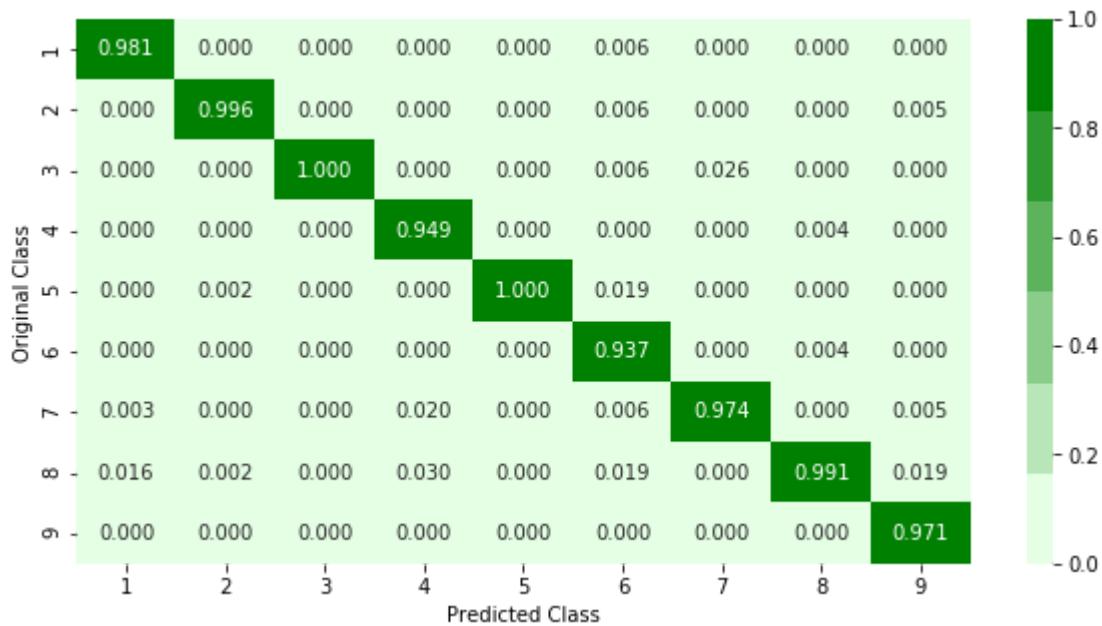


For values of best alpha = 100 The train log loss is: 0.017685102096223693
 For values of best alpha = 100 The cross validation log loss is: 0.06071110372719098

For values of best alpha = 100 The test log loss is: 0.07136470795873413
 Number of misclassified points 1.517939282428703

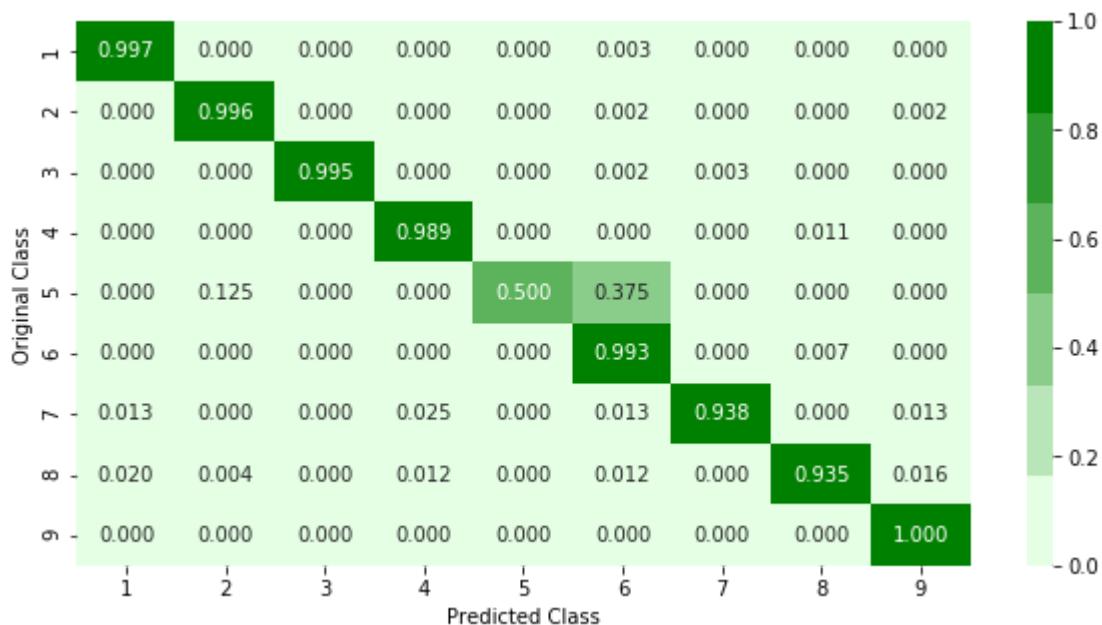


----- Precision matrix -----



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_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:   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_alpha=0, 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

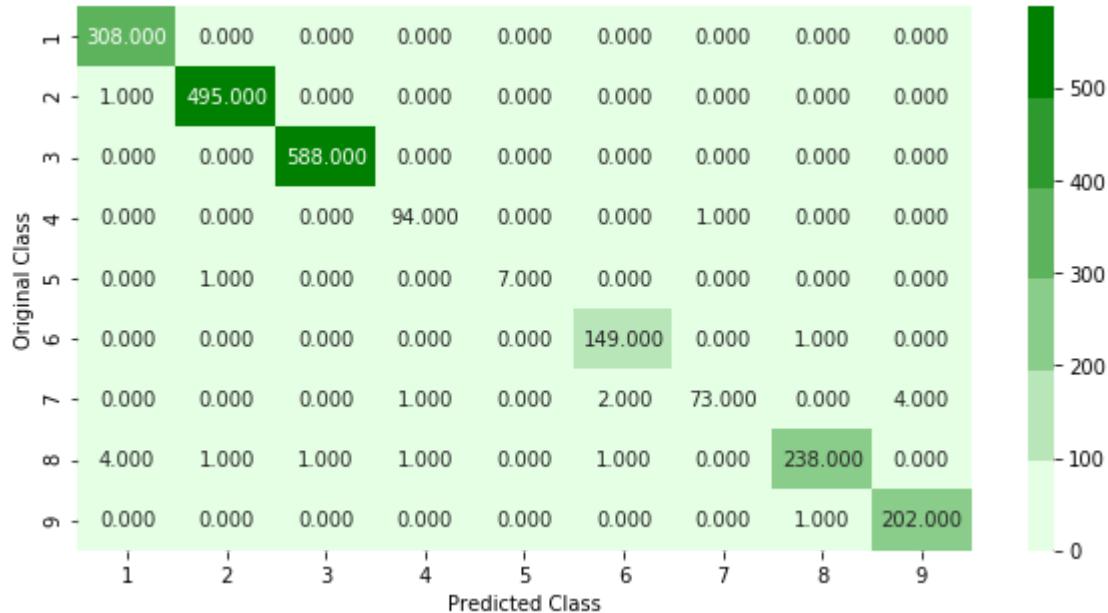
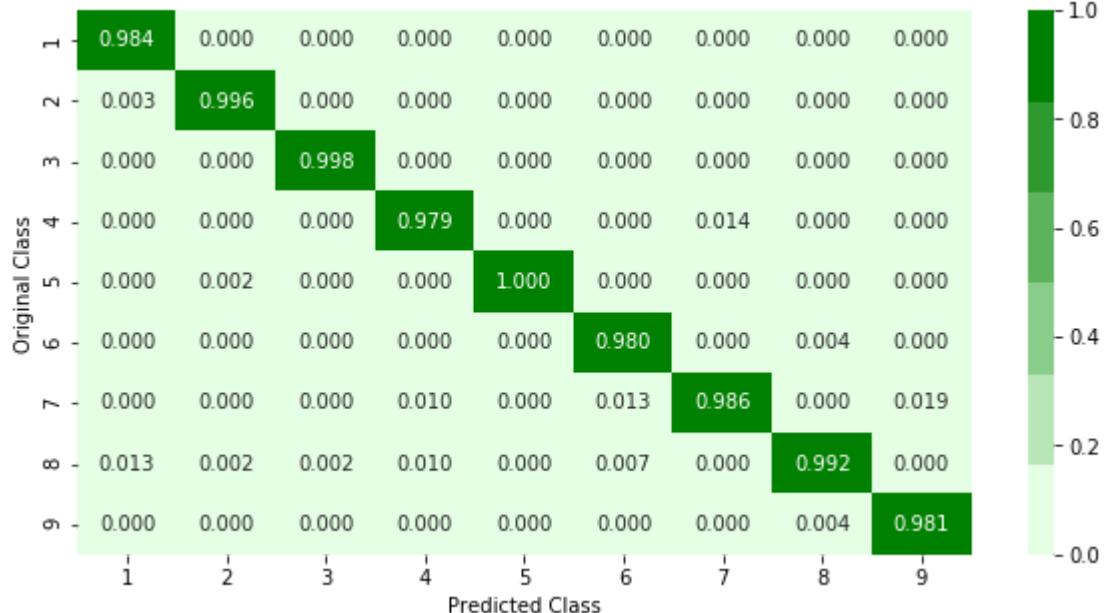
```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic',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

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


x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 500, colsample_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)

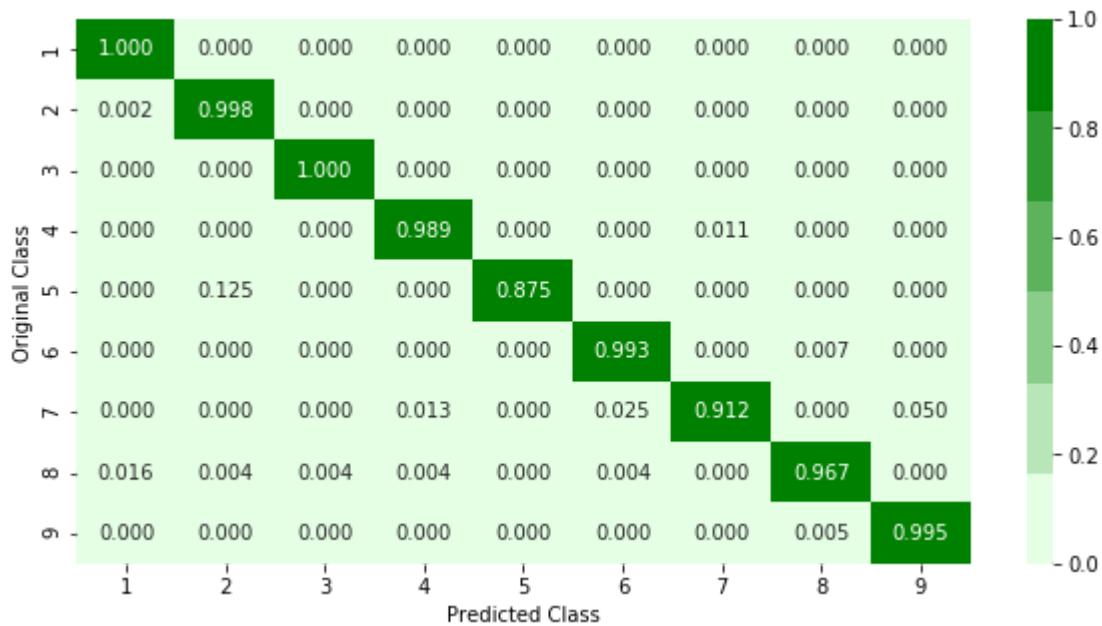
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

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('nbAgg')
# %matplotlib inline
```

```
In [4]: byte_vocab = "00,01,02,03,04,05,06,07,08,09,0a,0b,0c,0d,0e,0f,10,11,12,13,14,15,16,17,18,19,1a,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,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 forest
      # 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('eighth'))):
        f = open('eighth/' + 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('eighth')
    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=eighthprocess)
p9=Process(target=ninthprocess)
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()
```

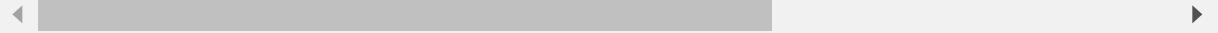
```
In [14]: bytetrigram1_df = (bytetrigram1_df.result())
bytetrigram2_df = (bytetrigram2_df.result())
bytetrigram3_df = (bytetrigram3_df.result())
bytetrigram4_df = (bytetrigram4_df.result())
bytetrigram5_df = (bytetrigram5_df.result())
bytetrigram6_df = (bytetrigram6_df.result())
bytetrigram7_df = (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	0.00
1	0.004334	0.002945	0.000346	0.000337	0.000654	0.000000	0.000000	0.00016	0.000113	0.00
2	0.002293	0.002945	0.000462	0.017520	0.000000	0.011777	0.000000	0.00352	0.000453	0.00
3	0.039613	0.141490	0.049313	0.253369	0.062102	0.093523	0.090713	0.05488	0.048709	0.00
4	0.002148	0.003239	0.000462	0.018194	0.000000	0.011777	0.000615	0.00288	0.000227	0.00

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 00 09
0	0.008908	0.010748	0.000231	0.001348	0.000981	0.000693	0.000308	0.00016	0.000453	0.000113
1	0.004334	0.002945	0.000346	0.000337	0.000654	0.000000	0.000000	0.00016	0.000113	0.000113
2	0.002293	0.002945	0.000462	0.017520	0.000000	0.011777	0.000000	0.00352	0.000453	0.000453
3	0.039613	0.141490	0.049313	0.253369	0.062102	0.093523	0.090713	0.05488	0.048709	0.048709
4	0.002148	0.003239	0.000462	0.018194	0.000000	0.011777	0.000615	0.00288	0.000227	0.000227

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 workers.

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)`

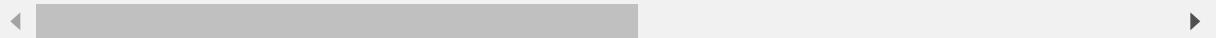
Out[36]: 1003

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 00 33 ff c5 d6	00 ff ...
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 00	33 ff	c5 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 output variable '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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

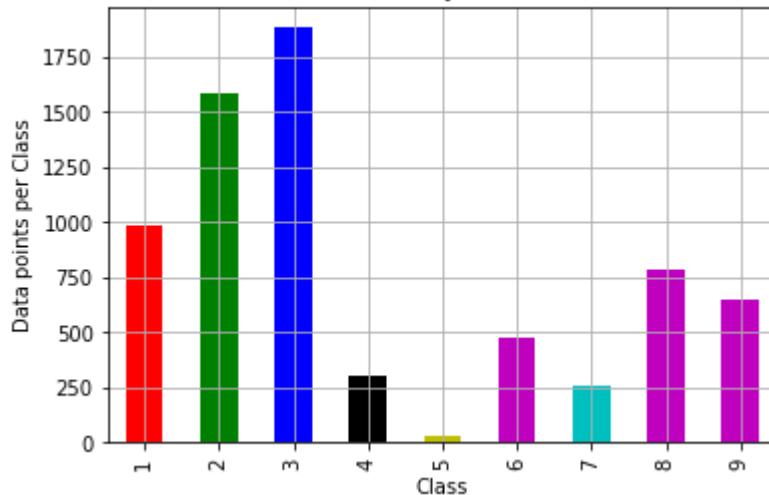
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

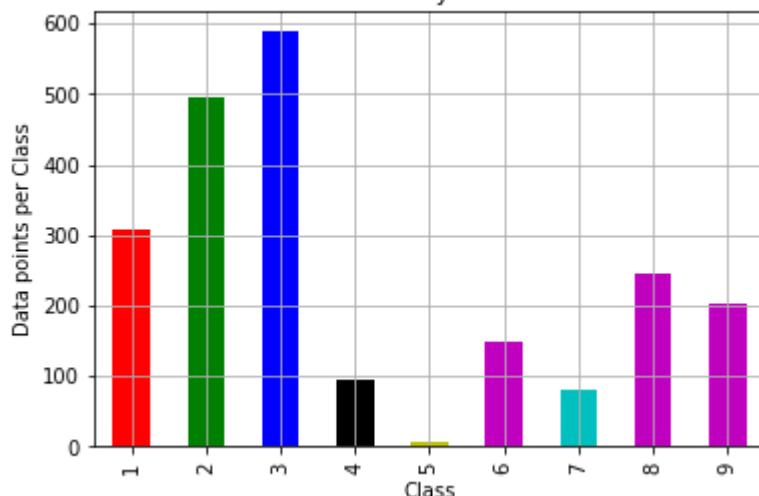
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

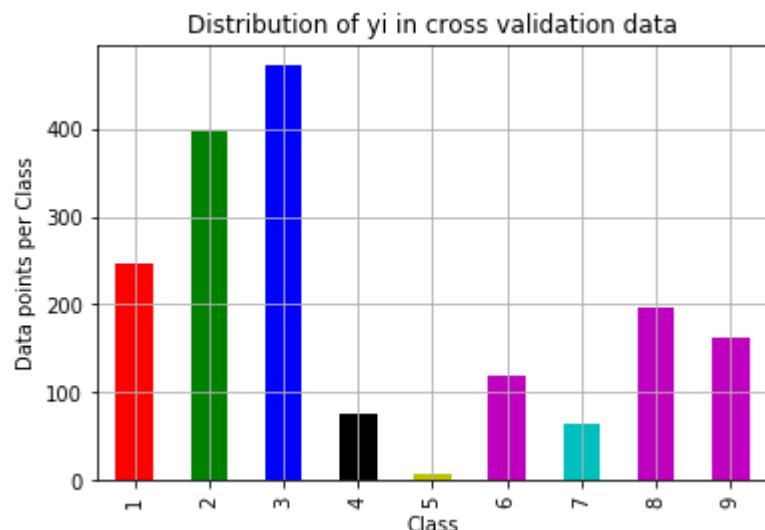
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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', 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()

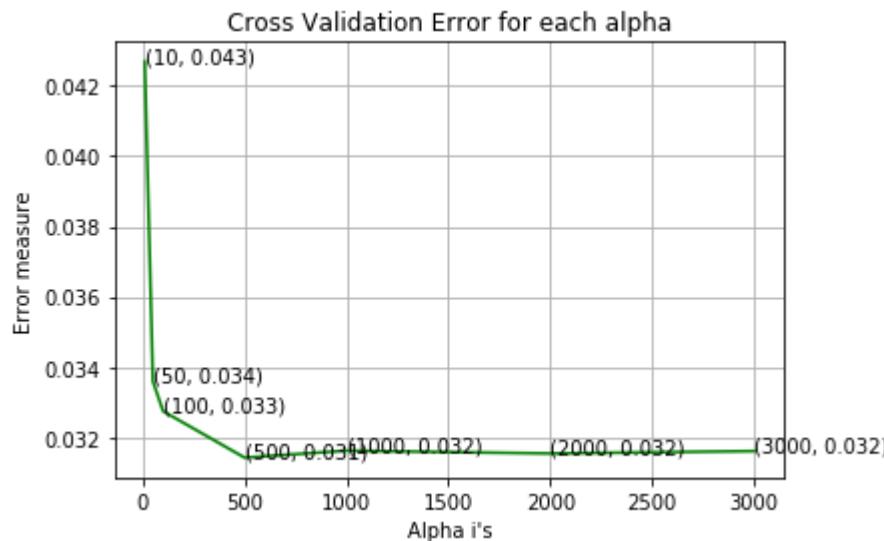
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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

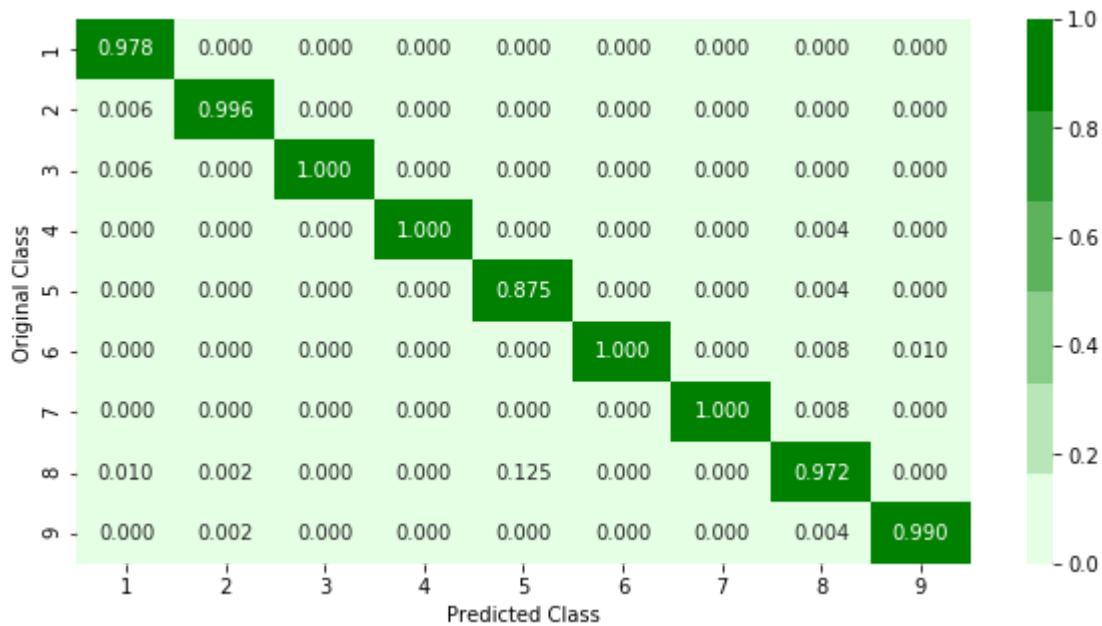


For values of best alpha = 500 The train log loss is: 0.014935436107096032
 For values of best alpha = 500 The cross validation log loss is: 0.031426635880770305
 For values of best alpha = 500 The test log loss is: 0.04329348834861496
 Number of misclassified points 0.8739650413983441

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

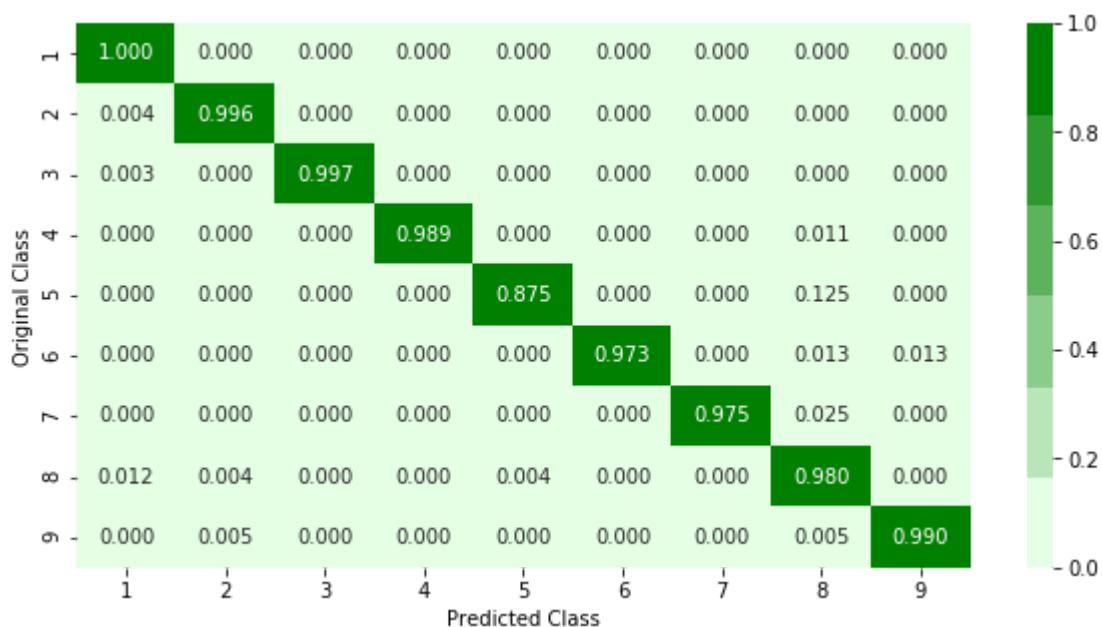
Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	None
1	308.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	2.000	494.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	2.000	0.000	586.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	94.000	0.000	0.000	0.000	1.000	0.000	0.000
5	0.000	0.000	0.000	0.000	7.000	0.000	0.000	1.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	146.000	0.000	2.000	2.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	78.000	2.000	0.000	0.000
8	3.000	1.000	0.000	0.000	1.000	0.000	0.000	241.000	0.000	0.000
9	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	201.000	0.000

----- 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_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:  2.1min 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_alpha=1,  
                                         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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1, max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

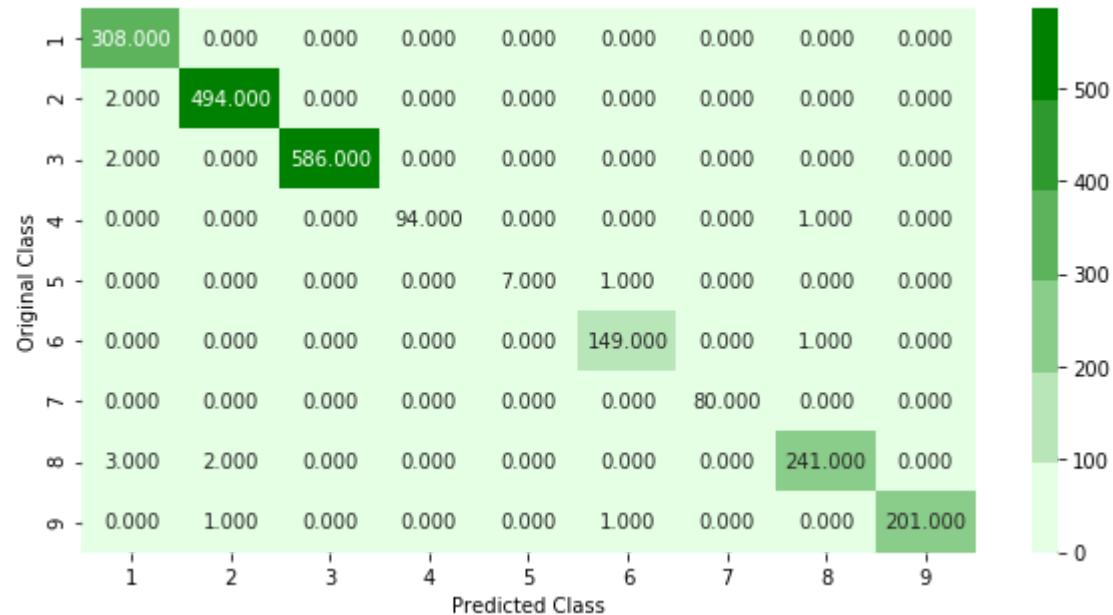
# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: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


x_cfl=XGBClassifier(learning_rate= 0.03, subsample= 0.5, n_estimators= 500, colsample_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)

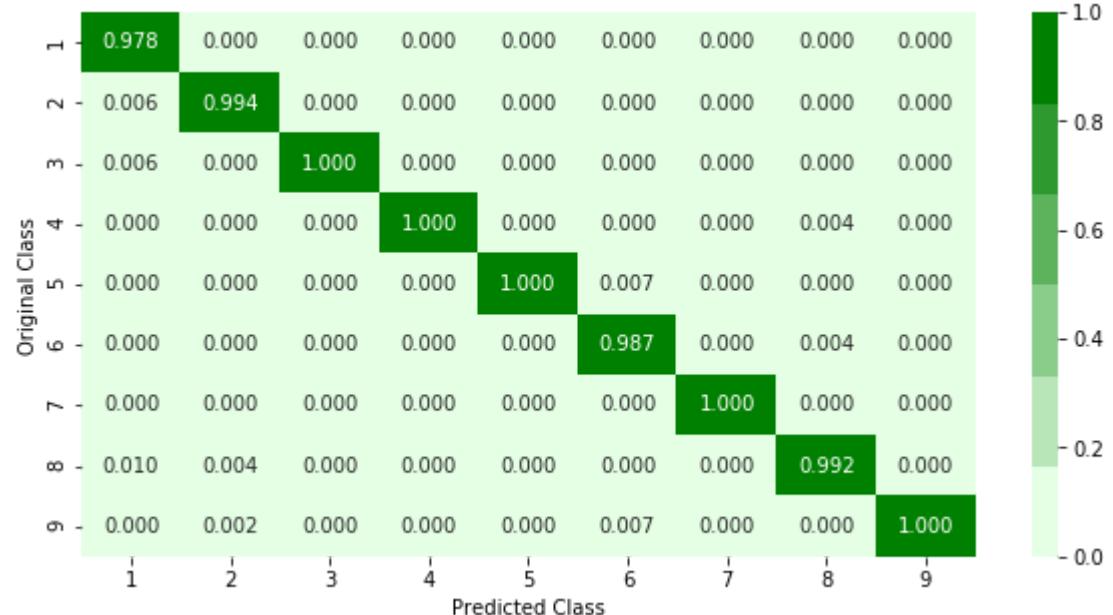
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

train loss 0.012230363341002245
cv loss 0.027439246142274578
test loss 0.03738227661138209
Number of misclassified points 0.6439742410303588

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

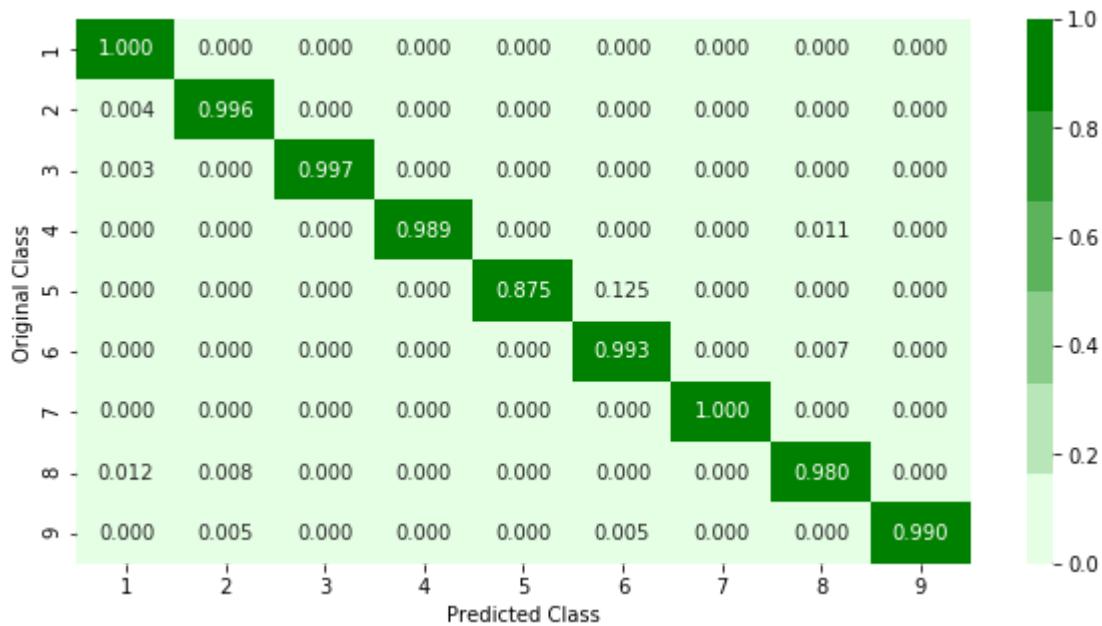


----- Precision matrix -----



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

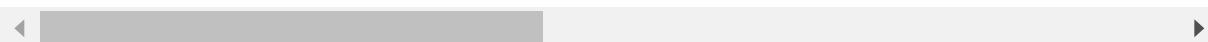
```
In [1]: import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
from sklearn import preprocessing
import pandas as pd
from 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('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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

5 rows × 1003 columns

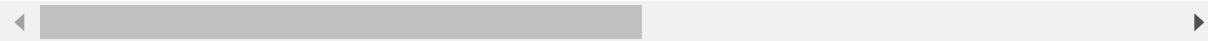


In [3]: `bytetrigram_df = pd.read_csv('bytetrigram_final_rf_reduced_df')
bytetrigram_df.head()`

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 00 33 ff c5 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','Class'],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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

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 output variable '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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

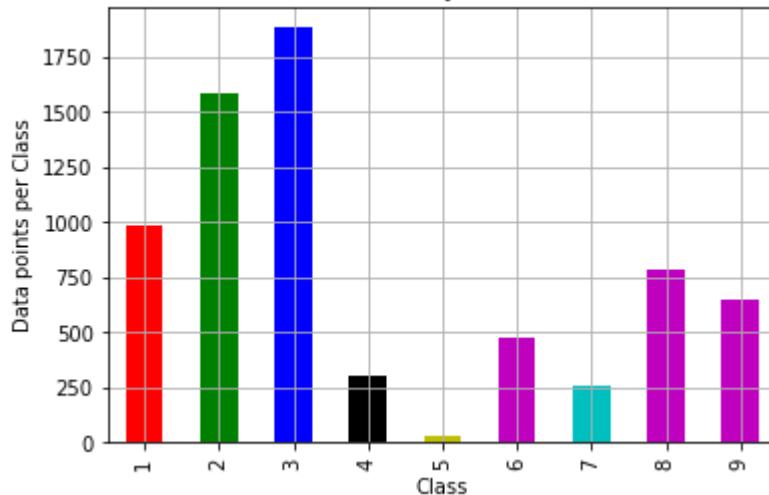
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

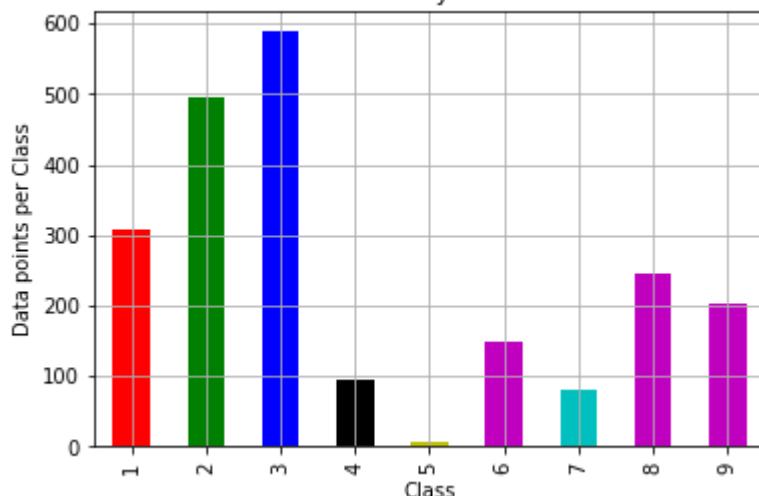
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

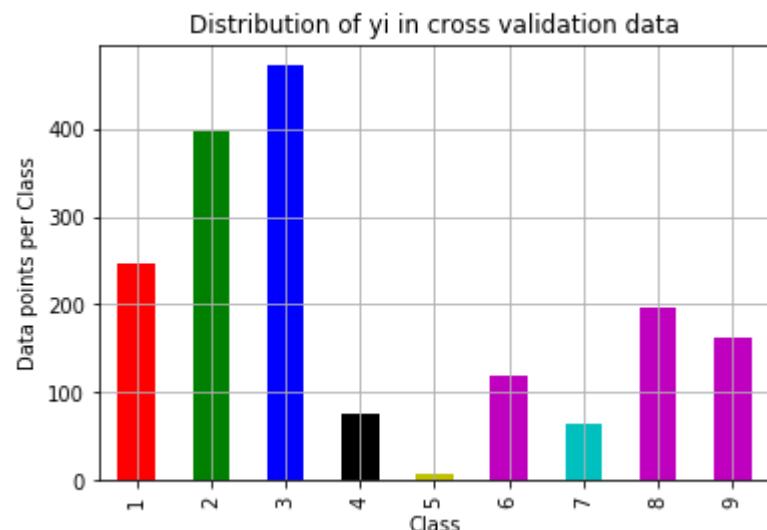
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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', 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()

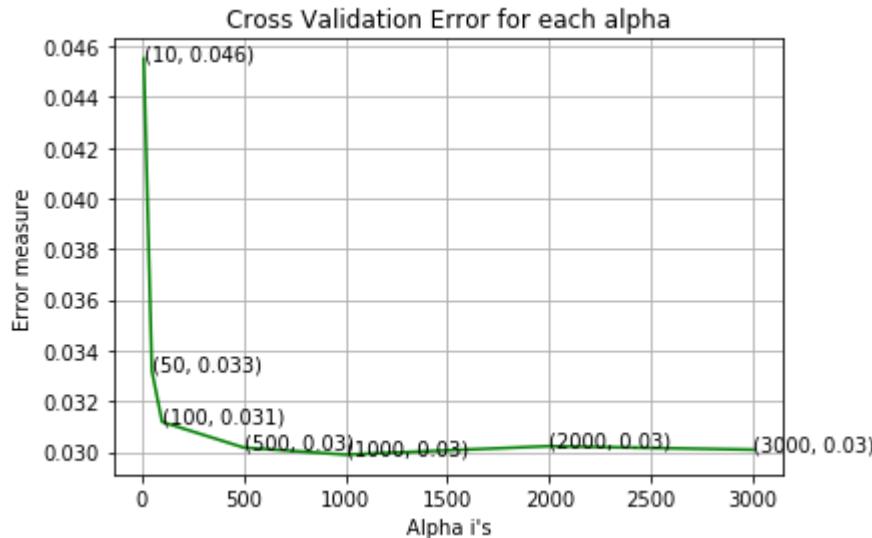
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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



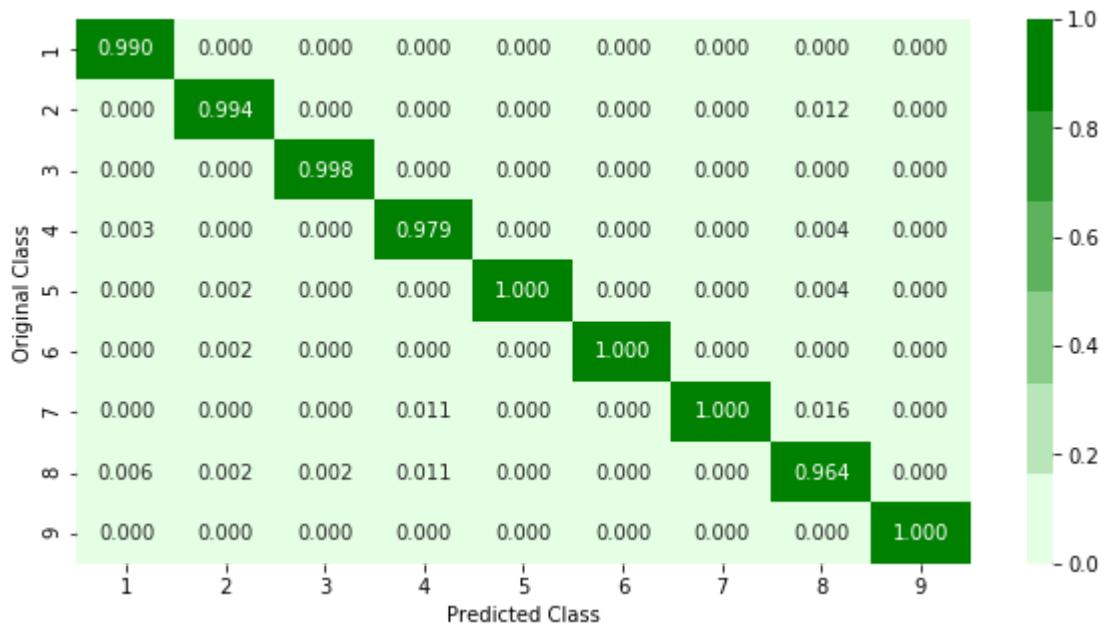
For values of best alpha = 1000 The train log loss is: 0.014702410007220173
 For values of best alpha = 1000 The cross validation log loss is: 0.029890840290377148

For values of best alpha = 1000 The test log loss is: 0.03918666032311394
 Number of misclassified points 0.8279668813247469

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

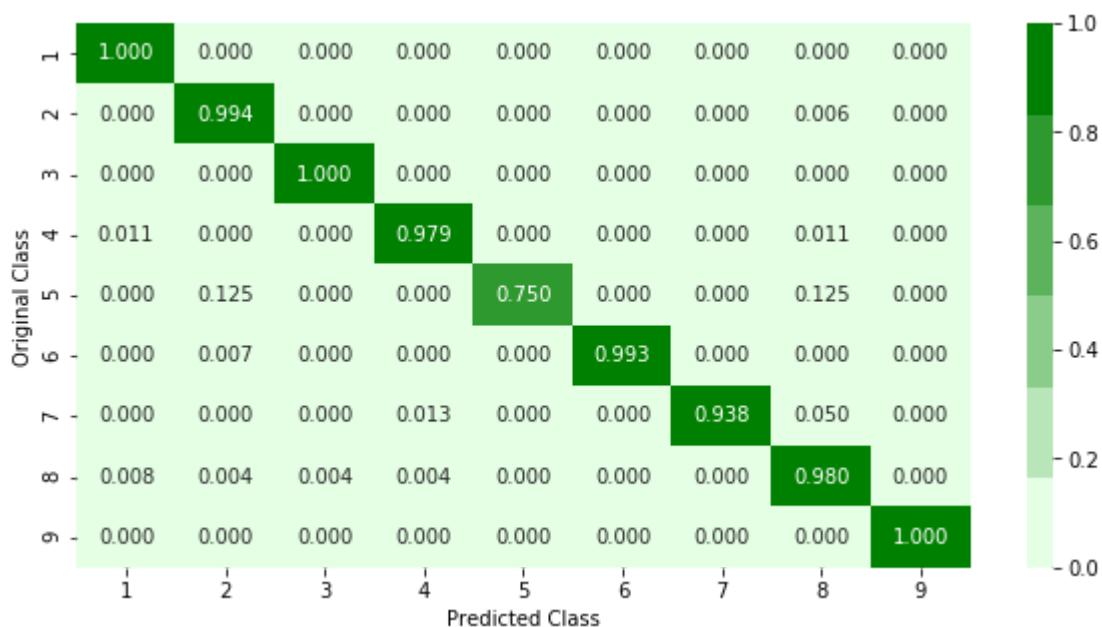
Original Class	Predicted Class								
	1	2	3	4	5	6	7	8	9
1	308.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	493.000	0.000	0.000	0.000	0.000	0.000	3.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	1.000	0.000	0.000	93.000	0.000	0.000	0.000	1.000	0.000
5	0.000	1.000	0.000	0.000	6.000	0.000	0.000	1.000	0.000
6	0.000	1.000	0.000	0.000	0.000	149.000	0.000	0.000	0.000
7	0.000	0.000	0.000	1.000	0.000	0.000	75.000	4.000	0.000
8	2.000	1.000	1.000	1.000	0.000	0.000	0.000	241.000	0.000
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 [18]: # Training a hyper-parameter tuned Xg-Boost regressor on our train data

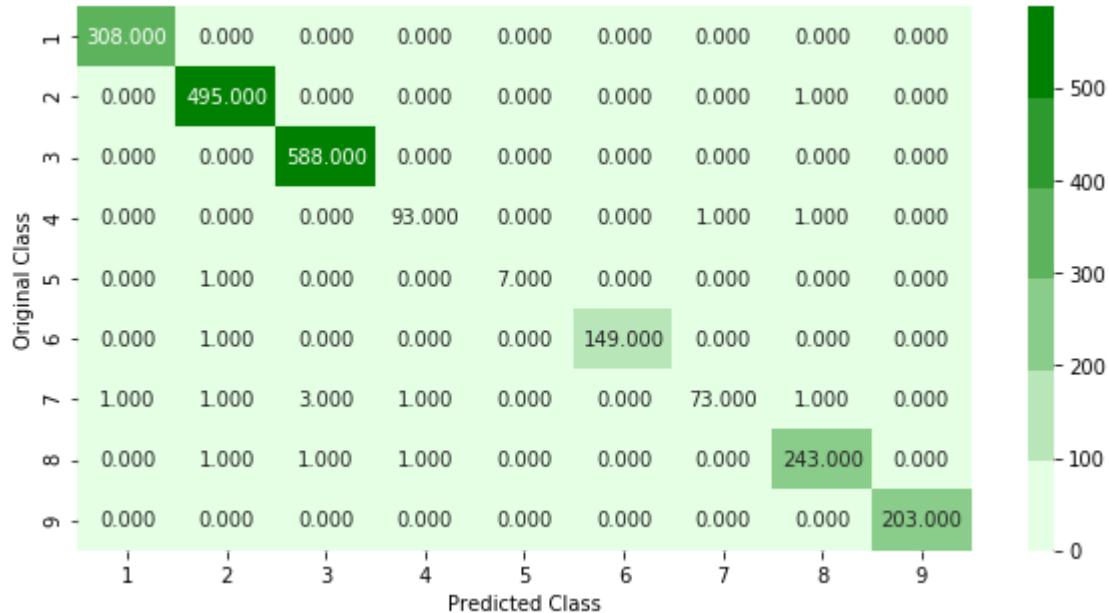
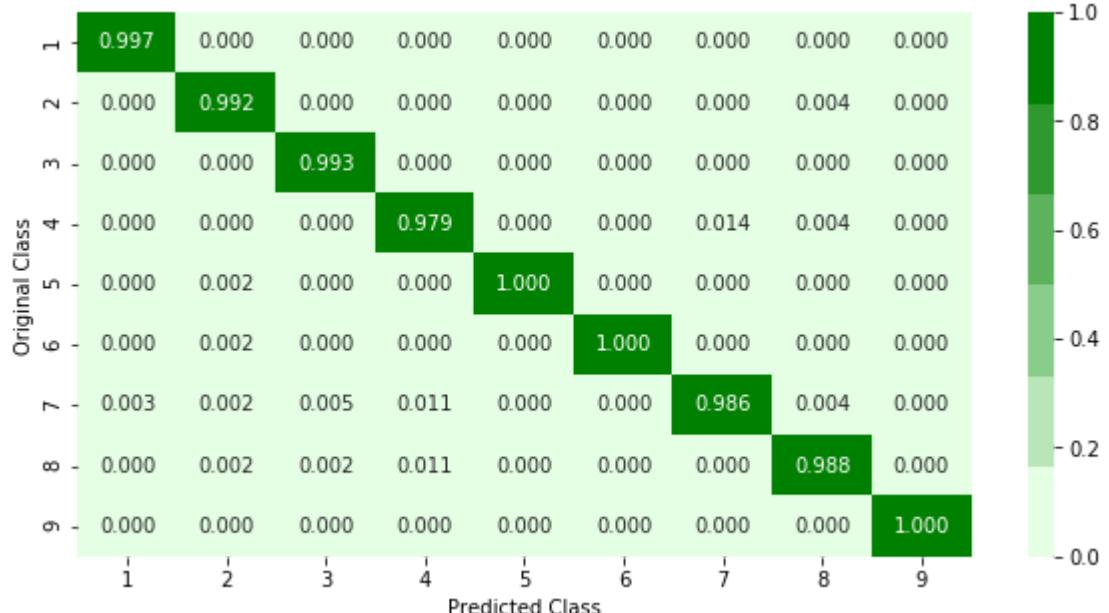
```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic',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

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


x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 500, colsample_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)

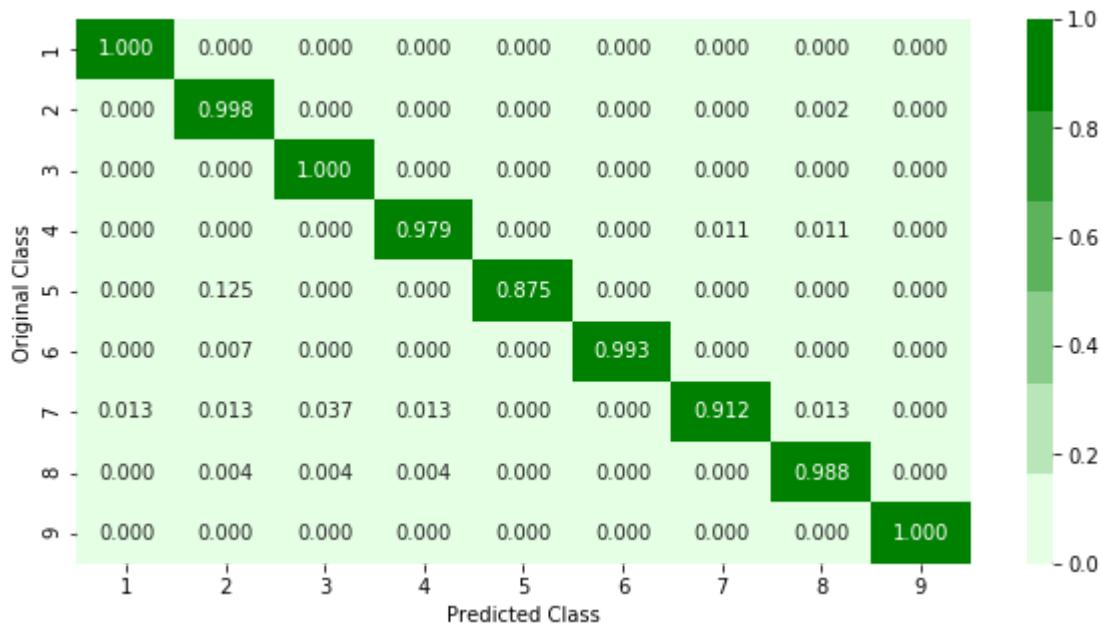
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

**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 create 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 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 .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 generated from the above two cells) will contain all 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\_stat.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	aYRoe1Nvt4J8Bz6LbS25	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='ID', 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('nbAgg')
# %matplotlib 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()`

```
1 files ----- done
2 files ----- done
3 files ----- done
4 files ----- done
5 files ----- done
6 files ----- done
7 files ----- done
8 files ----- done
9 files ----- done
10 files ----- done
11 files ----- done
12 files ----- done
13 files ----- done
14 files ----- done
15 files ----- done
16 files ----- done
17 files ----- done
18 files ----- done
19 files ----- done
20 files ----- done
21 files ----- done
22 files ----- done
23 files ----- done
24 files ----- done
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26 files ----- done
27 files ----- done
28 files ----- done
29 files ----- done
30 files ----- done
31 files ----- done
32 files ----- done
33 files ----- done
34 files ----- done
35 files ----- done
36 files ----- done
37 files ----- done
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41 files ----- done
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43 files ----- done
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57 files ----- done
```

58 files ----- done
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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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```

```
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	01kcPWA9K2B0xQeS5Rju	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(asn_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

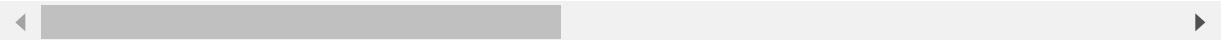
```
In [10]: # https://stackoverflow.com/a/29651514
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class') and str(feature_name)!=str('size')):
            max_value = df[feature_name].max()
            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')
```

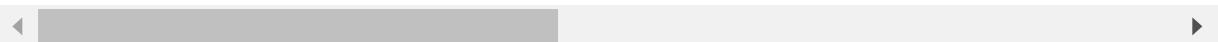
```
In [12]: # final_result_asm.to_csv('asm_img_final_rf_reduced_df', index=False)
```

```
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 output variable 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_result_asm.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 variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

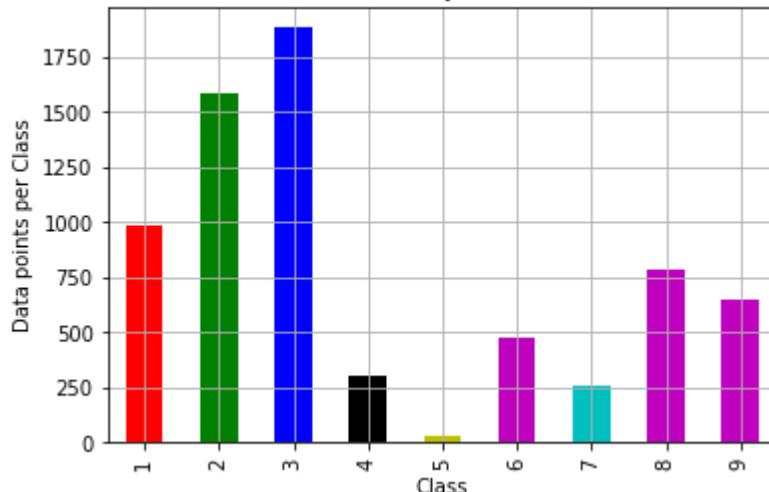
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

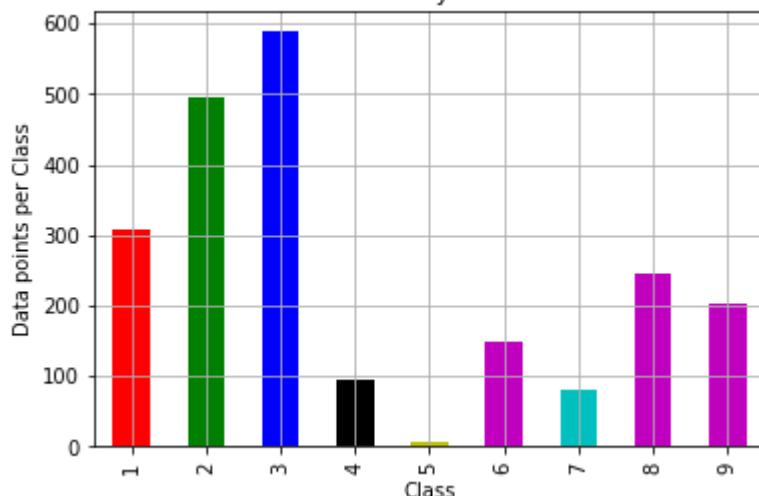
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

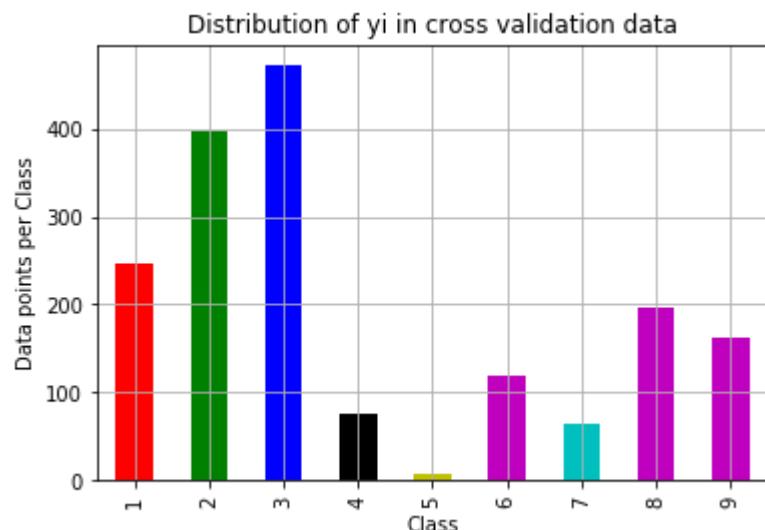
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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', 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()

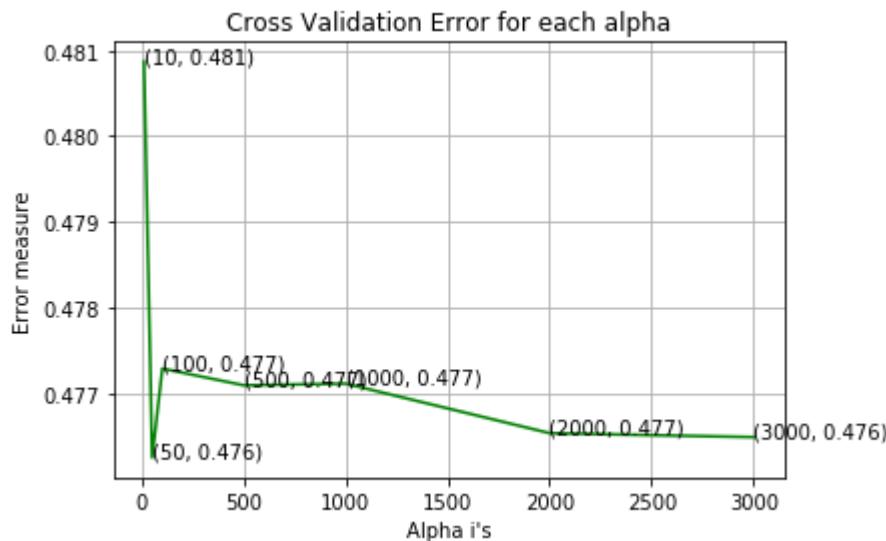
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

```
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 is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
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: 0.4762451178521051

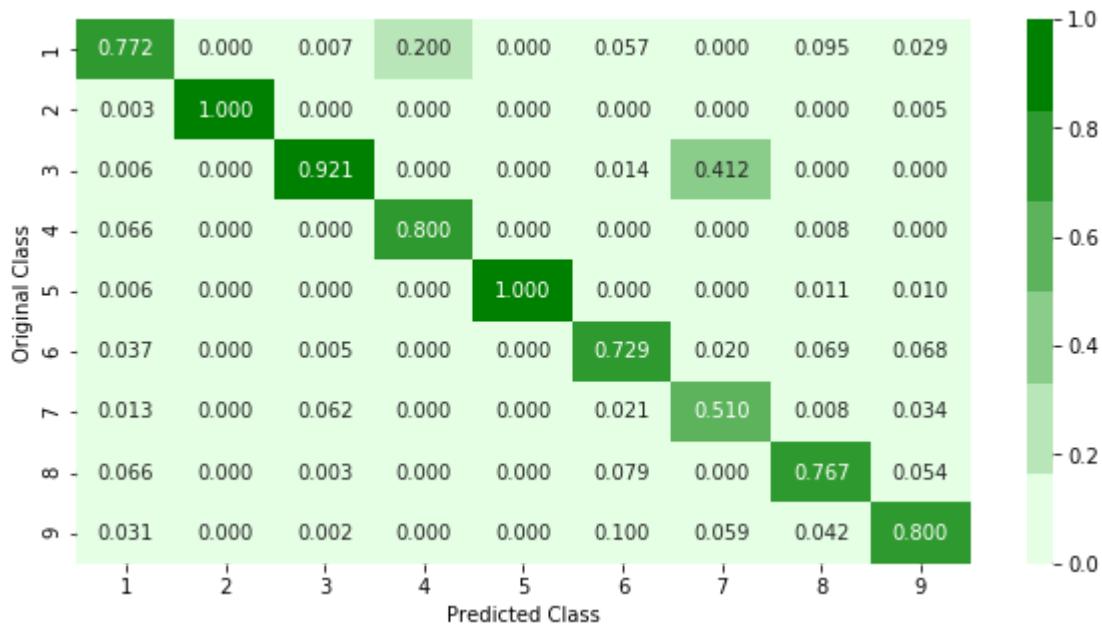
For values of best alpha = 50 The test log loss is: 0.4834634633772229

Number of misclassified points 13.983440662373505

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

Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	0
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_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:  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_alpha=0, 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]: `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

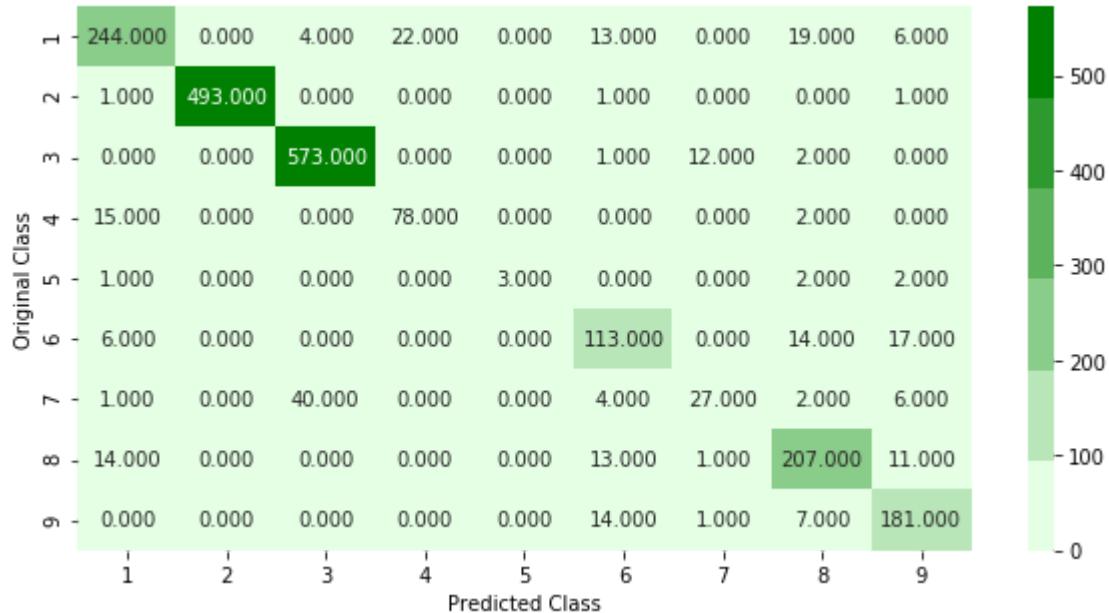
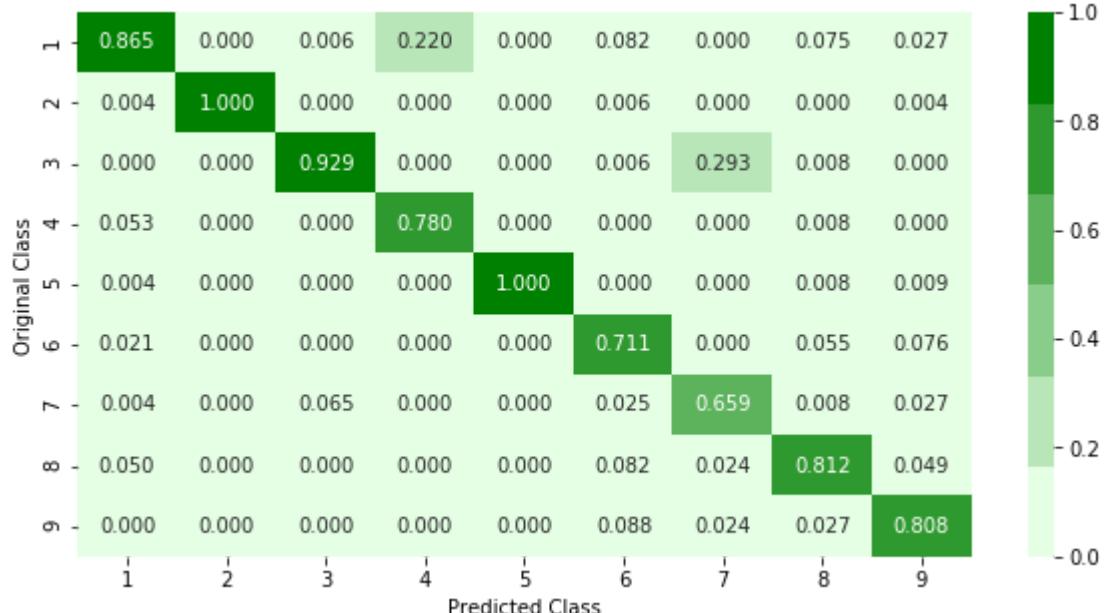
```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
# # objective='binary:logistic', booster='gbtree',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

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

x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 200, colsample_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)

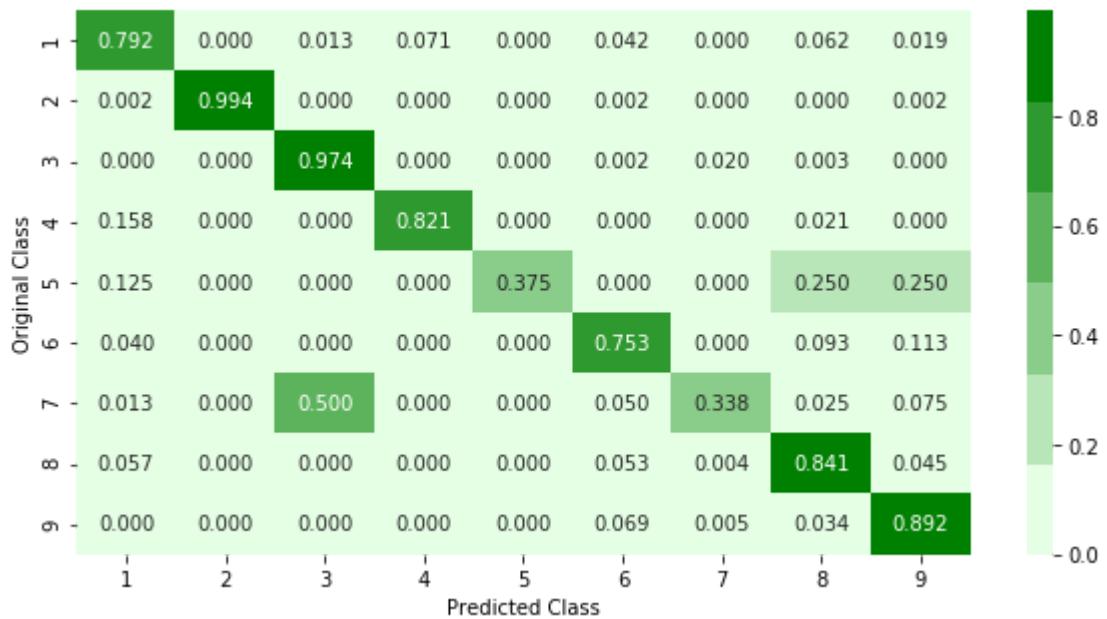
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

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)

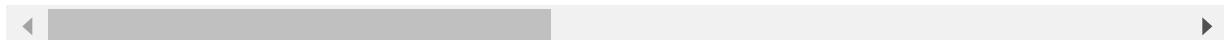
```
In [2]: import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
from sklearn import preprocessing
import pandas as pd
from 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('nbAgg')
# %matplotlib 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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

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 00	33 ff	...
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

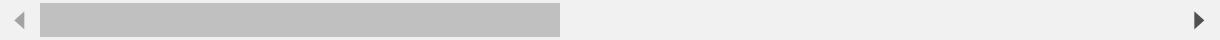


```
In [15]: final_result_asm = pd.read_csv('asm_img_final_rf_reduced_df')
final_result_asm.head()
```

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','Class'],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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

5 rows × 2003 columns

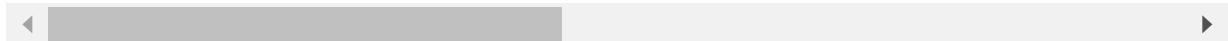


```
In [16]: final_result_asm = final_result_asm.rename(columns={"Class": "Class_y"})
final_result_asm.head()
```

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=False), 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 last.
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 variable '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 variable '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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

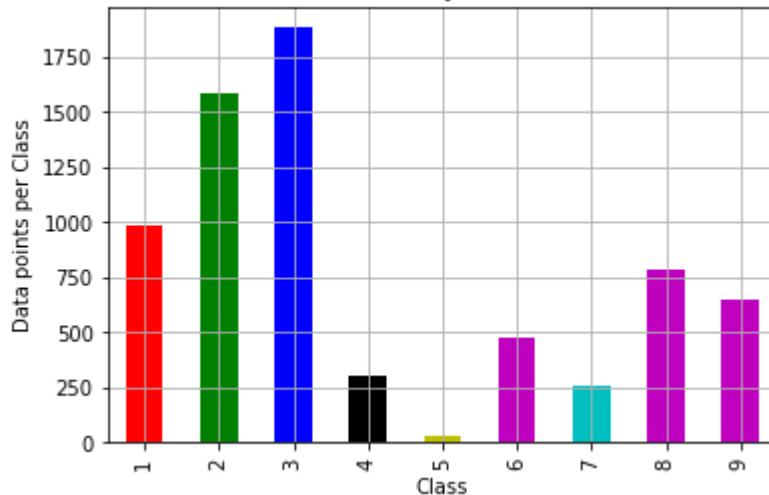
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

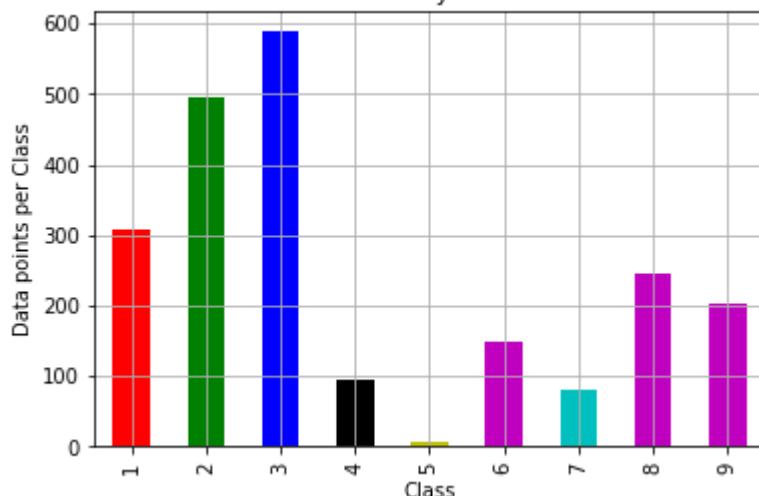
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

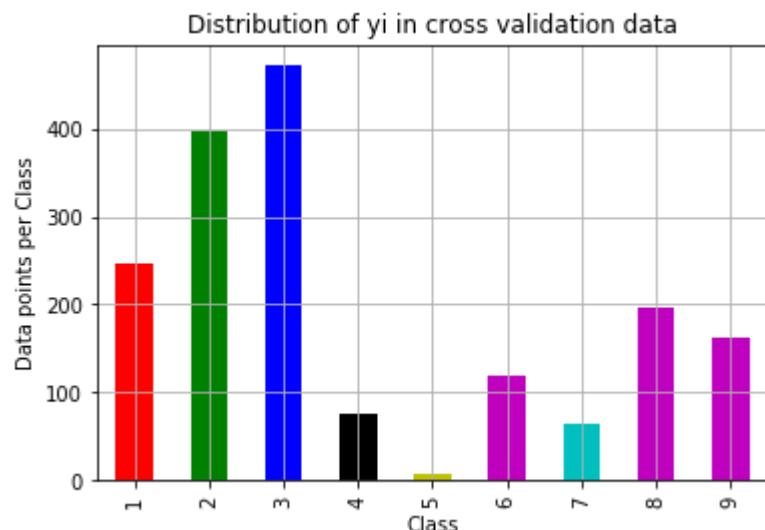
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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()

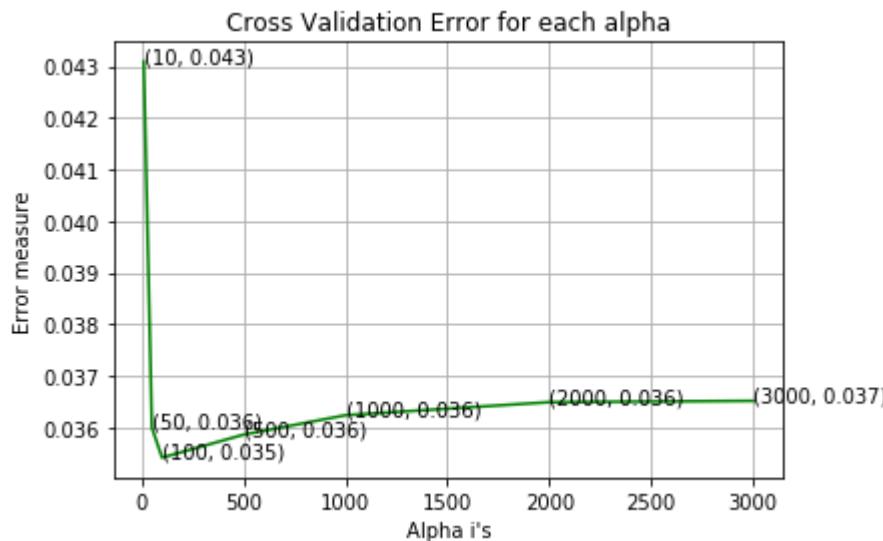
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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

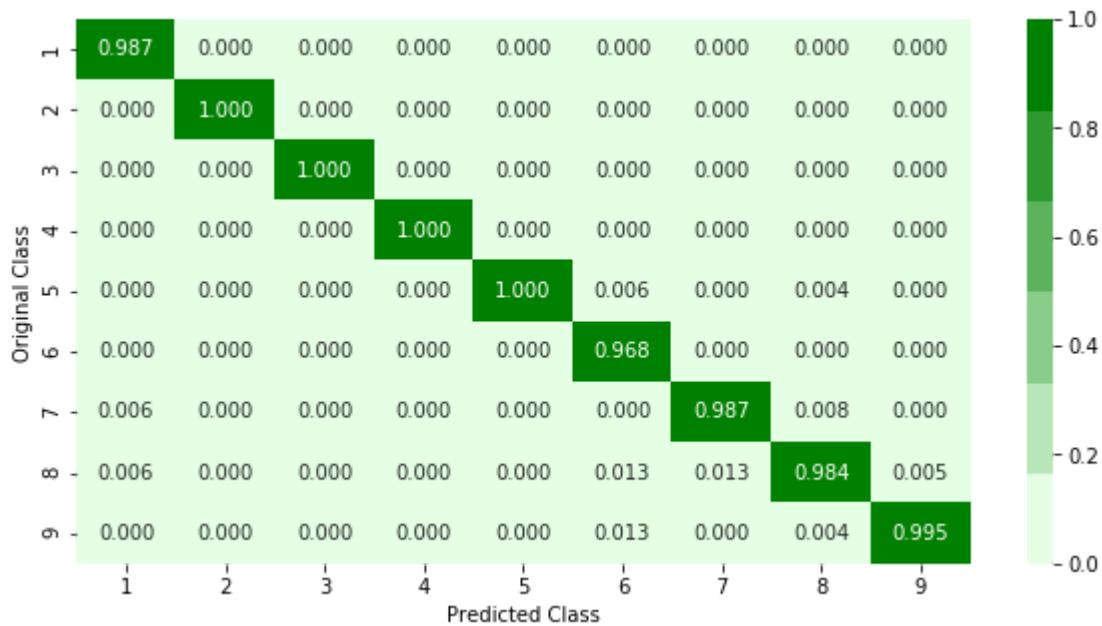


For values of best alpha = 100 The train log loss is: 0.012124677415981173
 For values of best alpha = 100 The cross validation log loss is: 0.03540899557199856
 For values of best alpha = 100 The test log loss is: 0.034260776724482855
 Number of misclassified points 0.6899724011039559

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

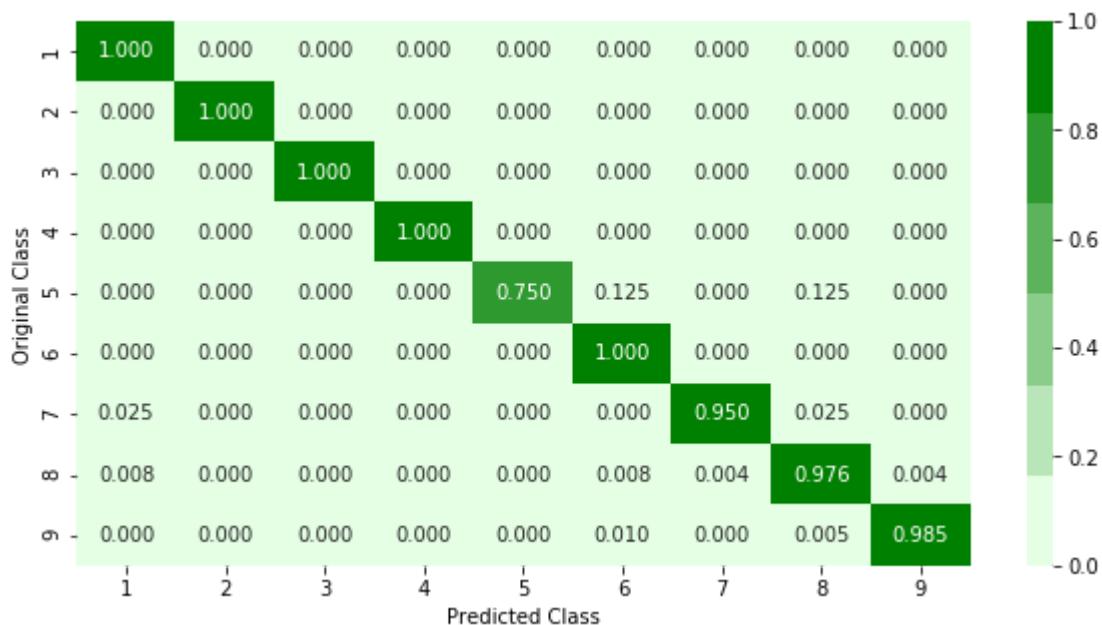
Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	
1	308.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	496.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	95.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	6.000	1.000	0.000	1.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	150.000	0.000	0.000	0.000	0.000
7	2.000	0.000	0.000	0.000	0.000	0.000	76.000	2.000	0.000	0.000
8	2.000	0.000	0.000	0.000	0.000	2.000	1.000	240.000	1.000	0.000
9	0.000	0.000	0.000	0.000	0.000	2.000	0.000	1.000	200.000	0.000

----- 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 [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_alpha=0, 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]: `print (random_cfl1.best_params_)`

```
{'subsample': 0.5, 'colsample_bytree': 0.1, 'learning_rate': 0.01, 'max_depth': 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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1, max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

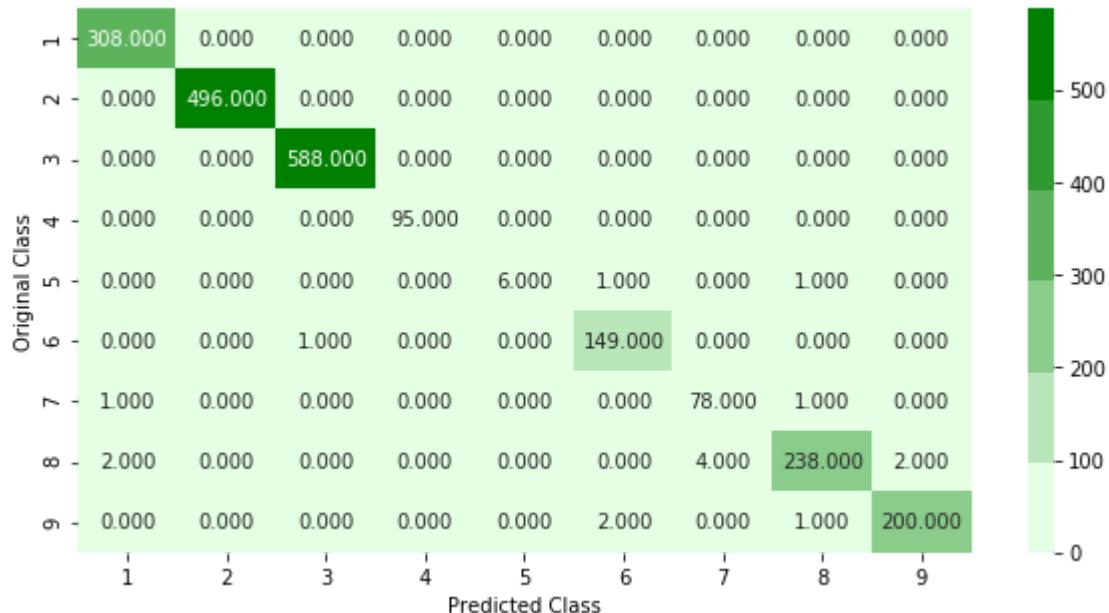
# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: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


x_cfl=XGBClassifier(learning_rate= 0.01, subsample= 0.5, n_estimators= 1000, colsample_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)

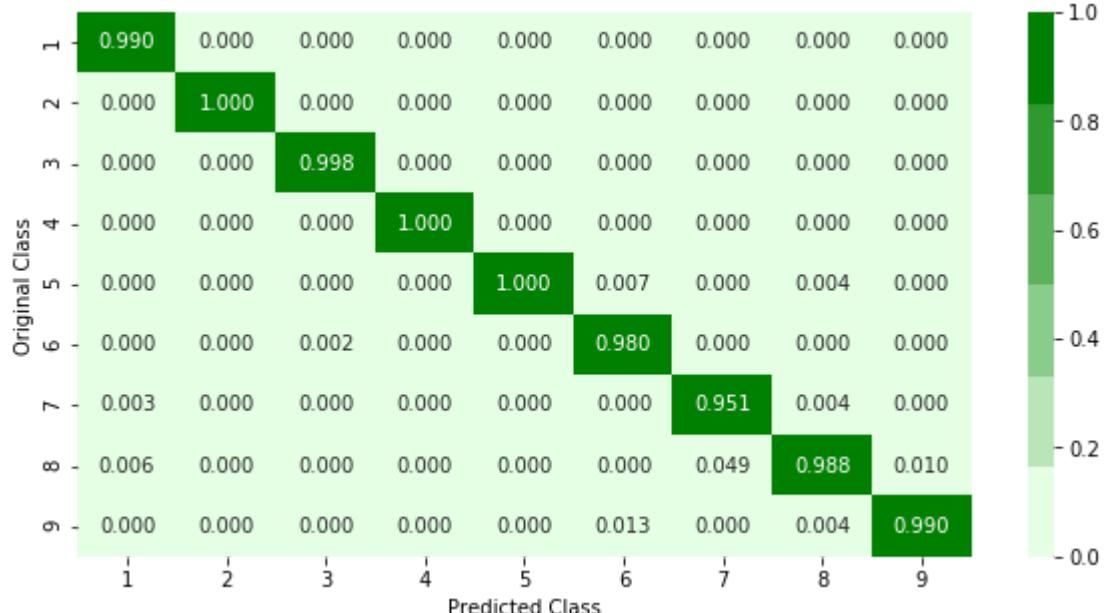
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

train loss 0.011437101388726102
cv loss 0.03412791942023307
test loss 0.03762675975742778
Number of misclassified points 0.7359705611775529

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

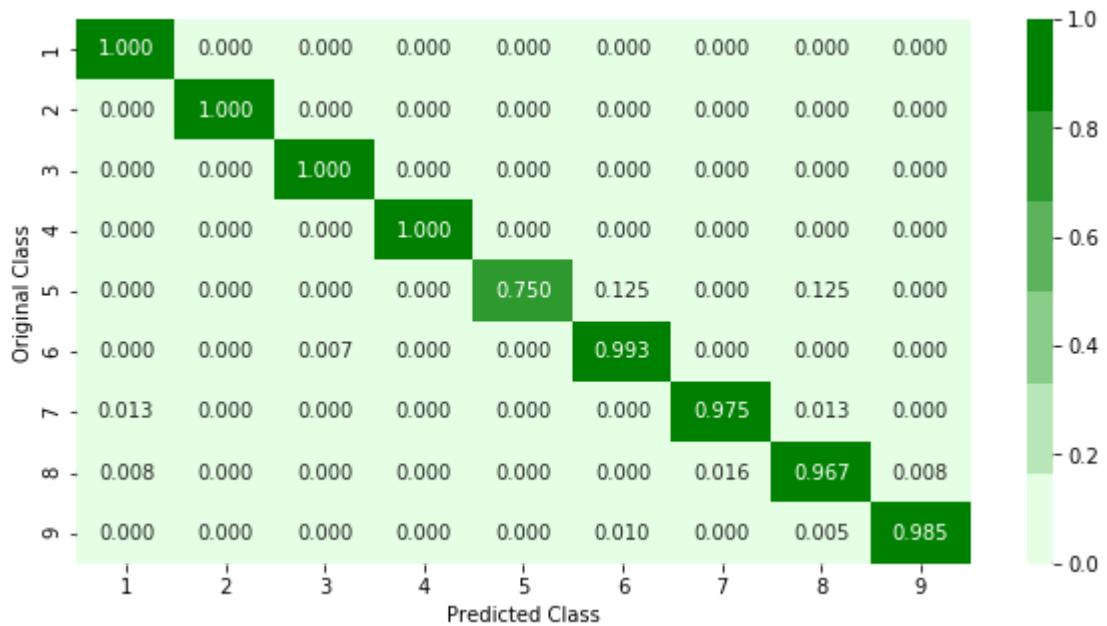


----- Precision matrix -----



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('nbAgg')
# %matplotlib 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	01lsoiSMh5gxyDYTI4CB	39755	8337	7249	7186	8663	6844	8420	7589	...	
2	2	01jsnpXSAlg6aPeDxrU	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_value - 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
1	0.000092	01lsoiSMh5gxyDYTI4CB	0.017358	0.011737	0.004033	0.003876	0.005303
2	0.000184	01jsnpXSAlg6aPeDxrU	0.040827	0.013434	0.001429	0.001315	0.005464
3	0.000276	01kcPWA9K2BOxQeS5Rju	0.009209	0.001708	0.000404	0.000441	0.000770
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.008629	0.001000	0.000168	0.000234	0.000342

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('nbAgg')
# %matplotlib inline
```

```
In [3]: # asmoutfile.csv(output generated from the above two cells) will contain all the extracted features from .asm files
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutfile.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	01kcPWA9K2B0xQeS5Rju	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/0A32eTdBKayjCWhZqD0Q.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\_stat.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	aMSX71vrZeCBwE9kUnDf	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_value - 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:	.edata:
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



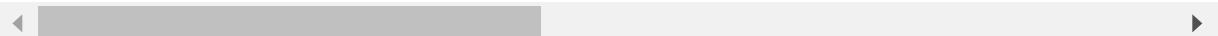
Byte bigrams 1000 features

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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

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('nbAgg')
# %matplotlib 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')
# %matplotlib inline
```

```
In [30]: # Calculate Shannon's Entropy, https://en.wikipedia.org/wiki/Entropy_(information_theory)
# https://github.com/dchad/malware-detection/blob/master/mmcc/feature-extraction.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 = 'eighth/'
    tfiles = os.listdir('eighth/')
    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('eighth_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=eighthprocess)
    p9=Process(target=ninthprocess)
    p10=Process(target=tenthprocess)
    p11=Process(target=eleventhprocess)
    p12=Process(target=twelfthprocess)
    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('eighth_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()
eighth_entropy_df = eigthprocess()
ningth_entropy_df = ningthprocess()
tenths_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())
eighth_entropy_df = (eighth_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	18SQsaz6IMJIZCknYpgL	0.746360
1	3hfRptP5gUEqDHICkMYX	0.218112
2	invl0ZhpcKaBLtyMTsfx	0.450236
3	9gL8j0XVyEOe5sSmIpv2	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,eig
th_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	GhHS0zL9cgNXFK6j1dIJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	IHiArX1xcbZgv69o4s0a	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	GhHS0zL9cgNXFK6j1dIJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	IHiArX1xcbZgv69o4s0a	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')
# %matplotlib 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 = 'eighth_'
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= '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]], 'eighth_')
    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('eighth_')) + \
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('eighth_')),
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

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](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 ='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()

#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 ='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()

# 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 ='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 fourthprocess():
```

```
op_file = open("opcode_file4.txt", "w+")
for asmfile in os.listdir('fourth_'):
    opcode_str = ""
    with codecs.open('fourth_/' + 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 fifthprocess():

    op_file = open("opcode_file5.txt", "w+")
    for asmfile in os.listdir('fifth_'):
        opcode_str = ""
        with codecs.open('fifth_/' + 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 sixthprocess():

    op_file = open("opcode_file6.txt", "w+")
    for asmfile in os.listdir('sixth_'):
        opcode_str = ""
        with codecs.open('sixth_/' + 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 seventhprocess():

    op_file = open("opcode_file7.txt", "w+")
    for asmfile in os.listdir('seventh_'):
        opcode_str = ""
        with codecs.open('seventh_/' + 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 eigthprocess():

    op_file = open("opcode_file8.txt", "w+")
    for asmfile in os.listdir('eighth_'):
        opcode_str = ""
        with codecs.open('eighth_/' + 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 ningthprocess():

    op_file = open("opcode_file9.txt", "w+")
    for asmfile in os.listdir('ningth_'):
        opcode_str = ""
        with codecs.open('ningth_/' + 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 tenthprocess():

    op_file = open("opcode_file10.txt", "w+")
    for asmfile in os.listdir('tenth_'):
        opcode_str = ""
        with codecs.open('tenth_/' + 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 eleventhprocess():

    op_file = open("opcode_file11.txt", "w+")
    for asmfile in os.listdir('eleventh_'):
        opcode_str = ""
        with codecs.open('eleventh_/' + 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 twelvethprocess():

    op_file = open("opcode_file12.txt", "w+")
    for asmfile in os.listdir('twelveth_'):
        opcode_str = ""
        with codecs.open('twelveth_/' + 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 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=eighthprocess)
p9=Process(target=ninthprocess)
p10=Process(target=tenthprocess)
p11=Process(target=eleventhprocess)
p12=Process(target=twelfthprocess)
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_opcode[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_opcode[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_opcode[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_opcode[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_opcode[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_opcode[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_opcode[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_opcode[indx]]))
opcodebivect = opcodebivect.todense()
opcodebigram_df8 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
opcodebigram_df8['ID'] = os.listdir('eighth_')
opcodebigram_df8.to_csv('opcodebigram_df8.csv',index=False)

def ninthprocess():
    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_opcode[indx]]))
    opcodebivect = opcodebivect.todense()
    opcodebigram_df9 = pd.DataFrame(opcodebivect, columns = asmopcodebigram)
    opcodebigram_df9['ID'] = os.listdir('ninth_')
    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_opcode[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_opcode[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_opcode[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_opcode[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_opcode[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=eighthprocess)
    p9=Process(target=ninthprocess)
    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_df3,opcodebigram_df4,opcodebigram_df5,opcodebigram_df6,opcodebigram_df7,opcodebigram_df8,opcodebigram_df9,opcodebigram_df10,opcodebigram_df11,opcodebigram_df12,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='left')`
`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 ref	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	0.0	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	0.000000	...	0.0
2	0.000000	0.000000	0.0	0.000000	0.000000	0.0000	0.0	0.0	0.0	0.000000	0.000000	...	0.0
3	0.000000	0.000000	0.0	0.000471	0.000000	0.0000	0.0	0.0	0.0	0.000000	0.000000	...	0.0
4	0.000000	0.000000	0.0	0.000471	0.000000	0.0000	0.0	0.0	0.0	0.000000	0.000000	...	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_idx = np.argsort(rf.feature_importances_)[-1]
    print(len(features), len(imp_feature_idx))
    imp_feature_name = np.take(features, imp_feature_idx)
    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 workers.
[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 0.0
1	0.000000	0.000484	0.033143	0.000091	0.000000	0.000000	0.005545	0.000000	0.000126 0.0
2	0.000000	0.000605	0.033143	0.000000	0.000000	0.000000	0.005480	0.000000	0.000253 0.0
3	0.000151	0.000363	0.026815	0.000091	0.000000	0.000000	0.004632	0.000089	0.000126 0.0
4	0.000000	0.000121	0.002410	0.000000	0.000000	0.000348	0.000065	0.000000	0.000126 0.0

5 rows × 303 columns



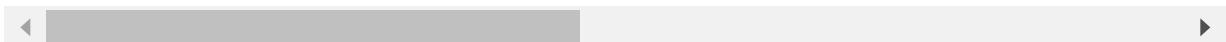
```
In [34]: # final_opcodebigram_df.to_csv('opcodebigram_final_rf_reduced_df.csv', index=False)
```

```
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 0.0
1	0.000000	0.000484	0.033143	0.000091	0.000000	0.000000	0.005545	0.000000	0.000126 0.0
2	0.000000	0.000605	0.033143	0.000000	0.000000	0.000000	0.005480	0.000000	0.000253 0.0
3	0.000151	0.000363	0.026815	0.000091	0.000000	0.000000	0.004632	0.000089	0.000126 0.0
4	0.000000	0.000121	0.002410	0.000000	0.000000	0.000348	0.000065	0.000000	0.000126 0.0

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 output variable '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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

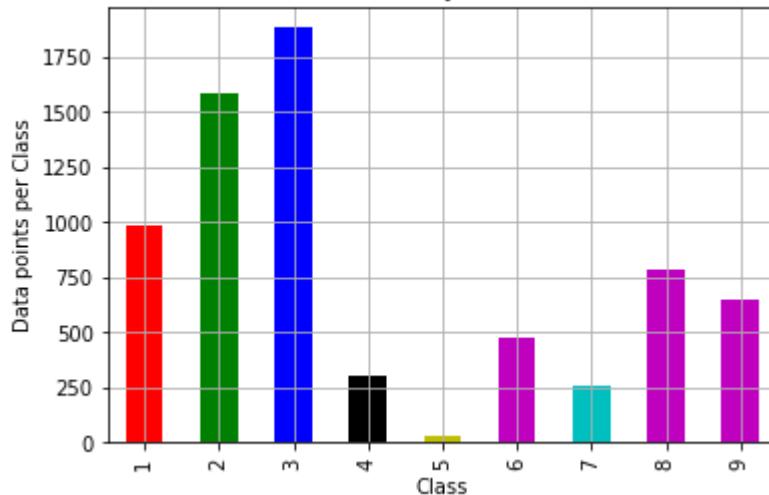
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

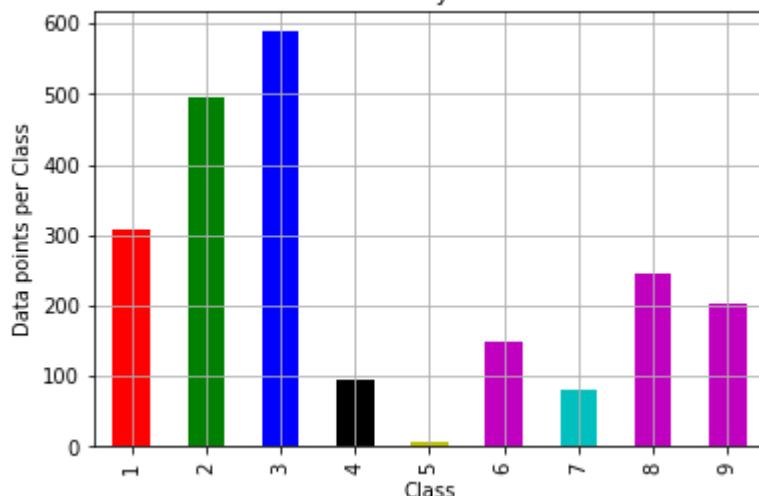
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

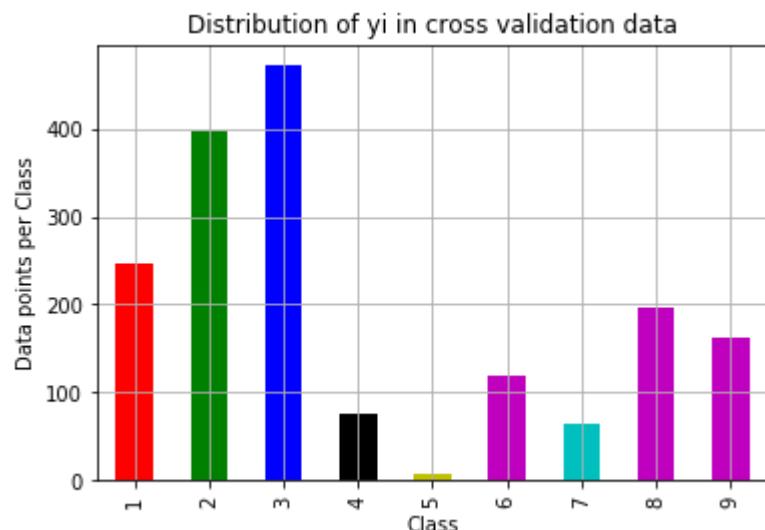
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 %)

Distribution of y_i in test data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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

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

alpha = [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)

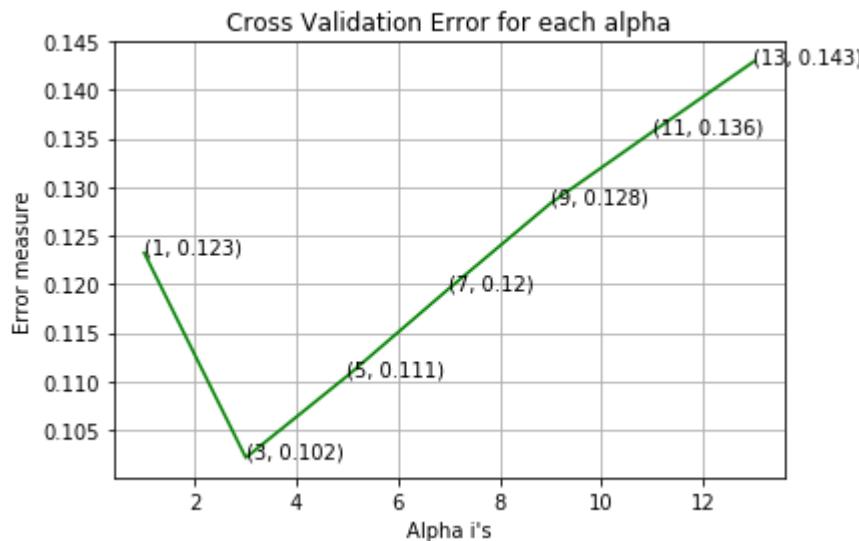
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

```
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 is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
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: 0.10214532275881437

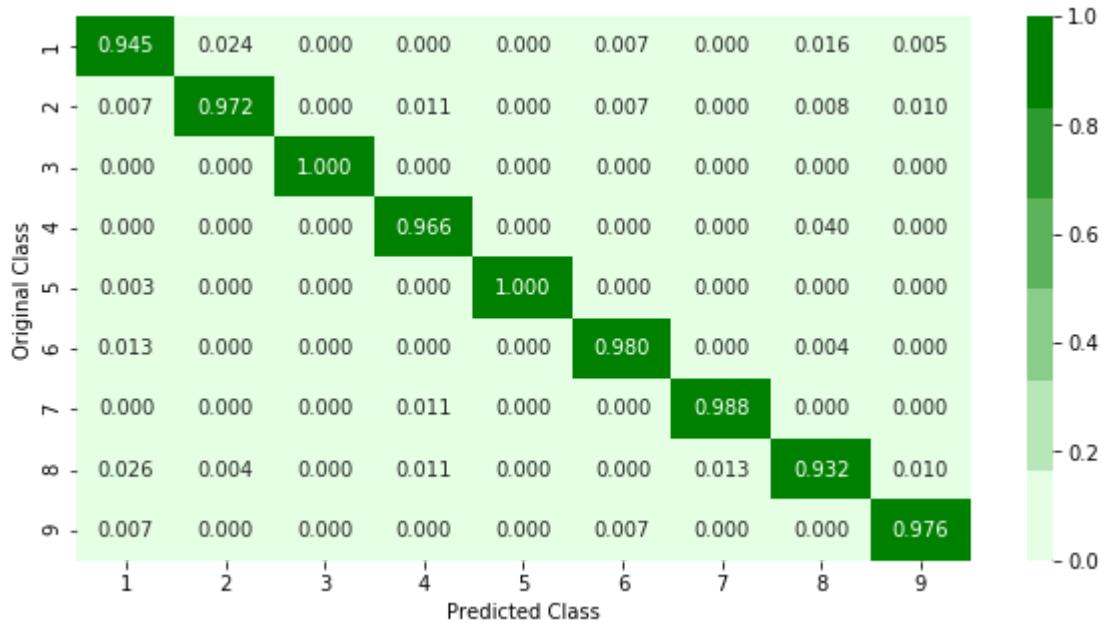
For values of best alpha = 3 The test log loss is: 0.112712223177701

Number of misclassified points 2.7598896044158234

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

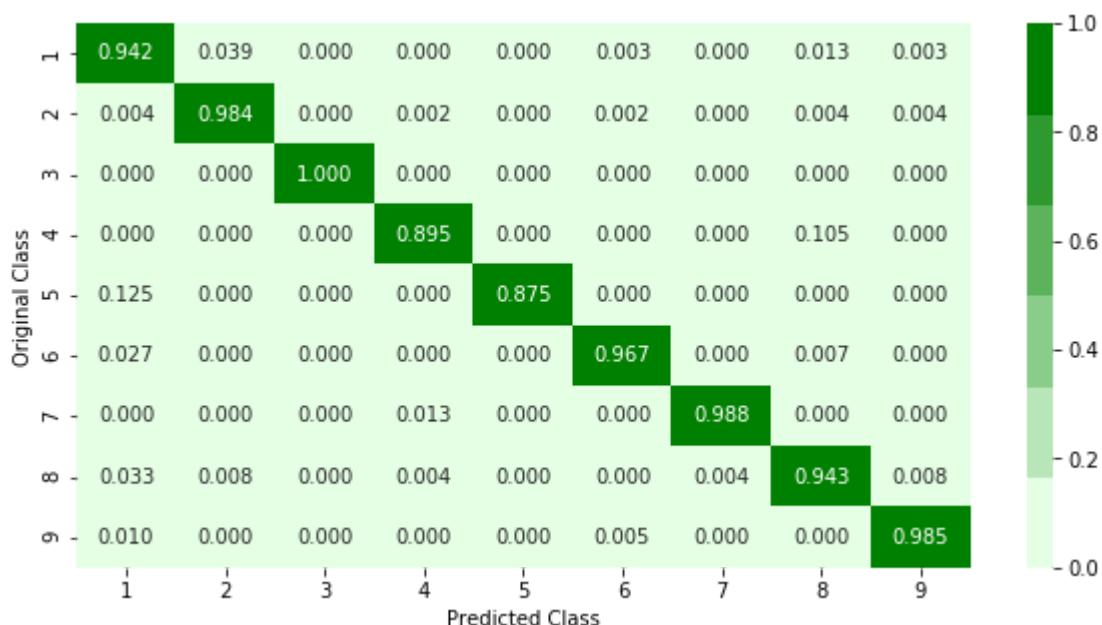
Original Class	Predicted Class								
	1	2	3	4	5	6	7	8	9
1	290.000	12.000	0.000	0.000	0.000	1.000	0.000	4.000	1.000
2	2.000	488.000	0.000	1.000	0.000	1.000	0.000	2.000	2.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	85.000	0.000	0.000	0.000	10.000	0.000
5	1.000	0.000	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)

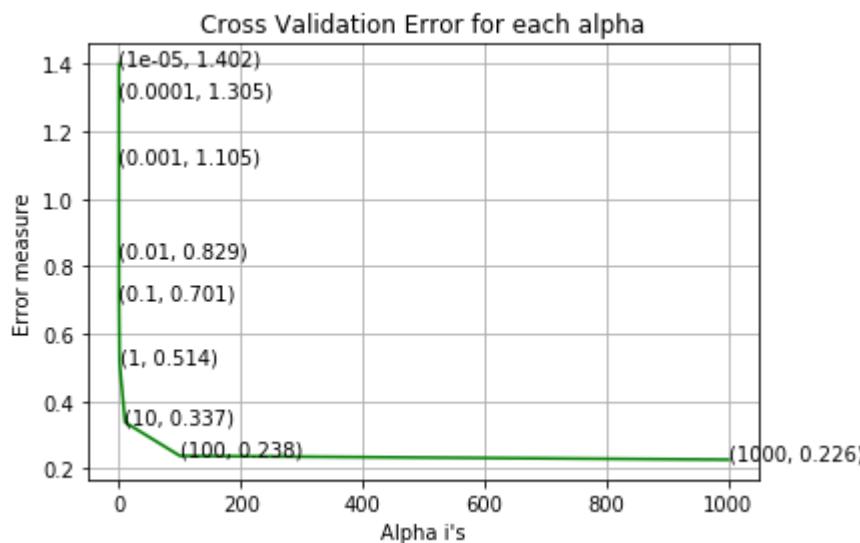
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

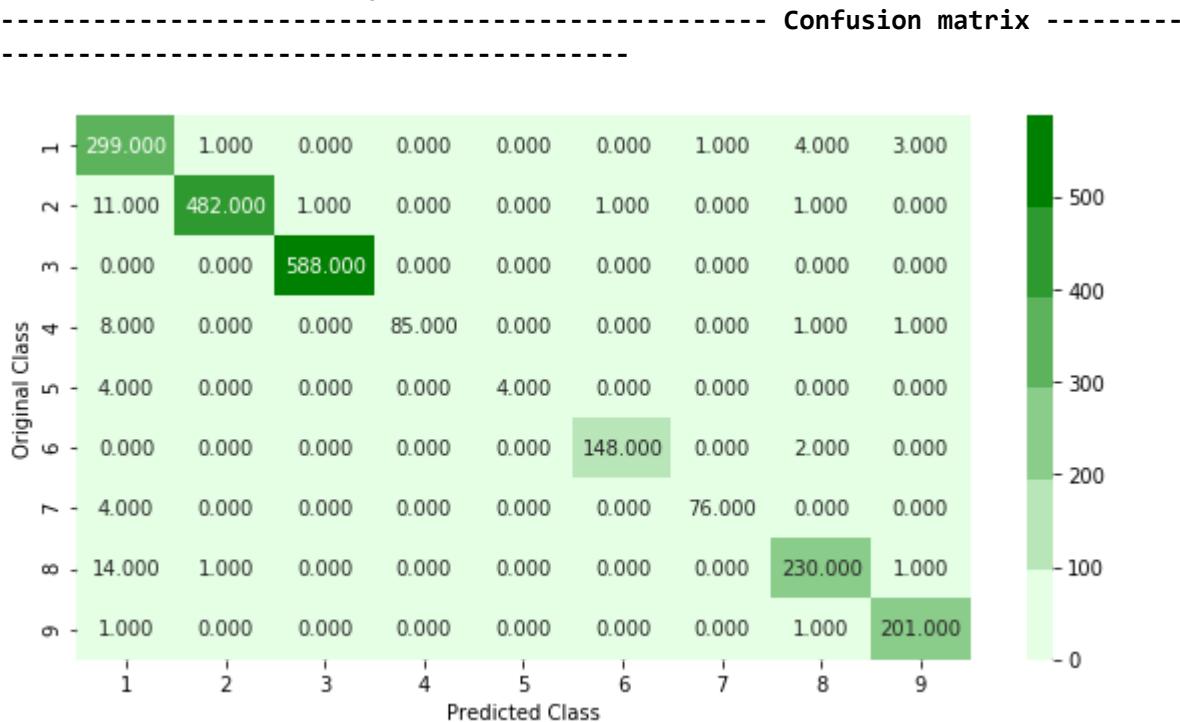
predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, eps=1e-15))
```

```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.classes_, 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.classes_, 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
```

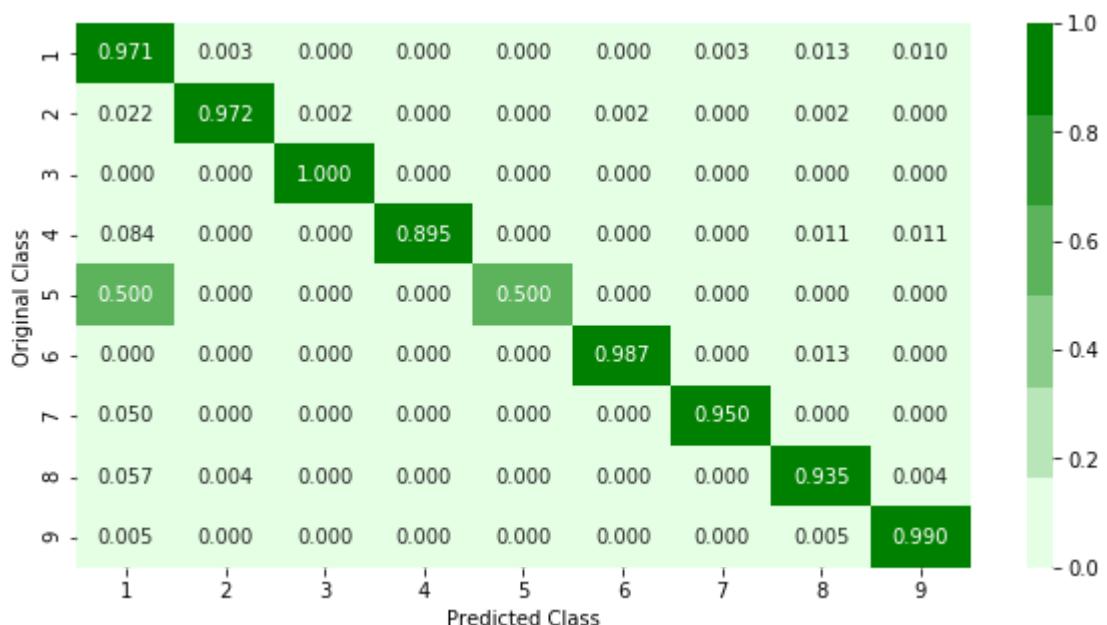


----- Precision matrix -----



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', 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()

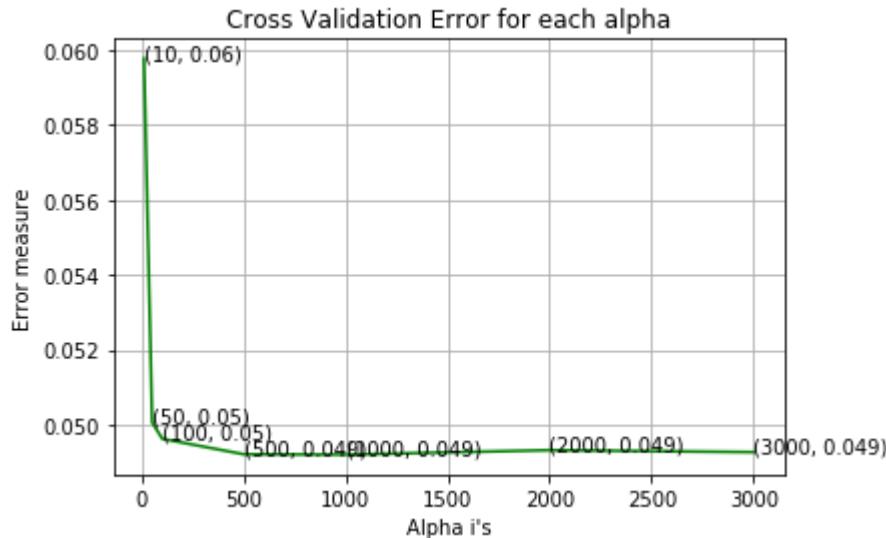
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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

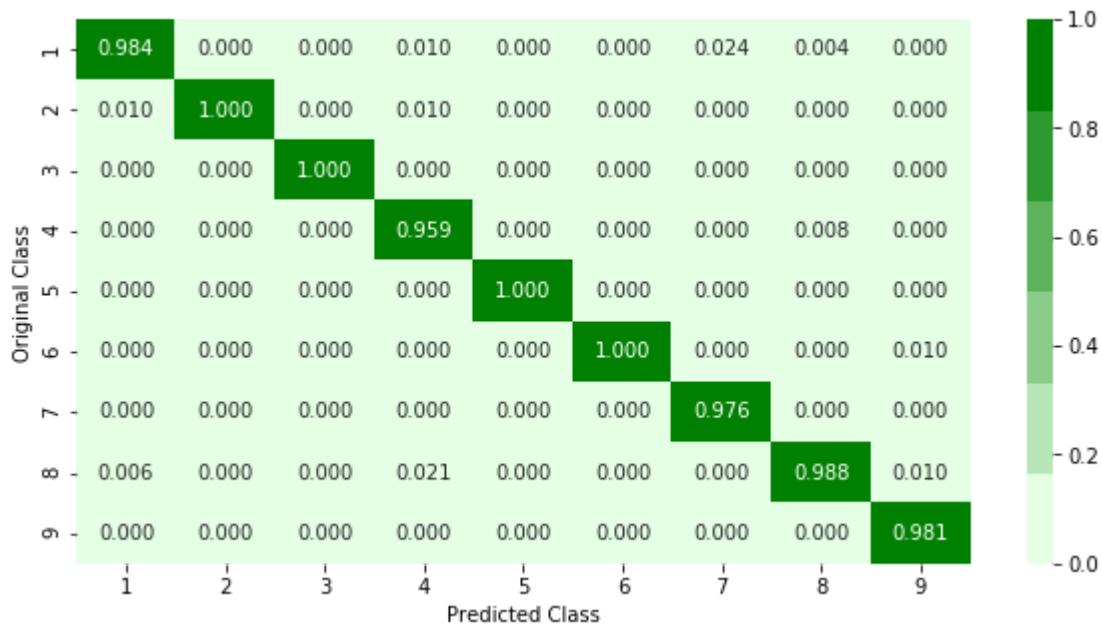


For values of best alpha = 1000 The train log loss is: 0.02729217419796757
 For values of best alpha = 1000 The cross validation log loss is: 0.04920568486568558
 For values of best alpha = 1000 The test log loss is: 0.04403411243756223
 Number of misclassified points 0.8279668813247469

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

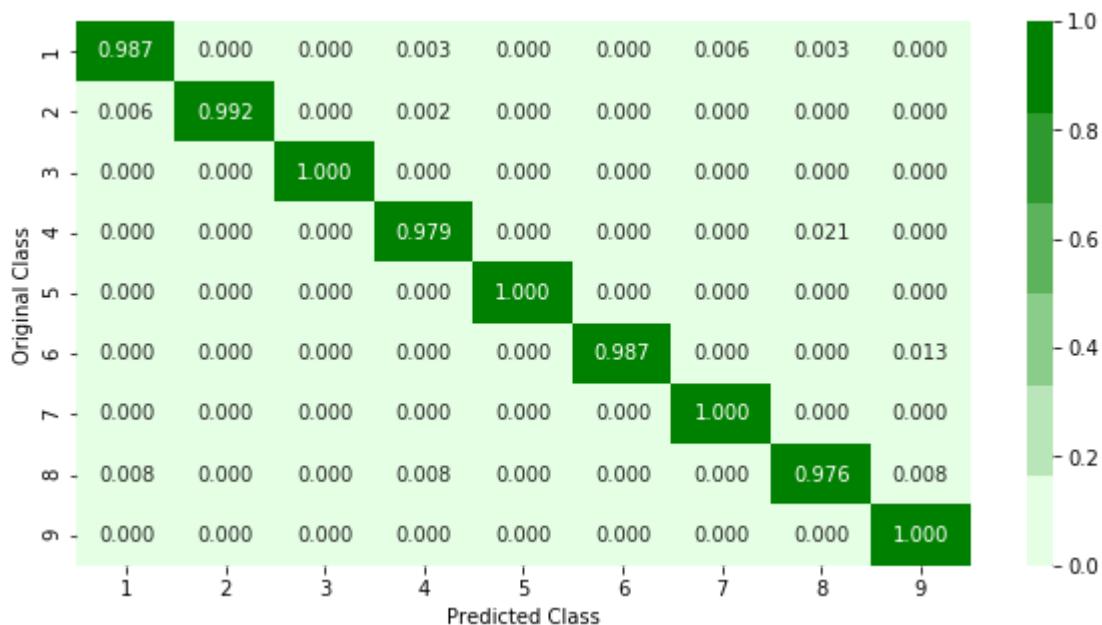
Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	Others
1	304.000	0.000	0.000	1.000	0.000	0.000	2.000	1.000	0.000	0.000
2	3.000	492.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	93.000	0.000	0.000	0.000	2.000	0.000	0.000
5	0.000	0.000	0.000	0.000	8.000	0.000	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	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	80.000	0.000	0.000	0.000
8	2.000	0.000	0.000	2.000	0.000	0.000	0.000	240.000	2.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	203.000	0.000

----- 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_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:   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_alpha=0, 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]: `print (random_cfl1.best_params_)`

```
{'max_depth': 3, 'learning_rate': 0.05, 'subsample': 0.5, 'n_estimators': 200, '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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1, max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

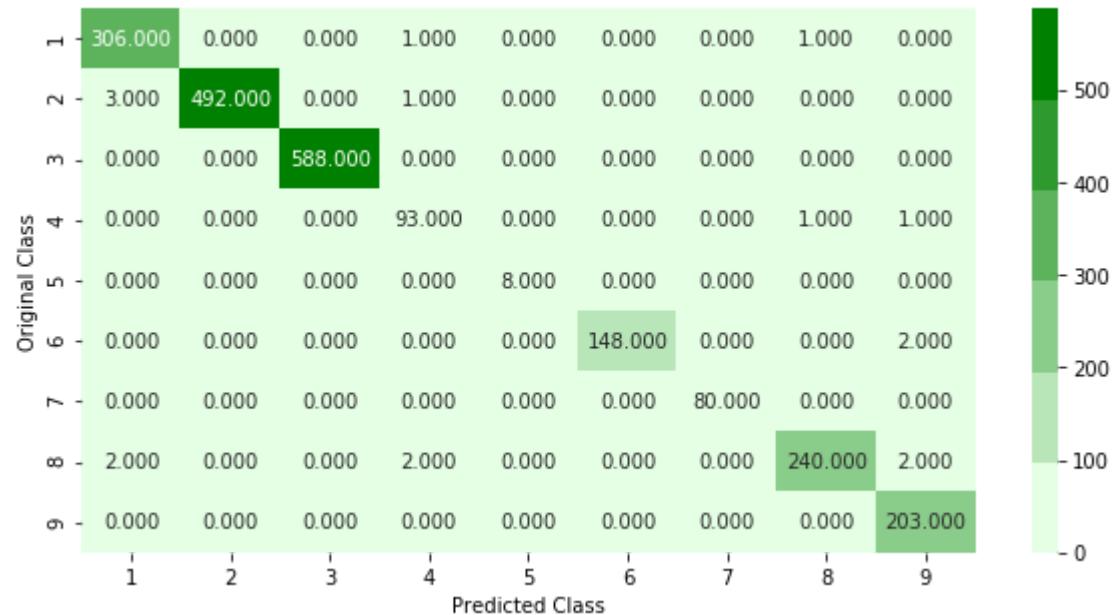
# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: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


x_cfl=XGBClassifier(learning_rate= 0.05, subsample= 0.5, n_estimators= 2000, colsample_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 -----

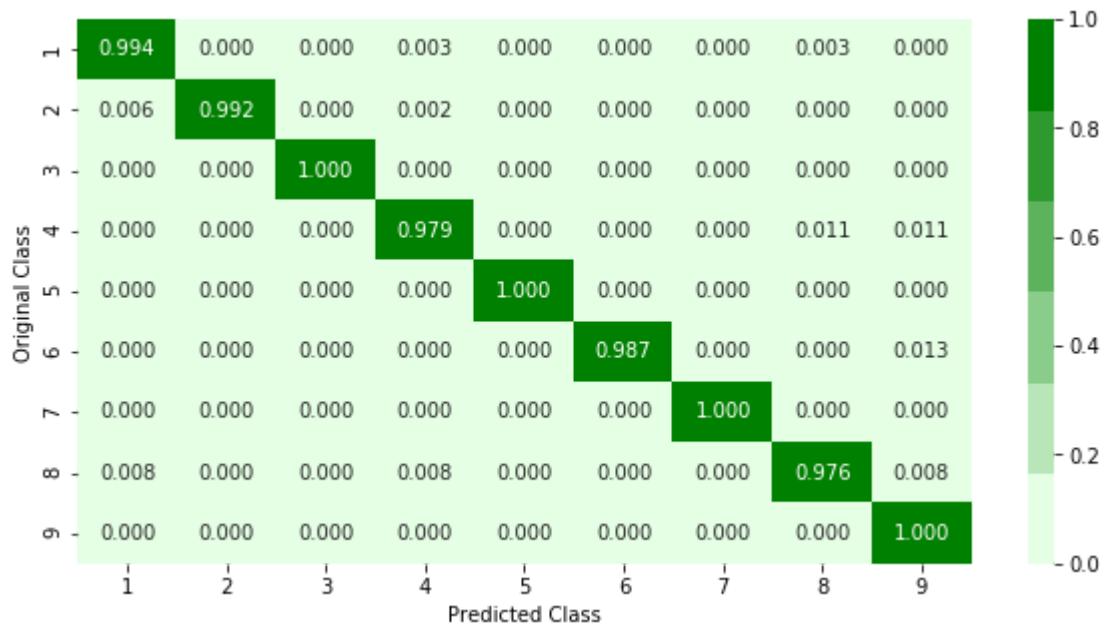


----- Precision matrix -----



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 []:

```
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')
# %matplotlib 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 = 'eighth_'
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= '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]], 'eighth_')
    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('eighth_')) + \
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('eighth_')),
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 asmopcodetrigram():
    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])
)
asmopcodetrigram()
```

```
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('eighth_')
    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 = asmopcodetrigram)
)
    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()
```

```

opcodebitmap_df11 = pd.DataFrame(opcodevect, columns = asmopcodebitmap)
opcodebitmap_df11[ 'ID' ] = os.listdir('eleventh_')
opcodebitmap_df11.to_csv('opcodebitmap_df11.csv',index=False)

def twelfthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodebitmap)
    opcodevect = scipy.sparse.csr_matrix((776, len(asmopcodebitmap)))
    raw_opcode = open('opcode_file12.txt').read().split('\n')

    for indx in range(776):
        opcodevect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_opcode[indx]]))
    opcodevect = opcodevect.todense()
    opcodebitmap_df12 = pd.DataFrame(opcodevect, columns = asmopcodebitmap)
    opcodebitmap_df12[ 'ID' ] = os.listdir('twelfth_')
    opcodebitmap_df12.to_csv('opcodebitmap_df12.csv',index=False)

def thirteenthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodebitmap)
    opcodevect = scipy.sparse.csr_matrix((776, len(asmopcodebitmap)))
    raw_opcode = open('opcode_file13.txt').read().split('\n')

    for indx in range(776):
        opcodevect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_opcode[indx]]))
    opcodevect = opcodevect.todense()
    opcodebitmap_df13 = pd.DataFrame(opcodevect, columns = asmopcodebitmap)
    opcodebitmap_df13[ 'ID' ] = os.listdir('thirteenth_')
    opcodebitmap_df13.to_csv('opcodebitmap_df13.csv',index=False)

def fourteenthprocess():

    vect = CountVectorizer(ngram_range=(3, 3), vocabulary = asmopcodebitmap)
    opcodevect = scipy.sparse.csr_matrix((776, len(asmopcodebitmap)))
    raw_opcode = open('opcode_file14.txt').read().split('\n')

    for indx in range(776):
        opcodevect[indx, :] += scipy.sparse.csr_matrix(vect.transform([raw_opcode[indx]]))
    opcodevect = opcodevect.todense()
    opcodebitmap_df14 = pd.DataFrame(opcodevect, columns = asmopcodebitmap)
    opcodebitmap_df14[ 'ID' ] = os.listdir('fourteenth_')
    opcodebitmap_df14.to_csv('opcodebitmap_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=eighthprocess)
p9=Process(target=ninthprocess)
p10=Process(target=tenthprocess)
p11=Process(target=eleventhprocess)
p12=Process(target=twelfthprocess)
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()

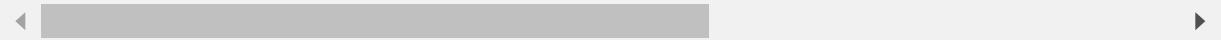
if __name__=="__main__":
    main()
```

```
In [59]: opcodetrigram_df14 = pd.read_csv('opcodetrigram_df14.csv')
opcodetrigram_df14.head()
```

Out[59]:

	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	jmp	movzx	movzx	movzx	movzx	r
	jmp	jmp	jmp	jmp	jmp	xor	jmp	jmp	nop	jmp	sub	inc	...	movzx	movzx	movzx	movzx	r
	jmp	mov	retf	push	pop		retn						call	shl	ror	rol		
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	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	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	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	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	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,opcodetrigram_df3,opcodetrigram_df4,opcodetrigram_df5,opcodetrigram_df6,opcodetrigram_df7,opcodetrigram_df8,opcodetrigram_df9,opcodetrigram_df10,opcodetrigram_df11,opcodetrigram_df12,opcodetrigram_df13,opcodetrigram_df14])
```

In [62]: `opcodetrigram_df['ID'] = opcodetrigram_df['ID'].str[:-4]`
`opcodetrigram_df.head()`

Out[62]:

	jmp	movzx	movzx	movzx	movzx	n													
	jmp	movzx	movzx	movzx	movzx	n													
	jmp	call	shl	ror	rol	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	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	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	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	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	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	01kcPWA9K2B0xQeS5Rju	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='left')`
`final_opcodetrigram_df.head()`

Out[64]:

	jmp	movzx	movzx	movzx	movzx	n													
	jmp	movzx	movzx	movzx	movzx	n													
	jmp	call	shl	ror	jnb	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	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	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	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	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	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 ref	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_idx = np.argsort(rf.feature_importances_)[-1]
    print(len(features), len(imp_feature_idx))
    imp_feature_name = np.take(features, imp_feature_idx)
    return imp_feature_name
```

```
In [69]: opcode_tri_names = imp_features(final_opcode_trigram_df.drop(['ID','Class','size'],axis=1,inplace=False), asmopcode_trigram)
```

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

```
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('asmopcode_trigram_imp_features.pkl', 'wb') as f:
#     pickle.dump(opcode_tri_names, f)
with open('asmopcode_trigram_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_opcode_trigram_df = final_opcode_trigram_df[opcode_tri_names]
```

```
In [74]: len(final_opcode_trigram_df.columns)
```

```
Out[74]: 703
```

```
In [75]: final_opcode_trigram_df.head()
```

```
Out[75]:
```

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	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_opcode_trigram_df.to_csv('opcode_trigram_final_rf_reduced_df.csv', index=False)
```

In [77]: `final_opcodefreq_df = pd.read_csv('opcodefreq_final_rf_reduced_df.csv')
final_opcodefreq_df.head()`

Out[77]:

	pop add pop	call add pop	mov add mov	dec sub mov	or mov mov	add pop retn	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_opcodefreq_df['Class']
split the data into test and train by maintaining same distribution of output variable 'y_true' [stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(final_opcodefreq_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 distribution of output variable '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 [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 points 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.argsort.html
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', train_class_distribution.values[i], '(', np.round((train_class_distribution.values[i]/y_train.shape[0]*100), 3), '%')

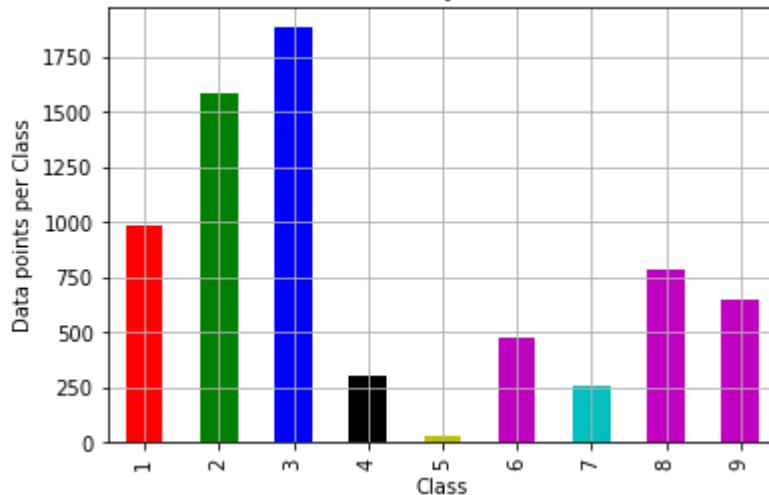
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

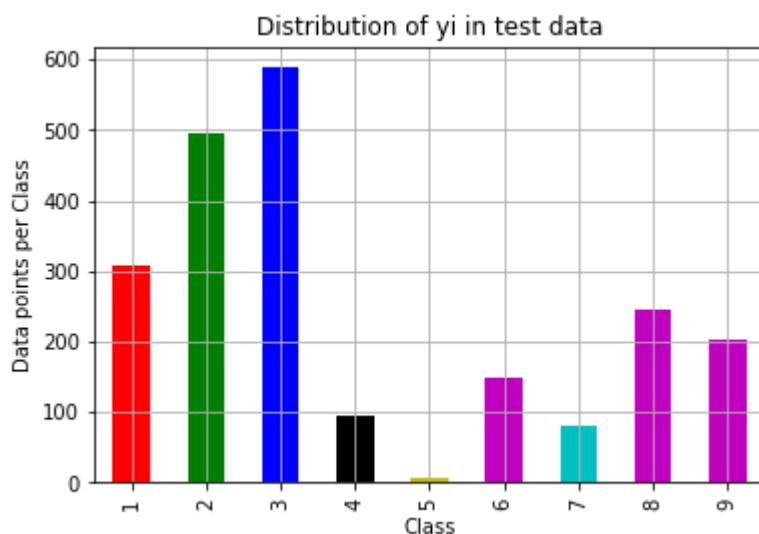
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

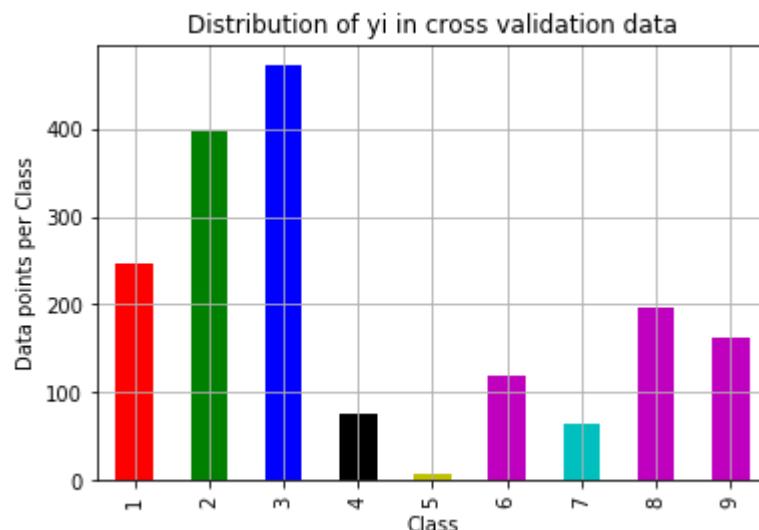
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

Distribution of y_i in train data

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 are predicted class j

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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/modules/generated/sklearn.neighbors.KNeighborsClassifier.html
# -----
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=2,
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

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

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

alpha = [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)

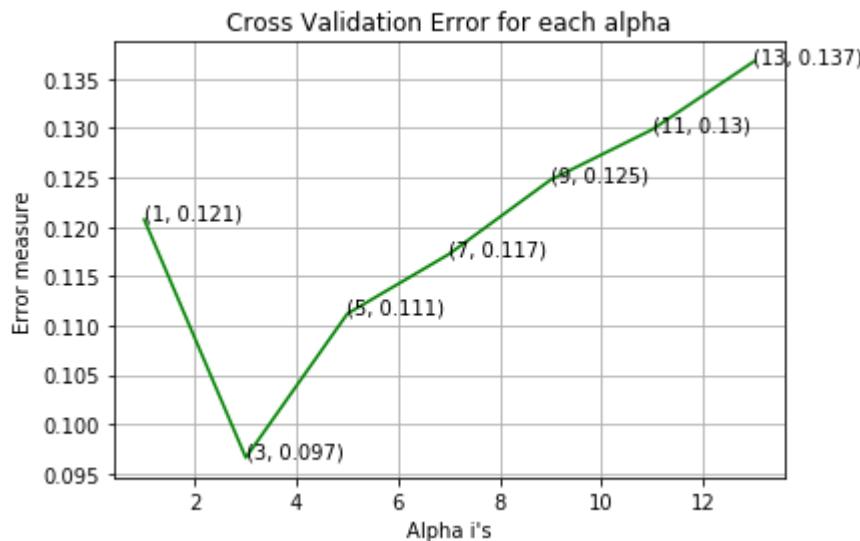
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

```
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 is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
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: 0.09662362520423909

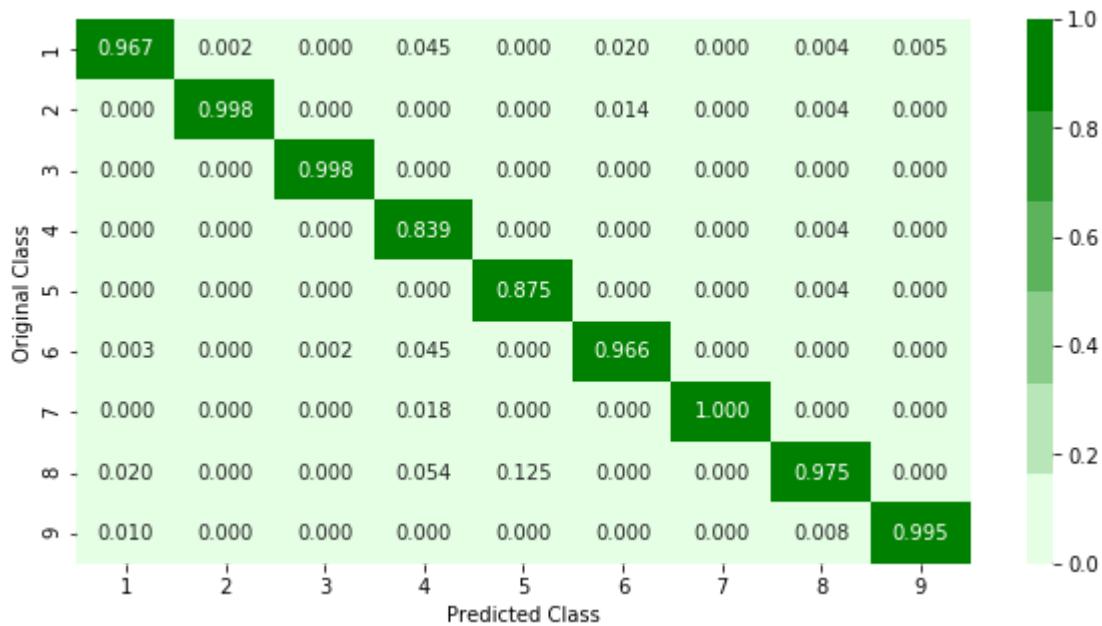
For values of best alpha = 3 The test log loss is: 0.10060749393460935

Number of misclassified points 1.9779208831646733

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

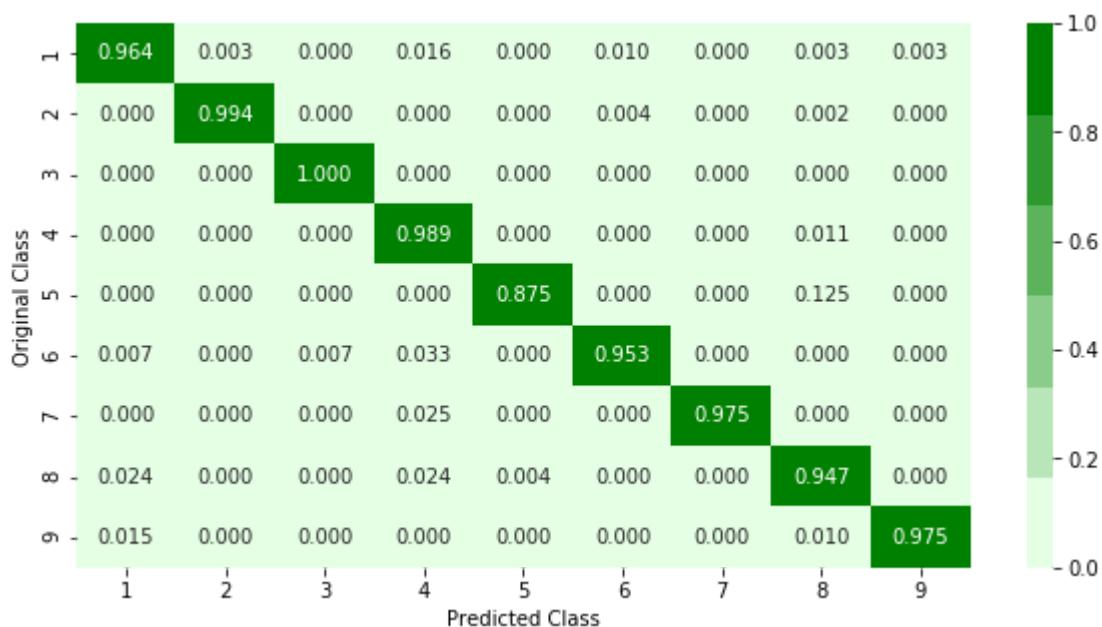
Original Class	Predicted Class								
	1	2	3	4	5	6	7	8	9
1	297.000	1.000	0.000	5.000	0.000	3.000	0.000	1.000	1.000
2	0.000	493.000	0.000	0.000	0.000	2.000	0.000	1.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	94.000	0.000	0.000	0.000	1.000	0.000
5	0.000	0.000	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)

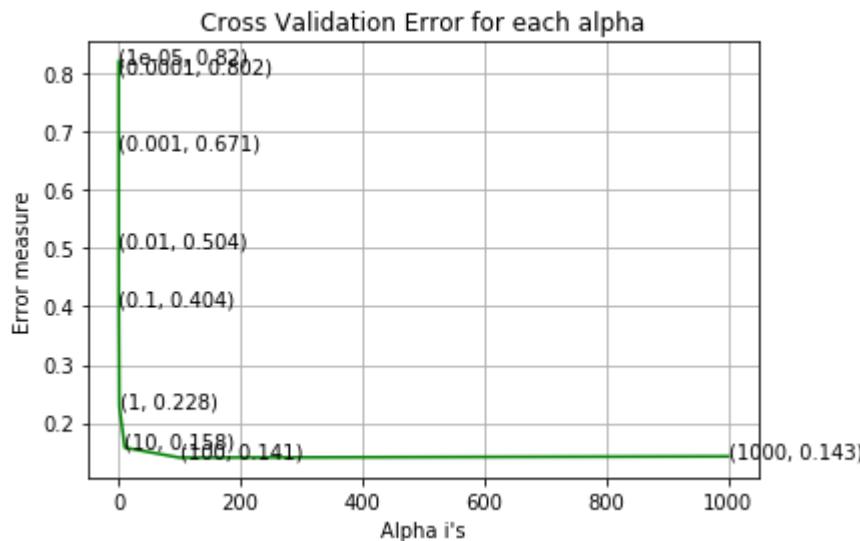
fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error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

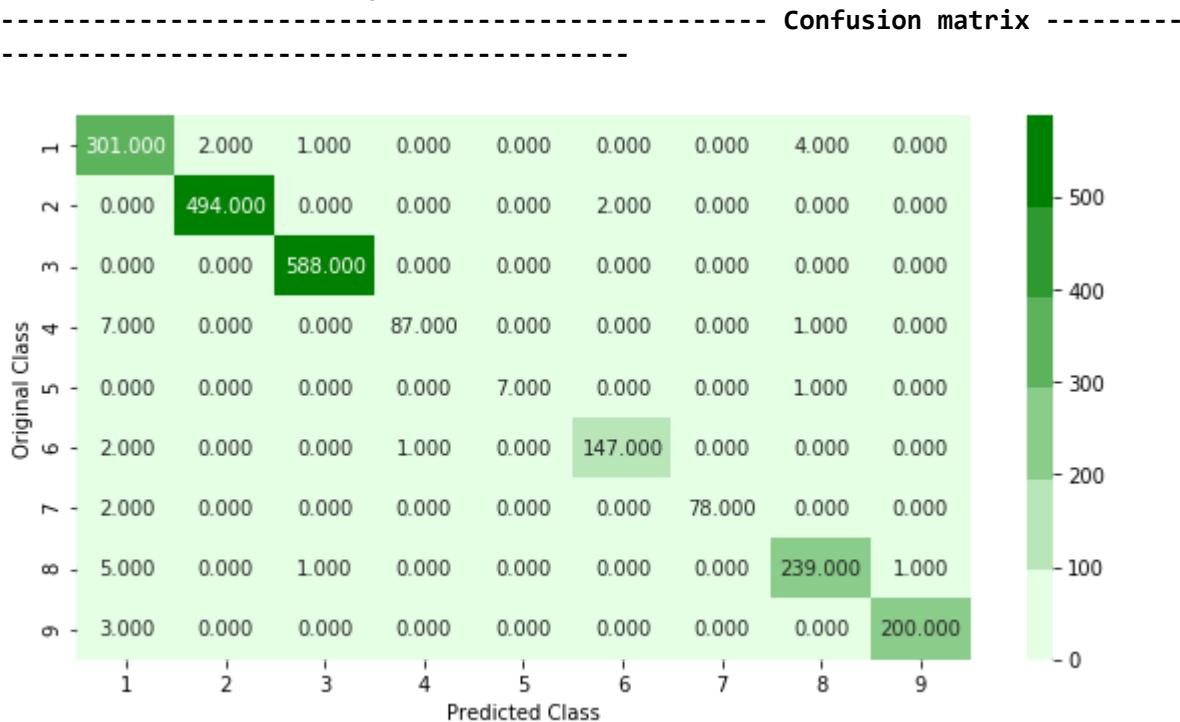
predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, eps=1e-15))
```

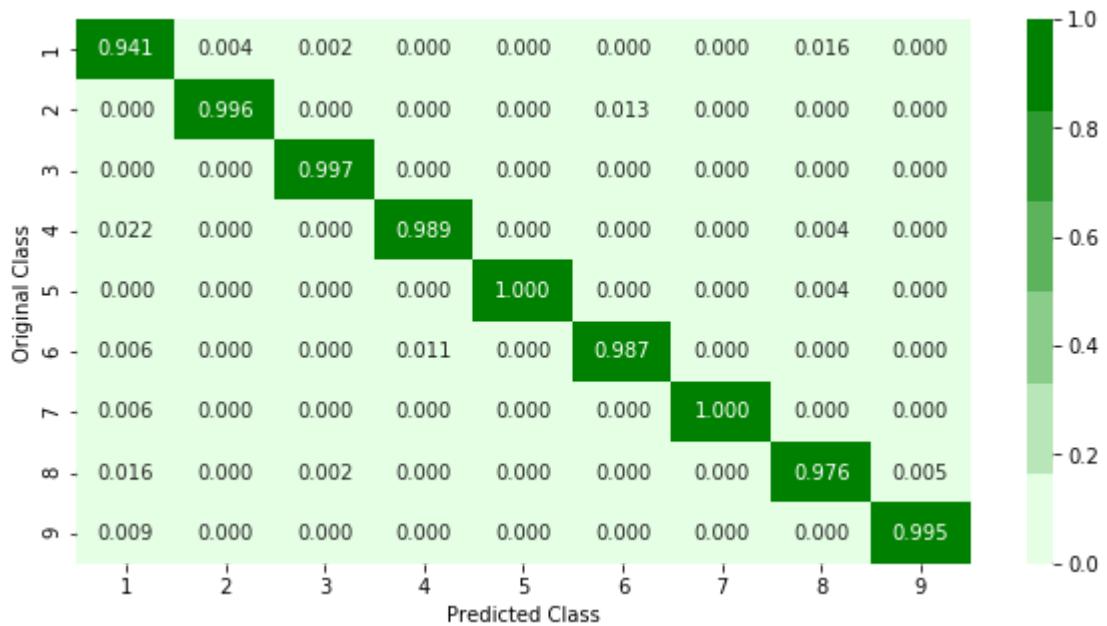
```
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.classes_, eps=1e-15))
plot_confusion_matrix(y_test,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



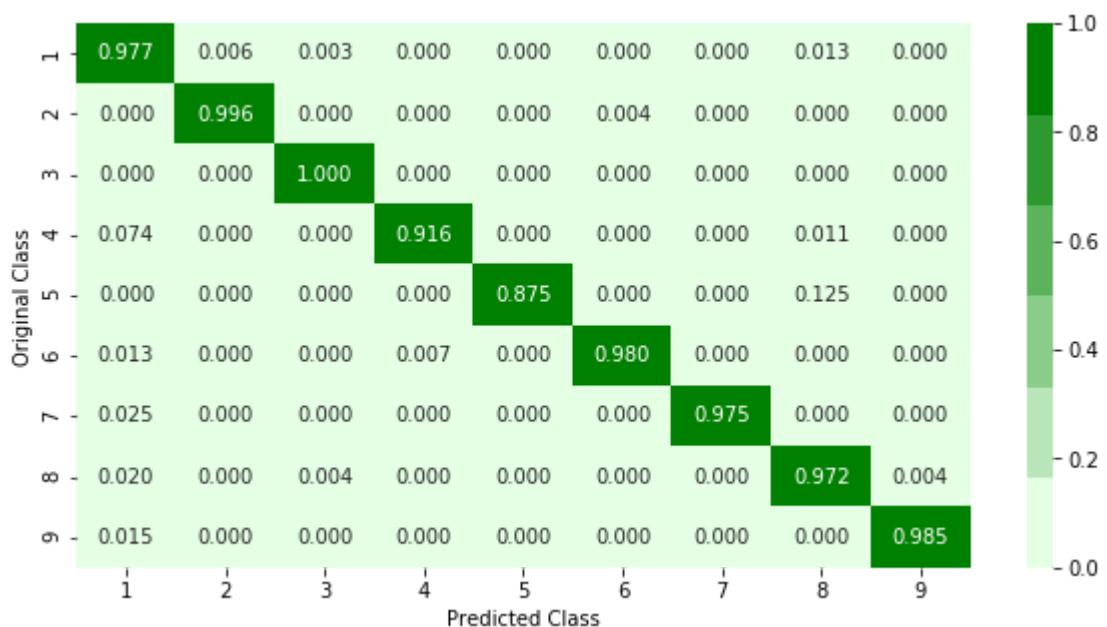
```
log loss for train data 0.11284165997114552
log loss for cv data 0.1405495639371003
log loss for test data 0.12969790479813978
Number of misclassified points 1.517939282428703
```





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', 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()

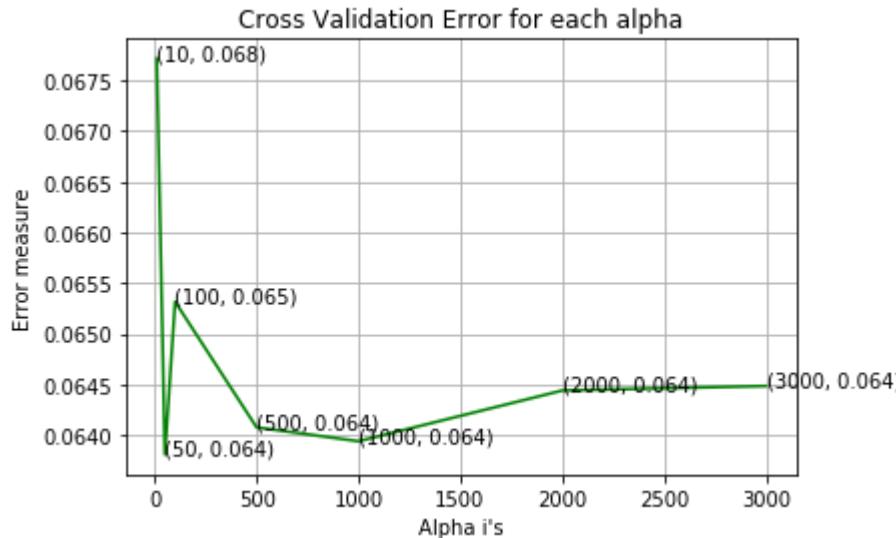
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

```
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 is:",log_loss(y_train, predict_y))
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:",log_loss(y_cv, predict_y))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y))
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 0.0640750666674595
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: 0.06380559237406035

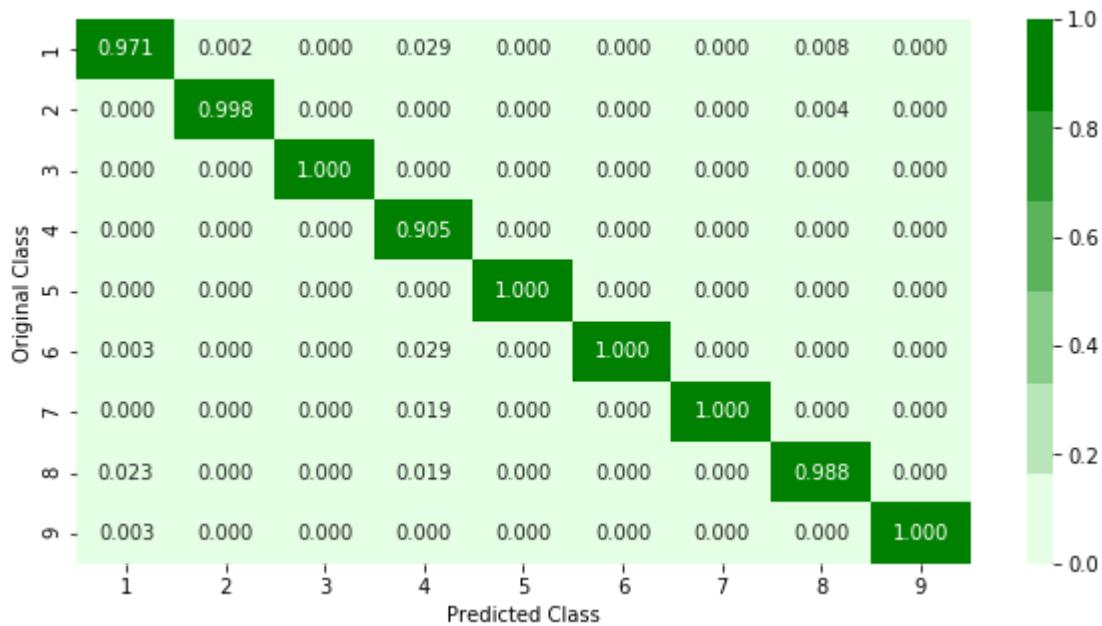
For values of best alpha = 50 The test log loss is: 0.0509767311310544

Number of misclassified points 1.0579576816927323

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

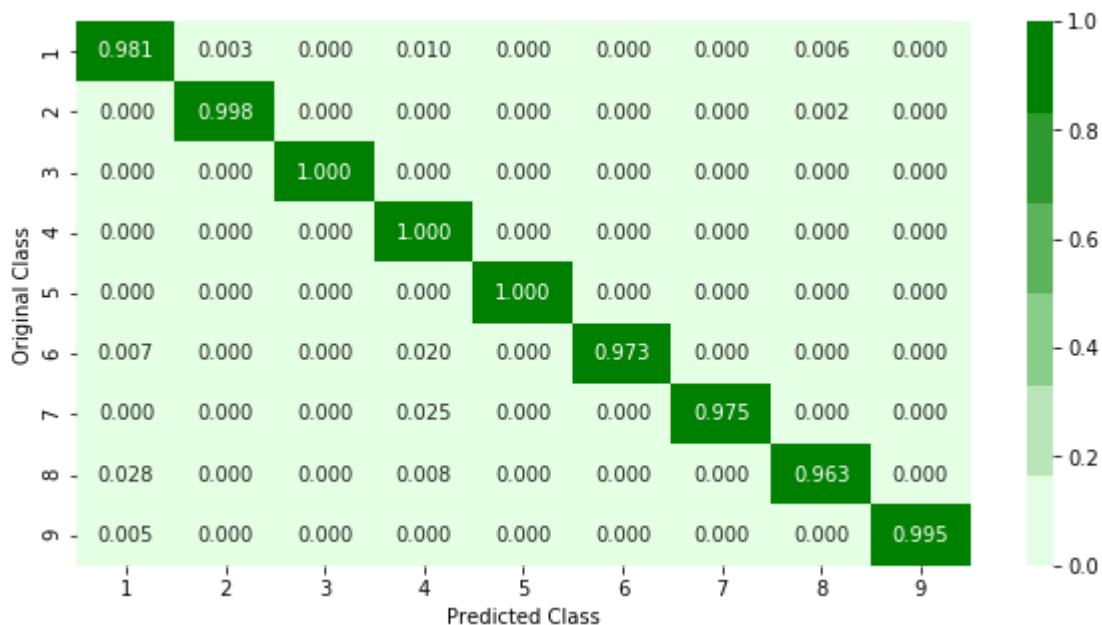
Original Class	Predicted Class								
	1	2	3	4	5	6	7	8	9
1	302.000	1.000	0.000	3.000	0.000	0.000	0.000	2.000	0.000
2	0.000	495.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
3	0.000	0.000	588.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	95.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	8.000	0.000	0.000	0.000	0.000
6	1.000	0.000	0.000	3.000	0.000	146.000	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	7.000	0.000	0.000	2.000	0.000	0.000	0.000	237.000	0.000
9	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	202.000

----- 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 [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_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:  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_alpha=1,  
                                         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/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, Learning_rate=0.1, n_estimators=100, silent=True,
#                             objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0,
#                             min_child_weight=1, max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_Lambda=1,
#                             scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

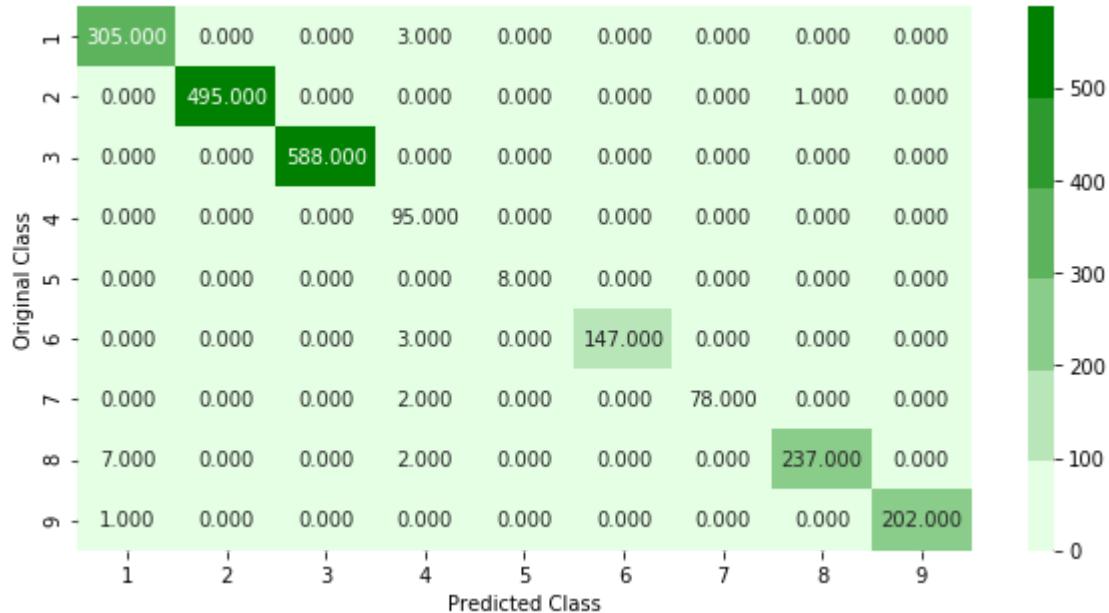
# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None, verbose=True, xgb_model=None)
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: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


x_cfl=XGBClassifier(learning_rate= 0.1, subsample= 0.3, n_estimators= 1000, colsample_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)

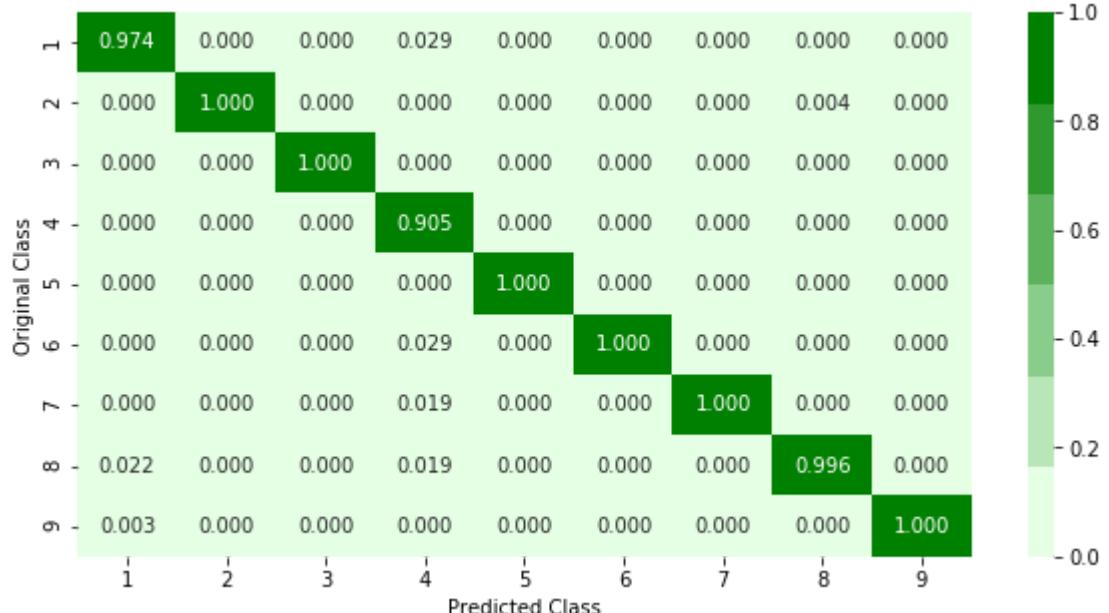
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

train loss 0.026067096568778484
cv loss 0.0617486470212045
test loss 0.04639167793516503
Number of misclassified points 0.8739650413983441

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

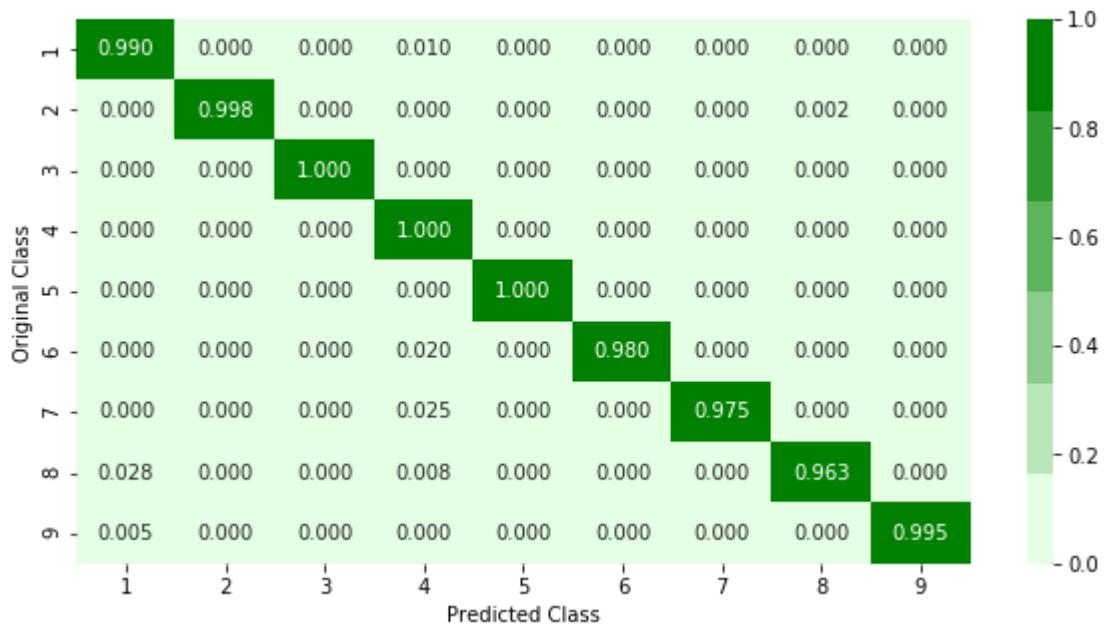


----- Precision matrix -----



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('nbAgg')
# %matplotlib 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	01azqd4lnC7m9JpocGv5	0.262806	0.005498	0.001567	0.002067	0.002048 0.001
1	0.000092	01lsoiSMh5gxyDYTI4CB	0.017358	0.011737	0.004033	0.003876	0.005303 0.003
2	0.000184	01jsnpXSAlg6aPeDxrU	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

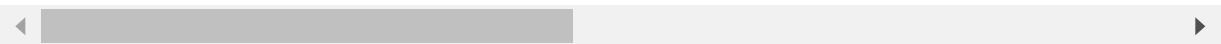
Asm unigrams

```
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



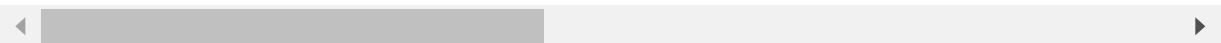
Byte bigrams 1000 features

```
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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

5 rows × 1002 columns



Asm image 500 features

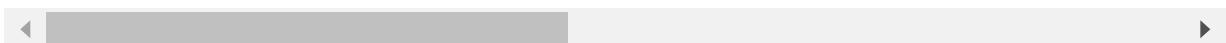
```
In [6]: # final_result_asm.to_csv('asm_img_final_rf_reduced_df',index=False)
```

```
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	GhHS0zL9cgNXFK6j1dIJ	0.805813
1	8qCPkhNr1KJaGtZ35pBc	0.938477
2	bLGq2tnA8CuxsF4Py9RO	0.475621
3	C0uidNjwV8lrPgzt1JSG	0.800508
4	IHiArX1xcBZgv69o4s0a	0.633535

Opcode Bigrams

```
In [11]: # final_opcodebigram_df.to_csv('opcodebigram_final_rf_reduced_df.csv',index=False)
```

```
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	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



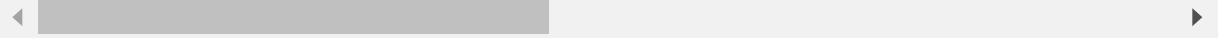
First we'll merge Byte unigrams and asm unigrams

```
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 last.
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	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 × 311 columns



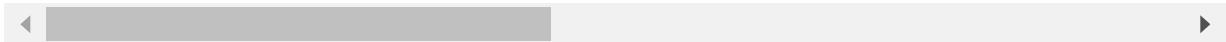
Now we'll combine Byte bigrams 1000 features and image 500 features

```
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 df1
bigrams_image_combined_df['ID']=df1 # add ID series as a 'new' column in the last.
df2 = bigrams_image_combined_df.pop('Class') # remove column ID and store it in df2
bigrams_image_combined_df['Class']=df2 # add ID series as a 'new' column in the 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
1	0.010204	0.000000	0.000000	0.001415	0.002577	0.000103	0.007212	0.000000	0.000000
2	0.183673	0.051724	0.016369	0.004717	0.028351	0.000413	0.026442	0.001627	0.054393
3	0.000000	0.008621	0.001488	0.000472	0.002577	0.000103	0.026442	0.000000	0.000000
4	0.193878	0.293103	0.032738	0.012264	0.051546	0.000929	0.043269	0.001550	0.058577

5 rows × 1502 columns



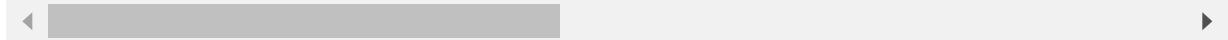
Now we'll combine Entropy , Opcode bygrams , Opcode trigrams

```
In [28]: entropy_opcodebigram_combined_df = pd.merge(final_entropy_df, final_opcodebigram_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 in the last.
df2 = entropy_opcodebigram_combined_df.pop('Class') # remove column ID and store it in df1
entropy_opcodebigram_combined_df['Class']=df2 # add ID series as a 'new' column in the last.
df3 = entropy_opcodebigram_combined_df.pop('entropy') # remove column ID and store it in df1
entropy_opcodebigram_combined_df['entropy']=df3 # add ID series as a 'new' column 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=True)
entropy_opbi_optri_combined_df = pd.merge(final_OPCODETRIGRAM_DF, entropy_opcodebigram_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_image_combined_df, on='ID', how='left')
df1 = unigrams_bigrams_image_combined_df.pop('ID') # remove column ID and store 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' column in the last.
df3 = unigrams_bigrams_image_combined_df.pop('Class') # remove column ID and store it in df1
unigrams_bigrams_image_combined_df['Class']=df3 # add ID series as a 'new' column 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
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 × 1811 columns

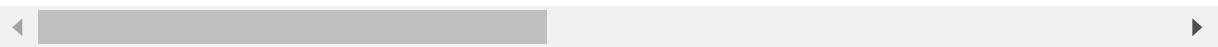
Now finally we merge the remaining df's to get the final df i.e
unigrams_bigrams_image_combined_df and
entropy_opbi_optri_combined_df

```
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_opbi_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 df1
final_all_combined_df['Class']=df3 # add ID series as a 'new' column in the last.
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 output variable '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 distribution of output variable '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=0.10)
```

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

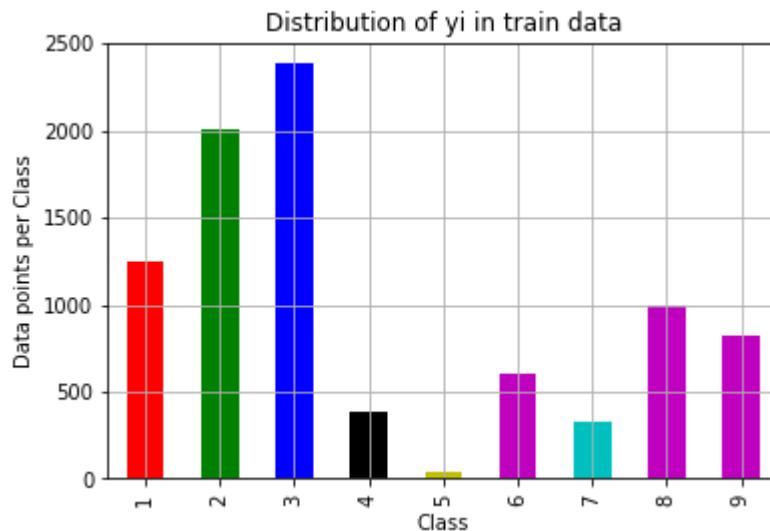
print('*'*80)
# my_colors = 'rgbkymc'
test_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in test data')
plt.grid()
plt.show()

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

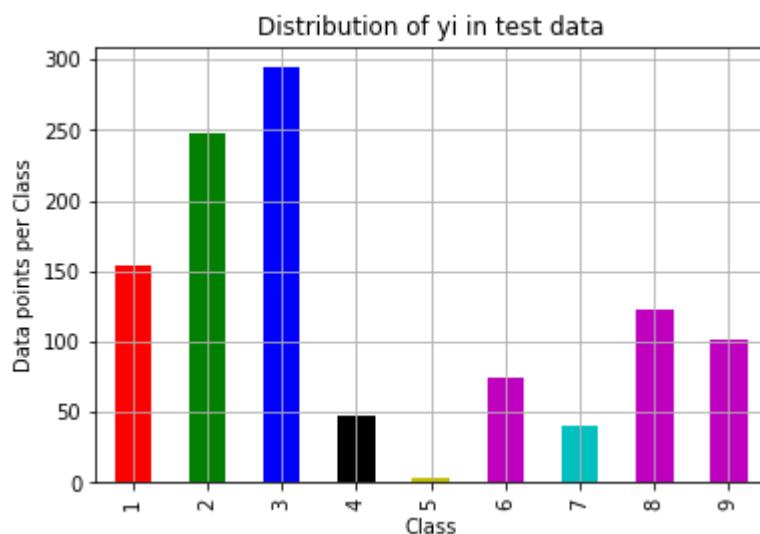
print('*'*80)
# my_colors = 'rgbkymc'
cv_class_distribution.plot(kind='bar', color=my_colors)
plt.xlabel('Class')
plt.ylabel('Data points per Class')
plt.title('Distribution of yi in cross validation data')
plt.grid()
plt.show()

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

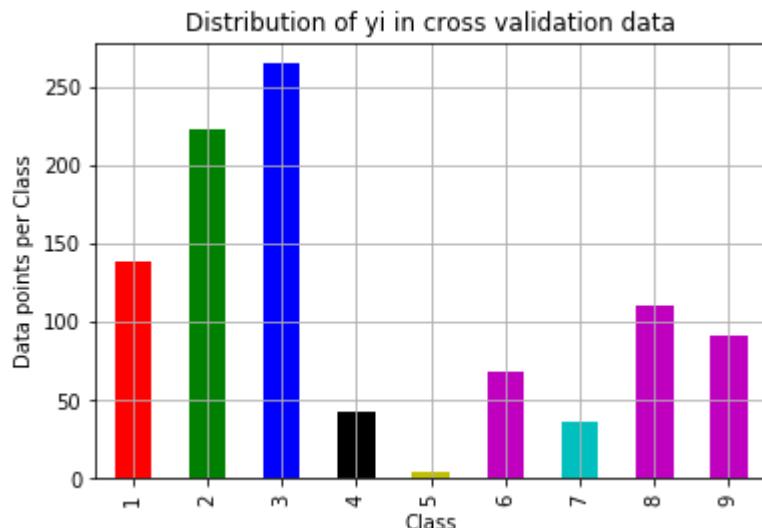
```
# -(train_class_distribution.values): the minus sign will give us in decreasing order
sorted_yi = np.argsort(-train_class_distribution.values)
for i in sorted_yi:
    print('Number of data points in class', i+1, ':', cv_class_distribution.values[i], '(', np.round((cv_class_distribution.values[i]/y_cv.shape[0])*100),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

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

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

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

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

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

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

```
# representing B in heatmap format
print("-"*50, "Recall matrix" , "-"*50)
plt.figure(figsize=(10,5))
sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, 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 Learning 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()

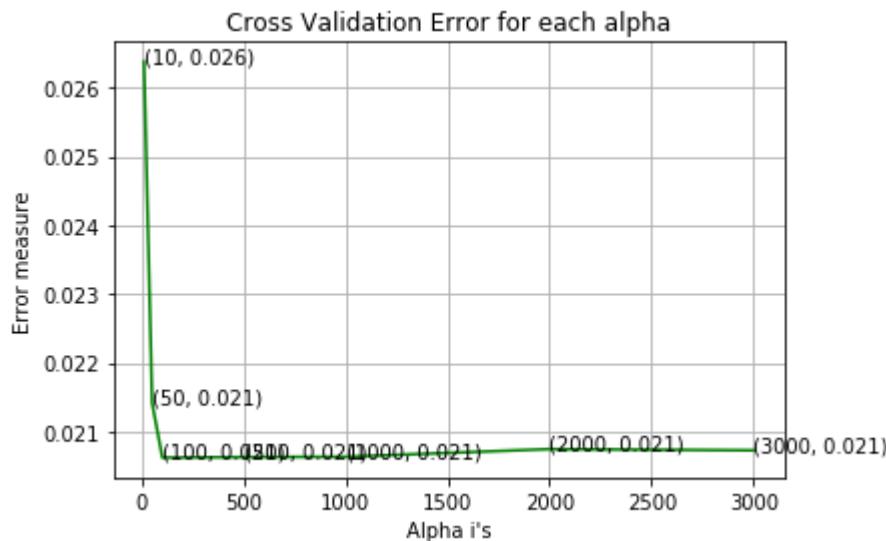
r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_

```

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



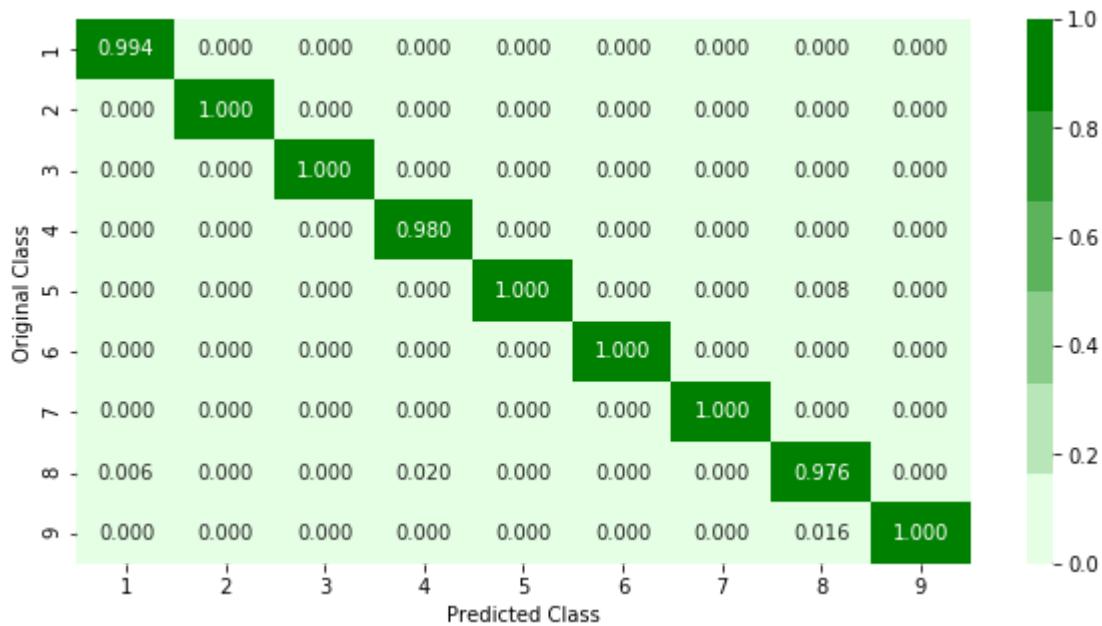
For values of best alpha = 100 The train log loss is: 0.011049375927013985
 For values of best alpha = 100 The cross validation log loss is: 0.020619472025640306

For values of best alpha = 100 The test log loss is: 0.019597358899095856
 Number of misclassified points 0.45998160073597055

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

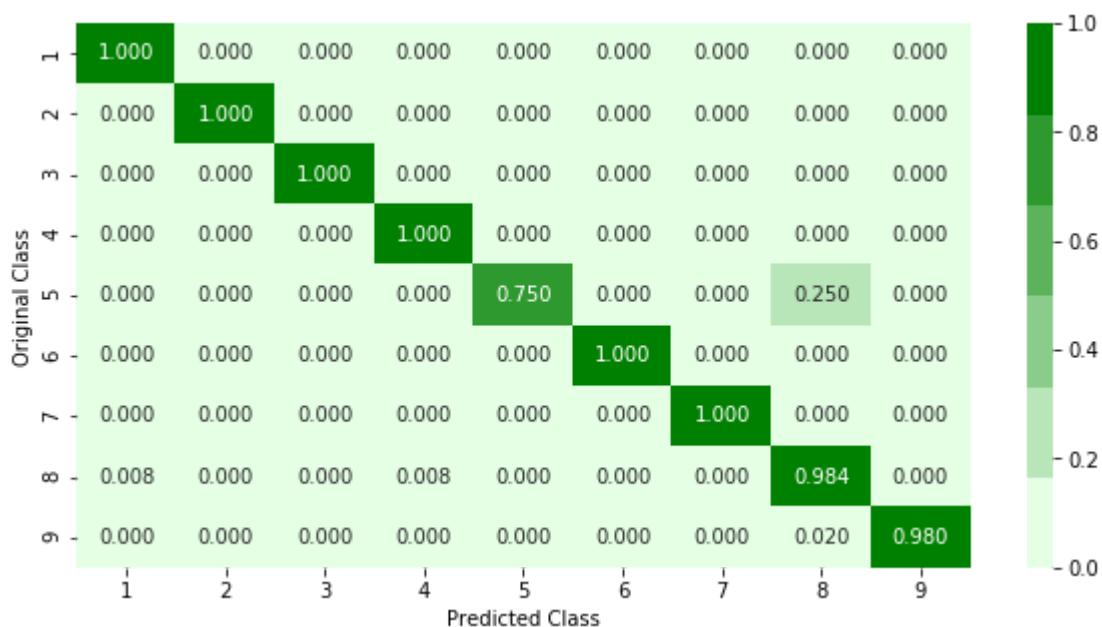
Original Class	Predicted Class									
	1	2	3	4	5	6	7	8	9	
1	154.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	248.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	294.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	48.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	3.000	0.000	0.000	1.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	75.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	40.000	0.000	0.000	0.000
8	1.000	0.000	0.000	1.000	0.000	0.000	0.000	121.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000	99.000	0.000

----- 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 [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_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:  2.0min 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_alpha=0, 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

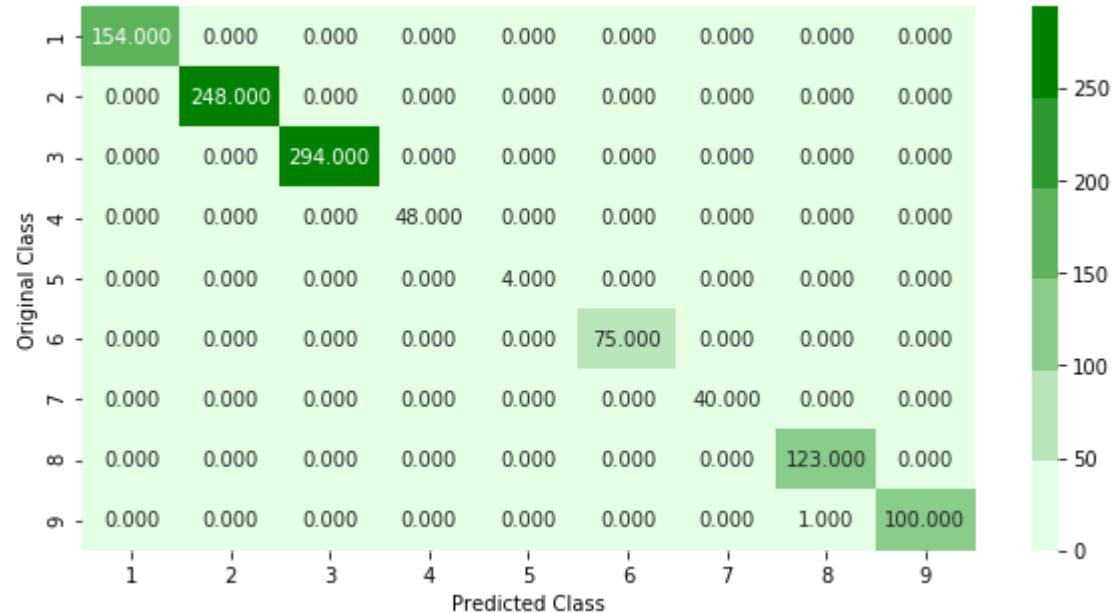
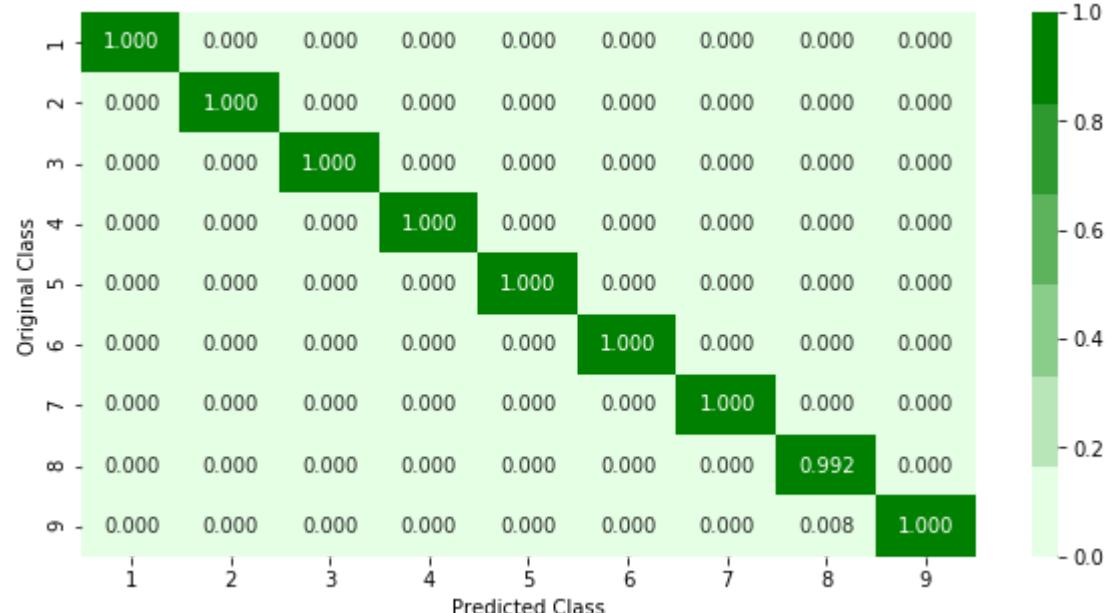
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/python/python_api.html?#xgboost.XGBClassifier
# -----
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True,
# objective='binary:logistic', booster='gbtree',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

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

x_cfl=XGBClassifier(learning_rate= 0.2, subsample= 1, n_estimators= 2000, colsample_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)

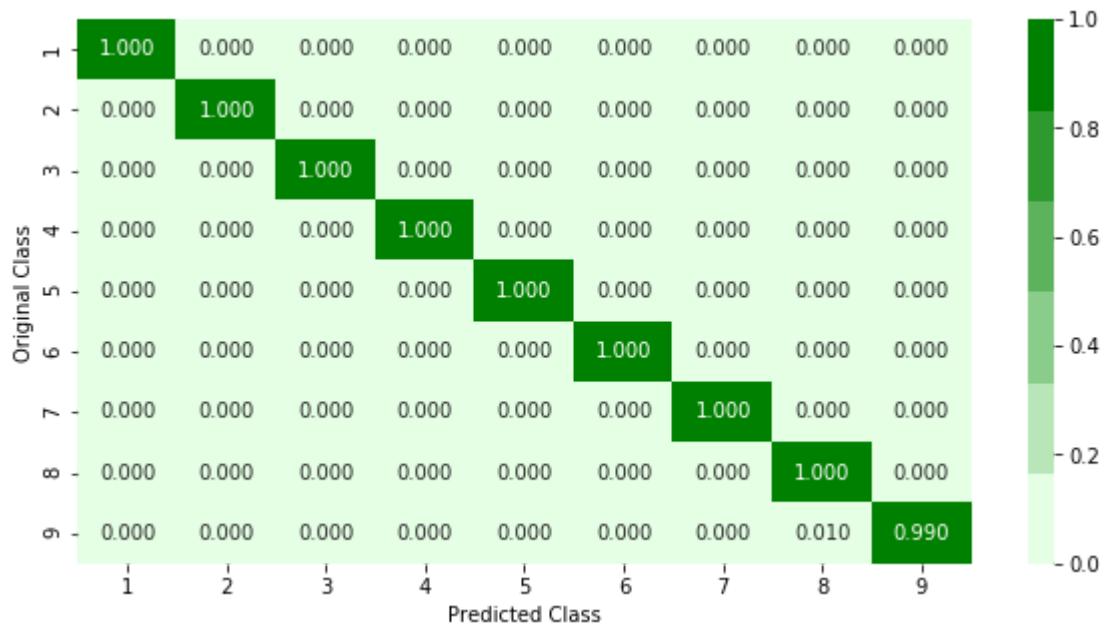
predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
plot_confusion_matrix(y_test, c_cfl.predict(X_test))
```

**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(1000)}", 0.034])
x.add_row([ "XGBoost(Hypertuned)", "{ASM image features(500)+byte bigrams(1000)+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 features(500) + entropy + opcode bigrams(300) + opcode trigrams(700)}", 0.019])
x.add_row([ "XGBoost(Hypertuned)", "{asm and byte unigrams + byte bigrams(1000) + image features(500) + entropy + opcode bigrams(300) + opcode trigrams(700)}", 0.012])
print(x)
```

Model	Test log-
Features loss	
Knn yte bigrams(1000) 0.187	{B}
LR yte bigrams(1000) 0.2	{B}
RF yte bigrams(1000) 0.036	{B}
XGBoost yte bigrams(1000) 0.071	{B}
XGBoost(Hypertuned) yte bigrams(1000) 0.041	{B}
RF te trigrams(1000) 0.043	{By}
XGBoost(Hypertuned) te trigrams(1000) 0.037	{By}
RF s(1000) and trigrams(1000) 0.039	{Byte bigram}
XGBoost(Hypertuned) s(1000) and trigrams(1000) 0.034	{Byte bigram}
RF image features(500) 0.483	{ASM}
XGBoost(Hypertuned) image features(500) 0.431	{ASM}
RF +byte bigrams(1000)+byte trigrams(1000) 0.034	{ASM image features(500)}
XGBoost(Hypertuned) +byte bigrams(1000)+byte trigrams(1000) 0.037	{ASM image features(500)}

```

|           |
|           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 []: