Hyperspectral Imaging Data

Absract

Remote sensing involves understanding activities on surface of the earth based on the reflected light from the surface. Devices which help us get this information are the cameras on board satellites, Surveillance planes/ UAVs/Drones. There are multiple methods of collecting information of activities of surface of the earth as mentioned in https://en.wikipedia.org/wiki/Remote_sensing. Hyper spectral imaging is one of the method which help us peek into the unseen light by collecting signals of multiple narrow bands of wavelength beyond visible light spectrum.

In remote sensing, hyperspectral images help study surface of the earth. It captures unique information associated with specific activity or structures (natural or human) on the surface. This can help Agriculture, Minerals Exploration, Defense,Surveillance etc. These images can help monitor Earths surface activity.

Based on the image data we can segment the areas of our interest. With image and segmented data we can train a Deep Learning algorithm which can in future generate segmented image from a raw image.

Problem

At the present we have limited data available to train a DL model to make segmentation of any given patch of earth's surface based on the hyperspectral image. For study purpose there are images collected through airbornes or satellites. The data set is available in the link - http://www.ehu.eus/ccwintco/index.php/Hyperspectral_Remote_Sensing_Scenes#Indian_Pines

The scene was gathered by AVIRIS sensor over the Indian Pines test site in North-western Indiana and consists of 145x145 pixels and 224 spectral reflectance bands in the wavelength range 0.4–2.5 10^(-6) meters. This scene is a subset of a larger one.

The ground truth available is designated into 16 classes and is not all mutually exclusive. The number of bands are reduced to 200 by removing bands covering the region of water absorption. (In the same link we can observe other patchs of HS images, which can be explored for study)

Now we have to come up with system that should be able to segment the regions based on the available Hyper Spectral(HS) image data.

Deep Learning is one of the techniques which can predict classification of specific data based on the information associated with data. Deeplearning invovles different kinds of Neural Network architecture to be built and trained on the data.

Refer the blog in the link mentioned, which captures overview of simple to complex neural network architectures-https://www.sabrepc.com/blog/Deep-Learning-and-AI/6-types-of-neural-networks-to-know-about

Module imports

In [1]:

```
import scipy.io
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sb
from sklearn.model_selection import train_test_split
import tensorflow as tf
from tensorflow.keras.layers import Input
from tensorflow.keras.layers import Dense,Dropout
from tensorflow.keras.layers import Flatten
from tensorflow.keras.losses import categorical_crossentropy
from tensorflow.keras import Model, initializers, regularizers
from tensorflow.keras.utils import plot_model, to_categorical
from sklearn.metrics import f1_score,roc_auc_score
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.callbacks import EarlyStopping,ReduceLROnPlateau
from tensorflow.keras.callbacks import LearningRateScheduler
import time, os
from tensorflow.python.keras.callbacks import TensorBoard
from datetime import datetime
```

```
from datetime import datetime
from sklearn.preprocessing import MinMaxScaler, StandardScaler
from sklearn.utils import class_weight
from sklearn.metrics import confusion_matrix, cohen_kappa_score
from tensorflow.keras import optimizers
```

In [2]:

```
# Data Source : http://www.ehu.eus/ccwintco/index.php/Hyperspectral_Remote_Sensing_Scenes#Indian_Pines
!wget wget --header="Host: www.ehu.eus" --header="User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/97.0.4692.71 Safari/537.36" --header="Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.9" --header="Accept-Language: en-US,en;q=0.9" --header="Referer: http://www.ehu.eus/ccwintco/index.php/Hyperspectral_Remote_Sensing_Scenes" "http://www.ehu.eus/ccwintco/uploads/6/67/Indian_pines_corrected.mat" -c -O 'Indian_pines_corrected.mat'
!unzip Indian_pines_corrected.mat
```

```
--2022-02-26 02:09:01--  http://wget/
Resolving wget (wget)... failed: Name or service not known.
wget: unable to resolve host address ‘wget’
--2022-02-26 02:09:01--  http://www.ehu.eus/ccwintco/uploads/6/67/Indian_pines_corrected.mat
Resolving www.ehu.eus (www.ehu.eus)... 158.227.0.65, 2001:720:1410::65
Connecting to www.ehu.eus (www.ehu.eus)|158.227.0.65|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 5953527 (5.7M)
Saving to: ‘Indian_pines_corrected.mat’

Indian_pines_correc 100%[===================>]   5.68M   742KB/s    in 8.6s

2022-02-26 02:09:10 (677 KB/s) - ‘Indian_pines_corrected.mat’ saved [5953527/5953527]

FINISHED --2022-02-26 02:09:10--
Total wall clock time: 9.0s
Downloaded: 1 files, 5.7M in 8.6s (677 KB/s)
Archive:  Indian_pines_corrected.mat
  End-of-central-directory signature not found.  Either this file is not
  a zipfile, or it constitutes one disk of a multi-part archive.  In the
  latter case the central directory and zipfile comment will be found on
  the last disk(s) of this archive.
unzip:  cannot find zipfile directory in one of Indian_pines_corrected.mat or
        Indian_pines_corrected.mat.zip, and cannot find Indian_pines_corrected.mat.ZIP, period.
```

In [3]:

```
# mat = scipy.io.loadmat('HSI_Data\Indian_pines_corrected.mat')
mat = scipy.io.loadmat('Indian_pines_corrected.mat')
```

Indian pines Image data

Shape

In [4]:

```
mat['indian_pines_corrected'].shape
```

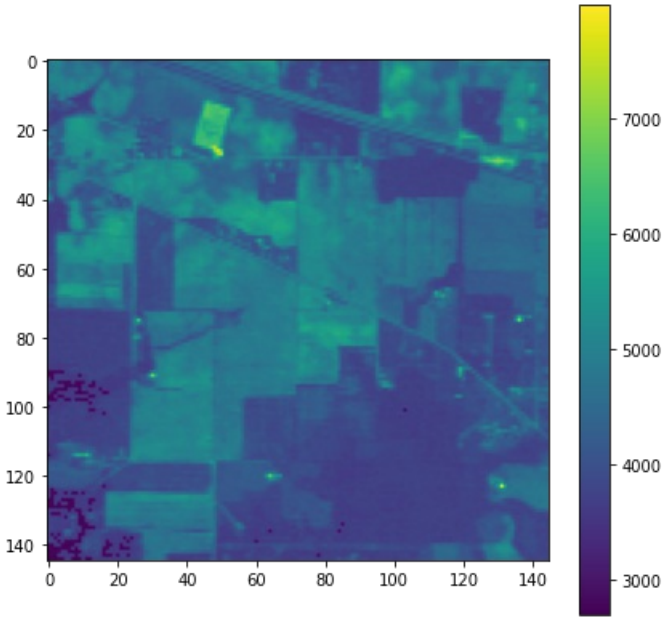
Out[4]:

```
(145, 145, 200)
```

Image

In [5]:

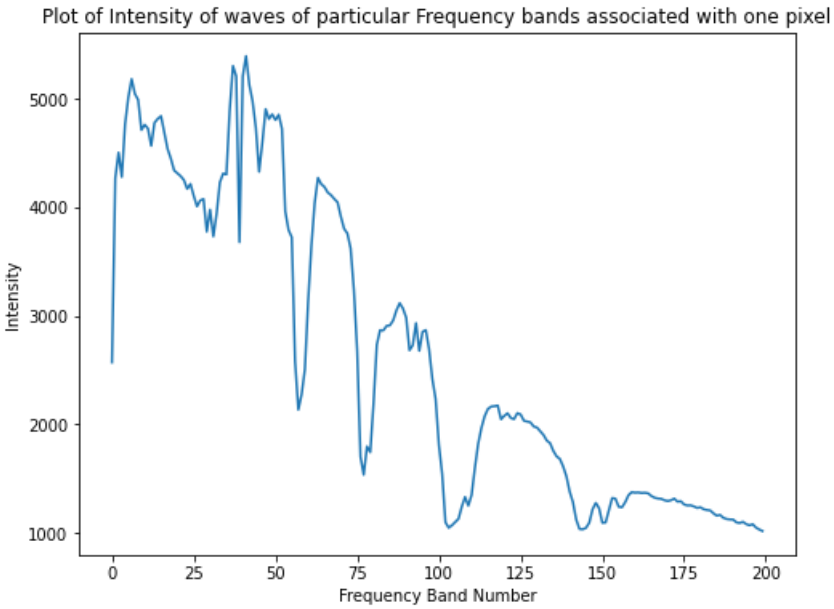
```
plt.figure(figsize=(7,7))
plt.imshow(mat['indian_pines_corrected'][:,:,10])
plt.colorbar()
plt.show()
```



Information in one Pixel

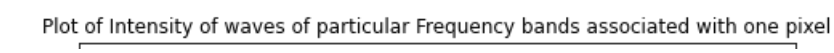
In [35]:

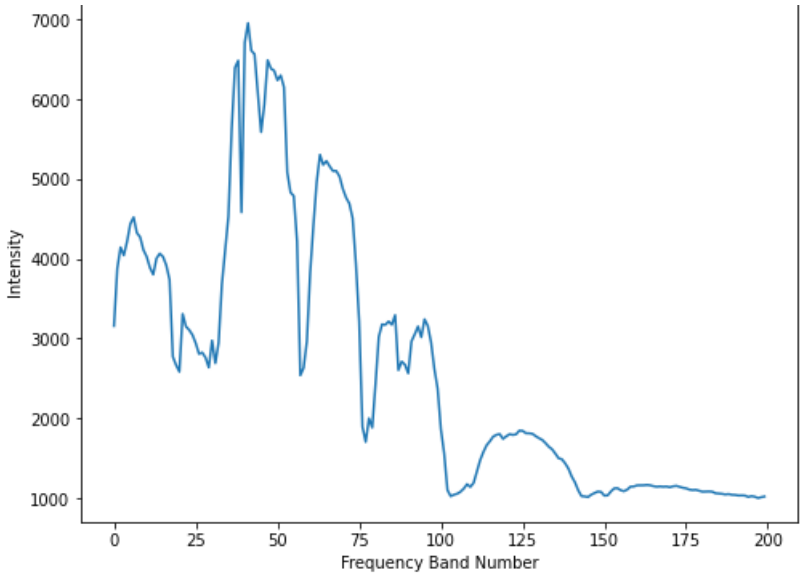
```
plt.figure(figsize=(8,6))
plt.plot(mat['indian_pines_corrected'][1,20,:])
plt.title('Plot of Intensity of waves of particular Frequency bands associated with one pixel')
plt.xlabel('Frequency Band Number')
plt.ylabel('Intensity')
plt.show()
```



In [36]:

```
plt.figure(figsize=(8,6))
plt.plot(mat['indian_pines_corrected'][20,30,:])
plt.title('Plot of Intensity of waves of particular Frequency bands associated with one pixel')
plt.xlabel('Frequency Band Number')
plt.ylabel('Intensity')
plt.show()
```





In [8]:

```
np.max(mat['indian_pines_corrected']), np.min(mat['indian_pines_corrected'])
```

Out[8]:

```
(9604, 955)
```

Ground Truth image

In [9]:

```
# mat_gt = scipy.io.loadmat('HSI_Data\Indian_pines_gt.mat')
mat_gt = scipy.io.loadmat('Indian_pines_gt.mat')
```

In [10]:

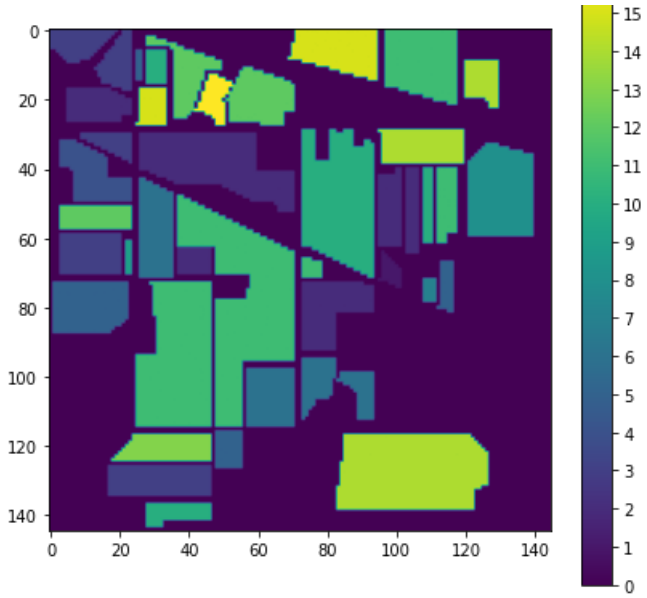
```
mat_gt['indian_pines_gt'][25:40,15:30]
```

Out[10]:

```
array([[ 2,  2,  2,  2,  2,  2,  0,  0,  0,  0,  0, 15, 15, 15, 15],
       [ 2,  2,  2,  2,  2,  2,  0,  0,  0,  0,  0, 15, 15, 15, 15],
       [ 0,  0,  0,  0,  0,  0,  0,  0,  0,  0, 15, 15, 15, 15, 15],
       [ 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,  3,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 3,  3,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 3,  3,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 3,  3,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 3,  3,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 0,  0,  3,  3,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 4,  0,  0,  0,  3,  3,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 4,  4,  0,  0,  0,  0,  3,  3,  3,  0,  0,  2,  2,  2,  2],
       [ 4,  4,  0,  0,  0,  0,  0,  0,  3,  0,  0,  2,  2,  2,  2],
       [ 4,  4,  0,  0,  0,  0,  0,  0,  0,  0,  0,  2,  2,  2,  2]],
      dtype=uint8)
```

In [33]:

```
plt.figure(figsize=(7,7))
plt.imshow(mat_gt['indian_pines_gt'])
plt.colorbar(ticks=range(0,17))
plt.show()
```



In [12]:

```
mat_gt['indian_pines_gt'].shape
```

Out[12]:

```
(145, 145)
```

Pixelwise classification using Neural Network

Reshaping of the image (3 dimension - x,y,l) into rows and columns. Each row represents the each pixel at location(x,y). Each column represents the third dimension(l) which captures the intensity of different frequency bands.

In [13]:

```
# https://panjeh.medium.com/convert-numpy-3d-array-to-2d-array-in-python-931a4cdf8b12
```

In [14]:

```
mat_rshp = mat['indian_pines_corrected'].reshape(-1,200)
```

In [15]:

```
mat_gt_rshp = mat_gt['indian_pines_gt'].reshape(-1,1)
```

In [16]:

```
px_data_full = pd.DataFrame(mat_rshp)
```

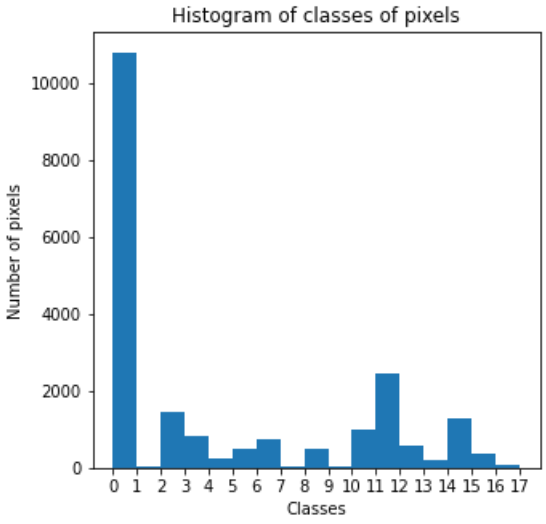
In [17]:

```
# px_class_data = pd.DataFrame(mat_gt_rshp)
```

In [18]:

```
# px_class_data.value_counts()
plt.figure(figsize=(5,5))
plt.hist(mat_gt_rshp,bins=range(0,18,1))
plt.xticks(range(0,18,1))
plt.title('Histogram of classes of pixels')
plt.xlabel('Classes')
plt.ylabel('Number of pixels')
```

```
plt.show()
```



Reshape verification

In [19]:

```
# mat_rshp_chk = mat_rshp.reshape(145,145,200)
```

In [20]:

```
# plt.imshow(mat_rshp_chk[:,:,20])
# plt.show()
```

In [21]:

```
# mat_gt_rshp_chk = mat_gt_rshp.reshape(145,145)
```

In [22]:

```
# plt.imshow(mat_gt_rshp_chk)
# plt.show()
```

Pixelwise data

In [23]:

```
px_data = pd.DataFrame(mat_rshp)
px_data
```

Out[23]:

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	3172	4142	4506	4279	4782	5048	5213	5106	5053	4750	4816	4769	4610	4805	4828	4861	4767	4624	4549
1	2580	4266	4502	4426	4853	5249	5352	5353	5347	5065	5141	5100	4994	5172	5290	5289	5217	5053	5033
2	3687	4266	4421	4498	5019	5293	5438	5427	5383	5132	5227	5172	5097	5313	5411	5412	5341	5191	5140
3	2749	4258	4603	4493	4958	5234	5417	5355	5349	5096	5147	5078	5040	5237	5321	5344	5255	5121	5035
4	2746	4018	4675	4417	4886	5117	5215	5096	5098	4834	4853	4857	4734	4879	4976	4958	4885	4754	4647
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21020	2561	3987	4011	4023	4201	4377	4418	4248	4180	3838	3762	3696	3594	3750	3806	3764	3655	2611	3199
21021	2726	4104	4024	3880	4210	4377	4413	4174	4229	3900	3786	3696	3623	3726	3758	3725	3614	2584	3174

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
21022	3153	3864	4282	3889	4310	4372	4375	4208	4096	3878	3890	3683	3594	3714	3724	3700	2809	2564	3177
21023	3155	4104	4106	4027	4139	4318	4413	4174	4140	3933	3799	3627	2752	3667	3688	3628	2750	3245	3153
21024	3323	3860	4197	3952	4148	4279	4375	4225	3988	3866	3811	3639	3623	3686	3722	3673	2775	3315	3180

21025 rows × 200 columns

In [24]:

```
px_class = pd.DataFrame(mat_gt_rshp)
px_class
```

Out[24]:

	0
0	3
1	3
2	3
3	3
4	3
...	...
21020	0
21021	0
21022	0
21023	0
21024	0

21025 rows × 1 columns

In [25]:

```
# px_class[px_class[0]==0].index
```

In [26]:

```
# px_data = px_data.drop(px_class[px_class[0]==0].index,axis=0)
```

In [27]:

```
# px_class = px_class.drop(px_class[px_class[0]==0].index,axis=0)
```

In [28]:

```
px_class[0].describe()
```

Out[28]:

```
count    21025.000000
mean         4.224923
std          5.281972
min          0.000000
25%          0.000000
50%          0.000000
75%         10.000000
max         16.000000
Name: 0, dtype: float64
```

Train and Test Split

In [29]:

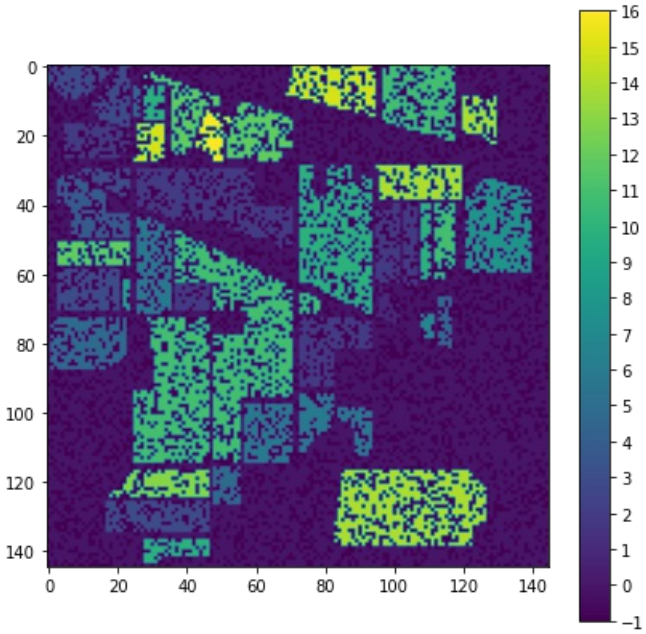
```
X_train, X_test, y_train, y_test = train_test_split(px_data, px_class, test_size=0.3, random_state=20,
stratify=px_class)
```

In [30]:

```
PX_class_train = y_train.reindex(px_data_full.index,fill_value=-1)
```

In [34]:

```
plt.figure(figsize=(7,7))
plt.imshow(PX_class_train.to_numpy().reshape((145,145)))
plt.colorbar(ticks=range(-1,17,1))
plt.show()
```



In [ ]:

```
y_ctg_train = to_categorical(y_train)
y_ctg_test = to_categorical(y_test)
```

In [ ]:

```
# y_ctg_train = y_ctg_train[:,1:]
# y_ctg_test = y_ctg_test[:,1:]
```

Feature Engineering

Standardization

In [ ]:

```
# Scaler = MinMaxScaler()
Scaler = StandardScaler()
X_train_std = pd.DataFrame(Scaler.fit_transform(X_train), index = X_train.index)
X_test_std = pd.DataFrame(Scaler.transform(X_test), index = X_test.index)
```

In [ ]:

In [ ]:

```
y_train
```

Out[ ]:

	0
7674	8
14004	0
17623	0
12672	11
15734	6
...	...
3002	0
14264	11
2104	0
7618	10
15062	0

14717 rows × 1 columns

Variance

In [ ]:

```
variance_data = X_train.var()
```

In [ ]:

```
variance_data
```

Out[ ]:

```
0      127297.253743
1       52361.818113
2       66493.685912
3       78627.459402
4      120039.036524
           ...
195       698.846583
196       885.827231
197       433.704496
198       129.637613
199        49.795652
Length: 200, dtype: float64
```

In [ ]:

```
min(variance_data)
```

Out[ ]:

```
49.79565233299031
```

In [ ]:

```
Feat_var_reject = variance_data[variance_data<0.01*variance_data.describe()['max']].index
Feat_var_reject
```

Out[ ]:

```
Int64Index([ 76,  77,  78,  79, 101, 102, 103, 104, 105, 106, 107, 109, 141,
            142, 143, 144, 145, 146, 147, 149, 150, 151, 152, 155, 156, 175,
            176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188,
            189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199],
           dtype='int64')
```

In [ ]:

```
X_train[Feat_var_reject]
```

Out[ ]:

	76	77	78	79	101	102	103	104	105	106	107	109	141	142	143	144	145	146	147
7674	1842	1676	1997	1884	1612	1095	1041	1060	1097	1112	1205	1233	1263	1126	1047	1025	1028	1059	1148
14004	1900	1686	1965	1874	1509	1090	1044	1052	1069	1065	1111	1137	1184	1080	1040	1015	1015	1045	1068
17623	1860	1678	1926	1821	1498	1059	1026	1046	1038	1050	1092	1104	1150	1063	1033	1010	1010	1018	1040
12672	1726	1552	1856	1762	1587	1120	1034	1070	1112	1133	1251	1278	1316	1154	1053	1040	1035	1116	1227
15734	1748	1579	1869	1753	1460	1085	1031	1038	1063	1060	1130	1144	1189	1088	1027	1011	1020	1051	1085
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3002	1587	1437	1689	1596	1416	1066	1020	1040	1073	1079	1163	1177	1184	1090	1038	1030	1013	1059	1131
14264	1759	1585	1827	1778	1598	1087	1057	1084	1102	1128	1256	1260	1311	1138	1048	1035	1040	1101	1208
2104	1804	1613	1884	1755	1484	1084	1028	1048	1062	1079	1134	1162	1186	1093	1043	1010	1035	1048	1102
7618	1755	1619	1901	1839	1643	1102	1034	1086	1116	1147	1298	1306	1329	1163	1051	1049	1058	1131	1268
15062	1806	1604	1918	1802	1532	1094	1034	1058	1071	1080	1144	1152	1198	1085	1033	1006	1024	1034	1084

14717 rows × 50 columns

Note: Varince is not low (not close to zero). each feature might have distribution of their own. So we will not consider dropping features based on variance.

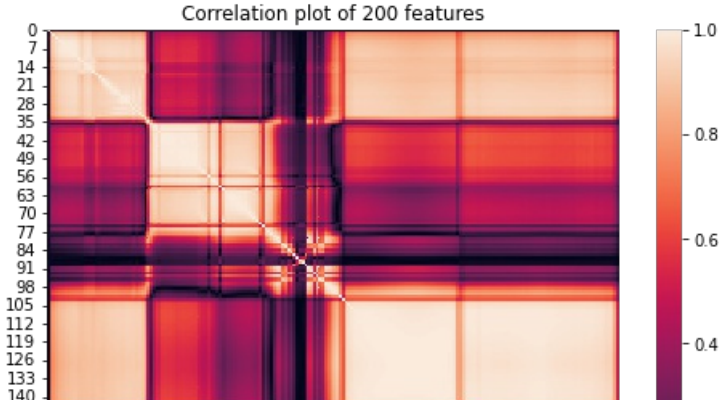
Correlation

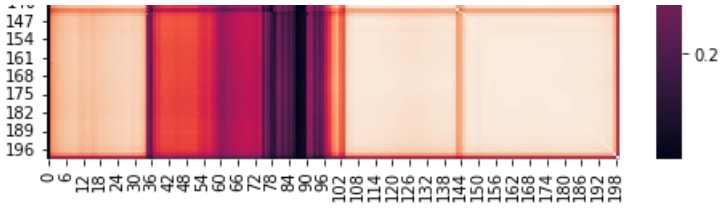
In [ ]:

```
# correlation evaluation of filtered dataset
Correlation_mat = X_train_std.corr('pearson')
```

In [ ]:

```
# Correlation heatmap on subset of features. Example plot as the feature size is large.
plt.figure(figsize=(8,6))
sb.heatmap(abs(Correlation_mat))#.iloc[40:60,40:60]),annot=True)
plt.title('Correlation plot of 200 features')
plt.show()
```





If there were no correlation among features, there would be high correlation (white colored) only on the diagonal of the above figure.

In [ ]:

```
def get_corr_features(corr_mat):
    '''This function returns feature list which have correlation above 0.99 for a given correlation mat
rix'''
    # list to store correlated features
    feature_correlated = []
    for i in range(len(corr_mat)):
        for j in range(i) : #This loop repeats only till one step before j=i, Thus captures information
from
                            #lower triangle matrix.
            if((corr_mat.iloc[i,j]>=0.99) and (corr_mat.columns[i] not in feature_correlated)):
                # features with correlation above 0.99 added to list.
                feature_correlated.append(corr_mat.columns[i])
    return feature_correlated
```

In [ ]:

```
# Correlation matrix of filtered train data passed to get_corr_features function to get list of feature
s with high correlation.
feature_correlated = get_corr_features(Correlation_mat)
```

In [ ]:

```
len(feature_correlated)
```

Out[ ]:

```
105
```

In [ ]:

```
feature_correlated
```

Out[ ]:

```
[7,
 8,
 9,
 15,
 24,
 27,
 28,
 38,
 40,
 41,
 42,
 43,
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```

```
 185,
 186,
 187,
 188,
 189,
 190]
```

Dropping features with high correlation

In [ ]:

```
X_train_std = X_train_std.drop(feature_correlated, axis=1)
X_test_std = X_test_std.drop(feature_correlated, axis=1)
```

In [ ]:

```
X_train_std.shape, X_test_std.shape
```

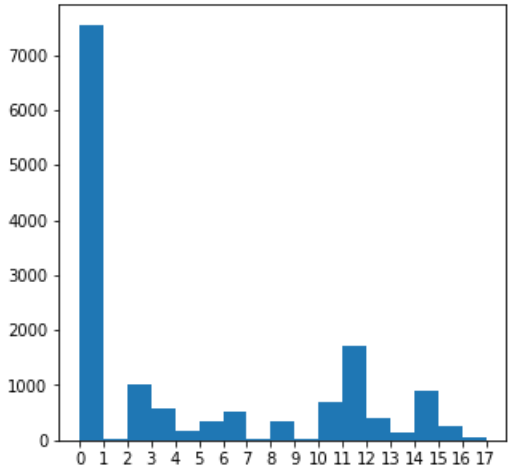
Out[ ]:

```
((14717, 95), (6308, 95))
```

Class Weights Evaluation

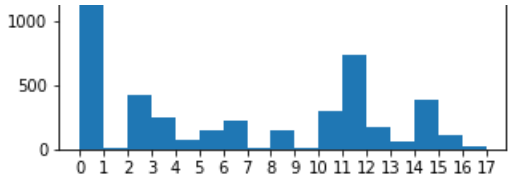
In [ ]:

```
plt.figure(figsize=(5,5))
plt.xticks(range(0,18,1))
plt.hist(y_train.to_numpy(),bins=range(0,18,1))
plt.show()
```



In [ ]:

```
plt.figure(figsize=(5,5))
plt.xticks(range(0,18,1))
plt.hist(y_test.to_numpy(),bins=range(0,18,1))
plt.show()
```



In [ ]:

```
y_train.shape
```

Out[ ]:

```
(14717, 1)
```

In [ ]:

```
np.squeeze(y_train.to_numpy()).shape
```

Out[ ]:

```
(14717,)
```

In [ ]:

```
# https://datascience.stackexchange.com/questions/13490/how-to-set-class-weights-for-imbalanced-classes-in-keras
# wts = n_samples / (n_classes * np.bincount(y))
# class_weights_1 = class_weight.compute_class_weight(class_weight='balanced',classes=np.unique(y_train),y=np.squeeze(y_train.to_numpy()))
```

In [ ]:

```
# class_wts_1 = dict(enumerate(class_weights_1/np.sum(class_weights_1)))
# class_wts_1
```

In [ ]:

```
# # Get the class weights for loss evaluation as the data has class imbalance
# https://medium.com/gumgum-tech/handling-class-imbalance-by-introducing-sample-weighting-in-the-loss-function-3bdebd8203b4
# https://neptune.ai/blog/keras-loss-functions
# https://keras.io/api/models/model_training_apis
class_count = y_train.value_counts().sort_index()
class_wts = 1/class_count
class_wts = class_wts/np.sum(class_wts)
class_wts = dict(enumerate(class_wts.to_list()))
class_wts
```

Out[ ]:

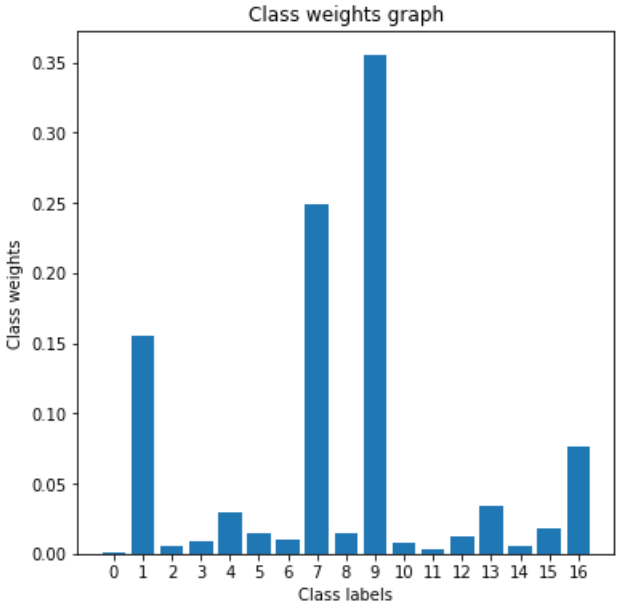
```
{0: 0.0006592993609901092,
 1: 0.15540922124838732,
 2: 0.0049730950799483946,
 3: 0.008559544027449904,
 4: 0.029958404096074667,
 5: 0.014713299053101758,
 6: 0.009732084305182768,
 7: 0.24865475399741974,
 8: 0.014845059940144461,
 9: 0.355221077139171,
 10: 0.0073133751175711685,
 11: 0.0028947002793646066,
 12: 0.011983361638429868,
 13: 0.03453538249964162,
 14: 0.00561931647451796,
 15: 0.018418870666475535,
 16: 0.07650915507612915}
```

In [ ]:

```
# class_wts.values()
```

In [ ]:

```
plt.figure(figsize=(6,6))
plt.bar(range(0,17,1),list(class_wts.values()))
plt.xlabel('Class labels')
plt.xticks(range(0,17,1))
plt.ylabel('Class weights')
plt.title('Class weights graph')
plt.show()
```



In [ ]:

```
list(class_wts.values())
```

Out[ ]:

```
[0.0006592993609901092,
 0.15540922124838732,
 0.004973095079948394 6,
 0.008559544027449904,
 0.029958404096074667,
 0.014713299053101758,
 0.009732084305182768,
 0.24865475399741974,
 0.014845059940144461,
 0.355221077139171,
 0.0073133751175711685,
 0.0028947002793646066,
 0.011983361638429868,
 0.03453538249964162,
 0.00561931647451796,
 0.018418870666475535,
 0.07650915507612915]
```

In [ ]:

```
np.argmax(list(class_wts.values()))
```

Out[ ]:

```
9
```

In [ ]:

```
np.argmin(list(class_wts.values()))
```

Out[ ]:

```
0
```

In [ ]:

```
sum(list(class_wts.values()))
```

Out[ ]:

```
1.0
```

In [ ]:

```
X_train_std.shape, y_ctg_train.shape
```

Out[ ]:

```
((14717, 95), (14717, 17))
```

In [ ]:

```
X_test_std.shape, y_ctg_test.shape
```

Out[ ]:

```
((6308, 95), (6308, 17))
```

In [ ]:

```
# y_ctg_train
```

Neural network model

F1 score calculation callback function definition

In [ ]:

```
class metric_calc(tf.keras.callbacks.Callback):

    def on_train_begin(self, logs={}):
        ## on begin of training, we are creating a instance varible called metrics
        ## it is a dict with keys [loss, acc, val_loss, val_acc]
        self.metrics={'micro_F1_train': [],
                      'micro_F1_val': [],
                      'val_acc':[]}

    def on_epoch_end(self, epoch, logs={}):
        ## on end of each epoch, we will get logs and update the self.metrics dict

        # Training score
        y_true = y_train
        y_pred = self.model.predict(X_train_std)

        yp = np.argmax(y_pred,axis=1)

        score = f1_score(y_true,yp,average='micro')

        self.metrics['micro_F1_train'].append(score)

        print('\n\nmicro F1 train: ',score)
```

```
        # Validation score
        y_true_val = y_test
        y_pred_val = self.model.predict(X_test_std)

        yp_val = np.argmax(y_pred_val,axis=1)

        score_val = f1_score(y_true_val,yp_val,average='micro')

        self.metrics['micro_F1_val'].append(score_val)

        print('\nmicro_F1_val: ',score_val)

        self.metrics['val_acc'].append(logs.get('val_acc'))

        #any NaN values(either weigths or loss) while training will terminate training
        loss = logs.get('loss')
        if loss is not None:
            if np.isnan(loss) or np.isinf(loss):
                print("Invalid loss and terminated at epoch {}".format(epoch))
                self.model.stop_training = True
```

Confusion matrix

In [ ]:

```
# code reference: appliedaicourse.com case studies
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 = 17x17 matrix, each cell (i,j) represents number of points of class i are predicted class j

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

    #Recall Matrix
    B =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in that row

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

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

    labels = list(range(0,17,1))
    cmap=sb.light_palette("green")
    # representing C in heatmap format
    print("-"*50, "Confusion matrix", "-"*50)
    plt.figure(figsize=(16,8))
    sb.heatmap(C, annot=True, cmap=cmap, fmt=".1f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    # representing A in heatmap format
    print("-"*50, "Precision matrix", "-"*50)
    plt.figure(figsize=(16,8))
```

```
    sb.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of columns in precision matrix",A.sum(axis=0))

    # representing B in heatmap format
    print("-"*50, "Recall matrix"    , "-"*50)
    plt.figure(figsize=(16,8))
    sb.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 rows in recall matrix",B.sum(axis=1))
```

1- Four layered network with relu activation and SGD optimizer

Model 1 Definition

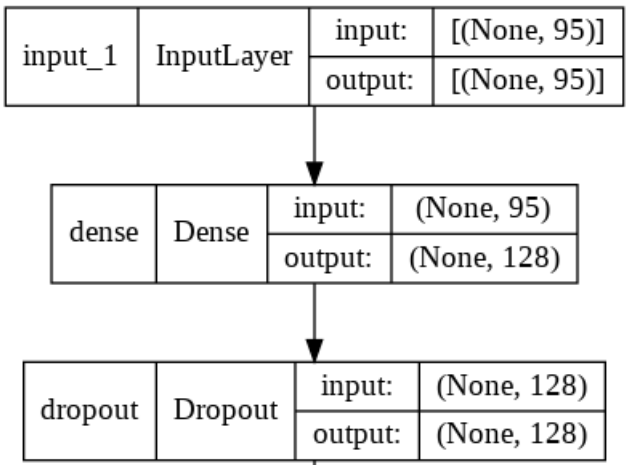
In [ ]:

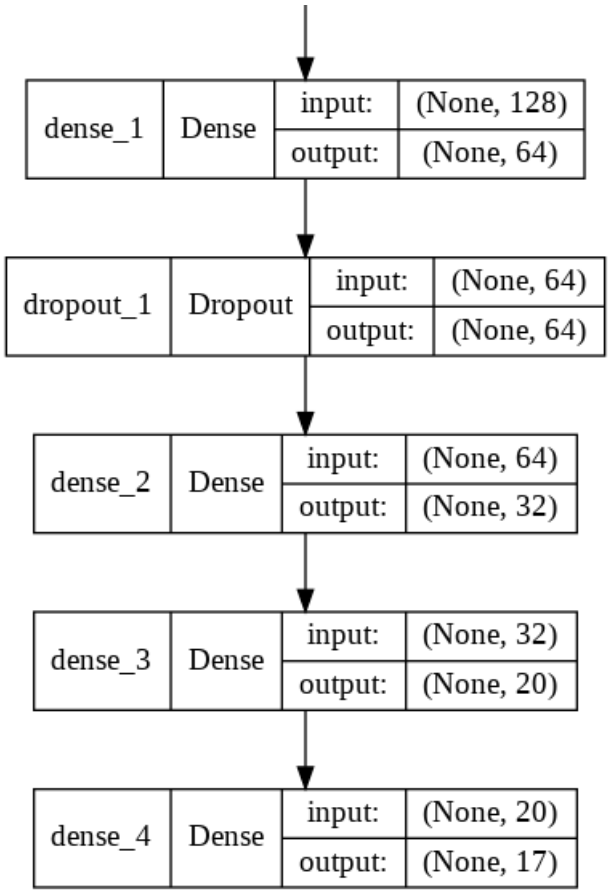
```
# del NeuNet_1
```

In [ ]:

```
In = Input(shape=(95,))
L1 = Dense(128,activation='relu',
           kernel_initializer=initializers.he_uniform())(In) #https://keras.io/api/layers/initializers/

L1_Drp = Dropout(0.4)(L1)

L2 = Dense(64,activation='relu',
          kernel_initializer=initializers.he_uniform())(L1_Drp)

L2_Drp = Dropout(0.3)(L2)

L3 = Dense(32,activation='relu',
          kernel_initializer=initializers.he_uniform())(L2_Drp)

L4 = Dense(20,activation='relu',
          kernel_initializer=initializers.he_uniform())(L3)

Out = Dense(17,activation='softmax',
           kernel_initializer=initializers.GlorotUniform())(L4)

NeuNet_1 = Model(inputs=In, outputs = Out)

# cce = categorical_crossentropy()
NeuNet_1.compile(loss='categorical_crossentropy', optimizer='SGD', metrics=['accuracy'])

plot_model(NeuNet_1,show_layer_names=True, show_shapes=True)#,to_file='NeuNet_1.png')
```

Out[ ]:





In [ ]:

```
NeuNet_1.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 95)]              0

 dense (Dense)               (None, 128)               12288

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 64)                8256

 dropout_1 (Dropout)         (None, 64)                0

 dense_2 (Dense)             (None, 32)                2080

 dense_3 (Dense)             (None, 20)                660

 dense_4 (Dense)             (None, 17)                357

=================================================================
Total params: 23,641
Trainable params: 23,641
Non-trainable params: 0
_________________________________________________________________
```

Model 1 Training

In [ ]:

```
logdir = os.path.join("logs", datetime.now().strftime("%Y%m%d-%H%M%S"))
print(datetime.now().strftime("%Y%m%d-%H%M%S"))
file_writer = tf.summary.create_file_writer(logdir + "/metrics")
# tensorboard = TensorBoard(log_dir=logdir)
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True, write_grads=True)
```

```
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True,write_grads=True)

metric_calc_1 = metric_calc()

# Saving model at every epoch if validation accuracy is improved from previous epoch
filepath_m1="model1_save/weights-{epoch:02d}-{val_accuracy:.4f}.hdf5"
checkpoint_m1 = ModelCheckpoint(filepath=filepath_m1, monitor='val_accuracy',  verbose=1,
                                save_best_only=True,
                                mode='auto')
earlystop_m1 = EarlyStopping(monitor='val_accuracy', min_delta=0.01, patience=20, verbose=1)
reduce_lr_m1 = ReduceLROnPlateau(monitor='val_loss', factor=0.9, patience=2, min_lr=0.001)

callback_list_1 = [metric_calc_1,
                   checkpoint_m1,
                   earlystop_m1,
                   reduce_lr_m1,
                   tensorboard]
# fit network
verbose_1, epochs_1, batch_size_1 = 1, 100, 10
start = time.time()
history_1 = NeuNet_1.fit(X_train_std, y_ctg_train,
                         class_weight = class_wts,
                         validation_data=(X_test_std,y_ctg_test),
                         epochs=epochs_1,
                         batch_size=batch_size_1,
                         verbose=verbose_1,
                         callbacks=callback_list_1)

# Passing the F1 score data of each epoch to tensor board
# https://stackoverflow.com/questions/58102016/how-visualize-in-tensorboard-a-metric-callback
for i in range(len(metric_calc_1.metrics['micro_F1_train'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_train', metric_calc_1.metrics['micro_F1_train'][i])
file_writer.flush()

for i in range(len(metric_calc_1.metrics['micro_F1_val'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_val', metric_calc_1.metrics['micro_F1_val'][i])
file_writer.flush()

stop = time.time()
print('Time Taken for training (sec): ',stop-start)
```

```
20220131-120445
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/100
   2/1472 [..............................] - ETA: 5:55 - loss: 0.1137 - accuracy: 0.0500 WARNING:tensor
flow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0042s vs
`on_train_batch_begin` time: 0.0223s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time:
0.0042s vs `on_train_batch_end` time: 0.0190s). Check your callbacks.
1465/1472 [============================>.] - ETA: 0s - loss: 0.0206 - accuracy: 0.0422

micro_F1_train:  0.029421757151593394

micro_F1_val:  0.03138871274571972

Epoch 00001: val_accuracy improved from -inf to 0.03139, saving model to model1_save/weights-01-0.0314.
hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0205 - accuracy: 0.0421 - val_loss:
3.2352 - val_accuracy: 0.0314 - lr: 0.0100
Epoch 2/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0185 - accuracy: 0.0435

micro_F1_train:  0.03981789766936196

micro_F1_val:  0.040424857324032976

Epoch 00002: val_accuracy improved from 0.03139 to 0.04042, saving model to model1_save/weights-02-0.04
04.hdf5
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0185 - accuracy: 0.0434 - val_loss:
3.0865 - val_accuracy: 0.0404 - lr: 0.0100
Epoch 3/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0173 - accuracy: 0.0481

micro_F1_train:  0.0485832710470884
```

```
micro_F1_val:  0.04787571337983513

Epoch 00003: val_accuracy improved from 0.04042 to 0.04788, saving model to model1_save/weights-03-0.04
79.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0173 - accuracy: 0.0482 - val_loss:
3.0311 - val_accuracy: 0.0479 - lr: 0.0100
Epoch 4/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0167 - accuracy: 0.0512

micro_F1_train:  0.05415505877556567

micro_F1_val:  0.05294863665187064

Epoch 00004: val_accuracy improved from 0.04788 to 0.05295, saving model to model1_save/weights-04-0.05
29.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0167 - accuracy: 0.0512 - val_loss:
3.0004 - val_accuracy: 0.0529 - lr: 0.0100
Epoch 5/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0163 - accuracy: 0.0513

micro_F1_train:  0.05809607936400082

micro_F1_val:  0.056753329105897275

Epoch 00005: val_accuracy improved from 0.05295 to 0.05675, saving model to model1_save/weights-05-0.05
68.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0164 - accuracy: 0.0514 - val_loss:
2.9746 - val_accuracy: 0.0568 - lr: 0.0100
Epoch 6/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0161 - accuracy: 0.0531

micro_F1_train:  0.06047428144322892

micro_F1_val:  0.059606848446417254

Epoch 00006: val_accuracy improved from 0.05675 to 0.05961, saving model to model1_save/weights-06-0.05
96.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0161 - accuracy: 0.0533 - val_loss:
2.9592 - val_accuracy: 0.0596 - lr: 0.0100
Epoch 7/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0157 - accuracy: 0.0570

micro_F1_train:  0.06292043215329211

micro_F1_val:  0.06246036778693722

Epoch 00007: val_accuracy improved from 0.05961 to 0.06246, saving model to model1_save/weights-07-0.06
25.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0157 - accuracy: 0.0570 - val_loss:
2.9489 - val_accuracy: 0.0625 - lr: 0.0100
Epoch 8/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0156 - accuracy: 0.0576

micro_F1_train:  0.06400761024665352

micro_F1_val:  0.06293595434369055

Epoch 00008: val_accuracy improved from 0.06246 to 0.06294, saving model to model1_save/weights-08-0.06
29.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0156 - accuracy: 0.0578 - val_loss:
2.9436 - val_accuracy: 0.0629 - lr: 0.0100
Epoch 9/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0154 - accuracy: 0.0613

micro_F1_train:  0.06550248012502548

micro_F1_val:  0.06515535827520609

Epoch 00009: val_accuracy improved from 0.06294 to 0.06516, saving model to model1_save/weights-09-0.06
52.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0154 - accuracy: 0.0613 - val_loss:
2.9333 - val_accuracy: 0.0652 - lr: 0.0100
Epoch 10/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0151 - accuracy: 0.0624

micro_F1_train:  0.06631786369504654
```

```
micro_F1_val:  0.06563094483195941

Epoch 00010: val_accuracy improved from 0.06516 to 0.06563, saving model to model1_save/weights-10-0.06
56.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0151 - accuracy: 0.0623 - val_loss:
2.9269 - val_accuracy: 0.0656 - lr: 0.0100
Epoch 11/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0152 - accuracy: 0.0634

micro_F1_train:  0.06611401780254128

micro_F1_val:  0.06800887761572606

Epoch 00011: val_accuracy improved from 0.06563 to 0.06801, saving model to model1_save/weights-11-0.06
80.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0152 - accuracy: 0.0635 - val_loss:
2.9138 - val_accuracy: 0.0680 - lr: 0.0100
Epoch 12/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0150 - accuracy: 0.0641

micro_F1_train:  0.06747299041924305

micro_F1_val:  0.06927710843373494

Epoch 00012: val_accuracy improved from 0.06801 to 0.06928, saving model to model1_save/weights-12-0.06
93.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0150 - accuracy: 0.0641 - val_loss:
2.9077 - val_accuracy: 0.0693 - lr: 0.0100
Epoch 13/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0148 - accuracy: 0.0702

micro_F1_train:  0.07025888428348169

micro_F1_val:  0.07244768547875713

Epoch 00013: val_accuracy improved from 0.06928 to 0.07245, saving model to model1_save/weights-13-0.07
24.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0148 - accuracy: 0.0702 - val_loss:
2.9007 - val_accuracy: 0.0724 - lr: 0.0100
Epoch 14/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0146 - accuracy: 0.0641

micro_F1_train:  0.07297682951688524

micro_F1_val:  0.07276474318325936

Epoch 00014: val_accuracy improved from 0.07245 to 0.07276, saving model to model1_save/weights-14-0.07
28.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0146 - accuracy: 0.0641 - val_loss:
2.8893 - val_accuracy: 0.0728 - lr: 0.0100
Epoch 15/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0145 - accuracy: 0.0694

micro_F1_train:  0.07290888088605015

micro_F1_val:  0.07260621433100824

Epoch 00015: val_accuracy did not improve from 0.07276
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0146 - accuracy: 0.0691 - val_loss:
2.8785 - val_accuracy: 0.0726 - lr: 0.0100
Epoch 16/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0145 - accuracy: 0.0725

micro_F1_train:  0.07297682951688524

micro_F1_val:  0.07403297400126824

Epoch 00016: val_accuracy improved from 0.07276 to 0.07403, saving model to model1_save/weights-16-0.07
40.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0145 - accuracy: 0.0724 - val_loss:
2.8714 - val_accuracy: 0.0740 - lr: 0.0100
Epoch 17/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0144 - accuracy: 0.0736

micro_F1_train:  0.07583067201195896
```

```
micro_F1_val:  0.0767279644895371

Epoch 00017: val_accuracy improved from 0.07403 to 0.07673, saving model to model1_save/weights-17-0.07
67.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0144 - accuracy: 0.0736 - val_loss:
2.8599 - val_accuracy: 0.0767 - lr: 0.0100
Epoch 18/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0142 - accuracy: 0.0795

micro_F1_train:  0.0773255418903309

micro_F1_val:  0.07894736842105263

Epoch 00018: val_accuracy improved from 0.07673 to 0.07895, saving model to model1_save/weights-18-0.07
89.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0142 - accuracy: 0.0796 - val_loss:
2.8479 - val_accuracy: 0.0789 - lr: 0.0100
Epoch 19/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0141 - accuracy: 0.0786

micro_F1_train:  0.07949989807705375

micro_F1_val:  0.08037412809131261

Epoch 00019: val_accuracy improved from 0.07895 to 0.08037, saving model to model1_save/weights-19-0.08
04.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0141 - accuracy: 0.0786 - val_loss:
2.8364 - val_accuracy: 0.0804 - lr: 0.0100
Epoch 20/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0141 - accuracy: 0.0765

micro_F1_train:  0.08167425426377659

micro_F1_val:  0.08275206087507926

Epoch 00020: val_accuracy improved from 0.08037 to 0.08275, saving model to model1_save/weights-20-0.08
28.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0141 - accuracy: 0.0764 - val_loss:
2.8243 - val_accuracy: 0.0828 - lr: 0.0100
Epoch 21/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0140 - accuracy: 0.0853

micro_F1_train:  0.08262553509546783

micro_F1_val:  0.08370323398858592

Epoch 00021: val_accuracy improved from 0.08275 to 0.08370, saving model to model1_save/weights-21-0.08
37.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0139 - accuracy: 0.0853 - val_loss:
2.8107 - val_accuracy: 0.0837 - lr: 0.0100
Epoch 22/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0138 - accuracy: 0.0857

micro_F1_train:  0.08357681592715907

micro_F1_val:  0.08639822447685479

Epoch 00022: val_accuracy improved from 0.08370 to 0.08640, saving model to model1_save/weights-22-0.08
64.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0138 - accuracy: 0.0859 - val_loss:
2.7995 - val_accuracy: 0.0864 - lr: 0.0100
Epoch 23/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0137 - accuracy: 0.0907

micro_F1_train:  0.08663450431473806

micro_F1_val:  0.08877615726062144

Epoch 00023: val_accuracy improved from 0.08640 to 0.08878, saving model to model1_save/weights-23-0.08
88.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0137 - accuracy: 0.0908 - val_loss:
2.7869 - val_accuracy: 0.0888 - lr: 0.0100
Epoch 24/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0136 - accuracy: 0.0915

micro_F1_train:  0.08785757966976965
```

```
micro_F1_val:  0.09051997463538364

Epoch 00024: val_accuracy improved from 0.08878 to 0.09052, saving model to model1_save/weights-24-0.09
05.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0136 - accuracy: 0.0915 - val_loss:
2.7717 - val_accuracy: 0.0905 - lr: 0.0100
Epoch 25/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0136 - accuracy: 0.0919

micro_F1_train:  0.09009988448732759

micro_F1_val:  0.09273937856689918

Epoch 00025: val_accuracy improved from 0.09052 to 0.09274, saving model to model1_save/weights-25-0.09
27.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0136 - accuracy: 0.0919 - val_loss:
2.7600 - val_accuracy: 0.0927 - lr: 0.0100
Epoch 26/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0135 - accuracy: 0.0977

micro_F1_train:  0.0917306516273697

micro_F1_val:  0.09590995561192138

Epoch 00026: val_accuracy improved from 0.09274 to 0.09591, saving model to model1_save/weights-26-0.09
59.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0134 - accuracy: 0.0978 - val_loss:
2.7437 - val_accuracy: 0.0959 - lr: 0.0100
Epoch 27/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0134 - accuracy: 0.0964

micro_F1_train:  0.0941768023374329

micro_F1_val:  0.0963855421686747

Epoch 00027: val_accuracy improved from 0.09591 to 0.09639, saving model to model1_save/weights-27-0.09
64.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0134 - accuracy: 0.0965 - val_loss:
2.7324 - val_accuracy: 0.0964 - lr: 0.0100
Epoch 28/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0133 - accuracy: 0.0967

micro_F1_train:  0.09641910715499083

micro_F1_val:  0.09844641724793912

Epoch 00028: val_accuracy improved from 0.09639 to 0.09845, saving model to model1_save/weights-28-0.09
84.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0133 - accuracy: 0.0967 - val_loss:
2.7198 - val_accuracy: 0.0984 - lr: 0.0100
Epoch 29/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0133 - accuracy: 0.1029

micro_F1_train:  0.0971665420941768

micro_F1_val:  0.09892200380469246

Epoch 00029: val_accuracy improved from 0.09845 to 0.09892, saving model to model1_save/weights-29-0.09
89.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0133 - accuracy: 0.1031 - val_loss:
2.7076 - val_accuracy: 0.0989 - lr: 0.0100
Epoch 30/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0132 - accuracy: 0.1046

micro_F1_train:  0.09798192566419786

micro_F1_val:  0.10098287888395688

Epoch 00030: val_accuracy improved from 0.09892 to 0.10098, saving model to model1_save/weights-30-0.10
10.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0132 - accuracy: 0.1047 - val_loss:
2.6948 - val_accuracy: 0.1010 - lr: 0.0100
Epoch 31/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0130 - accuracy: 0.1029

micro_F1_train:  0.10056397363593124
```

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micro_F1_val:  0.10304375396322131

Epoch 00031: val_accuracy improved from 0.10098 to 0.10304, saving model to model1_save/weights-31-0.10
30.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0130 - accuracy: 0.1029 - val_loss:
2.6780 - val_accuracy: 0.1030 - lr: 0.0100
Epoch 32/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0130 - accuracy: 0.1113

micro_F1_train:  0.10022423048175558

micro_F1_val:  0.10336081166772351

Epoch 00032: val_accuracy improved from 0.10304 to 0.10336, saving model to model1_save/weights-32-0.10
34.hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0130 - accuracy: 0.1112 - val_loss:
2.6597 - val_accuracy: 0.1034 - lr: 0.0100
Epoch 33/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0129 - accuracy: 0.1053

micro_F1_train:  0.10042807637426107

micro_F1_val:  0.10415345592897908

Epoch 00033: val_accuracy improved from 0.10336 to 0.10415, saving model to model1_save/weights-33-0.10
42.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0129 - accuracy: 0.1053 - val_loss:
2.6503 - val_accuracy: 0.1042 - lr: 0.0100
Epoch 34/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0128 - accuracy: 0.1100

micro_F1_train:  0.1019908948834681

micro_F1_val:  0.10605580215599239

Epoch 00034: val_accuracy improved from 0.10415 to 0.10606, saving model to model1_save/weights-34-0.10
61.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0128 - accuracy: 0.1101 - val_loss:
2.6321 - val_accuracy: 0.1061 - lr: 0.0100
Epoch 35/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0126 - accuracy: 0.1121

micro_F1_train:  0.10470884011687165

micro_F1_val:  0.10811667723525682

Epoch 00035: val_accuracy improved from 0.10606 to 0.10812, saving model to model1_save/weights-35-0.10
81.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0126 - accuracy: 0.1122 - val_loss:
2.6141 - val_accuracy: 0.1081 - lr: 0.0100
Epoch 36/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0125 - accuracy: 0.1132

micro_F1_train:  0.10695114493442957

micro_F1_val:  0.1095434369055168

Epoch 00036: val_accuracy improved from 0.10812 to 0.10954, saving model to model1_save/weights-36-0.10
95.hdf5
1472/1472 [==============================] - 14s 9ms/step - loss: 0.0125 - accuracy: 0.1129 - val_loss:
2.5957 - val_accuracy: 0.1095 - lr: 0.0100
Epoch 37/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0124 - accuracy: 0.1186

micro_F1_train:  0.10966909016783312

micro_F1_val:  0.11303107165504121

Epoch 00037: val_accuracy improved from 0.10954 to 0.11303, saving model to model1_save/weights-37-0.11
30.hdf5
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0124 - accuracy: 0.1186 - val_loss
: 2.5786 - val_accuracy: 0.1130 - lr: 0.0100
Epoch 38/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0125 - accuracy: 0.1114

micro_F1_train:  0.11021267921451385
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micro_F1_val:  0.11223842739378567

Epoch 00038: val_accuracy did not improve from 0.11303
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0125 - accuracy: 0.1114 - val_loss:
2.5641 - val_accuracy: 0.1122 - lr: 0.0100
Epoch 39/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0123 - accuracy: 0.1182

micro_F1_train:  0.11225113813956648

micro_F1_val:  0.11334812935954344

Epoch 00039: val_accuracy improved from 0.11303 to 0.11335, saving model to model1_save/weights-39-0.11
33.hdf5
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0123 - accuracy: 0.1182 - val_loss
: 2.5477 - val_accuracy: 0.1133 - lr: 0.0100
Epoch 40/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0120 - accuracy: 0.1177

micro_F1_train:  0.1163960046205069

micro_F1_val:  0.11715282181357008

Epoch 00040: val_accuracy improved from 0.11335 to 0.11715, saving model to model1_save/weights-40-0.11
72.hdf5
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0120 - accuracy: 0.1176 - val_loss
: 2.5277 - val_accuracy: 0.1172 - lr: 0.0100
Epoch 41/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0121 - accuracy: 0.1236

micro_F1_train:  0.12101651151729292

micro_F1_val:  0.12175015852885225

Epoch 00041: val_accuracy improved from 0.11715 to 0.12175, saving model to model1_save/weights-41-0.12
18.hdf5
1472/1472 [==============================] - 16s 11ms/step - loss: 0.0121 - accuracy: 0.1236 - val_loss
: 2.5059 - val_accuracy: 0.1218 - lr: 0.0100
Epoch 42/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0120 - accuracy: 0.1224

micro_F1_train:  0.12393830264320174

micro_F1_val:  0.12444514901712111

Epoch 00042: val_accuracy improved from 0.12175 to 0.12445, saving model to model1_save/weights-42-0.12
44.hdf5
1472/1472 [==============================] - 18s 12ms/step - loss: 0.0120 - accuracy: 0.1224 - val_loss
: 2.4902 - val_accuracy: 0.1244 - lr: 0.0100
Epoch 43/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0120 - accuracy: 0.1277

micro_F1_train:  0.1248216348440579

micro_F1_val:  0.12682308180088775

Epoch 00043: val_accuracy improved from 0.12445 to 0.12682, saving model to model1_save/weights-43-0.12
68.hdf5
1472/1472 [==============================] - 17s 11ms/step - loss: 0.0120 - accuracy: 0.1277 - val_loss
: 2.4821 - val_accuracy: 0.1268 - lr: 0.0100
Epoch 44/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0118 - accuracy: 0.1248

micro_F1_train:  0.12624855609159474

micro_F1_val:  0.12999365884590997

Epoch 00044: val_accuracy improved from 0.12682 to 0.12999, saving model to model1_save/weights-44-0.13
00.hdf5
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0118 - accuracy: 0.1248 - val_loss
: 2.4689 - val_accuracy: 0.1300 - lr: 0.0100
Epoch 45/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0118 - accuracy: 0.1289

micro_F1_train:  0.12849086090915268

micro_F1_val:  0.13157894736842105
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Epoch 00045: val_accuracy improved from 0.12999 to 0.13158, saving model to model1_save/weights-45-0.13
16.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0118 - accuracy: 0.1287 - val_loss:
2.4516 - val_accuracy: 0.1316 - lr: 0.0100
Epoch 46/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0117 - accuracy: 0.1266

micro_F1_train:  0.13229598423591765

micro_F1_val:  0.13474952441344323

Epoch 00046: val_accuracy improved from 0.13158 to 0.13475, saving model to model1_save/weights-46-0.13
47.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0117 - accuracy: 0.1265 - val_loss:
2.4355 - val_accuracy: 0.1347 - lr: 0.0100
Epoch 47/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.1307

micro_F1_train:  0.13358700822178432

micro_F1_val:  0.1355421686746988

Epoch 00047: val_accuracy improved from 0.13475 to 0.13554, saving model to model1_save/weights-47-0.13
55.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0116 - accuracy: 0.1305 - val_loss:
2.4162 - val_accuracy: 0.1355 - lr: 0.0100
Epoch 48/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0116 - accuracy: 0.1334

micro_F1_train:  0.13603315893184753

micro_F1_val:  0.13855421686746988

Epoch 00048: val_accuracy improved from 0.13554 to 0.13855, saving model to model1_save/weights-48-0.13
86.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0115 - accuracy: 0.1333 - val_loss:
2.4009 - val_accuracy: 0.1386 - lr: 0.0100
Epoch 49/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.1363

micro_F1_train:  0.1390228986885914

micro_F1_val:  0.14124920735573873

Epoch 00049: val_accuracy improved from 0.13855 to 0.14125, saving model to model1_save/weights-49-0.14
12.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0115 - accuracy: 0.1362 - val_loss:
2.3851 - val_accuracy: 0.1412 - lr: 0.0100
Epoch 50/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0114 - accuracy: 0.1375

micro_F1_train:  0.1391587959502616

micro_F1_val:  0.1404565630944832

Epoch 00050: val_accuracy did not improve from 0.14125
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0114 - accuracy: 0.1374 - val_loss:
2.3712 - val_accuracy: 0.1405 - lr: 0.0100
Epoch 51/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0113 - accuracy: 0.1388

micro_F1_train:  0.14561391587959502

micro_F1_val:  0.1469562460367787

Epoch 00051: val_accuracy improved from 0.14125 to 0.14696, saving model to model1_save/weights-51-0.14
70.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0113 - accuracy: 0.1388 - val_loss:
2.3564 - val_accuracy: 0.1470 - lr: 0.0100
Epoch 52/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0114 - accuracy: 0.1381

micro_F1_train:  0.14683699123462662

micro_F1_val:  0.14774889029803423
```

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Epoch 00052: val_accuracy improved from 0.14696 to 0.14775, saving model to model1_save/weights-52-0.14
77.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0114 - accuracy: 0.1382 - val_loss:
2.3439 - val_accuracy: 0.1477 - lr: 0.0100
Epoch 53/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0111 - accuracy: 0.1410

micro_F1_train:  0.1470408371271319

micro_F1_val:  0.14806594800253647

Epoch 00053: val_accuracy improved from 0.14775 to 0.14807, saving model to model1_save/weights-53-0.14
81.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0111 - accuracy: 0.1409 - val_loss:
2.3270 - val_accuracy: 0.1481 - lr: 0.0100
Epoch 54/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0111 - accuracy: 0.1419

micro_F1_train:  0.15091390908473196

micro_F1_val:  0.15060240963855423

Epoch 00054: val_accuracy improved from 0.14807 to 0.15060, saving model to model1_save/weights-54-0.15
06.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0111 - accuracy: 0.1419 - val_loss:
2.3103 - val_accuracy: 0.1506 - lr: 0.0100
Epoch 55/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0111 - accuracy: 0.1481

micro_F1_train:  0.1553985187198478

micro_F1_val:  0.15298034242232086

Epoch 00055: val_accuracy improved from 0.15060 to 0.15298, saving model to model1_save/weights-55-0.15
30.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0111 - accuracy: 0.1482 - val_loss:
2.2968 - val_accuracy: 0.1530 - lr: 0.0100
Epoch 56/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0109 - accuracy: 0.1477

micro_F1_train:  0.15444723788815656

micro_F1_val:  0.15171211160431197

Epoch 00056: val_accuracy did not improve from 0.15298
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0109 - accuracy: 0.1474 - val_loss:
2.2846 - val_accuracy: 0.1517 - lr: 0.0100
Epoch 57/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0110 - accuracy: 0.1441

micro_F1_train:  0.15533057008901272

micro_F1_val:  0.15456563094483197

Epoch 00057: val_accuracy improved from 0.15298 to 0.15457, saving model to model1_save/weights-57-0.15
46.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0110 - accuracy: 0.1443 - val_loss:
2.2758 - val_accuracy: 0.1546 - lr: 0.0100
Epoch 58/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0109 - accuracy: 0.1449

micro_F1_train:  0.15811646395325135

micro_F1_val:  0.1566265060240964

Epoch 00058: val_accuracy improved from 0.15457 to 0.15663, saving model to model1_save/weights-58-0.15
66.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0110 - accuracy: 0.1449 - val_loss:
2.2677 - val_accuracy: 0.1566 - lr: 0.0100
Epoch 59/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0109 - accuracy: 0.1526

micro_F1_train:  0.16029082013997417

micro_F1_val:  0.15726062143310082

Epoch 00059: val_accuracy improved from 0.15663 to 0.15726, saving model to model1_save/weights-59-0.15
```

Epoch 00059: val_accuracy improved from 0.15973 to 0.16173, saving model to model1_save/weights-59-0.16
73.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0109 - accuracy: 0.1522 - val_loss:
2.2620 - val_accuracy: 0.1573 - lr: 0.0100
Epoch 60/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0109 - accuracy: 0.1499

micro_F1_train: 0.16423184072840932

micro_F1_val: 0.1621750158528852

Epoch 00060: val_accuracy improved from 0.15726 to 0.16218, saving model to model1_save/weights-60-0.16
22.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0109 - accuracy: 0.1498 - val_loss:
2.2497 - val_accuracy: 0.1622 - lr: 0.0100
Epoch 61/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0107 - accuracy: 0.1512

micro_F1_train: 0.16470748114425493

micro_F1_val: 0.16296766011414077

Epoch 00061: val_accuracy improved from 0.16218 to 0.16297, saving model to model1_save/weights-61-0.16
30.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0107 - accuracy: 0.1513 - val_loss:
2.2453 - val_accuracy: 0.1630 - lr: 0.0100
Epoch 62/100
1467/1472 [==============================>.] - ETA: 0s - loss: 0.0107 - accuracy: 0.1519

micro_F1_train: 0.16715363185431814

micro_F1_val: 0.16471147748890297

Epoch 00062: val_accuracy improved from 0.16297 to 0.16471, saving model to model1_save/weights-62-0.16
47.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0107 - accuracy: 0.1519 - val_loss:
2.2398 - val_accuracy: 0.1647 - lr: 0.0100
Epoch 63/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0106 - accuracy: 0.1486

micro_F1_train: 0.16654209417680232

micro_F1_val: 0.161857958148383

Epoch 00063: val_accuracy did not improve from 0.16471
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0106 - accuracy: 0.1486 - val_loss:
2.2291 - val_accuracy: 0.1619 - lr: 0.0100
Epoch 64/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0106 - accuracy: 0.1503

micro_F1_train: 0.16756132363932866

micro_F1_val: 0.16280913126188967

Epoch 00064: val_accuracy did not improve from 0.16471
1472/1472 [==============================] - 14s 9ms/step - loss: 0.0106 - accuracy: 0.1503 - val_loss:
2.2246 - val_accuracy: 0.1628 - lr: 0.0100
Epoch 65/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.1543

micro_F1_train: 0.17055106339607257

micro_F1_val: 0.16772352568167406

Epoch 00065: val_accuracy improved from 0.16471 to 0.16772, saving model to model1_save/weights-65-0.16
77.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0106 - accuracy: 0.1542 - val_loss:
2.2137 - val_accuracy: 0.1677 - lr: 0.0100
Epoch 66/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.1563

micro_F1_train: 0.17313311136780593

micro_F1_val: 0.1701014584654407

Epoch 00066: val_accuracy improved from 0.16772 to 0.17010, saving model to model1_save/weights-66-0.17
01.hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0105 - accuracy: 0.1566 - val_loss:

1472/1472 [==============================] - 12s 8ms/step - loss: 0.0106 - accuracy: 0.1509 - val_loss:
2.2068 - val_accuracy: 0.1701 - lr: 0.0100
Epoch 67/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0106 - accuracy: 0.1509

micro_F1_train: 0.17544336481619896

micro_F1_val: 0.17089410272669625

Epoch 00067: val_accuracy improved from 0.17010 to 0.17089, saving model to model1_save/weights-67-0.17
09.hdf5
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0106 - accuracy: 0.1513 - val_loss
: 2.2047 - val_accuracy: 0.1709 - lr: 0.0100
Epoch 68/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0105 - accuracy: 0.1529

micro_F1_train: 0.17938438540463408

micro_F1_val: 0.17533291058972733

Epoch 00068: val_accuracy improved from 0.17089 to 0.17533, saving model to model1_save/weights-68-0.17
53.hdf5
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0105 - accuracy: 0.1527 - val_loss
: 2.1946 - val_accuracy: 0.1753 - lr: 0.0100
Epoch 69/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0104 - accuracy: 0.1585

micro_F1_train: 0.17591900523204457

micro_F1_val: 0.16978440076093848

Epoch 00069: val_accuracy did not improve from 0.17533
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0104 - accuracy: 0.1585 - val_loss
: 2.1931 - val_accuracy: 0.1698 - lr: 0.0100
Epoch 70/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0104 - accuracy: 0.1609

micro_F1_train: 0.17782156689542702

micro_F1_val: 0.17200380469245402

Epoch 00070: val_accuracy did not improve from 0.17533
1472/1472 [==============================] - 17s 12ms/step - loss: 0.0104 - accuracy: 0.1609 - val_loss
: 2.1871 - val_accuracy: 0.1720 - lr: 0.0100
Epoch 71/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0104 - accuracy: 0.1557

micro_F1_train: 0.17829720731127270

micro_F1_val: 0.17247939124920736

Epoch 00071: val_accuracy did not improve from 0.17533
1472/1472 [==============================] - 16s 11ms/step - loss: 0.0104 - accuracy: 0.1557 - val_loss
: 2.1866 - val_accuracy: 0.1725 - lr: 0.0100
Epoch 72/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0102 - accuracy: 0.1608

micro_F1_train: 0.17591900523204457

micro_F1_val: 0.17168674698795180

Epoch 00072: val_accuracy did not improve from 0.17533
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0102 - accuracy: 0.1608 - val_loss:
2.1843 - val_accuracy: 0.1717 - lr: 0.0100
Epoch 73/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0103 - accuracy: 0.1610

micro_F1_train: 0.17965617992797442

micro_F1_val: 0.17517438173747620

Epoch 00073: val_accuracy did not improve from 0.17533
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0103 - accuracy: 0.1610 - val_loss:
2.1765 - val_accuracy: 0.1752 - lr: 0.0100
Epoch 74/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0102 - accuracy: 0.1532

micro_F1_train: 0.18774206699735

micro_F1_train: 0.18774206099755

micro_F1_val: 0.17945466074825622

Epoch 00074: val_accuracy improved from 0.17533 to 0.17945, saving model to model1_save/weights-74-0.17
95.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0102 - accuracy: 0.1532 - val_loss:
2.1708 - val_accuracy: 0.1795 - lr: 0.0100
Epoch 75/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0103 - accuracy: 0.1578

micro_F1_train: 0.18624719711897803

micro_F1_val: 0.17913760304375398

Epoch 00075: val_accuracy did not improve from 0.17945
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0103 - accuracy: 0.1579 - val_loss:
2.1671 - val_accuracy: 0.1791 - lr: 0.0100
Epoch 76/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0100 - accuracy: 0.1601

micro_F1_train: 0.1906638581232588

micro_F1_val: 0.18611287254280276

Epoch 00076: val_accuracy improved from 0.17945 to 0.18611, saving model to model1_save/weights-76-0.18
61.hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0100 - accuracy: 0.1601 - val_loss:
2.1587 - val_accuracy: 0.1861 - lr: 0.0100
Epoch 77/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0101 - accuracy: 0.1609

micro_F1_train: 0.19841000203845893

micro_F1_val: 0.19340519974635384

Epoch 00077: val_accuracy improved from 0.18611 to 0.19341, saving model to model1_save/weights-77-0.19
34.hdf5
1472/1472 [==============================] - 14s 9ms/step - loss: 0.0101 - accuracy: 0.1610 - val_loss:
2.1506 - val_accuracy: 0.1934 - lr: 0.0100
Epoch 78/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0100 - accuracy: 0.1670

micro_F1_train: 0.20126384453353266

micro_F1_val: 0.19546607482561829

Epoch 00078: val_accuracy improved from 0.19341 to 0.19547, saving model to model1_save/weights-78-0.19
55.hdf5
1472/1472 [==============================] - 18s 12ms/step - loss: 0.0101 - accuracy: 0.1671 - val_loss
: 2.1462 - val_accuracy: 0.1955 - lr: 0.0100
Epoch 79/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0102 - accuracy: 0.1661

micro_F1_train: 0.19643949174424136

micro_F1_val: 0.1911857958148383

Epoch 00079: val_accuracy did not improve from 0.19547
1472/1472 [==============================] - 14s 9ms/step - loss: 0.0102 - accuracy: 0.1661 - val_loss:
2.1551 - val_accuracy: 0.1912 - lr: 0.0100
Epoch 80/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0101 - accuracy: 0.1615

micro_F1_train: 0.19474077597336414

micro_F1_val: 0.19007609384908053

Epoch 00080: val_accuracy did not improve from 0.19547
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0101 - accuracy: 0.1614 - val_loss:
2.1543 - val_accuracy: 0.1901 - lr: 0.0100
Epoch 81/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0100 - accuracy: 0.1656

micro_F1_train: 0.19154719032411494

micro_F1_val: 0.18738110336081168

```
Epoch 00081: val_accuracy did not improve from 0.19547
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0101 - accuracy: 0.1655 - val_loss:
2.1490 - val_accuracy: 0.1874 - lr: 0.0090
Epoch 82/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0101 - accuracy: 0.1591

micro_F1_train:  0.19657538900591154

micro_F1_val:  0.1932466708941027

Epoch 00082: val_accuracy did not improve from 0.19547
1472/1472 [==============================] - 18s 12ms/step - loss: 0.0101 - accuracy: 0.1589 - val_loss
: 2.1436 - val_accuracy: 0.1932 - lr: 0.0090
Epoch 83/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0099 - accuracy: 0.1668

micro_F1_train:  0.19888564245430454

micro_F1_val:  0.19483195941661383

Epoch 00083: val_accuracy did not improve from 0.19547
1472/1472 [==============================] - 13s 9ms/step - loss: 0.0099 - accuracy: 0.1670 - val_loss:
2.1397 - val_accuracy: 0.1948 - lr: 0.0090
Epoch 84/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0101 - accuracy: 0.1688

micro_F1_train:  0.2003805123326765

micro_F1_val:  0.19657577679137603

Epoch 00084: val_accuracy improved from 0.19547 to 0.19658, saving model to model1_save/weights-84-0.19
66.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0101 - accuracy: 0.1693 - val_loss:
2.1371 - val_accuracy: 0.1966 - lr: 0.0090
Epoch 85/100
1471/1472 [==============================>.] - ETA: 0s - loss: 0.0101 - accuracy: 0.1610

micro_F1_train:  0.19752666983760278

micro_F1_val:  0.1941978440076094

Epoch 00085: val_accuracy did not improve from 0.19658
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0101 - accuracy: 0.1610 - val_loss:
2.1427 - val_accuracy: 0.1942 - lr: 0.0090
Epoch 86/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0099 - accuracy: 0.1655

micro_F1_train:  0.201535639056873

micro_F1_val:  0.19720989220038046

Epoch 00086: val_accuracy improved from 0.19658 to 0.19721, saving model to model1_save/weights-86-0.19
72.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0099 - accuracy: 0.1657 - val_loss:
2.1301 - val_accuracy: 0.1972 - lr: 0.0090
Epoch 87/100
1465/1472 [==============================>.] - ETA: 0s - loss: 0.0098 - accuracy: 0.1653

micro_F1_train:  0.19949718013182036

micro_F1_val:  0.19800253646163601

Epoch 00087: val_accuracy improved from 0.19721 to 0.19800, saving model to model1_save/weights-87-0.19
80.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0098 - accuracy: 0.1655 - val_loss:
2.1352 - val_accuracy: 0.1980 - lr: 0.0090
Epoch 88/100
1470/1472 [==============================>.] - ETA: 0s - loss: 0.0098 - accuracy: 0.1643

micro_F1_train:  0.20568050553781342

micro_F1_val:  0.2010145846544071

Epoch 00088: val_accuracy improved from 0.19800 to 0.20101, saving model to model1_save/weights-88-0.20
10.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0098 - accuracy: 0.1644 - val_loss:
2.1342 - val_accuracy: 0.2010 - lr: 0.0090
```

```
2.1242 - val_accuracy: 0.2010 - lr: 0.0090
Epoch 89/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0099 - accuracy: 0.1630

micro_F1_train:  0.20568050553781342

micro_F1_val:  0.1999048826886493

Epoch 00089: val_accuracy did not improve from 0.20101
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0098 - accuracy: 0.1631 - val_loss:
2.1241 - val_accuracy: 0.1999 - lr: 0.0090
Epoch 90/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0099 - accuracy: 0.1620

micro_F1_train:  0.20119589590269757

micro_F1_val:  0.19863665187064045

Epoch 00090: val_accuracy did not improve from 0.20101
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0098 - accuracy: 0.1619 - val_loss:
2.1263 - val_accuracy: 0.1986 - lr: 0.0090
Epoch 91/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1684

micro_F1_train:  0.20853434803288712

micro_F1_val:  0.20434369055168042

Epoch 00091: val_accuracy improved from 0.20101 to 0.20434, saving model to model1_save/weights-91-0.20
43.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0097 - accuracy: 0.1690 - val_loss:
2.1148 - val_accuracy: 0.2043 - lr: 0.0090
Epoch 92/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1755

micro_F1_train:  0.20404973839777127

micro_F1_val:  0.20228281547241597

Epoch 00092: val_accuracy did not improve from 0.20434
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0097 - accuracy: 0.1756 - val_loss:
2.1144 - val_accuracy: 0.2023 - lr: 0.0090
Epoch 93/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1691

micro_F1_train:  0.2081266562478766

micro_F1_val:  0.20481927710843376

Epoch 00093: val_accuracy improved from 0.20434 to 0.20482, saving model to model1_save/weights-93-0.20
48.hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0097 - accuracy: 0.1692 - val_loss:
2.1120 - val_accuracy: 0.2048 - lr: 0.0090
Epoch 94/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1699

micro_F1_train:  0.21159203642046612

micro_F1_val:  0.21020925808497146

Epoch 00094: val_accuracy improved from 0.20482 to 0.21021, saving model to model1_save/weights-94-0.21
02.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0097 - accuracy: 0.1699 - val_loss:
2.1073 - val_accuracy: 0.2102 - lr: 0.0090
Epoch 95/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0097 - accuracy: 0.1650

micro_F1_train:  0.20669973500033975

micro_F1_val:  0.20656309448319593

Epoch 00095: val_accuracy did not improve from 0.21021
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0097 - accuracy: 0.1650 - val_loss:
2.1060 - val_accuracy: 0.2066 - lr: 0.0090
Epoch 96/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1645

micro_F1_train:  0.20867024520455735
```

```
micro_F1_train:  0.20867024529455735

micro_F1_val:  0.20672162333544702

Epoch 00096: val_accuracy did not improve from 0.21021
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0098 - accuracy: 0.1648 - val_loss:
2.1023 - val_accuracy: 0.2067 - lr: 0.0090
Epoch 97/100
1471/1472 [==============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1664

micro_F1_train:  0.21668818373309776

micro_F1_val:  0.21496512365250475

Epoch 00097: val_accuracy improved from 0.21021 to 0.21497, saving model to model1_save/weights-97-0.21
50.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0097 - accuracy: 0.1663 - val_loss:
2.0933 - val_accuracy: 0.2150 - lr: 0.0090
Epoch 98/100
1465/1472 [==============================>.] - ETA: 0s - loss: 0.0096 - accuracy: 0.1694

micro_F1_train:  0.2098933206495889

micro_F1_val:  0.20703868103994927

Epoch 00098: val_accuracy did not improve from 0.21497
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0096 - accuracy: 0.1695 - val_loss:
2.0963 - val_accuracy: 0.2070 - lr: 0.0090
Epoch 99/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0097 - accuracy: 0.1686

micro_F1_train:  0.21193177957464157

micro_F1_val:  0.2098922003804692

Epoch 00099: val_accuracy did not improve from 0.21497
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0097 - accuracy: 0.1687 - val_loss:
2.1020 - val_accuracy: 0.2099 - lr: 0.0090
Epoch 100/100
1462/1472 [==============================>.] - ETA: 0s - loss: 0.0095 - accuracy: 0.1733

micro_F1_train:  0.21458177617721003

micro_F1_val:  0.215282181357007

Epoch 00100: val_accuracy improved from 0.21497 to 0.21528, saving model to model1_save/weights-100-0.2
153.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0095 - accuracy: 0.1733 - val_loss:
2.0998 - val_accuracy: 0.2153 - lr: 0.0081
Time Taken for training (sec):  1120.963470697403
```

In [ ]:

```
# http://localhost:6006/
%load_ext tensorboard
%tensorboard --logdir logs --host localhost
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard


Reusing TensorBoard on port 6006 (pid 2268), started 0:22:00 ago. (Use '!kill 2268' to kill it.)
```

Model 1 Predictions

In [ ]:

```
NeuNet_1.load_weights("/content/m1_weights-97-0.2150.hdf5")
```

In [ ]:

```
px_data_std = pd.DataFrame(Scaler.transform(px_data))
px_data_std = px_data_std.drop(feature_correlated,axis=1)
```

In [ ]:

```
y_pred_1 = NeuNet_1.predict(px_data_std)
```

In [ ]:

```
np.argmax(y_pred_1,axis=1)
```

Out[ ]:

```
array([10, 11,  3, ..., 14, 14, 14])
```

In [ ]:

```
y_pred_pd_1 = pd.DataFrame(np.argmax(y_pred_1,axis=1),index=px_data.index)
# y_pred_pd[0] = y_pred_pd[0]+1
```

In [ ]:

```
# y_pred_pd_1
```

In [ ]:

```
y_pred_pd_1.value_counts()
```

Out[ ]:

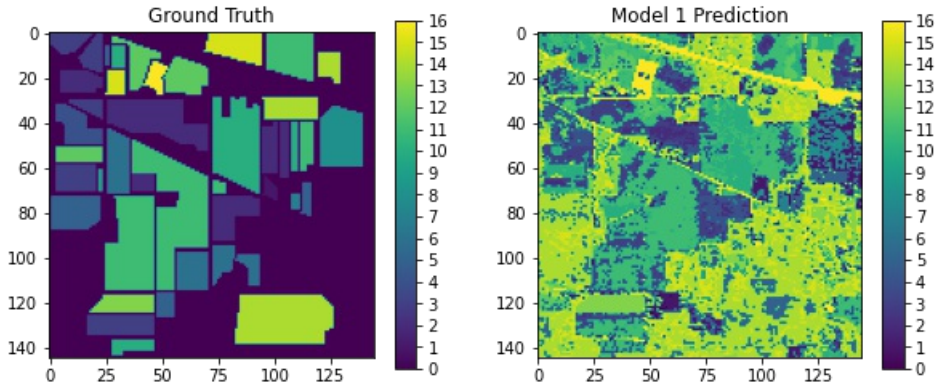
```
14    4694
11    3394
15    2198
3     1900
13    1568
10    1436
5     1179
16     865
12     752
4      713
1      694
8      464
2      383
9      347
0      205
7      144
6       89
dtype: int64
```

In [ ]:

```
# px_data.index
```

In [ ]:

```
figr,axis = plt.subplots(1,2,figsize=(10,10))
im0 = axis[0].imshow(mat_gt['indian_pines_gt'])#,cmap='jet')
axis[0].set_title('Ground Truth')
plt.colorbar(im0,ax=axis[0],shrink=0.4,aspect=16, ticks=range(0,17,1))

im1 = axis[1].imshow(y_pred_pd_1.to_numpy().reshape((145,145)))#,cmap='jet')
axis[1].set_title('Model 1 Prediction')
plt.colorbar(im1,ax=axis[1],shrink=0.4,aspect=16, ticks=range(0,17,1))
plt.savefig('NeuNet_1_e100.png')
plt.show()
```



Observation

Confusion Matrix

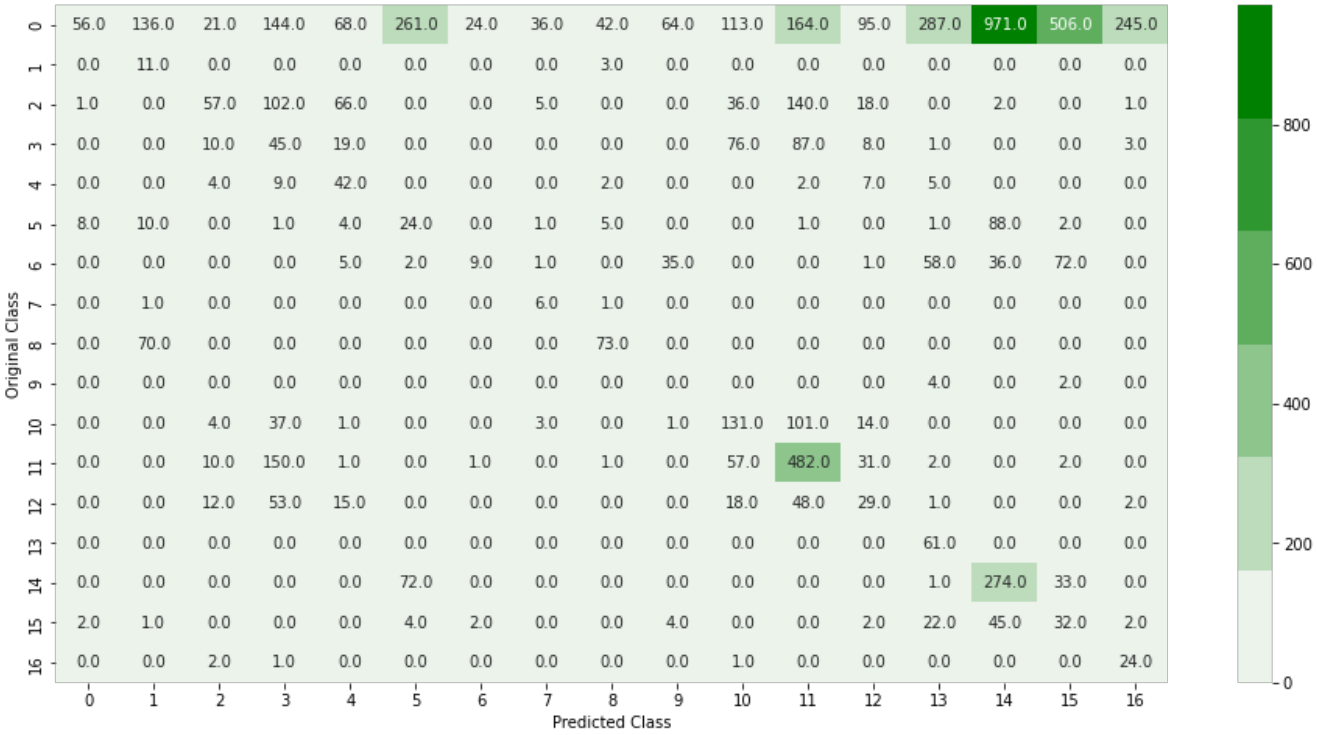
In [ ]:

```
y_pred_1_test = NeuNet_1.predict(X_test_std)
y_pred_pd_1_test = pd.DataFrame(np.argmax(y_pred_1_test,axis=1),index=y_test.index)
```

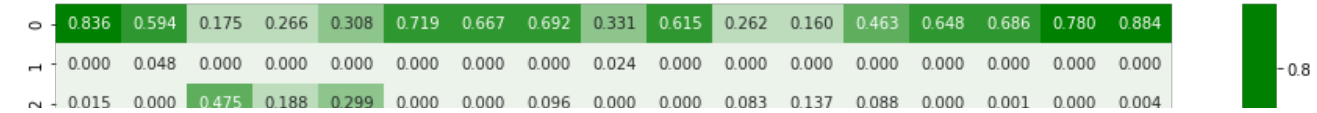
In [ ]:

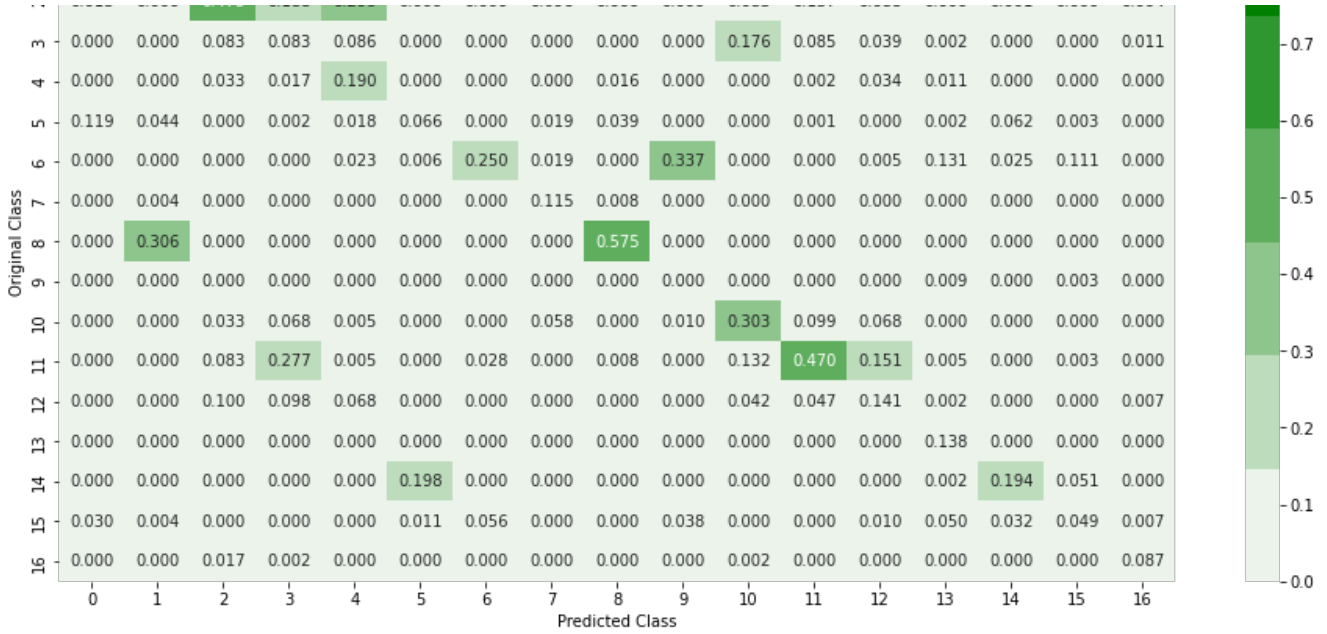
```
# plot_confusion_matrix(px_class,y_pred_pd_1)
plot_confusion_matrix(y_test,y_pred_pd_1_test)
```

```
Number of misclassified points  78.50348763474952
---------------------------------------------------- Confusion matrix ----------------------------------
---------------
```

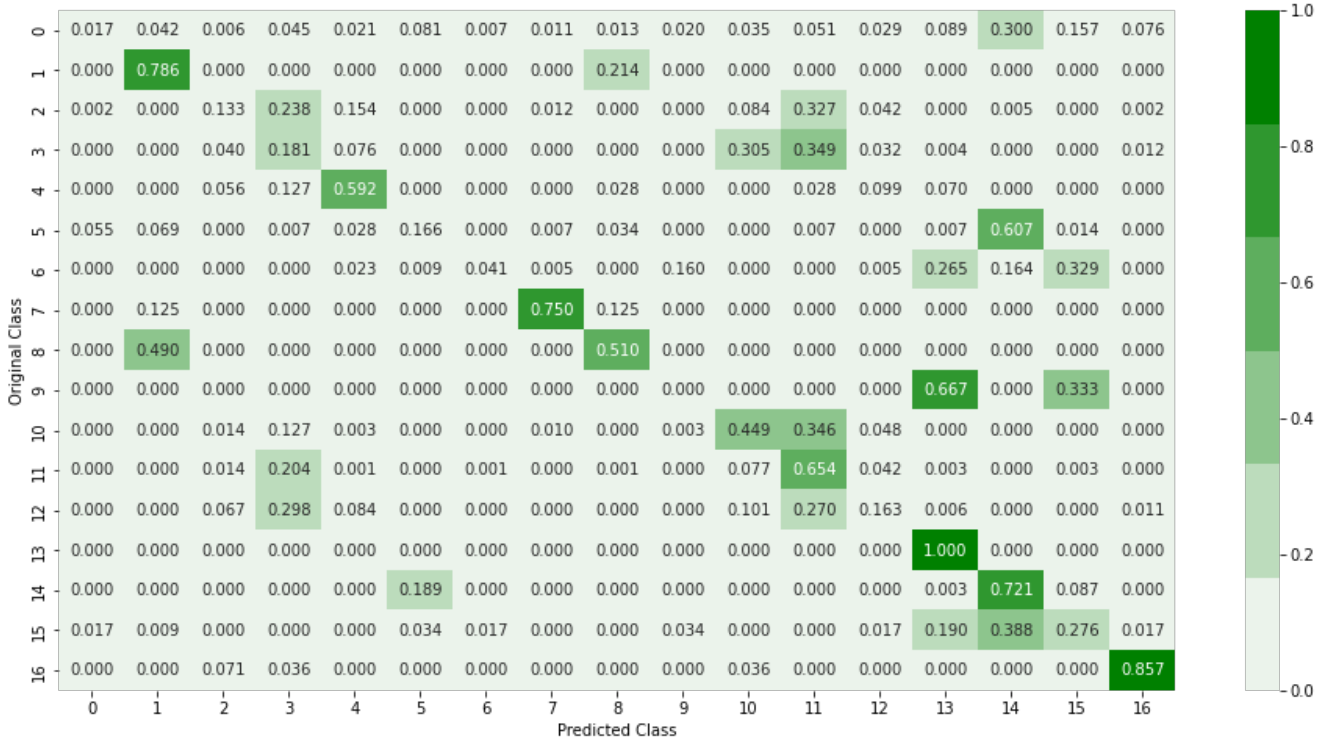



```
---------------------------------------------------- Precision matrix ----------------------------------
---------------
```






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




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

Model prediction doesnt match ground truth very well. From Recall matrix we can see that only 2 of the classes have been predicted high recall. Precisions are all low for all classes except for class 'zero'.

2- Four layered network with relu activation and ADAM optimizer

Model 2 Definition

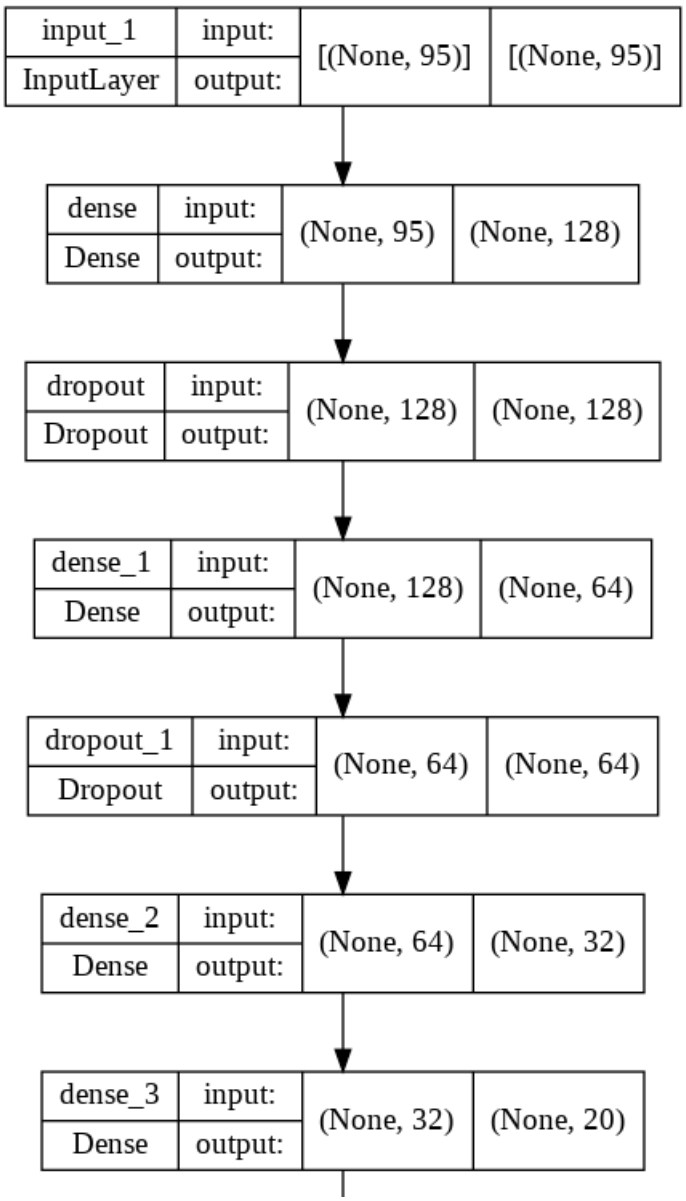
In [ ]:

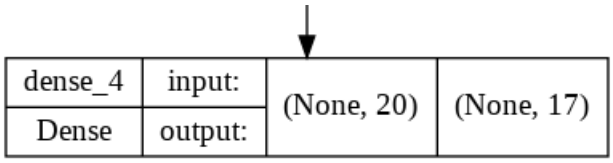
```
# del NeuNet_2
```

In [ ]:

```
In = Input(shape=(95,))
L1 = Dense(128,activation='relu',
           kernel_initializer=initializers.he_uniform())(In) #https://keras.io/api/layers/initializers/

L1_Drp = Dropout(0.4)(L1)

L2 = Dense(64,activation='relu',
          kernel_initializer=initializers.he_uniform())(L1_Drp)

L2_Drp = Dropout(0.3)(L2)

L3 = Dense(32,activation='relu',
          kernel_initializer=initializers.he_uniform())(L2_Drp)

L4 = Dense(20,activation='relu',
          kernel_initializer=initializers.he_uniform())(L3)

Out = Dense(17,activation='softmax',
           kernel_initializer=initializers.GlorotUniform())(L4)

NeuNet_2 = Model(inputs=In, outputs = Out)

# cce = categorical_crossentropy()
NeuNet_2.compile(loss='categorical_crossentropy', optimizer='Adam', metrics=['accuracy'])

plot_model(NeuNet_2,show_layer_names=True, show_shapes=True)#,to_file='NeuNet_2.png')
```

Out[ ]:





In [ ]:

```
NeuNet_2.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                 Output Shape              Param #
=================================================================
 input_1 (InputLayer)         [(None, 95)]              0

 dense (Dense)                (None, 128)               12288

 dropout (Dropout)            (None, 128)               0

 dense_1 (Dense)              (None, 64)                8256

 dropout_1 (Dropout)          (None, 64)                0

 dense_2 (Dense)              (None, 32)                2080

 dense_3 (Dense)              (None, 20)                660

 dense_4 (Dense)              (None, 17)                357

=================================================================
Total params: 23,641
Trainable params: 23,641
Non-trainable params: 0
_________________________________________________________________
```

Model 2 Training

In [ ]:

```
logdir = os.path.join("logs", datetime.now().strftime("%Y%m%d-%H%M%S"))
print(logdir)
file_writer = tf.summary.create_file_writer(logdir + "/metrics")
# tensorboard = TensorBoard(log_dir=logdir)
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True,write_grads=True)

metric_calc_2 = metric_calc()

# Saving model at every epoch if validation accuracy is improved from previous epoch
filepath_m2="model2_save/weights-{epoch:02d}-{val_accuracy:.4f}.hdf5"
checkpoint_m2 = ModelCheckpoint(filepath=filepath_m2, monitor='val_accuracy',  verbose=1,
                                save_best_only=True,
                                mode='auto')
earlystop_m2 = EarlyStopping(monitor='val_accuracy', min_delta=0.01, patience=20, verbose=1)
reduce_lr_m2 = ReduceLROnPlateau(monitor='val_loss', factor=0.9, patience=2, min_lr=0.001)

callback_list_2 = [metric_calc_2,
                   checkpoint_m2,
                   earlystop_m2,
                   reduce_lr_m2,
                   tensorboard]
# fit network
verbose_2, epochs_2, batch_size_2 = 1, 100, 10
start = time.time()
history_2 = NeuNet_2.fit(X_train_std, y_ctg_train,
                         class_weight = class_wts,
                         validation_data=(X_test_std,y_ctg_test),
                         epochs=epochs_2,
                         batch_size=batch_size_2,
                         verbose=verbose_2,
                         callbacks=callback_list_2)
```

```
# Passing the F1 score data of each epoch to tensor board
# https://stackoverflow.com/questions/58102016/how-visualize-in-tensorboard-a-metric-callback
for i in range(len(metric_calc_2.metrics['micro_F1_train'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_train', metric_calc_2.metrics['micro_F1_train'][i])
file_writer.flush()

for i in range(len(metric_calc_2.metrics['micro_F1_val'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_val', metric_calc_2.metrics['micro_F1_val'][i])
file_writer.flush()

stop = time.time()
print('Time Taken for training (sec): ',stop-start)
```

```
logs/20220131-122955
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/100
   2/1472 [..............................] - ETA: 5:57 - loss: 0.0230 - accuracy: 0.1500 WARNING:tensor
flow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0045s vs
`on_train_batch_begin` time: 0.0233s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time:
0.0045s vs `on_train_batch_end` time: 0.0195s). Check your callbacks.
1463/1472 [============================>.] - ETA: 0s - loss: 0.0124 - accuracy: 0.1524

micro_F1_train:  0.23754841339947

micro_F1_val:  0.2382688649334179

Epoch 00001: val_accuracy improved from -inf to 0.23827, saving model to model2_save/weights-01-0.2383.
hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0124 - accuracy: 0.1527 - val_loss:
2.0437 - val_accuracy: 0.2383 - lr: 0.0010
Epoch 2/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0092 - accuracy: 0.1820

micro_F1_train:  0.2711829856628389

micro_F1_val:  0.27060875079264424

Epoch 00002: val_accuracy improved from 0.23827 to 0.27061, saving model to model2_save/weights-02-0.27
06.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0092 - accuracy: 0.1820 - val_loss:
1.8567 - val_accuracy: 0.2706 - lr: 0.0010
Epoch 3/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0081 - accuracy: 0.2037

micro_F1_train:  0.24454712237548412

micro_F1_val:  0.24381737476220672

Epoch 00003: val_accuracy did not improve from 0.27061
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0081 - accuracy: 0.2038 - val_loss:
1.8605 - val_accuracy: 0.2438 - lr: 0.0010
Epoch 4/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0074 - accuracy: 0.2148

micro_F1_train:  0.2746483658354284

micro_F1_val:  0.27869372225745087

Epoch 00004: val_accuracy improved from 0.27061 to 0.27869, saving model to model2_save/weights-04-0.27
87.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0074 - accuracy: 0.2146 - val_loss:
1.8081 - val_accuracy: 0.2787 - lr: 0.0010
Epoch 5/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0074 - accuracy: 0.2215

micro_F1_train:  0.2765509274988109

micro_F1_val:  0.2710843373493976

Epoch 00005: val_accuracy did not improve from 0.27869
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0074 - accuracy: 0.2218 - val_loss:
1.7603 - val_accuracy: 0.2711 - lr: 0.0010
```

```
Epoch 6/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0067 - accuracy: 0.2359

micro_F1_train:  0.28348168784398997

micro_F1_val:  0.28233988585922637

Epoch 00006: val_accuracy improved from 0.27869 to 0.28234, saving model to model2_save/weights-06-0.28
23.hdf5
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0067 - accuracy: 0.2358 - val_loss
: 1.7780 - val_accuracy: 0.2823 - lr: 0.0010
Epoch 7/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0066 - accuracy: 0.2540

micro_F1_train:  0.33750084935788544

micro_F1_val:  0.3333861762840837

Epoch 00007: val_accuracy improved from 0.28234 to 0.33339, saving model to model2_save/weights-07-0.33
34.hdf5
1472/1472 [==============================] - 16s 11ms/step - loss: 0.0066 - accuracy: 0.2539 - val_loss
: 1.7090 - val_accuracy: 0.3334 - lr: 0.0010
Epoch 8/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0062 - accuracy: 0.2718

micro_F1_train:  0.32180471563498

micro_F1_val:  0.3181674064679772

Epoch 00008: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0062 - accuracy: 0.2715 - val_loss
: 1.6405 - val_accuracy: 0.3182 - lr: 0.0010
Epoch 9/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0061 - accuracy: 0.2695

micro_F1_train:  0.3173880546306992

micro_F1_val:  0.31436271401395055

Epoch 00009: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 13s 9ms/step - loss: 0.0061 - accuracy: 0.2696 - val_loss:
1.6644 - val_accuracy: 0.3144 - lr: 0.0010
Epoch 10/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0059 - accuracy: 0.2889

micro_F1_train:  0.3394034110212679

micro_F1_val:  0.3316423589093215

Epoch 00010: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0059 - accuracy: 0.2890 - val_loss:
1.6379 - val_accuracy: 0.3316 - lr: 0.0010
Epoch 11/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0059 - accuracy: 0.2905

micro_F1_train:  0.3082829380987973

micro_F1_val:  0.30469245402663286

Epoch 00011: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0059 - accuracy: 0.2907 - val_loss:
1.7137 - val_accuracy: 0.3047 - lr: 0.0010
Epoch 12/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0057 - accuracy: 0.3025

micro_F1_train:  0.32635727390093 09

micro_F1_val:  0.32228915662650603

Epoch 00012: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0057 - accuracy: 0.3023 - val_loss:
1.5551 - val_accuracy: 0.3223 - lr: 0.0010
Epoch 13/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0056 - accuracy: 0.2993

micro_F1_train:  0.33743290072705034
```

```
micro_F1_val:  0.3298985415345593

Epoch 00013: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 17s 11ms/step - loss: 0.0056 - accuracy: 0.2995 - val_loss
: 1.5404 - val_accuracy: 0.3299 - lr: 0.0010
Epoch 14/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0054 - accuracy: 0.3140

micro_F1_train:  0.3401508459604539

micro_F1_val:  0.3333861762840837

Epoch 00014: val_accuracy did not improve from 0.33339
1472/1472 [==============================] - 18s 12ms/step - loss: 0.0053 - accuracy: 0.3137 - val_loss
: 1.5316 - val_accuracy: 0.3334 - lr: 0.0010
Epoch 15/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0056 - accuracy: 0.3155

micro_F1_train:  0.3558469796833594

micro_F1_val:  0.34923906150919465

Epoch 00015: val_accuracy improved from 0.33339 to 0.34924, saving model to model2_save/weights-15-0.34
92.hdf5
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0056 - accuracy: 0.3155 - val_loss
: 1.5412 - val_accuracy: 0.3492 - lr: 0.0010
Epoch 16/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0057 - accuracy: 0.3058

micro_F1_train:  0.3654277366311069

micro_F1_val:  0.3563728598604946

Epoch 00016: val_accuracy improved from 0.34924 to 0.35637, saving model to model2_save/weights-16-0.35
64.hdf5
1472/1472 [==============================] - 15s 11ms/step - loss: 0.0057 - accuracy: 0.3059 - val_loss
: 1.4910 - val_accuracy: 0.3564 - lr: 0.0010
Epoch 17/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0051 - accuracy: 0.3223

micro_F1_train:  0.3849969423116124

micro_F1_val:  0.3780913126188966

Epoch 00017: val_accuracy improved from 0.35637 to 0.37809, saving model to model2_save/weights-17-0.37
81.hdf5
1472/1472 [==============================] - 15s 10ms/step - loss: 0.0051 - accuracy: 0.3223 - val_loss
: 1.4848 - val_accuracy: 0.3781 - lr: 0.0010
Epoch 18/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0056 - accuracy: 0.3255

micro_F1_train:  0.35618672283753483

micro_F1_val:  0.3495561192136969

Epoch 00018: val_accuracy did not improve from 0.37809
1472/1472 [==============================] - 14s 10ms/step - loss: 0.0056 - accuracy: 0.3255 - val_loss
: 1.4967 - val_accuracy: 0.3496 - lr: 0.0010
Epoch 19/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0053 - accuracy: 0.3197

micro_F1_train:  0.4064007610246654

micro_F1_val:  0.4058338617628409

Epoch 00019: val_accuracy improved from 0.37809 to 0.40583, saving model to model2_save/weights-19-0.40
58.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0053 - accuracy: 0.3196 - val_loss:
1.4312 - val_accuracy: 0.4058 - lr: 0.0010
Epoch 20/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0055 - accuracy: 0.3392

micro_F1_train:  0.3650200448460964

micro_F1_val:  0.36699429296131897

Epoch 00020: val_accuracy did not improve from 0.40583
```

```
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0055 - accuracy: 0.3391 - val_loss:
1.5724 - val_accuracy: 0.3670 - lr: 0.0010
Epoch 21/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3473

micro_F1_train:  0.39627641503023714

micro_F1_val:  0.38950538998097656

Epoch 00021: val_accuracy did not improve from 0.40583
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0048 - accuracy: 0.3470 - val_loss:
1.4315 - val_accuracy: 0.3895 - lr: 0.0010
Epoch 22/100
1461/1472 [==============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3434

micro_F1_train:  0.35605082557586465

micro_F1_val:  0.34369055168040585

Epoch 00022: val_accuracy did not improve from 0.40583
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0046 - accuracy: 0.3434 - val_loss:
1.5183 - val_accuracy: 0.3437 - lr: 0.0010
Epoch 23/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0053 - accuracy: 0.3256

micro_F1_train:  0.36787388734117005

micro_F1_val:  0.3611287254280279

Epoch 00023: val_accuracy did not improve from 0.40583
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0053 - accuracy: 0.3255 - val_loss:
1.4602 - val_accuracy: 0.3611 - lr: 0.0010
Epoch 24/100
1463/1472 [==============================>.] - ETA: 0s - loss: 0.0055 - accuracy: 0.3218

micro_F1_train:  0.3920635999184616

micro_F1_val:  0.3853836398224477

Epoch 00024: val_accuracy did not improve from 0.40583
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0055 - accuracy: 0.3217 - val_loss:
1.4365 - val_accuracy: 0.3854 - lr: 0.0010
Epoch 25/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3445

micro_F1_train:  0.4119725487531426

micro_F1_val:  0.4078947368421052

Epoch 00025: val_accuracy improved from 0.40583 to 0.40789, saving model to model2_save/weights-25-0.40
79.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0048 - accuracy: 0.3446 - val_loss:
1.3854 - val_accuracy: 0.4079 - lr: 0.0010
Epoch 26/100
1467/1472 [==============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3503

micro_F1_train:  0.37820207922810356

micro_F1_val:  0.3703233988585923

Epoch 00026: val_accuracy did not improve from 0.40789
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0047 - accuracy: 0.3504 - val_loss:
1.5111 - val_accuracy: 0.3703 - lr: 0.0010
Epoch 27/100
1470/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3458

micro_F1_train:  0.35842902765509277

micro_F1_val:  0.35003170577045023

Epoch 00027: val_accuracy did not improve from 0.40789
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.3458 - val_loss:
1.4912 - val_accuracy: 0.3500 - lr: 0.0010
Epoch 28/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0048 - accuracy: 0.3563

micro_F1_train:  0.3736495209621526
```

```
micro_F1_val:  0.3636651870640456

Epoch 00028: val_accuracy did not improve from 0.40789
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.3563 - val_loss:
1.5120 - val_accuracy: 0.3637 - lr: 0.0010
Epoch 29/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3538

micro_F1_train:  0.43364816198953593

micro_F1_val:  0.4292961318960051

Epoch 00029: val_accuracy improved from 0.40789 to 0.42930, saving model to model2_save/weights-29-0.42
93.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.3544 - val_loss:
1.3837 - val_accuracy: 0.4293 - lr: 0.0010
Epoch 30/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3667

micro_F1_train:  0.42155330570089006

micro_F1_val:  0.4085288522511097

Epoch 00030: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0046 - accuracy: 0.3668 - val_loss:
1.3478 - val_accuracy: 0.4085 - lr: 0.0010
Epoch 31/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3683

micro_F1_train:  0.35972005164095944

micro_F1_val:  0.3557387444514902

Epoch 00031: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.3682 - val_loss:
1.5477 - val_accuracy: 0.3557 - lr: 0.0010
Epoch 32/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3582

micro_F1_train:  0.37759054155058774

micro_F1_val:  0.36731135066582116

Epoch 00032: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0048 - accuracy: 0.3582 - val_loss:
1.5076 - val_accuracy: 0.3673 - lr: 0.0010
Epoch 33/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0053 - accuracy: 0.3516

micro_F1_train:  0.40130461371203363

micro_F1_val:  0.39267596702599866

Epoch 00033: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0054 - accuracy: 0.3517 - val_loss:
1.4726 - val_accuracy: 0.3927 - lr: 0.0010
Epoch 34/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3583

micro_F1_train:  0.4133994700006795

micro_F1_val:  0.40932149651236527

Epoch 00034: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3585 - val_loss:
1.3839 - val_accuracy: 0.4093 - lr: 0.0010
Epoch 35/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3587

micro_F1_train:  0.40762383637969696

micro_F1_val:  0.40091946734305645

Epoch 00035: val_accuracy did not improve from 0.42930
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0046 - accuracy: 0.3588 - val_loss:
1.4080 - val accuracy: 0.4009 - lr: 0.0010
```

```
Epoch 36/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0047 - accuracy: 0.3797

micro_F1_train:  0.4494122443432765

micro_F1_val:  0.44705136334812934

Epoch 00036: val_accuracy improved from 0.42930 to 0.44705, saving model to model2_save/weights-36-0.44
71.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3797 - val_loss:
1.3930 - val_accuracy: 0.4471 - lr: 0.0010
Epoch 37/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3825

micro_F1_train:  0.4080315281647075

micro_F1_val:  0.40107799619530754

Epoch 00037: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0047 - accuracy: 0.3824 - val_loss:
1.4483 - val_accuracy: 0.4011 - lr: 0.0010
Epoch 38/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3719

micro_F1_train:  0.3994700006794863

micro_F1_val:  0.39505389980976535

Epoch 00038: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.3717 - val_loss:
1.5196 - val_accuracy: 0.3951 - lr: 0.0010
Epoch 39/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3757

micro_F1_train:  0.4134674186315146

micro_F1_val:  0.40456563094483194

Epoch 00039: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3754 - val_loss:
1.3823 - val_accuracy: 0.4046 - lr: 0.0010
Epoch 40/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3788

micro_F1_train:  0.4231161242100972

micro_F1_val:  0.41597970830691183

Epoch 00040: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3789 - val_loss:
1.3911 - val_accuracy: 0.4160 - lr: 0.0010
Epoch 41/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3705

micro_F1_train:  0.37432900727050344

micro_F1_val:  0.3639822447685479

Epoch 00041: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.3710 - val_loss:
1.4946 - val_accuracy: 0.3640 - lr: 0.0010
Epoch 42/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0049 - accuracy: 0.3554

micro_F1_train:  0.41122511381395666

micro_F1_val:  0.4053582752060875

Epoch 00042: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0049 - accuracy: 0.3559 - val_loss:
1.4960 - val_accuracy: 0.4054 - lr: 0.0010
Epoch 43/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3830

micro_F1_train:  0.4212815111775498

micro F1 val:  0.4145529486366519
```

```
 — —

Epoch 00043: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0048 - accuracy: 0.3826 - val_loss:
1.3951 - val_accuracy: 0.4146 - lr: 0.0010
Epoch 44/100
1467/1472 [==============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3866

micro_F1_train:  0.4064687096555004

micro_F1_val:  0.38966391883322765

Epoch 00044: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.3866 - val_loss:
1.4096 - val_accuracy: 0.3897 - lr: 0.0010
Epoch 45/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0046 - accuracy: 0.3778

micro_F1_train:  0.41183665149147247

micro_F1_val:  0.40456563094483194

Epoch 00045: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0046 - accuracy: 0.3778 - val_loss:
1.3966 - val_accuracy: 0.4046 - lr: 0.0010
Epoch 46/100
1464/1472 [==============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.3699

micro_F1_train:  0.3883943738533668

micro_F1_val:  0.37888395688015225

Epoch 00046: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0044 - accuracy: 0.3696 - val_loss:
1.4585 - val_accuracy: 0.3789 - lr: 0.0010
Epoch 47/100
1464/1472 [==============================>.] - ETA: 0s - loss: 0.0050 - accuracy: 0.3661

micro_F1_train:  0.3610790242576612

micro_F1_val:  0.3530437539632213

Epoch 00047: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0050 - accuracy: 0.3660 - val_loss:
1.7086 - val_accuracy: 0.3530 - lr: 0.0010
Epoch 48/100
1462/1472 [==============================>.] - ETA: 0s - loss: 0.0050 - accuracy: 0.3791

micro_F1_train:  0.42141740843921993

micro_F1_val:  0.4085288522511097

Epoch 00048: val_accuracy did not improve from 0.44705
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0050 - accuracy: 0.3793 - val_loss:
1.3880 - val_accuracy: 0.4085 - lr: 0.0010
Epoch 49/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3746

micro_F1_train:  0.4534212135625467

micro_F1_val:  0.4475269499048827

Epoch 00049: val_accuracy improved from 0.44705 to 0.44753, saving model to model2_save/weights-49-0.44
75.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0047 - accuracy: 0.3746 - val_loss:
1.3921 - val_accuracy: 0.4475 - lr: 0.0010
Epoch 50/100
1471/1472 [==============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3761

micro_F1_train:  0.4205340762383638

micro_F1_val:  0.41407736207989854

Epoch 00050: val_accuracy did not improve from 0.44753
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3760 - val_loss:
1.4187 - val_accuracy: 0.4141 - lr: 0.0010
Epoch 51/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0050 - accuracy: 0.3822
```

```
micro_F1_train:  0.4580417204593327

micro_F1_val:  0.44467343056436265

Epoch 00051: val_accuracy did not improve from 0.44753
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0050 - accuracy: 0.3816 - val_loss:
1.3375 - val_accuracy: 0.4447 - lr: 0.0010
Epoch 52/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.3806

micro_F1_train:  0.40966229530474957

micro_F1_val:  0.4018706404565631

Epoch 00052: val_accuracy did not improve from 0.44753
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0044 - accuracy: 0.3809 - val_loss:
1.3657 - val_accuracy: 0.4019 - lr: 0.0010
Epoch 53/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0043 - accuracy: 0.3875

micro_F1_train:  0.4181558741591357

micro_F1_val:  0.41169942929613196

Epoch 00053: val_accuracy did not improve from 0.44753
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0043 - accuracy: 0.3875 - val_loss:
1.4696 - val_accuracy: 0.4117 - lr: 0.0010
Epoch 54/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.3818

micro_F1_train:  0.464360943126996

micro_F1_val:  0.46163601775523144

Epoch 00054: val_accuracy improved from 0.44753 to 0.46164, saving model to model2_save/weights-54-0.46
16.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0043 - accuracy: 0.3820 - val_loss:
1.3096 - val_accuracy: 0.4616 - lr: 0.0010
Epoch 55/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0049 - accuracy: 0.3851

micro_F1_train:  0.39913025752531084

micro_F1_val:  0.38966391883322765

Epoch 00055: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0049 - accuracy: 0.3854 - val_loss:
1.4138 - val_accuracy: 0.3897 - lr: 0.0010
Epoch 56/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3937

micro_F1_train:  0.411496908337297

micro_F1_val:  0.4021876981610653

Epoch 00056: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.3934 - val_loss:
1.3916 - val_accuracy: 0.4022 - lr: 0.0010
Epoch 57/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0051 - accuracy: 0.3657

micro_F1_train:  0.4449955833389957

micro_F1_val:  0.43547875713379836

Epoch 00057: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0051 - accuracy: 0.3657 - val_loss:
1.3446 - val_accuracy: 0.4355 - lr: 0.0010
Epoch 58/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.3694

micro_F1_train:  0.44261738125976763

micro_F1_val:  0.43785668991756493

Epoch 00058: val_accuracy did not improve from 0.46164
```

Epoch 00058: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0044 - accuracy: 0.3698 - val_loss: 1.3529 - val_accuracy: 0.4379 - lr: 0.0010
Epoch 59/100
1471/1472 [==============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3878

micro_F1_train: 0.42196099748590066

micro_F1_val: 0.4151870640456563

Epoch 00059: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0046 - accuracy: 0.3878 - val_loss: 1.3434 - val_accuracy: 0.4152 - lr: 0.0010
Epoch 60/100
1471/1472 [==============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.3874

micro_F1_train: 0.4337161106203711

micro_F1_val: 0.43040583386176284

Epoch 00060: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0044 - accuracy: 0.3873 - val_loss: 1.3440 - val_accuracy: 0.4304 - lr: 0.0010
Epoch 61/100
1470/1472 [==============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3843

micro_F1_train: 0.4333763674661955

micro_F1_val: 0.4246987951807229

Epoch 00061: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.3845 - val_loss: 1.3543 - val_accuracy: 0.4247 - lr: 0.0010
Epoch 62/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3888

micro_F1_train: 0.4271250934293674

micro_F1_val: 0.4153455928979074

Epoch 00062: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.3887 - val_loss: 1.3517 - val_accuracy: 0.4153 - lr: 0.0010
Epoch 63/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0051 - accuracy: 0.3772

micro_F1_train: 0.43806482299381666

micro_F1_val: 0.42945466074825617

Epoch 00063: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0051 - accuracy: 0.3777 - val_loss: 1.3482 - val_accuracy: 0.4295 - lr: 0.0010
Epoch 64/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3926

micro_F1_train: 0.44920839845077126

micro_F1_val: 0.4456246036778694

Epoch 00064: val_accuracy did not improve from 0.46164
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0042 - accuracy: 0.3926 - val_loss: 1.3529 - val_accuracy: 0.4456 - lr: 0.0010
Epoch 65/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0042 - accuracy: 0.4035

micro_F1_train: 0.49860705306788067

micro_F1_val: 0.4936588459099556

Epoch 00065: val_accuracy improved from 0.46164 to 0.49366, saving model to model2_save/weights-65-0.4937.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0042 - accuracy: 0.4035 - val_loss: 1.2149 - val_accuracy: 0.4937 - lr: 0.0010
Epoch 66/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.4031

micro_F1_train: 0.3989264116328057

```
micro_F1_train:  0.39692041110320037

micro_F1_val:  0.3922003804692454

Epoch 00066: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.4031 - val_loss:
1.4344 - val_accuracy: 0.3922 - lr: 0.0010
Epoch 67/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0050 - accuracy: 0.3862

micro_F1_train:  0.4152340830332269

micro_F1_val:  0.40424857324032976

Epoch 00067: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0050 - accuracy: 0.3859 - val_loss:
1.4106 - val_accuracy: 0.4042 - lr: 0.0010
Epoch 68/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.3949

micro_F1_train:  0.45274172725419587

micro_F1_val:  0.4430881420418516

Epoch 00068: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0041 - accuracy: 0.3951 - val_loss:
1.3557 - val_accuracy: 0.4431 - lr: 0.0010
Epoch 69/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3886

micro_F1_train:  0.43290072705034993

micro_F1_val:  0.4212111604311985

Epoch 00069: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0047 - accuracy: 0.3887 - val_loss:
1.3916 - val_accuracy: 0.4212 - lr: 0.0010
Epoch 70/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3835

micro_F1_train:  0.4408507168580554

micro_F1_val:  0.4329422954977806

Epoch 00070: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0047 - accuracy: 0.3840 - val_loss:
1.4188 - val_accuracy: 0.4329 - lr: 0.0010
Epoch 71/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0042 - accuracy: 0.4040

micro_F1_train:  0.43643405585377454

micro_F1_val:  0.4292961318960051

Epoch 00071: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0042 - accuracy: 0.4040 - val_loss:
1.3792 - val_accuracy: 0.4293 - lr: 0.0010
Epoch 72/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3839

micro_F1_train:  0.4518583950533397

micro_F1_val:  0.4394419784400761

Epoch 00072: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.3841 - val_loss:
1.3069 - val_accuracy: 0.4394 - lr: 0.0010
Epoch 73/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4007

micro_F1_train:  0.4305904736019569

micro_F1_val:  0.42105263157894735

Epoch 00073: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0041 - accuracy: 0.4010 - val_loss:
1.3538 - val_accuracy: 0.4211 - lr: 0.0010
Epoch 74/100
```

```
Epoch 74/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3905

micro_F1_train:  0.46938914180879254

micro_F1_val:  0.4575142675967026

Epoch 00074: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0042 - accuracy: 0.3912 - val_loss:
1.3082 - val_accuracy: 0.4575 - lr: 0.0010
Epoch 75/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0049 - accuracy: 0.3893

micro_F1_train:  0.42549432628932526

micro_F1_val:  0.4139188332276474

Epoch 00075: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0049 - accuracy: 0.3894 - val_loss:
1.3696 - val_accuracy: 0.4139 - lr: 0.0010
Epoch 76/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0041 - accuracy: 0.4119

micro_F1_train:  0.42997893592444114

micro_F1_val:  0.41867469879518066

Epoch 00076: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0041 - accuracy: 0.4119 - val_loss:
1.3972 - val_accuracy: 0.4187 - lr: 0.0010
Epoch 77/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4018

micro_F1_train:  0.42284432968675684

micro_F1_val:  0.4126506024096386

Epoch 00077: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.4021 - val_loss:
1.3950 - val_accuracy: 0.4127 - lr: 0.0010
Epoch 78/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.3935

micro_F1_train:  0.40701229870218114

micro_F1_val:  0.39600507292327203

Epoch 00078: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.3935 - val_loss:
1.4341 - val_accuracy: 0.3960 - lr: 0.0010
Epoch 79/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3973

micro_F1_train:  0.427600733845213

micro_F1_val:  0.41708941027266955

Epoch 00079: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0045 - accuracy: 0.3972 - val_loss:
1.4227 - val_accuracy: 0.4171 - lr: 0.0010
Epoch 80/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3930

micro_F1_train:  0.4573622341509819

micro_F1_val:  0.4513316423589093

Epoch 00080: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0045 - accuracy: 0.3933 - val_loss:
1.3088 - val_accuracy: 0.4513 - lr: 0.0010
Epoch 81/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.4003

micro_F1_train:  0.43473534008289727

micro_F1_val:  0.42675967025998734

Epoch 00081: val_accuracy did not improve from 0.49366
```

```
Epoch 00081: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0043 - accuracy: 0.3997 - val_loss:
1.3251 - val_accuracy: 0.4268 - lr: 0.0010
Epoch 82/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4205

micro_F1_train:  0.42284432968675684

micro_F1_val:  0.41550412175015855

Epoch 00082: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0037 - accuracy: 0.4204 - val_loss:
1.3754 - val_accuracy: 0.4155 - lr: 0.0010
Epoch 83/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4188

micro_F1_train:  0.44071481959638514

micro_F1_val:  0.43896639188332276

Epoch 00083: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4193 - val_loss:
1.3575 - val_accuracy: 0.4390 - lr: 0.0010
Epoch 84/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4116

micro_F1_train:  0.44513148060066593

micro_F1_val:  0.4367469879518072

Epoch 00084: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0041 - accuracy: 0.4116 - val_loss:
1.3252 - val_accuracy: 0.4367 - lr: 0.0010
Epoch 85/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.4014

micro_F1_train:  0.47108785757966976

micro_F1_val:  0.46496512365250475

Epoch 00085: val_accuracy did not improve from 0.49366
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0044 - accuracy: 0.4013 - val_loss:
1.2943 - val_accuracy: 0.4650 - lr: 0.0010
Epoch 00085: early stopping
Time Taken for training (sec):  919.1604928970337
```

In [ ]:

```
# http://localhost:6006/
%load_ext tensorboard
%tensorboard --logdir logs --host localhost
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard


Reusing TensorBoard on port 6006 (pid 2268), started 0:43:48 ago. (Use '!kill 2268' to kill it.)
```

Model 2 Predictions

In [ ]:

```
NeuNet_2.load_weights("/content/m2_weights-65-0.4937.hdf5")
```

In [ ]:

```
y_pred_2 = NeuNet_2.predict(px_data_std)
```

In [ ]:

```
np.argmax(y_pred_2,axis=1)
```

Out[ ]:

```
array([ 3,  3,  3, ..., 14, 14, 14])
```

In [ ]:

```
y_pred_pd_2 = pd.DataFrame(np.argmax(y_pred_2,axis=1),index=px_data.index)
# y_pred_pd[0] = y_pred_pd[0]+1
```

In [ ]:

```
# y_pred_pd_2
```

In [ ]:

```
y_pred_pd_2.value_counts()
```

Out[ ]:

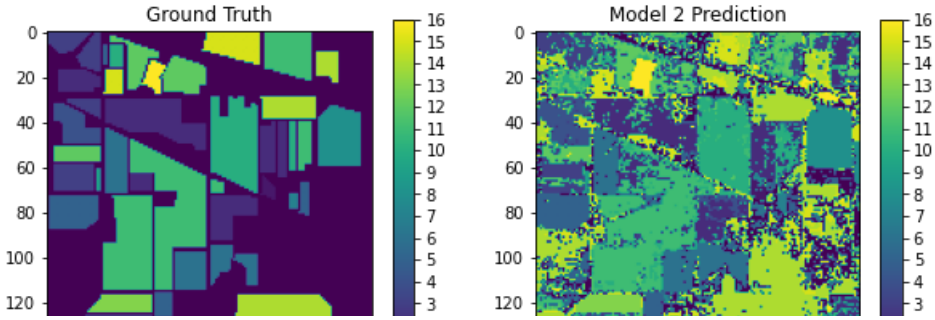
```
14    3795
0     2726
11    2244
15    2170
2     1747
10    1594
12    1408
6     1347
5      945
3      794
4      766
8      691
13     292
16     247
7      103
1       82
9       74
dtype: int64
```

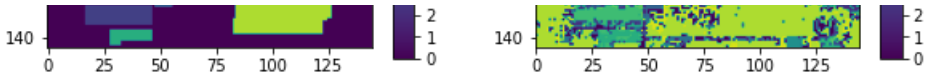
In [ ]:

```
# px_data.index
```

In [ ]:

```
figr,axis = plt.subplots(1,2,figsize=(10,10))
im0 = axis[0].imshow(mat_gt['indian_pines_gt'])#,cmap='jet')
axis[0].set_title('Ground Truth')
plt.colorbar(im0,ax=axis[0],shrink=0.4,aspect=16, ticks=range(0,17,1))

im1 = axis[1].imshow(y_pred_pd_2.to_numpy().reshape((145,145)))#,cmap='jet')
axis[1].set_title('Model 2 Prediction')
plt.colorbar(im1,ax=axis[1],shrink=0.4,aspect=16, ticks=range(0,17,1))
plt.savefig('NeuNet_2_e100.png')
plt.show()
```





Observation

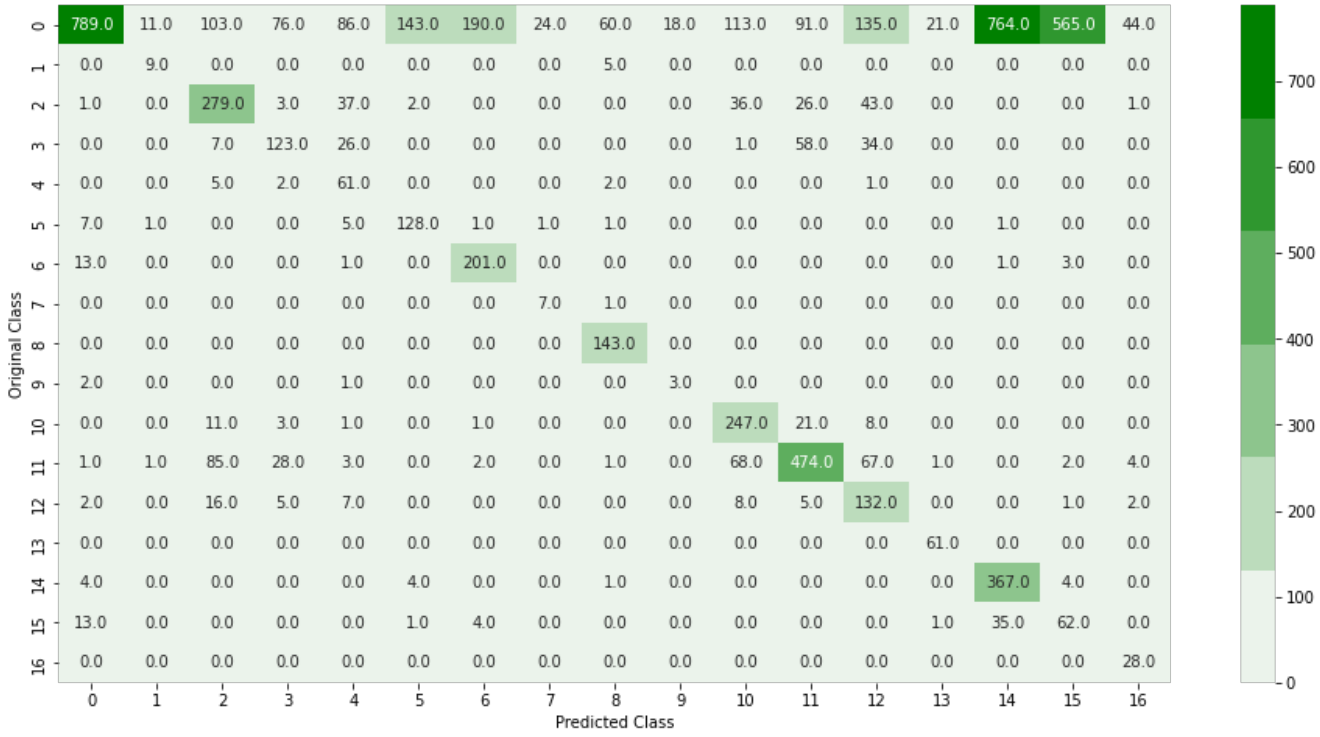
In [ ]:

```
y_pred_2_test = NeuNet_2.predict(X_test_std)
y_pred_pd_2_test = pd.DataFrame(np.argmax(y_pred_2_test,axis=1),index=y_test.index)
```

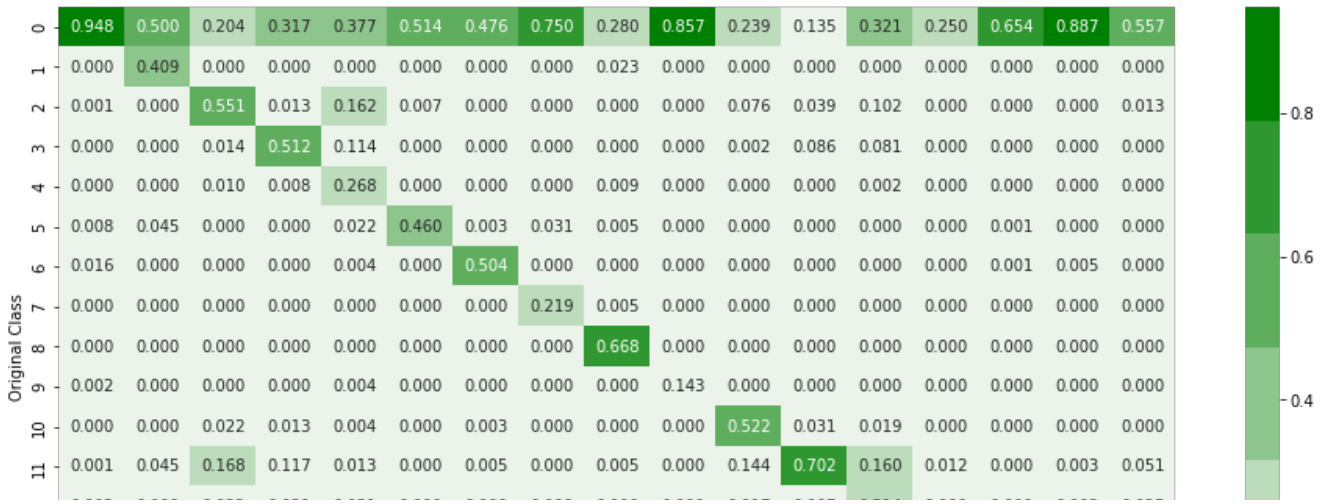
In [ ]:

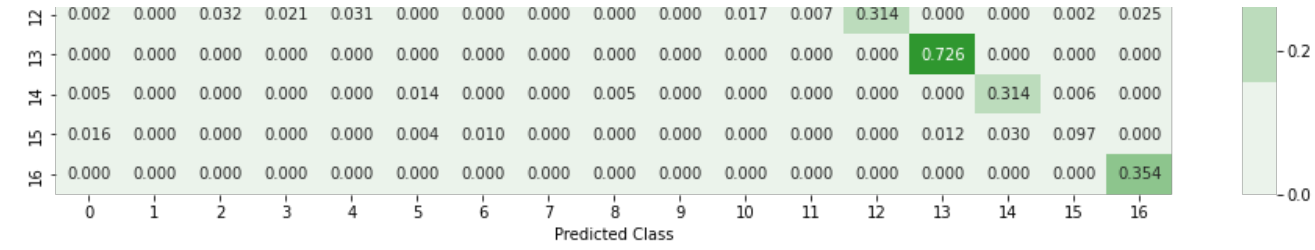
```
# plot_confusion_matrix(px_class,y_pred_pd_2)
plot_confusion_matrix(y_test,y_pred_pd_2_test)
```

```
Number of misclassified points  50.634115409004444
---------------------------------------------------- Confusion matrix ----------------------------------
---------------
```

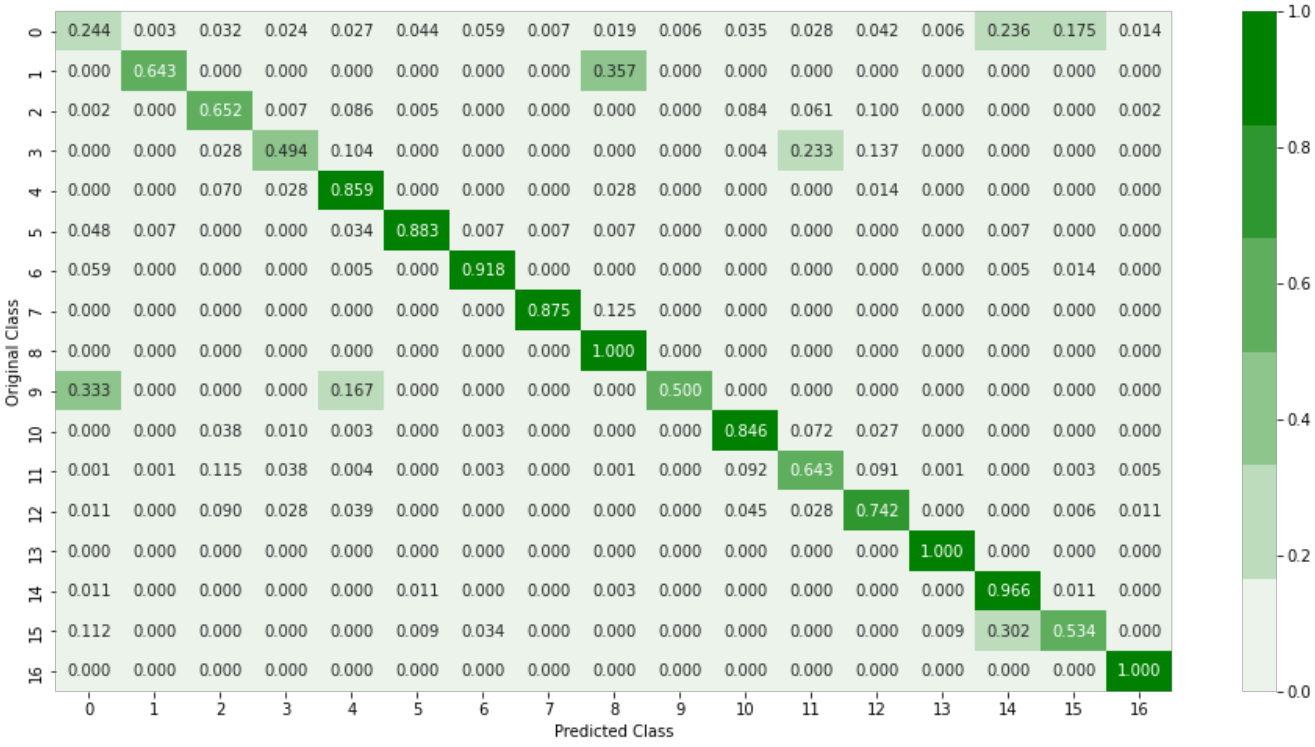



```
---------------------------------------------------- Precision matrix ----------------------------------
---------------
```






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




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

- From Recall matrix we can see that most of the classes have been predicted with high recall.
- Precisions are low for most classes except for class 'zero'.
- From precision matrix (first row), we observe that model finds there are similarity among class 'zero' and other classes.

3- Four layered network with tanh activation and SGD optimizer

Model 3 Definition

In [ ]:

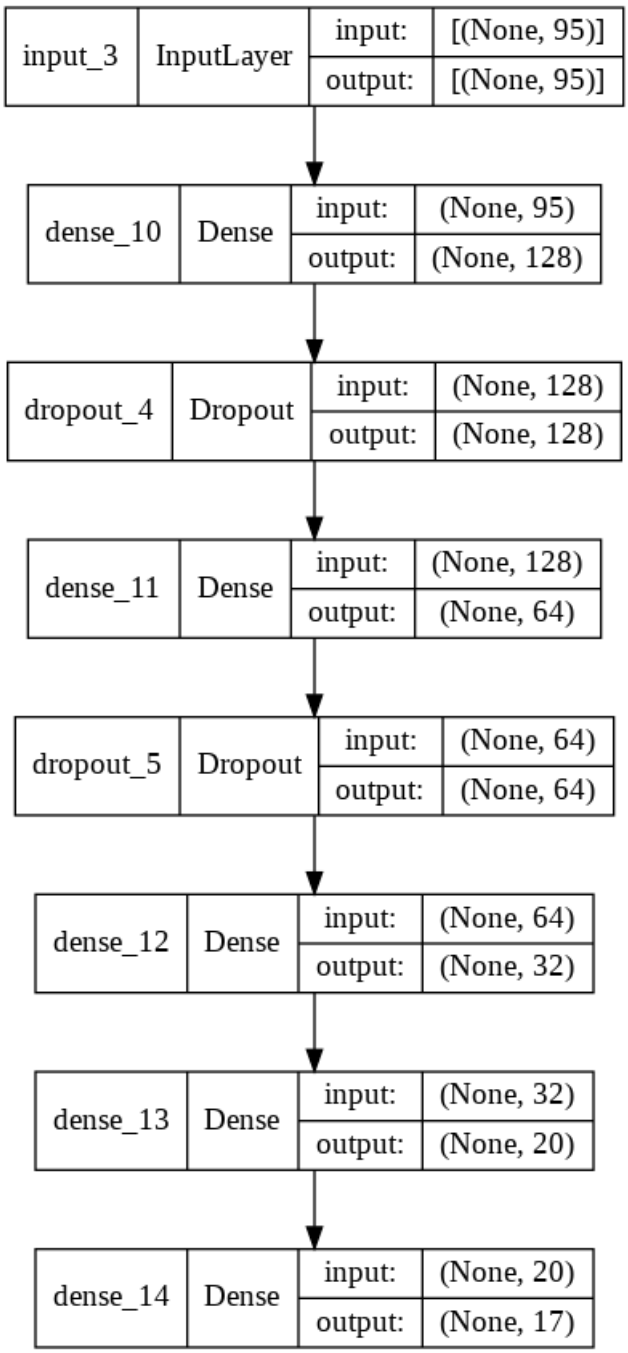
```
# del NeuNet_3
```

In [ ]:

```
In = Input(shape=(95,))
L1 = Dense(128,activation='tanh',
           kernel_initializer=initializers.he_uniform())(In) #https://keras.io/api/layers/initializers/

L1_Drp = Dropout(0.4)(L1)

L2 = Dense(64,activation='tanh',
          kernel_initializer=initializers.he_uniform())(L1_Drp)

L2_Drp = Dropout(0.3)(L2)
```

```
L3 = Dense(32,activation='tanh',
           kernel_initializer=initializers.he_uniform())(L2_Drp)

L4 = Dense(20,activation='tanh',
           kernel_initializer=initializers.he_uniform())(L3)

Out = Dense(17,activation='softmax',
            kernel_initializer=initializers.GlorotUniform())(L4)

NeuNet_3 = Model(inputs=In, outputs = Out)

# cce = categorical_crossentropy()
NeuNet_3.compile(loss='categorical_crossentropy', optimizer='SGD', metrics=['accuracy'])

plot_model(NeuNet_3,show_layer_names=True, show_shapes=True)#,to_file='NeuNet_3.png')
```

Out[ ]:



In [ ]:

```
NeuNet_3.summary()
```

```
Model: "model_2"
_________________________________________________________________
 Layer (type)                 Output Shape              Param #
=================================================================
 input_3 (InputLayer)         [(None, 95)]              0

 dense_10 (Dense)             (None, 128)               12288

 dropout_4 (Dropout)          (None, 128)               0

 dense_11 (Dense)             (None, 64)                8256

 dropout_5 (Dropout)          (None, 64)                0

 dense_12 (Dense)             (None, 32)                2080

 dense_13 (Dense)             (None, 20)                660

 dense_14 (Dense)             (None, 17)                357

=================================================================
Total params: 23,641
Trainable params: 23,641
Non-trainable params: 0
_________________________________________________________________
```

Model 3 Training

In [ ]:

```
logdir = os.path.join("logs", datetime.now().strftime("%Y%m%d-%H%M%S"))
print(logdir)
file_writer = tf.summary.create_file_writer(logdir + "/metrics")
# tensorboard = TensorBoard(log_dir=logdir)
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True,write_grads=True)

metric_calc_3 = metric_calc()

# Saving model at every epoch if validation accuracy is improved from previous epoch
filepath_m3="model3_save/weights-{epoch:02d}-{val_accuracy:.4f}.hdf5"
checkpoint_m3 = ModelCheckpoint(filepath=filepath_m3, monitor='val_accuracy',  verbose=1,
                                save_best_only=True,
                                mode='auto')
earlystop_m3 = EarlyStopping(monitor='val_accuracy', min_delta=0.01, patience=20, verbose=1)
reduce_lr_m3 = ReduceLROnPlateau(monitor='val_loss', factor=0.9, patience=2, min_lr=0.001)

callback_list_3 = [metric_calc_3,
                   checkpoint_m3,
                   earlystop_m3,
                   reduce_lr_m3,
                   tensorboard]
# fit network
verbose_3, epochs_3, batch_size_3 = 1, 100, 10
start = time.time()
history_3 = NeuNet_3.fit(X_train_std, y_ctg_train,
                         class_weight = class_wts,
                         validation_data=(X_test_std,y_ctg_test),
                         epochs=epochs_3,
                         batch_size=batch_size_3,
                         verbose=verbose_3,
                         callbacks=callback_list_3)

# Passing the F1 score data of each epoch to tensor board
# https://stackoverflow.com/questions/58102016/how-visualize-in-tensorboard-a-metric-callback
for i in range(len(metric_calc_3.metrics['micro_F1_train'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_train', metric_calc_3.metrics['micro_F1_train'][i])
file_writer.flush ()

for i in range(len(metric_calc_3.metrics['micro_F1_val'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_val', metric_calc_3.metrics['micro_F1_val'][i])
file_writer.flush ()
```

```
stop = time.time()
print('Time Taken for training (sec): ',stop-start)
```

```
logs/20220131-130044
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/100
   2/1472 [..............................] - ETA: 5:40 - loss: 0.0167 - accuracy: 0.1500 WARNING:tensor
flow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0041s vs
`on_train_batch_begin` time: 0.0226s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time:
0.0041s vs `on_train_batch_end` time: 0.0171s). Check your callbacks.
1461/1472 [============================>.] - ETA: 0s - loss: 0.0171 - accuracy: 0.0643

micro_F1_train:  0.05802813073316573

micro_F1_val:  0.060875079264426125

Epoch 00001: val_accuracy improved from -inf to 0.06088, saving model to model3_save/weights-01-0.0609.
hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0171 - accuracy: 0.0643 - val_loss:
3.0213 - val_accuracy: 0.0609 - lr: 0.0100
Epoch 2/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0169 - accuracy: 0.0724

micro_F1_train:  0.06427940476999389

micro_F1_val:  0.06800887761572606

Epoch 00002: val_accuracy improved from 0.06088 to 0.06801, saving model to model3_save/weights-02-0.06
80.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0169 - accuracy: 0.0724 - val_loss:
2.9864 - val_accuracy: 0.0680 - lr: 0.0100
Epoch 3/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0168 - accuracy: 0.0743

micro_F1_train:  0.0713460623768431

micro_F1_val:  0.07688649334178821

Epoch 00003: val_accuracy improved from 0.06801 to 0.07689, saving model to model3_save/weights-03-0.07
69.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0168 - accuracy: 0.0744 - val_loss:
2.9584 - val_accuracy: 0.0769 - lr: 0.0100
Epoch 4/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0165 - accuracy: 0.0762

micro_F1_train:  0.07725759325949583

micro_F1_val:  0.08608116677235257

Epoch 00004: val_accuracy improved from 0.07689 to 0.08608, saving model to model3_save/weights-04-0.08
61.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0165 - accuracy: 0.0766 - val_loss:
2.9263 - val_accuracy: 0.0861 - lr: 0.0100
Epoch 5/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0164 - accuracy: 0.0827

micro_F1_train:  0.08330502140381871

micro_F1_val:  0.0911540900443881

Epoch 00005: val_accuracy improved from 0.08608 to 0.09115, saving model to model3_save/weights-05-0.09
12.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0164 - accuracy: 0.0825 - val_loss:
2.9009 - val_accuracy: 0.0912 - lr: 0.0100
Epoch 6/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0161 - accuracy: 0.0853

micro_F1_train:  0.0881973228239451

micro_F1_val:  0.09559289790741915

Epoch 00006: val_accuracy improved from 0.09115 to 0.09559, saving model to model3_save/weights-06-0.09
56.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0161 - accuracy: 0.0853 - val_loss:
2.8728 - val_accuracy: 0.0956 - lr: 0.0100
```

```
Epoch 7/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0159 - accuracy: 0.0882

micro_F1_train:  0.09213834341238024

micro_F1_val:  0.10082435003170578

Epoch 00007: val_accuracy improved from 0.09559 to 0.10082, saving model to model3_save/weights-07-0.10
08.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0159 - accuracy: 0.0881 - val_loss:
2.8477 - val_accuracy: 0.1008 - lr: 0.0100
Epoch 8/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0157 - accuracy: 0.0905

micro_F1_train:  0.09798192566419786

micro_F1_val:  0.10732403297400127

Epoch 00008: val_accuracy improved from 0.10082 to 0.10732, saving model to model3_save/weights-08-0.10
73.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0157 - accuracy: 0.0908 - val_loss:
2.8253 - val_accuracy: 0.1073 - lr: 0.0100
Epoch 9/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0156 - accuracy: 0.0948

micro_F1_train:  0.10416525107019094

micro_F1_val:  0.11176284083703233

Epoch 00009: val_accuracy improved from 0.10732 to 0.11176, saving model to model3_save/weights-09-0.11
18.hdf5
1472/1472 [==============================] - 16s 11ms/step - loss: 0.0156 - accuracy: 0.0949 - val_loss
: 2.8003 - val_accuracy: 0.1118 - lr: 0.0100
Epoch 10/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0153 - accuracy: 0.1031

micro_F1_train:  0.1091934497519875

micro_F1_val:  0.11905516804058339

Epoch 00010: val_accuracy improved from 0.11176 to 0.11906, saving model to model3_save/weights-10-0.11
91.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0153 - accuracy: 0.1032 - val_loss:
2.7759 - val_accuracy: 0.1191 - lr: 0.0100
Epoch 11/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0152 - accuracy: 0.0984

micro_F1_train:  0.1145613915879595

micro_F1_val:  0.12492073557387444

Epoch 00011: val_accuracy improved from 0.11906 to 0.12492, saving model to model3_save/weights-11-0.12
49.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0152 - accuracy: 0.0985 - val_loss:
2.7594 - val_accuracy: 0.1249 - lr: 0.0100
Epoch 12/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0151 - accuracy: 0.1000

micro_F1_train:  0.11931779574641571

micro_F1_val:  0.12698161065313887

Epoch 00012: val_accuracy improved from 0.12492 to 0.12698, saving model to model3_save/weights-12-0.12
70.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0151 - accuracy: 0.1000 - val_loss:
2.7410 - val_accuracy: 0.1270 - lr: 0.0100
Epoch 13/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0150 - accuracy: 0.1078

micro_F1_train:  0.12570496704491405

micro_F1_val:  0.13157894736842105

Epoch 00013: val_accuracy improved from 0.12698 to 0.13158, saving model to model3_save/weights-13-0.13
16.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0150 - accuracy: 0.1075 - val_loss:
2.7219 - val_accuracy: 0.1316 - lr: 0.0100
```

```
Epoch 14/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0148 - accuracy: 0.1069

micro_F1_train:  0.13059726846504044

micro_F1_val:  0.13474952441344323

Epoch 00014: val_accuracy improved from 0.13158 to 0.13475, saving model to model3_save/weights-14-0.13
47.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0148 - accuracy: 0.1069 - val_loss:
2.7055 - val_accuracy: 0.1347 - lr: 0.0100
Epoch 15/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0146 - accuracy: 0.1089

micro_F1_train:  0.13453828905347556

micro_F1_val:  0.1388712745719721

Epoch 00015: val_accuracy improved from 0.13475 to 0.13887, saving model to model3_save/weights-15-0.13
89.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0147 - accuracy: 0.1089 - val_loss:
2.6893 - val_accuracy: 0.1389 - lr: 0.0100
Epoch 16/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0145 - accuracy: 0.1133

micro_F1_train:  0.13895495005775635

micro_F1_val:  0.14267596702599875

Epoch 00016: val_accuracy improved from 0.13887 to 0.14268, saving model to model3_save/weights-16-0.14
27.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0145 - accuracy: 0.1138 - val_loss:
2.6744 - val_accuracy: 0.1427 - lr: 0.0100
Epoch 17/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0143 - accuracy: 0.1094

micro_F1_train:  0.14242033023034587

micro_F1_val:  0.14426125554850983

Epoch 00017: val_accuracy improved from 0.14268 to 0.14426, saving model to model3_save/weights-17-0.14
43.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0143 - accuracy: 0.1093 - val_loss:
2.6624 - val_accuracy: 0.1443 - lr: 0.0100
Epoch 18/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0144 - accuracy: 0.1132

micro_F1_train:  0.14690493986546171

micro_F1_val:  0.14901712111604312

Epoch 00018: val_accuracy improved from 0.14426 to 0.14902, saving model to model3_save/weights-18-0.14
90.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0144 - accuracy: 0.1132 - val_loss:
2.6501 - val_accuracy: 0.1490 - lr: 0.0100
Epoch 19/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0142 - accuracy: 0.1181

micro_F1_train:  0.14894339879051438

micro_F1_val:  0.15266328471781865

Epoch 00019: val_accuracy improved from 0.14902 to 0.15266, saving model to model3_save/weights-19-0.15
27.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0142 - accuracy: 0.1178 - val_loss:
2.6379 - val_accuracy: 0.1527 - lr: 0.0100
Epoch 20/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0141 - accuracy: 0.1210

micro_F1_train:  0.15091390908473196

micro_F1_val:  0.1569435637285986

Epoch 00020: val_accuracy improved from 0.15266 to 0.15694, saving model to model3_save/weights-20-0.15
69.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0140 - accuracy: 0.1212 - val_loss:
2.6265 - val_accuracy: 0.1569 - lr: 0.0100
```

```
Epoch 21/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0138 - accuracy: 0.1229

micro_F1_train:  0.15349595705646532

micro_F1_val:  0.15710209258084973

Epoch 00021: val_accuracy improved from 0.15694 to 0.15710, saving model to model3_save/weights-21-0.15
71.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0138 - accuracy: 0.1230 - val_loss:
2.6166 - val_accuracy: 0.1571 - lr: 0.0100
Epoch 22/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0139 - accuracy: 0.1235

micro_F1_train:  0.15397159747231093

micro_F1_val:  0.1586873811033608

Epoch 00022: val_accuracy improved from 0.15710 to 0.15869, saving model to model3_save/weights-22-0.15
87.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0138 - accuracy: 0.1235 - val_loss:
2.6087 - val_accuracy: 0.1587 - lr: 0.0100
Epoch 23/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0136 - accuracy: 0.1251

micro_F1_train:  0.15512672419650744

micro_F1_val:  0.15900443880786302

Epoch 00023: val_accuracy improved from 0.15869 to 0.15900, saving model to model3_save/weights-23-0.15
90.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0136 - accuracy: 0.1251 - val_loss:
2.6010 - val_accuracy: 0.1590 - lr: 0.0100
Epoch 24/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0136 - accuracy: 0.1235

micro_F1_train:  0.15743697764490044

micro_F1_val:  0.16058972733037413

Epoch 00024: val_accuracy improved from 0.15900 to 0.16059, saving model to model3_save/weights-24-0.16
06.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0136 - accuracy: 0.1235 - val_loss:
2.5937 - val_accuracy: 0.1606 - lr: 0.0100
Epoch 25/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0135 - accuracy: 0.1264

micro_F1_train:  0.16090235781749

micro_F1_val:  0.1631261889663919

Epoch 00025: val_accuracy improved from 0.16059 to 0.16313, saving model to model3_save/weights-25-0.16
31.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0135 - accuracy: 0.1262 - val_loss:
2.5856 - val_accuracy: 0.1631 - lr: 0.0100
Epoch 26/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0133 - accuracy: 0.1291

micro_F1_train:  0.1626690222192023

micro_F1_val:  0.16582117945466074

Epoch 00026: val_accuracy improved from 0.16313 to 0.16582, saving model to model3_save/weights-26-0.16
58.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0133 - accuracy: 0.1293 - val_loss:
2.5781 - val_accuracy: 0.1658 - lr: 0.0100
Epoch 27/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0133 - accuracy: 0.1269

micro_F1_train:  0.1655908133451111

micro_F1_val:  0.16724793912492072

Epoch 00027: val_accuracy improved from 0.16582 to 0.16725, saving model to model3_save/weights-27-0.16
72.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0133 - accuracy: 0.1271 - val_loss:
2.5708 - val_accuracy: 0.1672 - lr: 0.0100
```

```
Epoch 28/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0132 - accuracy: 0.1327

micro_F1_train:  0.16756132363932866

micro_F1_val:  0.16804058338617628

Epoch 00028: val_accuracy improved from 0.16725 to 0.16804, saving model to model3_save/weights-28-0.16
80.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0132 - accuracy: 0.1327 - val_loss:
2.5647 - val_accuracy: 0.1680 - lr: 0.0100
Epoch 29/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0130 - accuracy: 0.1359

micro_F1_train:  0.16871645036352517

micro_F1_val:  0.1683576410906785

Epoch 00029: val_accuracy improved from 0.16804 to 0.16836, saving model to model3_save/weights-29-0.16
84.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0130 - accuracy: 0.1360 - val_loss:
2.5577 - val_accuracy: 0.1684 - lr: 0.0100
Epoch 30/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0129 - accuracy: 0.1388

micro_F1_train:  0.1697356798260515

micro_F1_val:  0.16851616994292962

Epoch 00030: val_accuracy improved from 0.16836 to 0.16852, saving model to model3_save/weights-30-0.16
85.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0130 - accuracy: 0.1387 - val_loss:
2.5512 - val_accuracy: 0.1685 - lr: 0.0100
Epoch 31/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0129 - accuracy: 0.1377

micro_F1_train:  0.17245362505945505

micro_F1_val:  0.1713696892834496

Epoch 00031: val_accuracy improved from 0.16852 to 0.17137, saving model to model3_save/weights-31-0.17
14.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0129 - accuracy: 0.1377 - val_loss:
2.5456 - val_accuracy: 0.1714 - lr: 0.0100
Epoch 32/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0128 - accuracy: 0.1346

micro_F1_train:  0.17422028946116735

micro_F1_val:  0.173430564362714

Epoch 00032: val_accuracy improved from 0.17137 to 0.17343, saving model to model3_save/weights-32-0.17
34.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0128 - accuracy: 0.1347 - val_loss:
2.5414 - val_accuracy: 0.1734 - lr: 0.0100
Epoch 33/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0126 - accuracy: 0.1412

micro_F1_train:  0.17578310797037439

micro_F1_val:  0.17438173747622068

Epoch 00033: val_accuracy improved from 0.17343 to 0.17438, saving model to model3_save/weights-33-0.17
44.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0127 - accuracy: 0.1413 - val_loss:
2.5371 - val_accuracy: 0.1744 - lr: 0.0100
Epoch 34/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0127 - accuracy: 0.1366

micro_F1_train:  0.17782156689542702

micro_F1_val:  0.17707672796448953

Epoch 00034: val_accuracy improved from 0.17438 to 0.17708, saving model to model3_save/weights-34-0.17
71.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0127 - accuracy: 0.1366 - val_loss:
2.5331 - val_accuracy: 0.1771 - lr: 0.0100
```

```
Epoch 35/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0126 - accuracy: 0.1440

micro_F1_train:  0.1804715634979955

micro_F1_val:  0.1797717184527584

Epoch 00035: val_accuracy improved from 0.17708 to 0.17977, saving model to model3_save/weights-35-0.17
98.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0126 - accuracy: 0.1441 - val_loss:
2.5285 - val_accuracy: 0.1798 - lr: 0.0100
Epoch 36/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0125 - accuracy: 0.1446

micro_F1_train:  0.18203438200720257

micro_F1_val:  0.18167406467977168

Epoch 00036: val_accuracy improved from 0.17977 to 0.18167, saving model to model3_save/weights-36-0.18
17.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0125 - accuracy: 0.1444 - val_loss:
2.5236 - val_accuracy: 0.1817 - lr: 0.0100
Epoch 37/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0125 - accuracy: 0.1403

micro_F1_train:  0.1833254059930692

micro_F1_val:  0.18373493975903613

Epoch 00037: val_accuracy improved from 0.18167 to 0.18373, saving model to model3_save/weights-37-0.18
37.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0125 - accuracy: 0.1401 - val_loss:
2.5197 - val_accuracy: 0.1837 - lr: 0.0100
Epoch 38/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0124 - accuracy: 0.1442

micro_F1_train:  0.1848202758714412

micro_F1_val:  0.18516169942929614

Epoch 00038: val_accuracy improved from 0.18373 to 0.18516, saving model to model3_save/weights-38-0.18
52.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0124 - accuracy: 0.1442 - val_loss:
2.5160 - val_accuracy: 0.1852 - lr: 0.0100
Epoch 39/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0122 - accuracy: 0.1486

micro_F1_train:  0.18631514574981312

micro_F1_val:  0.18753963221306277

Epoch 00039: val_accuracy improved from 0.18516 to 0.18754, saving model to model3_save/weights-39-0.18
75.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0123 - accuracy: 0.1489 - val_loss:
2.5124 - val_accuracy: 0.1875 - lr: 0.0100
Epoch 40/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0122 - accuracy: 0.1529

micro_F1_train:  0.18679078616565875

micro_F1_val:  0.18896639188332276

Epoch 00040: val_accuracy improved from 0.18754 to 0.18897, saving model to model3_save/weights-40-0.18
90.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0122 - accuracy: 0.1534 - val_loss:
2.5098 - val_accuracy: 0.1890 - lr: 0.0100
Epoch 41/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0122 - accuracy: 0.1524

micro_F1_train:  0.18713052931983418

micro_F1_val:  0.18896639188332276

Epoch 00041: val_accuracy did not improve from 0.18897
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0122 - accuracy: 0.1523 - val_loss:
2.5067 - val_accuracy: 0.1890 - lr: 0.0100
Epoch 42/100
```

```
1466/1472 [============================>.] - ETA: 0s - loss: 0.0120 - accuracy: 0.1494

micro_F1_train:  0.18848950193653602

micro_F1_val:  0.1897590361445783

Epoch 00042: val_accuracy improved from 0.18897 to 0.18976, saving model to model3_save/weights-42-0.18
98.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0121 - accuracy: 0.1491 - val_loss:
2.5036 - val_accuracy: 0.1898 - lr: 0.0100
Epoch 43/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0121 - accuracy: 0.1515

micro_F1_train:  0.18950873139906233

micro_F1_val:  0.19261255548509829

Epoch 00043: val_accuracy improved from 0.18976 to 0.19261, saving model to model3_save/weights-43-0.19
26.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0121 - accuracy: 0.1515 - val_loss:
2.5005 - val_accuracy: 0.1926 - lr: 0.0100
Epoch 44/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0120 - accuracy: 0.1483

micro_F1_train:  0.19012026907657811

micro_F1_val:  0.19150285351934052

Epoch 00044: val_accuracy did not improve from 0.19261
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0120 - accuracy: 0.1483 - val_loss:
2.4975 - val_accuracy: 0.1915 - lr: 0.0100
Epoch 45/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0118 - accuracy: 0.1515

micro_F1_train:  0.19100360127743427

micro_F1_val:  0.19261255548509829

Epoch 00045: val_accuracy did not improve from 0.19261
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0119 - accuracy: 0.1513 - val_loss:
2.4954 - val_accuracy: 0.1926 - lr: 0.0100
Epoch 46/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0118 - accuracy: 0.1489

micro_F1_train:  0.19059590949242372

micro_F1_val:  0.19292961318960005

Epoch 00046: val_accuracy improved from 0.19261 to 0.19293, saving model to model3_save/weights-46-0.19
29.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0118 - accuracy: 0.1490 - val_loss:
2.4933 - val_accuracy: 0.1929 - lr: 0.0100
Epoch 47/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0117 - accuracy: 0.1542

micro_F1_train:  0.19079975538492897

micro_F1_val:  0.19308814204185162

Epoch 00047: val_accuracy improved from 0.19293 to 0.19309, saving model to model3_save/weights-47-0.19
31.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0117 - accuracy: 0.1538 - val_loss:
2.4912 - val_accuracy: 0.1931 - lr: 0.0100
Epoch 48/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0117 - accuracy: 0.1521

micro_F1_train:  0.19141129306244478

micro_F1_val:  0.19356372859860496

Epoch 00048: val_accuracy improved from 0.19309 to 0.19356, saving model to model3_save/weights-48-0.19
36.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0117 - accuracy: 0.1530 - val_loss:
2.4889 - val_accuracy: 0.1936 - lr: 0.0100
Epoch 49/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0116 - accuracy: 0.1565
```

```
micro_F1_train:  0.19215872800163078

micro_F1_val:  0.19435637285986046

Epoch 00049: val_accuracy improved from 0.19356 to 0.19436, saving model to model3_save/weights-49-0.19
44.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0116 - accuracy: 0.1565 - val_loss:
2.4866 - val_accuracy: 0.1944 - lr: 0.0100
Epoch 50/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0116 - accuracy: 0.1579

micro_F1_train:  0.19243052252497111

micro_F1_val:  0.19435637285986046

Epoch 00050: val_accuracy did not improve from 0.19436
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0116 - accuracy: 0.1578 - val_loss:
2.4841 - val_accuracy: 0.1944 - lr: 0.0100
Epoch 51/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.1563

micro_F1_train:  0.1937215465108378

micro_F1_val:  0.19499048826886492

Epoch 00051: val_accuracy improved from 0.19436 to 0.19499, saving model to model3_save/weights-51-0.19
50.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0115 - accuracy: 0.1559 - val_loss:
2.4821 - val_accuracy: 0.1950 - lr: 0.0100
Epoch 52/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0115 - accuracy: 0.1587

micro_F1_train:  0.1944010328191887

micro_F1_val:  0.19641724793912493

Epoch 00052: val_accuracy improved from 0.19499 to 0.19642, saving model to model3_save/weights-52-0.19
64.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0115 - accuracy: 0.1587 - val_loss:
2.4801 - val_accuracy: 0.1964 - lr: 0.0100
Epoch 53/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.1529

micro_F1_train:  0.19480872460419923

micro_F1_val:  0.199429296131896

Epoch 00053: val_accuracy improved from 0.19642 to 0.19943, saving model to model3_save/weights-53-0.19
94.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0115 - accuracy: 0.1529 - val_loss:
2.4795 - val_accuracy: 0.1994 - lr: 0.0100
Epoch 54/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0114 - accuracy: 0.1589

micro_F1_train:  0.1941971869266834

micro_F1_val:  0.1992707672796449

Epoch 00054: val_accuracy did not improve from 0.19943
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0114 - accuracy: 0.1589 - val_loss:
2.4779 - val_accuracy: 0.1993 - lr: 0.0100
Epoch 55/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0113 - accuracy: 0.1581

micro_F1_train:  0.19460487871169396

micro_F1_val:  0.19863665187064045

Epoch 00055: val_accuracy did not improve from 0.19943
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0113 - accuracy: 0.1581 - val_loss:
2.4769 - val_accuracy: 0.1986 - lr: 0.0100
Epoch 56/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0113 - accuracy: 0.1606

micro_F1_train:  0.19460487871169396

micro F1 val:  0.19879518072289157
```

```
 — —

Epoch 00056: val_accuracy did not improve from 0.19943
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0113 - accuracy: 0.1606 - val_loss:
2.4751 - val_accuracy: 0.1988 - lr: 0.0100
Epoch 57/100
1470/1472 [==============================>.] - ETA: 0s - loss: 0.0112 - accuracy: 0.1556

micro_F1_train:  0.1948766732350343

micro_F1_val:  0.19863665187064045

Epoch 00057: val_accuracy did not improve from 0.19943
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0112 - accuracy: 0.1557 - val_loss:
2.4740 - val_accuracy: 0.1986 - lr: 0.0100
Epoch 58/100
1467/1472 [==============================>.] - ETA: 0s - loss: 0.0112 - accuracy: 0.1605

micro_F1_train:  0.19501257049670445

micro_F1_val:  0.20006341154090043

Epoch 00058: val_accuracy improved from 0.19943 to 0.20006, saving model to model3_save/weights-58-0.20
01.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0112 - accuracy: 0.1605 - val_loss:
2.4724 - val_accuracy: 0.2001 - lr: 0.0100
Epoch 59/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0111 - accuracy: 0.1575

micro_F1_train:  0.1960317999592308

micro_F1_val:  0.2010145846544071

Epoch 00059: val_accuracy improved from 0.20006 to 0.20101, saving model to model3_save/weights-59-0.20
10.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0111 - accuracy: 0.1576 - val_loss:
2.4712 - val_accuracy: 0.2010 - lr: 0.0100
Epoch 60/100
1462/1472 [==============================>.] - ETA: 0s - loss: 0.0112 - accuracy: 0.1561

micro_F1_train:  0.1960317999592308

micro_F1_val:  0.20085605580215599

Epoch 00060: val_accuracy did not improve from 0.20101
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0112 - accuracy: 0.1562 - val_loss:
2.4704 - val_accuracy: 0.2009 - lr: 0.0100
Epoch 61/100
1461/1472 [==============================>.] - ETA: 0s - loss: 0.0110 - accuracy: 0.1613

micro_F1_train:  0.19657538900591154

micro_F1_val:  0.20117311350665817

Epoch 00061: val_accuracy improved from 0.20101 to 0.20117, saving model to model3_save/weights-61-0.20
12.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0110 - accuracy: 0.1612 - val_loss:
2.4693 - val_accuracy: 0.2012 - lr: 0.0100
Epoch 62/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0110 - accuracy: 0.1652

micro_F1_train:  0.19623564585173608

micro_F1_val:  0.2010145846544071

Epoch 00062: val_accuracy did not improve from 0.20117
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0110 - accuracy: 0.1653 - val_loss:
2.4677 - val_accuracy: 0.2010 - lr: 0.0100
Epoch 63/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0110 - accuracy: 0.1587

micro_F1_train:  0.19589590269756063

micro_F1_val:  0.20196575776791376

Epoch 00063: val_accuracy improved from 0.20117 to 0.20197, saving model to model3_save/weights-63-0.20
20.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0110 - accuracy: 0.1589 - val_loss:
```

```
2.4663 - val_accuracy: 0.2020 - lr: 0.0100
Epoch 00063: early stopping
Time Taken for training (sec):  629.2495293617249
```

In [ ]:

```
# http://localhost:6006/
%load_ext tensorboard
%tensorboard --logdir logs --host localhost
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

```
Reusing TensorBoard on port 6006 (pid 2268), started 1:51:16 ago. (Use '!kill 2268' to kill it.)
```

Model 3 Predictions

In [ ]:

```
NeuNet_3.load_weights("/content/m3_weights-63-0.2020.hdf5")
```

In [ ]:

```
y_pred_3 = NeuNet_3.predict(px_data_std)
```

In [ ]:

```
np.argmax(y_pred_3,axis=1)
```

Out[ ]:

```
array([10, 11, 11, ..., 14, 14, 14])
```

In [ ]:

```
y_pred_pd_3 = pd.DataFrame(np.argmax(y_pred_3,axis=1),index=px_data.index)
# y_pred_pd[0] = y_pred_pd[0]+1
```

In [ ]:

```
# y_pred_pd_3
```

In [ ]:

```
y_pred_pd_3.value_counts()
```

Out[ ]:

```
14    4500
11    3797
10    2370
15    2099
6     1585
12    1151
9     1028
16     882
13     778
1      577
7      532
4      504
8      462
3      435
2      263
```

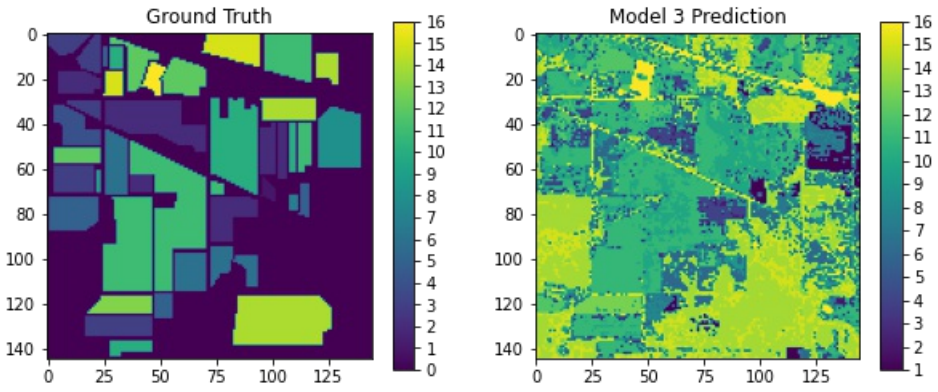
```
5        62
dtype: int64
```

In [ ]:

```
# px_data.index
```

In [ ]:

```
figr,axis = plt.subplots(1,2,figsize=(10,10))
im0 = axis[0].imshow(mat_gt['indian_pines_gt'])#,cmap='jet')
axis[0].set_title('Ground Truth')
plt.colorbar(im0,ax=axis[0],shrink=0.4,aspect=16, ticks=range(0,17,1))

im1 = axis[1].imshow(y_pred_pd_3.to_numpy().reshape((145,145)))#,cmap='jet')
axis[1].set_title('Model 3 Prediction')
plt.colorbar(im1,ax=axis[1],shrink=0.4,aspect=16, ticks=range(0,17,1))
plt.savefig('NeuNet_3_e100.png')
plt.show()
```



Observation

In [ ]:

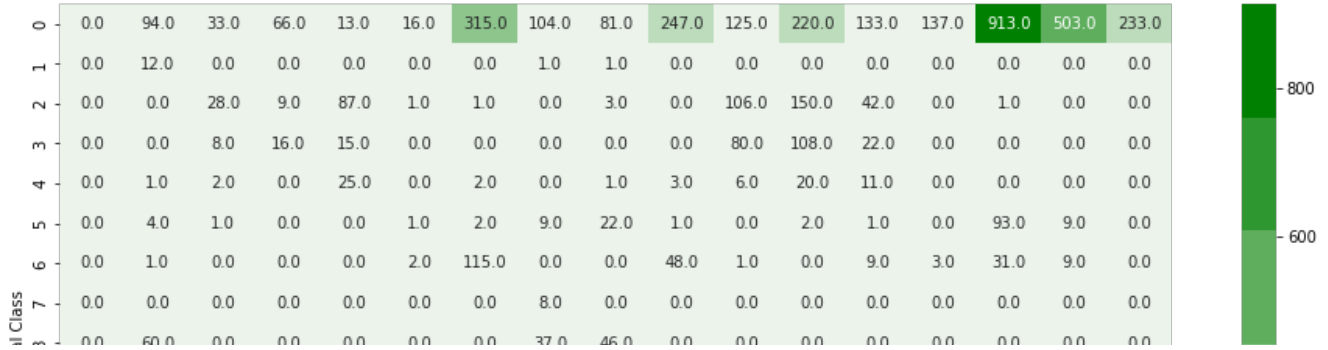
```
y_pred_3_test = NeuNet_3.predict(X_test_std)
y_pred_pd_3_test = pd.DataFrame(np.argmax(y_pred_3_test,axis=1),index=y_test.index)
```

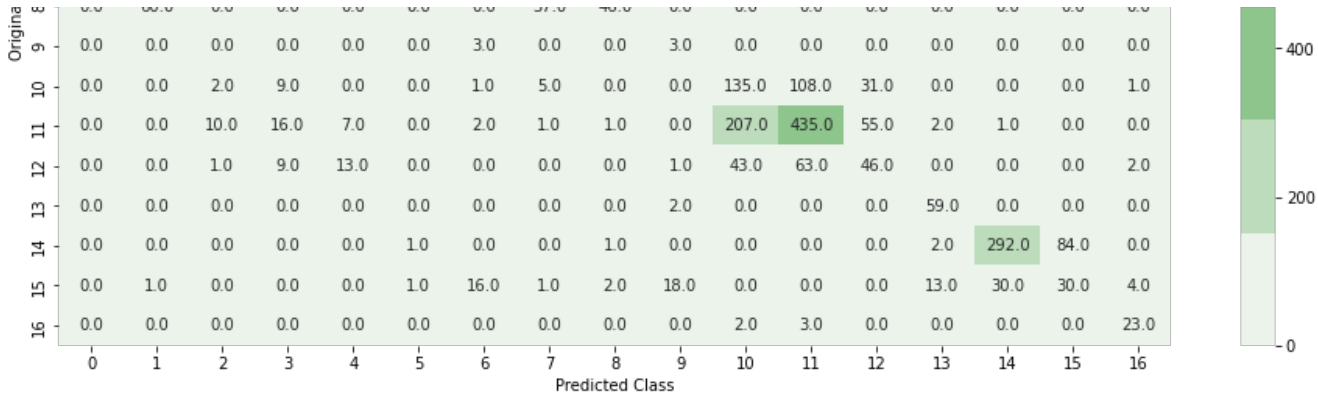
In [ ]:

```
# plot_confusion_matrix(px_class,y_pred_pd_3)
plot_confusion_matrix(y_test,y_pred_pd_3_test)
```

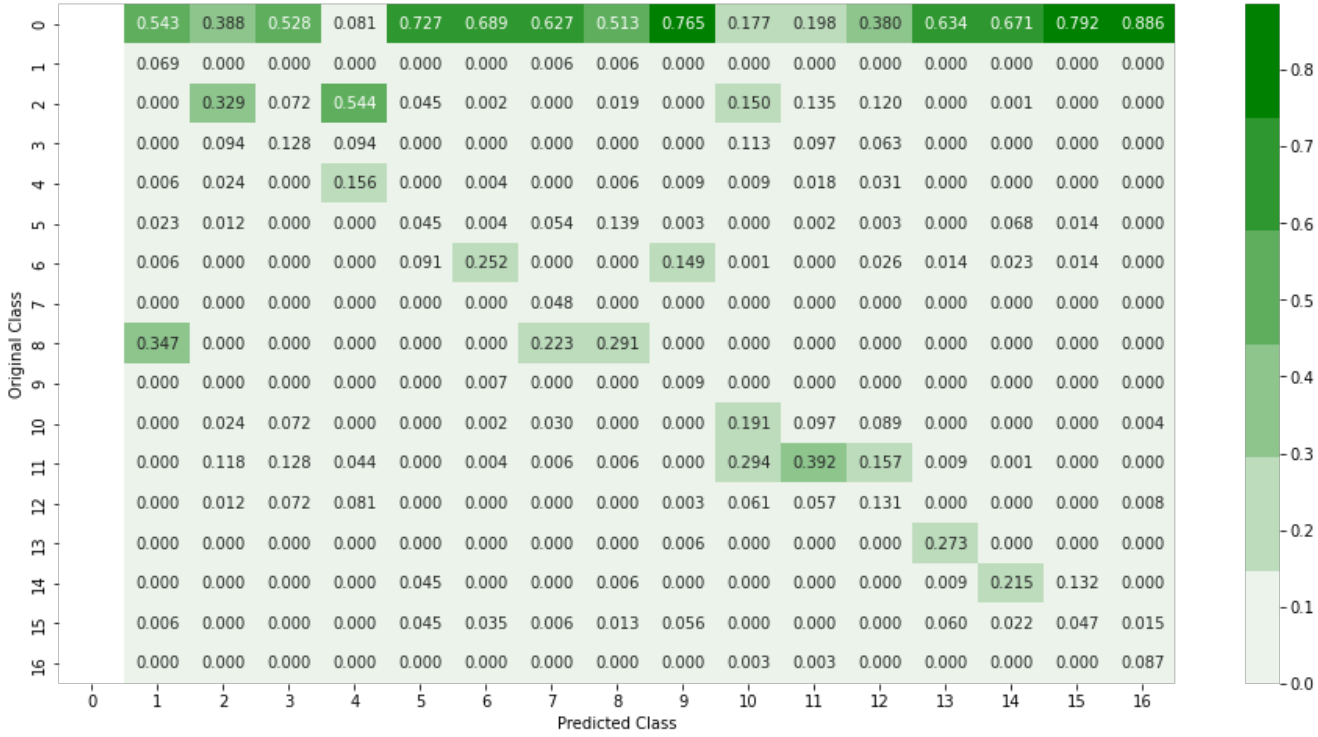
```
Number of misclassified points  79.80342422320862
-------------------------------------------------- Confusion matrix ----------------------------------
---------------
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:23: RuntimeWarning: invalid value encounte
red in true_divide
```



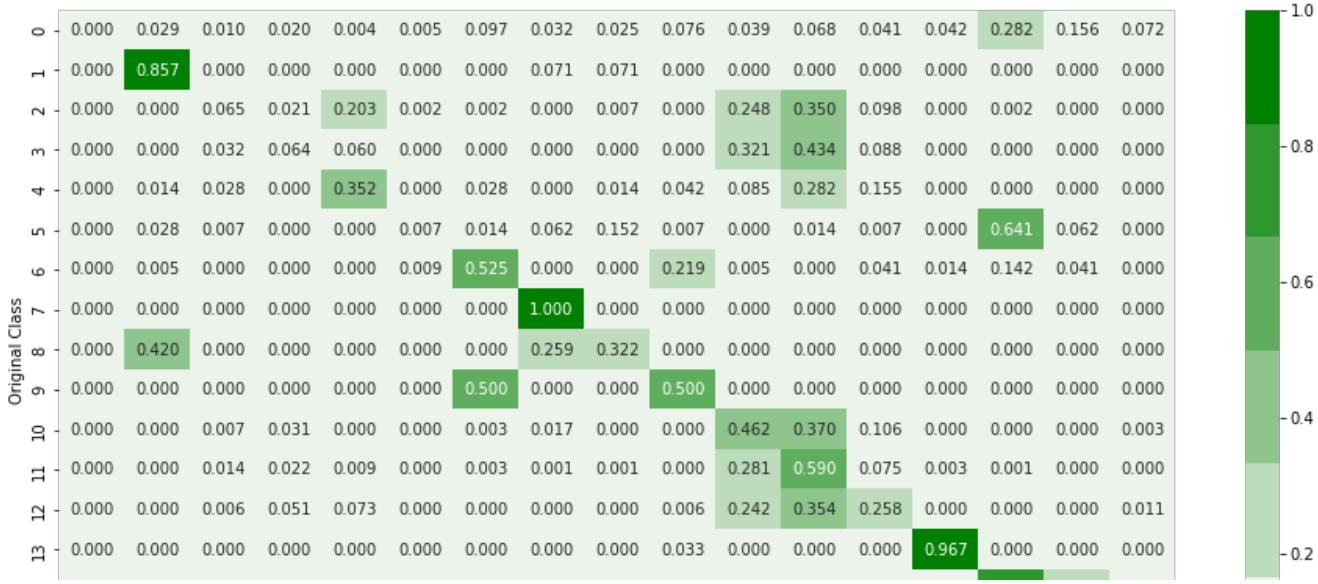


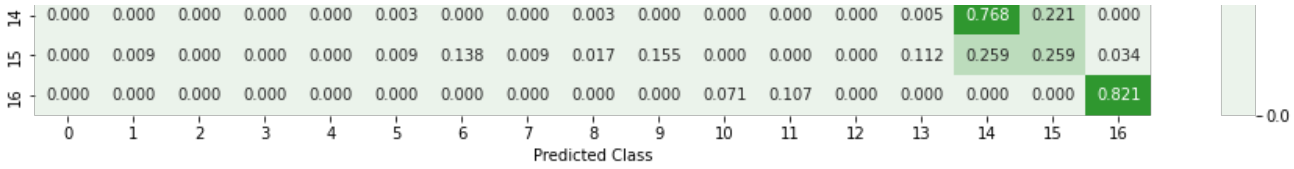
---------- Precision matrix ----------



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

---------- Recall matrix ----------






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

Model prediction doesnt match ground truth very well. Similar to Model 1 we can see that in recall matrix have only 2 of the classes have been predicted with high recall. Precisions are all low for all classes except for class 'zero'.

Model is not able to predict regions of class 'zero'. pixels of class 'zero' are classified into different class

4- Four layered network with tanh activation and Adam optimizer

Model 4 Definition

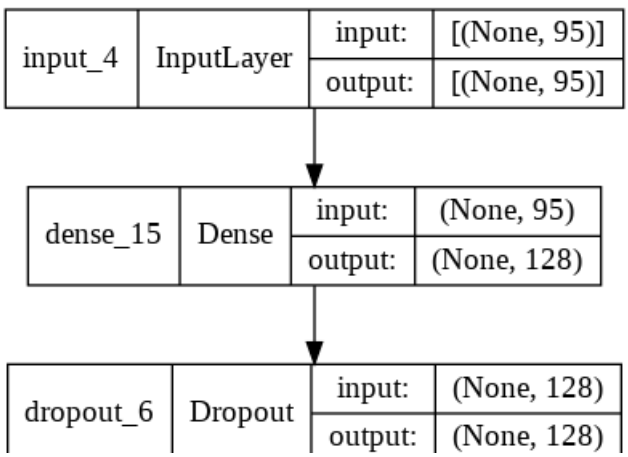
In [ ]:

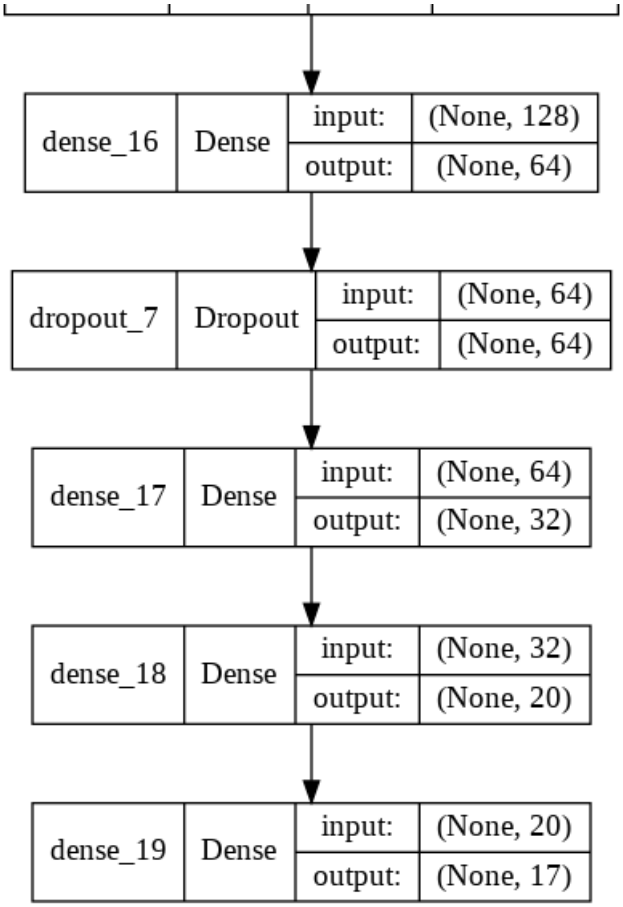
```
# del NeuNet_4
```

In [ ]:

```
In = Input(shape=(95,))
L1 = Dense(128,activation='tanh',
           kernel_initializer=initializers.he_uniform())(In) #https://keras.io/api/layers/initializers/

L1_Drp = Dropout(0.4)(L1)

L2 = Dense(64,activation='tanh',
          kernel_initializer=initializers.he_uniform())(L1_Drp)

L2_Drp = Dropout(0.3)(L2)

L3 = Dense(32,activation='tanh',
          kernel_initializer=initializers.he_uniform())(L2_Drp)

L4 = Dense(20,activation='tanh',
          kernel_initializer=initializers.he_uniform())(L3)

Out = Dense(17,activation='softmax',
           kernel_initializer=initializers.GlorotUniform())(L4)

NeuNet_4 = Model(inputs=In, outputs = Out)

# cce = categorical_crossentropy()
NeuNet_4.compile(loss='categorical_crossentropy', optimizer='Adam', metrics=['accuracy'])

plot_model(NeuNet_4,show_layer_names=True, show_shapes=True)#,to_file='NeuNet_4.png')
```

Out[ ]:





In [ ]:

```
NeuNet_4.summary()
```

```
Model: "model_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_4 (InputLayer)        [(None, 95)]              0

 dense_15 (Dense)            (None, 128)               12288

 dropout_6 (Dropout)         (None, 128)               0

 dense_16 (Dense)            (None, 64)                8256

 dropout_7 (Dropout)         (None, 64)                0

 dense_17 (Dense)            (None, 32)                2080

 dense_18 (Dense)            (None, 20)                660

 dense_19 (Dense)            (None, 17)                357

=================================================================
Total params: 23,641
Trainable params: 23,641
Non-trainable params: 0
_________________________________________________________________
```

Model 4 Training

In [ ]:

```
logdir = os.path.join("logs", datetime.now().strftime("%Y%m%d-%H%M%S"))
print(logdir)
file_writer = tf.summary.create_file_writer(logdir + "/metrics")
# tensorboard = TensorBoard(log_dir=logdir)
```

```
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True,write_grads=True)

metric_calc_4 = metric_calc()

# Saving model at every epoch if validation accuracy is improved from previous epoch
filepath_m4="model_4_save/weights-{epoch:02d}-{val_accuracy:.4f}.hdf5"
checkpoint_m4 = ModelCheckpoint(filepath=filepath_m4, monitor='val_accuracy',  verbose=1,
                                save_best_only=True,
                                mode='auto')
earlystop_m4 = EarlyStopping(monitor='val_accuracy', min_delta=0.01, patience=20, verbose=1)
reduce_lr_m4 = ReduceLROnPlateau(monitor='val_loss', factor=0.9, patience=2, min_lr=0.001)

callback_list_4 = [metric_calc_4,
                   checkpoint_m4,
                   earlystop_m4,
                   reduce_lr_m4,
                   tensorboard]
# fit network
verbose_4, epochs_4, batch_size_4 = 1, 100, 10
start = time.time()
history_4 = NeuNet_4.fit(X_train_std, y_ctg_train,
                         class_weight = class_wts,
                         validation_data=(X_test_std,y_ctg_test),
                         epochs=epochs_4,
                         batch_size=batch_size_4,
                         verbose=verbose_4,
                         callbacks=callback_list_4)

# Passing the F1 score data of each epoch to tensor board
# https://stackoverflow.com/questions/58102016/how-visualize-in-tensorboard-a-metric-callback
for i in range(len(metric_calc_4.metrics['micro_F1_train'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_train', metric_calc_4.metrics['micro_F1_train'][i])
file_writer.flush ()

for i in range(len(metric_calc_4.metrics['micro_F1_val'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_val', metric_calc_4.metrics['micro_F1_val'][i])
file_writer.flush ()

stop = time.time()
print('Time Taken for training (sec): ',stop-start)
```

```
logs/20220131-132844
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/100
   2/1472 [..............................] - ETA: 5:34 - loss: 0.0208 - accuracy: 0.0500 WARNING:tensor
flow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0036s vs
`on_train_batch_begin` time: 0.0220s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time:
0.0036s vs `on_train_batch_end` time: 0.0182s). Check your callbacks.
1461/1472 [============================>.] - ETA: 0s - loss: 0.0115 - accuracy: 0.1502

micro_F1_train:  0.21845484813481006

micro_F1_val:  0.21623335447051364

Epoch 00001: val_accuracy improved from -inf to 0.21623, saving model to model_4_save/weights-01-0.2162
.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0116 - accuracy: 0.1503 - val_loss:
2.3319 - val_accuracy: 0.2162 - lr: 0.0010
Epoch 2/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0093 - accuracy: 0.1753

micro_F1_train:  0.1535639056873004

micro_F1_val:  0.1548826886493342

Epoch 00002: val_accuracy did not improve from 0.21623
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0093 - accuracy: 0.1750 - val_loss:
2.3473 - val_accuracy: 0.1549 - lr: 0.0010
Epoch 3/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0084 - accuracy: 0.1810

micro_F1_train:  0.22531765984915403
```

```
micro_F1_val:  0.22114774889029803

Epoch 00003: val_accuracy improved from 0.21623 to 0.22115, saving model to model_4_save/weights-03-0.2
211.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0084 - accuracy: 0.1809 - val_loss:
2.2647 - val_accuracy: 0.2211 - lr: 0.0010
Epoch 4/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0077 - accuracy: 0.2034

micro_F1_train:  0.26160222871509137

micro_F1_val:  0.25586556753329104

Epoch 00004: val_accuracy improved from 0.22115 to 0.25587, saving model to model_4_save/weights-04-0.2
559.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0077 - accuracy: 0.2030 - val_loss:
2.1440 - val_accuracy: 0.2559 - lr: 0.0010
Epoch 5/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0075 - accuracy: 0.2177

micro_F1_train:  0.2238227899707821

micro_F1_val:  0.22352568167406467

Epoch 00005: val_accuracy did not improve from 0.25587
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0075 - accuracy: 0.2177 - val_loss:
2.0571 - val_accuracy: 0.2235 - lr: 0.0010
Epoch 6/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0068 - accuracy: 0.2512

micro_F1_train:  0.2877624515866005

micro_F1_val:  0.2880469245402663

Epoch 00006: val_accuracy improved from 0.25587 to 0.28805, saving model to model_4_save/weights-06-0.2
880.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0068 - accuracy: 0.2511 - val_loss:
2.0150 - val_accuracy: 0.2880 - lr: 0.0010
Epoch 7/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0066 - accuracy: 0.2596

micro_F1_train:  0.28932527009580755

micro_F1_val:  0.2923272035510463

Epoch 00007: val_accuracy improved from 0.28805 to 0.29233, saving model to model_4_save/weights-07-0.2
923.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0066 - accuracy: 0.2598 - val_loss:
1.9131 - val_accuracy: 0.2923 - lr: 0.0010
Epoch 8/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0064 - accuracy: 0.2734

micro_F1_train:  0.31779574641570973

micro_F1_val:  0.31467977171845274

Epoch 00008: val_accuracy improved from 0.29233 to 0.31468, saving model to model_4_save/weights-08-0.3
147.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0064 - accuracy: 0.2736 - val_loss:
1.9168 - val_accuracy: 0.3147 - lr: 0.0010
Epoch 9/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0061 - accuracy: 0.2843

micro_F1_train:  0.32316368825168174

micro_F1_val:  0.31642358909321494

Epoch 00009: val_accuracy improved from 0.31468 to 0.31642, saving model to model_4_save/weights-09-0.3
164.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0061 - accuracy: 0.2842 - val_loss:
1.8760 - val_accuracy: 0.3164 - lr: 0.0010
Epoch 10/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0060 - accuracy: 0.2991

micro_F1_train:  0.30875857851464295

micro_F1_val:  0.3004121750158529
```

```
micro_F1_val:  0.3001121730180329

Epoch 00010: val_accuracy did not improve from 0.31642
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0060 - accuracy: 0.2991 - val_loss:
1.8970 - val_accuracy: 0.3004 - lr: 0.0010
Epoch 11/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0058 - accuracy: 0.3052

micro_F1_train:  0.3207175375416185

micro_F1_val:  0.325142675967026

Epoch 00011: val_accuracy improved from 0.31642 to 0.32514, saving model to model_4_save/weights-11-0.3
251.hdf5
1472/1472 [==============================] - 13s 9ms/step - loss: 0.0058 - accuracy: 0.3055 - val_loss:
1.8485 - val_accuracy: 0.3251 - lr: 0.0010
Epoch 12/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0055 - accuracy: 0.3170

micro_F1_train:  0.30739960589794113

micro_F1_val:  0.30675332910589725

Epoch 00012: val_accuracy did not improve from 0.32514
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0055 - accuracy: 0.3171 - val_loss:
1.8111 - val_accuracy: 0.3068 - lr: 0.0010
Epoch 13/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0056 - accuracy: 0.3202

micro_F1_train:  0.3555072365291839

micro_F1_val:  0.3557387444514902

Epoch 00013: val_accuracy improved from 0.32514 to 0.35574, saving model to model_4_save/weights-13-0.3
557.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0056 - accuracy: 0.3208 - val_loss:
1.7490 - val_accuracy: 0.3557 - lr: 0.0010
Epoch 14/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0054 - accuracy: 0.3300

micro_F1_train:  0.3377046952503907

micro_F1_val:  0.3313253012048193

Epoch 00014: val_accuracy did not improve from 0.35574
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0054 - accuracy: 0.3300 - val_loss:
1.7275 - val_accuracy: 0.3313 - lr: 0.0010
Epoch 15/100
1460/1472 [============================>.] - ETA: 0s - loss: 0.0052 - accuracy: 0.3276

micro_F1_train:  0.3885302711115037

micro_F1_val:  0.38031071655041215

Epoch 00015: val_accuracy improved from 0.35574 to 0.38031, saving model to model_4_save/weights-15-0.3
803.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0052 - accuracy: 0.3276 - val_loss:
1.6355 - val_accuracy: 0.3803 - lr: 0.0010
Epoch 16/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0052 - accuracy: 0.3331

micro_F1_train:  0.38601617177413877

micro_F1_val:  0.3769816106531389

Epoch 00016: val_accuracy did not improve from 0.38031
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0052 - accuracy: 0.3337 - val_loss:
1.7056 - val_accuracy: 0.3770 - lr: 0.0010
Epoch 17/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0050 - accuracy: 0.3470

micro_F1_train:  0.38791873343752126

micro_F1_val:  0.3815789473684211

Epoch 00017: val_accuracy improved from 0.38031 to 0.38158, saving model to model_4_save/weights-17-0.3
816.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0050 - accuracy: 0.3469 - val_loss:
```

1472/1472 [==============================] - 10s 7ms/step - loss: 0.0050 - accuracy: 0.3469 - val_loss:
1.6821 - val_accuracy: 0.3816 - lr: 0.0010
Epoch 18/100
1467/1472 [==============================>.] - ETA: 0s - loss: 0.0051 - accuracy: 0.3537

micro_F1_train: 0.3788136169056193

micro_F1_val: 0.36794546607482564

Epoch 00018: val_accuracy did not improve from 0.38158
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0051 - accuracy: 0.3537 - val_loss:
1.7052 - val_accuracy: 0.3679 - lr: 0.0010
Epoch 19/100
1460/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3551

micro_F1_train: 0.39247129170347217

micro_F1_val: 0.3787254280279011

Epoch 00019: val_accuracy did not improve from 0.38158
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0048 - accuracy: 0.3552 - val_loss:
1.6593 - val_accuracy: 0.3787 - lr: 0.0010
Epoch 20/100
1464/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3702

micro_F1_train: 0.3779982333355983

micro_F1_val: 0.3723842739378567

Epoch 00020: val_accuracy did not improve from 0.38158
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0048 - accuracy: 0.3703 - val_loss:
1.6900 - val_accuracy: 0.3724 - lr: 0.0010
Epoch 21/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0048 - accuracy: 0.3723

micro_F1_train: 0.4265135557518516

micro_F1_val: 0.40710209258084973

Epoch 00021: val_accuracy improved from 0.38158 to 0.40710, saving model to model_4_save/weights-21-0.4
071.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0048 - accuracy: 0.3723 - val_loss:
1.6024 - val_accuracy: 0.4071 - lr: 0.0010
Epoch 22/100
1464/1472 [==============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.3846

micro_F1_train: 0.4320173948494938

micro_F1_val: 0.42057704502219406

Epoch 00022: val_accuracy improved from 0.40710 to 0.42058, saving model to model_4_save/weights-22-0.4
206.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0048 - accuracy: 0.3849 - val_loss:
1.6121 - val_accuracy: 0.4206 - lr: 0.0010
Epoch 23/100
1461/1472 [==============================>.] - ETA: 0s - loss: 0.0047 - accuracy: 0.3888

micro_F1_train: 0.441394305904736

micro_F1_val: 0.430564362714014

Epoch 00023: val_accuracy improved from 0.42058 to 0.43056, saving model to model_4_save/weights-23-0.4
306.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0048 - accuracy: 0.3887 - val_loss:
1.5678 - val_accuracy: 0.4306 - lr: 0.0010
Epoch 24/100
1462/1472 [==============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3837

micro_F1_train: 0.43636610722293945

micro_F1_val: 0.4245402663284718

Epoch 00024: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0046 - accuracy: 0.3847 - val_loss:
1.6017 - val_accuracy: 0.4245 - lr: 0.0010
Epoch 25/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3829

```
micro_F1_train:  0.4169327988041041

micro_F1_val:  0.4039315155358275

Epoch 00025: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0046 - accuracy: 0.3829 - val_loss:
1.5791 - val_accuracy: 0.4039 - lr: 0.0010
Epoch 26/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0046 - accuracy: 0.3949

micro_F1_train:  0.422980226948427

micro_F1_val:  0.40868738110336084

Epoch 00026: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0046 - accuracy: 0.3953 - val_loss:
1.5544 - val_accuracy: 0.4087 - lr: 0.0010
Epoch 27/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.4034

micro_F1_train:  0.3976353876469389

micro_F1_val:  0.3869689283449588

Epoch 00027: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0045 - accuracy: 0.4032 - val_loss:
1.6266 - val_accuracy: 0.3870 - lr: 0.0010
Epoch 28/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.4008

micro_F1_train:  0.4361622613304342

micro_F1_val:  0.4237476220672162

Epoch 00028: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0044 - accuracy: 0.4005 - val_loss:
1.5835 - val_accuracy: 0.4237 - lr: 0.0010
Epoch 29/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.4039

micro_F1_train:  0.430658422232792

micro_F1_val:  0.4239061509194673

Epoch 00029: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.4042 - val_loss:
1.5951 - val_accuracy: 0.4239 - lr: 0.0010
Epoch 30/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.3949

micro_F1_train:  0.40144051097370387

micro_F1_val:  0.39283449587824987

Epoch 00030: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0045 - accuracy: 0.3948 - val_loss:
1.6342 - val_accuracy: 0.3928 - lr: 0.0010
Epoch 31/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.3911

micro_F1_train:  0.4216892029625603

micro_F1_val:  0.4120164870006341

Epoch 00031: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0044 - accuracy: 0.3914 - val_loss:
1.5577 - val_accuracy: 0.4120 - lr: 0.0010
Epoch 32/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.3991

micro_F1_train:  0.43813277162465175

micro_F1_val:  0.41915028535193405

Epoch 00032: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0043 - accuracy: 0.3994 - val_loss:
1.5430 - val_accuracy: 0.4192 - lr: 0.0010
```

```
1.5430 - val_accuracy: 0.4192 - lr: 0.0010
Epoch 33/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4013

micro_F1_train:  0.41951484677583745

micro_F1_val:  0.40076093849080535

Epoch 00033: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.4016 - val_loss:
1.6508 - val_accuracy: 0.4008 - lr: 0.0010
Epoch 34/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.4089

micro_F1_train:  0.4385404634096623

micro_F1_val:  0.4194673430564363

Epoch 00034: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0044 - accuracy: 0.4088 - val_loss:
1.5422 - val_accuracy: 0.4195 - lr: 0.0010
Epoch 35/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.4054

micro_F1_train:  0.432968675681185

micro_F1_val:  0.41708941027266955

Epoch 00035: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0044 - accuracy: 0.4054 - val_loss:
1.5679 - val_accuracy: 0.4171 - lr: 0.0010
Epoch 36/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4177

micro_F1_train:  0.42019433308418835

micro_F1_val:  0.40424857324032976

Epoch 00036: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.4179 - val_loss:
1.5954 - val_accuracy: 0.4042 - lr: 0.0010
Epoch 37/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0043 - accuracy: 0.4173

micro_F1_train:  0.4368417476387851

micro_F1_val:  0.4177235256816741

Epoch 00037: val_accuracy did not improve from 0.43056
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0043 - accuracy: 0.4173 - val_loss:
1.5475 - val_accuracy: 0.4177 - lr: 0.0010
Epoch 38/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4210

micro_F1_train:  0.45600326153428006

micro_F1_val:  0.4400760938490805

Epoch 00038: val_accuracy improved from 0.43056 to 0.44008, saving model to model_4_save/weights-38-0.4
401.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0040 - accuracy: 0.4209 - val_loss:
1.5117 - val_accuracy: 0.4401 - lr: 0.0010
Epoch 39/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4245

micro_F1_train:  0.45586736427260993

micro_F1_val:  0.43785668991756493

Epoch 00039: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4250 - val_loss:
1.5081 - val_accuracy: 0.4379 - lr: 0.0010
Epoch 40/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4169

micro_F1_train:  0.436026364068764

micro_F1_val:  0.41471147748890207
```

```
micro_F1_val:  0.41471147748890297

Epoch 00040: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0041 - accuracy: 0.4170 - val_loss:
1.5177 - val_accuracy: 0.4147 - lr: 0.0010
Epoch 41/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.4087

micro_F1_train:  0.4446558401848203

micro_F1_val:  0.4296131896005073

Epoch 00041: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0043 - accuracy: 0.4087 - val_loss:
1.5088 - val_accuracy: 0.4296 - lr: 0.0010
Epoch 42/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4224

micro_F1_train:  0.4373173880546308

micro_F1_val:  0.42136968928344964

Epoch 00042: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4224 - val_loss:
1.5312 - val_accuracy: 0.4214 - lr: 0.0010
Epoch 43/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4089

micro_F1_train:  0.42549432628932526

micro_F1_val:  0.409004438807863

Epoch 00043: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0042 - accuracy: 0.4090 - val_loss:
1.5749 - val_accuracy: 0.4090 - lr: 0.0010
Epoch 44/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4153

micro_F1_train:  0.44492763470816066

micro_F1_val:  0.4266011414077362

Epoch 00044: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0041 - accuracy: 0.4152 - val_loss:
1.5136 - val_accuracy: 0.4266 - lr: 0.0010
Epoch 45/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4219

micro_F1_train:  0.4427532785214378

micro_F1_val:  0.4281864299302473

Epoch 00045: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0041 - accuracy: 0.4219 - val_loss:
1.5545 - val_accuracy: 0.4282 - lr: 0.0010
Epoch 46/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4227

micro_F1_train:  0.43921994971801315

micro_F1_val:  0.42786937222574506

Epoch 00046: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0040 - accuracy: 0.4227 - val_loss:
1.5323 - val_accuracy: 0.4279 - lr: 0.0010
Epoch 47/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4226

micro_F1_train:  0.44948019297411157

micro_F1_val:  0.4323081800887762

Epoch 00047: val_accuracy did not improve from 0.44008
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0041 - accuracy: 0.4227 - val_loss:
1.5054 - val_accuracy: 0.4323 - lr: 0.0010
Epoch 48/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4183
```

```
micro_F1_train:  0.4580417204593327

micro_F1_val:  0.44086873811033606

Epoch 00048: val_accuracy improved from 0.44008 to 0.44087, saving model to model_4_save/weights-48-0.4
409.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0041 - accuracy: 0.4184 - val_loss:
1.4989 - val_accuracy: 0.4409 - lr: 0.0010
Epoch 49/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4268

micro_F1_train:  0.45743018278181696

micro_F1_val:  0.442136968928345

Epoch 00049: val_accuracy improved from 0.44087 to 0.44214, saving model to model_4_save/weights-49-0.4
421.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4268 - val_loss:
1.4942 - val_accuracy: 0.4421 - lr: 0.0010
Epoch 50/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4209

micro_F1_train:  0.45321736767004145

micro_F1_val:  0.43912492073557385

Epoch 00050: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4206 - val_loss:
1.4868 - val_accuracy: 0.4391 - lr: 0.0010
Epoch 51/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4280

micro_F1_train:  0.4455391723856764

micro_F1_val:  0.4315155358275206

Epoch 00051: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0039 - accuracy: 0.4285 - val_loss:
1.5114 - val_accuracy: 0.4315 - lr: 0.0010
Epoch 52/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4224

micro_F1_train:  0.44846096351158526

micro_F1_val:  0.4340519974635384

Epoch 00052: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0038 - accuracy: 0.4224 - val_loss:
1.5035 - val_accuracy: 0.4341 - lr: 0.0010
Epoch 53/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4223

micro_F1_train:  0.454440443025073

micro_F1_val:  0.4331008243500317

Epoch 00053: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0040 - accuracy: 0.4221 - val_loss:
1.5258 - val_accuracy: 0.4331 - lr: 0.0010
Epoch 54/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4278

micro_F1_train:  0.42902765509274987

micro_F1_val:  0.4215282181357007

Epoch 00054: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0038 - accuracy: 0.4276 - val_loss:
1.5114 - val_accuracy: 0.4215 - lr: 0.0010
Epoch 55/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4280

micro_F1_train:  0.4456071210165115

micro_F1_val:  0.43088142041851624
```

```
Epoch 00055: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0039 - accuracy: 0.4281 - val_loss:
1.5037 - val_accuracy: 0.4309 - lr: 0.0010
Epoch 56/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4360

micro_F1_train:  0.4512468573758239

micro_F1_val:  0.4334178820545339

Epoch 00056: val_accuracy did not improve from 0.44214
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0039 - accuracy: 0.4361 - val_loss:
1.5401 - val_accuracy: 0.4334 - lr: 0.0010
Epoch 57/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4316

micro_F1_train:  0.4708840116871645

micro_F1_val:  0.45450221940393154

Epoch 00057: val_accuracy improved from 0.44214 to 0.45450, saving model to model_4_save/weights-57-0.4
545.hdf5
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0039 - accuracy: 0.4315 - val_loss:
1.4401 - val_accuracy: 0.4545 - lr: 0.0010
Epoch 58/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4340

micro_F1_train:  0.4342596996670517

micro_F1_val:  0.4153455928979074

Epoch 00058: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0038 - accuracy: 0.4339 - val_loss:
1.4905 - val_accuracy: 0.4153 - lr: 0.0010
Epoch 59/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0037 - accuracy: 0.4188

micro_F1_train:  0.4500917306516274

micro_F1_val:  0.4348446417247939

Epoch 00059: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4188 - val_loss:
1.5612 - val_accuracy: 0.4348 - lr: 0.0010
Epoch 60/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0038 - accuracy: 0.4340

micro_F1_train:  0.4509750628524835

micro_F1_val:  0.435003170577045

Epoch 00060: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0038 - accuracy: 0.4340 - val_loss:
1.4701 - val_accuracy: 0.4350 - lr: 0.0010
Epoch 61/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4285

micro_F1_train:  0.4546442889175783

micro_F1_val:  0.439283449587825

Epoch 00061: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0038 - accuracy: 0.4283 - val_loss:
1.4457 - val_accuracy: 0.4393 - lr: 0.0010
Epoch 62/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4339

micro_F1_train:  0.4431609703064483

micro_F1_val:  0.43547875713379836

Epoch 00062: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0039 - accuracy: 0.4341 - val_loss:
1.5055 - val_accuracy: 0.4355 - lr: 0.0010
Epoch 63/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4310
```

```
micro_F1_train:  0.45634300468845555

micro_F1_val:  0.43912492073557385

Epoch 00063: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0038 - accuracy: 0.4312 - val_loss:
1.4645 - val_accuracy: 0.4391 - lr: 0.0010
Epoch 64/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4383

micro_F1_train:  0.46150710063192224

micro_F1_val:  0.4473684210526316

Epoch 00064: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 9s 6ms/step - loss: 0.0038 - accuracy: 0.4385 - val_loss:
1.4640 - val_accuracy: 0.4474 - lr: 0.0010
Epoch 65/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4364

micro_F1_train:  0.46103146021607666

micro_F1_val:  0.44720989220038043

Epoch 00065: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4362 - val_loss:
1.4423 - val_accuracy: 0.4472 - lr: 0.0010
Epoch 66/100
1466/1472 [==============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4460

micro_F1_train:  0.4481212203574098

micro_F1_val:  0.43864933417882057

Epoch 00066: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0038 - accuracy: 0.4458 - val_loss:
1.4839 - val_accuracy: 0.4386 - lr: 0.0010
Epoch 67/100
1469/1472 [==============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4343

micro_F1_train:  0.4634776109261398

micro_F1_val:  0.4495878249841471

Epoch 00067: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0038 - accuracy: 0.4344 - val_loss:
1.4611 - val_accuracy: 0.4496 - lr: 0.0010
Epoch 68/100
1468/1472 [==============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4372

micro_F1_train:  0.4476455799415642

micro_F1_val:  0.4342105263157895

Epoch 00068: val_accuracy did not improve from 0.45450
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0038 - accuracy: 0.4372 - val_loss:
1.4917 - val_accuracy: 0.4342 - lr: 0.0010
Epoch 69/100
1461/1472 [==============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4300

micro_F1_train:  0.4708840116871645

micro_F1_val:  0.458782498414711147

Epoch 00069: val_accuracy improved from 0.45450 to 0.45878, saving model to model_4_save/weights-69-0.4
588.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0037 - accuracy: 0.4296 - val_loss:
1.4593 - val_accuracy: 0.4588 - lr: 0.0010
Epoch 70/100
1462/1472 [==============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4392

micro_F1_train:  0.457905823197662254

micro_F1_val:  0.44150285351934054

Epoch 00070: val_accuracy did not improve from 0.45878
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0039 - accuracy: 0.4392 - val_loss:
```

```
1.4817 - val_accuracy: 0.4415 - lr: 0.0010
Epoch 71/100
1471/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4403

micro_F1_train:  0.4861045049942244

micro_F1_val:  0.4722574508560558

Epoch 00071: val_accuracy improved from 0.45878 to 0.47226, saving model to model_4_save/weights-71-0.4
723.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4402 - val_loss:
1.4383 - val_accuracy: 0.4723 - lr: 0.0010
Epoch 72/100
1467/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4514

micro_F1_train:  0.469728884962968

micro_F1_val:  0.4499048826886493

Epoch 00072: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0036 - accuracy: 0.4512 - val_loss:
1.4417 - val_accuracy: 0.4499 - lr: 0.0010
Epoch 73/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4433

micro_F1_train:  0.4709519603179996

micro_F1_val:  0.45624603677869374

Epoch 00073: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4431 - val_loss:
1.3985 - val_accuracy: 0.4562 - lr: 0.0010
Epoch 74/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4361

micro_F1_train:  0.449751987497451 93

micro_F1_val:  0.4300887761572606

Epoch 00074: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0039 - accuracy: 0.4362 - val_loss:
1.4969 - val_accuracy: 0.4301 - lr: 0.0010
Epoch 75/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4422

micro_F1_train:  0.4634096622953047

micro_F1_val:  0.4506975269499049

Epoch 00075: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0040 - accuracy: 0.4423 - val_loss:
1.4356 - val_accuracy: 0.4507 - lr: 0.0010
Epoch 76/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4388

micro_F1_train:  0.4601481280152205

micro_F1_val:  0.44720989220038043

Epoch 00076: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0038 - accuracy: 0.4388 - val_loss:
1.4803 - val_accuracy: 0.4472 - lr: 0.0010
Epoch 77/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4520

micro_F1_train:  0.4732622137663926

micro_F1_val:  0.45973367152821815

Epoch 00077: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0038 - accuracy: 0.4521 - val_loss:
1.4542 - val_accuracy: 0.4597 - lr: 0.0010
Epoch 78/100
1462/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4380

micro_F1_train:  0.4295032955085955
```

```
micro_F1_val:  0.41502853519340516

Epoch 00078: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0037 - accuracy: 0.4382 - val_loss:
1.5368 - val_accuracy: 0.4150 - lr: 0.0010
Epoch 79/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4396

micro_F1_train:  0.4713596521030101

micro_F1_val:  0.4576727964489537

Epoch 00079: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4396 - val_loss:
1.4292 - val_accuracy: 0.4577 - lr: 0.0010
Epoch 80/100
1465/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4475

micro_F1_train:  0.46565196711286266

micro_F1_val:  0.4513316423589093

Epoch 00080: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4472 - val_loss:
1.3940 - val_accuracy: 0.4513 - lr: 0.0010
Epoch 81/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4443

micro_F1_train:  0.46109940884691175

micro_F1_val:  0.4481610653138871

Epoch 00081: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0037 - accuracy: 0.4446 - val_loss:
1.4451 - val_accuracy: 0.4482 - lr: 0.0010
Epoch 82/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4437

micro_F1_train:  0.4787660528640348

micro_F1_val:  0.46163601775523144

Epoch 00082: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0038 - accuracy: 0.4438 - val_loss:
1.4157 - val_accuracy: 0.4616 - lr: 0.0010
Epoch 83/100
1469/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4462

micro_F1_train:  0.46021607664605557

micro_F1_val:  0.44705136334812934

Epoch 00083: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0036 - accuracy: 0.4461 - val_loss:
1.4151 - val_accuracy: 0.4471 - lr: 0.0010
Epoch 84/100
1468/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4281

micro_F1_train:  0.46334171366446963

micro_F1_val:  0.452282815472416

Epoch 00084: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0037 - accuracy: 0.4281 - val_loss:
1.4445 - val_accuracy: 0.4523 - lr: 0.0010
Epoch 85/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0037 - accuracy: 0.4399

micro_F1_train:  0.45240198410002036

micro_F1_val:  0.44356372859860493

Epoch 00085: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0037 - accuracy: 0.4399 - val_loss:
1.4524 - val_accuracy: 0.4436 - lr: 0.0010
Epoch 86/100
1461/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4420
```

```
micro_F1_train:  0.465923761636203

micro_F1_val:  0.452282815472416

Epoch 00086: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0038 - accuracy: 0.4419 - val_loss:
1.4724 - val_accuracy: 0.4523 - lr: 0.0010
Epoch 87/100
1466/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4447

micro_F1_train:  0.4564789019501257

micro_F1_val:  0.4464172479391249

Epoch 00087: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0037 - accuracy: 0.4451 - val_loss:
1.4322 - val_accuracy: 0.4464 - lr: 0.0010
Epoch 88/100
1472/1472 [==============================] - ETA: 0s - loss: 0.0037 - accuracy: 0.4436

micro_F1_train:  0.4756404158456207

micro_F1_val:  0.46337983512999364

Epoch 00088: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0037 - accuracy: 0.4436 - val_loss:
1.4167 - val_accuracy: 0.4634 - lr: 0.0010
Epoch 89/100
1464/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4524

micro_F1_train:  0.4640891486036556

micro_F1_val:  0.44673430564362715

Epoch 00089: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0037 - accuracy: 0.4525 - val_loss:
1.4537 - val_accuracy: 0.4467 - lr: 0.0010
Epoch 90/100
1463/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4504

micro_F1_train:  0.4608955629544065

micro_F1_val:  0.4445149017121116

Epoch 00090: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 10s 6ms/step - loss: 0.0036 - accuracy: 0.4506 - val_loss:
1.4686 - val_accuracy: 0.4445 - lr: 0.0010
Epoch 91/100
1470/1472 [============================>.] - ETA: 0s - loss: 0.0035 - accuracy: 0.4473

micro_F1_train:  0.48624040225589454

micro_F1_val:  0.47178186429930247

Epoch 00091: val_accuracy did not improve from 0.47226
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0035 - accuracy: 0.4473 - val_loss:
1.4211 - val_accuracy: 0.4718 - lr: 0.0010
Epoch 00091: early stopping
Time Taken for training (sec):  927.6565854549408
```

In [ ]:

```
# http://localhost:6006/
%load_ext tensorboard
%tensorboard --logdir logs --host localhost
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard


Reusing TensorBoard on port 6006 (pid 2268), started 1:51:23 ago. (Use '!kill 2268' to kill it.)
```

Model 4 Predictions

In [ ]:

```
NeuNet_4.load_weights("/content/m4_weights-71-0.4723.hdf5")
```

In [ ]:

```
y_pred_4 = NeuNet_4.predict(px_data_std)
```

In [ ]:

```
np.argmax(y_pred_4,axis=1)
```

Out[ ]:

```
array([ 3,  3,  3, ..., 14, 14, 14])
```

In [ ]:

```
y_pred_pd_4 = pd.DataFrame(np.argmax(y_pred_4,axis=1),index=px_data.index)
# y_pred_pd[0] = y_pred_pd[0]+1
```

In [ ]:

```
# y_pred_pd_4
```

In [ ]:

```
y_pred_pd_4.value_counts()
```

Out[ ]:

```
14    3583
0     2459
15    2396
11    2357
2     1825
10    1559
6     1341
5     1322
12    1211
3      829
8      648
4      601
13     317
16     248
1      136
7       98
9       95
dtype: int64
```

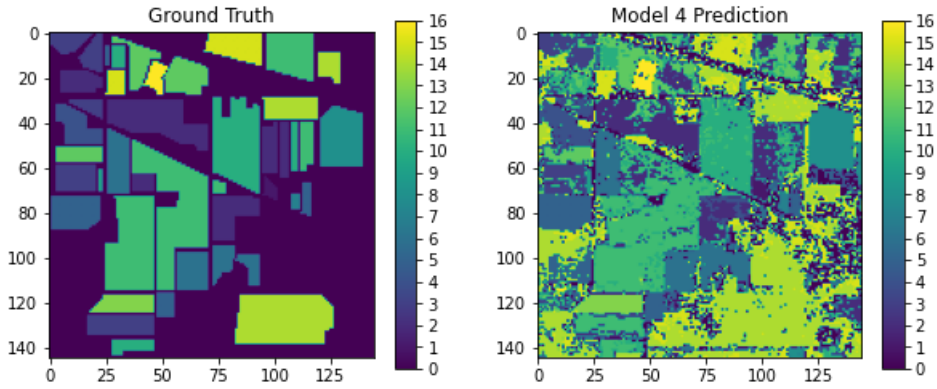
In [ ]:

```
# px_data.index
```

In [ ]:

```
figr,axis = plt.subplots(1,2,figsize=(10,10))
im0 = axis[0].imshow(mat_gt['indian_pines_gt'])#,cmap='jet')
axis[0].set_title('Ground Truth')
plt.colorbar(im0,ax=axis[0],shrink=0.4,aspect=16, ticks=range(0,17,1))

im1 = axis[1].imshow(y_pred_pd_4.to_numpy().reshape((145,145)))#,cmap='jet')
axis[1].set_title('Model 4 Prediction')
plt.colorbar(im1,ax=axis[1],shrink=0.4,aspect=16, ticks=range(0,17,1))
```

```
plt.savefig('NeuNet_4_e100.png')
plt.show()
```



Observation:

Model prediction better compared to model 1 but fails to predict '0' class

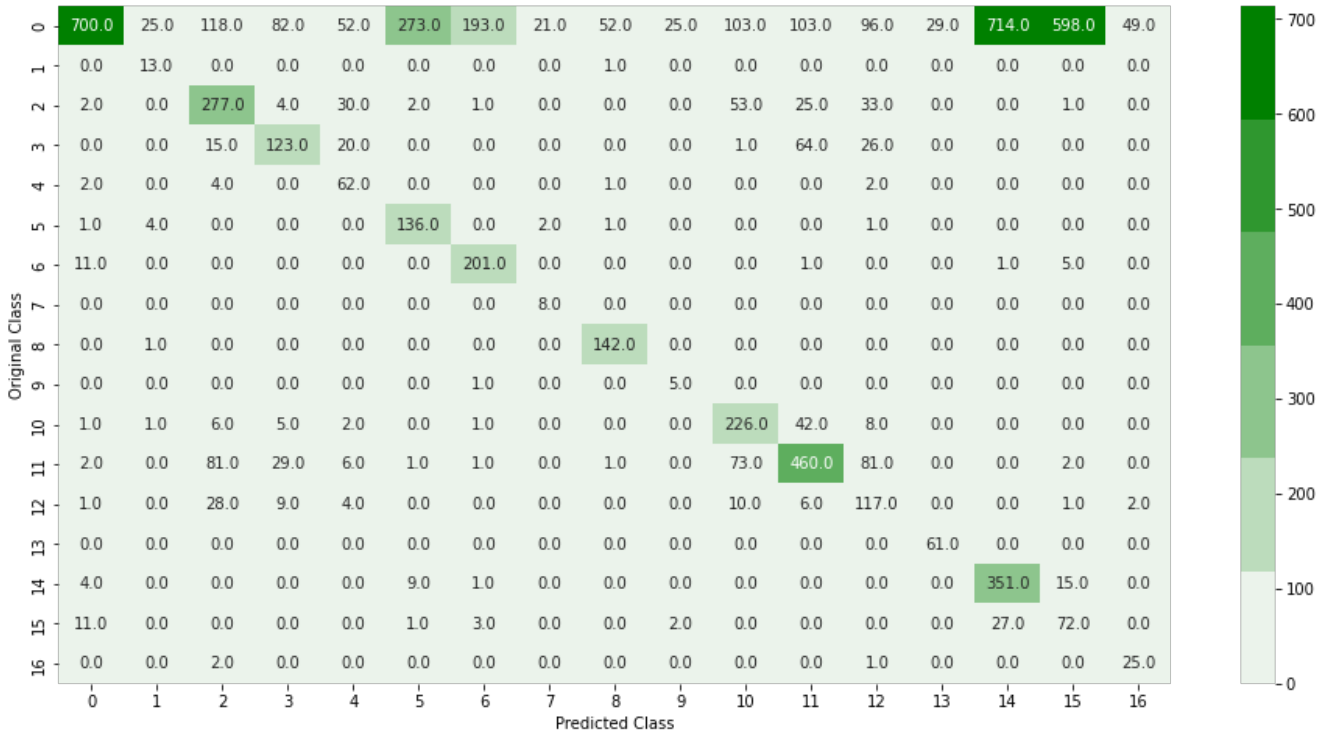
In [ ]:

```
y_pred_4_test = NeuNet_4.predict(X_test_std)
y_pred_pd_4_test = pd.DataFrame(np.argmax(y_pred_4_test,axis=1),index=y_test.index)
```

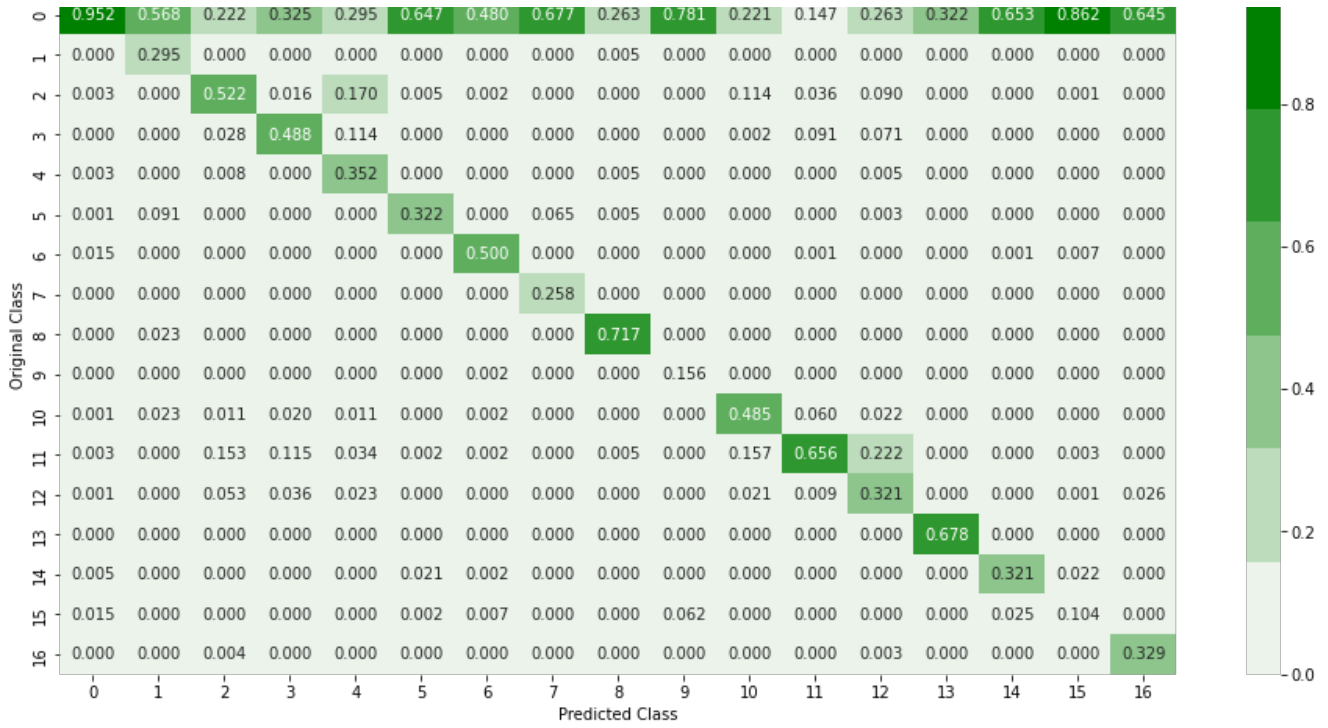
In [ ]:

```
# plot_confusion_matrix(px_class,y_pred_pd_4)
plot_confusion_matrix(y_test,y_pred_pd_4_test)
```

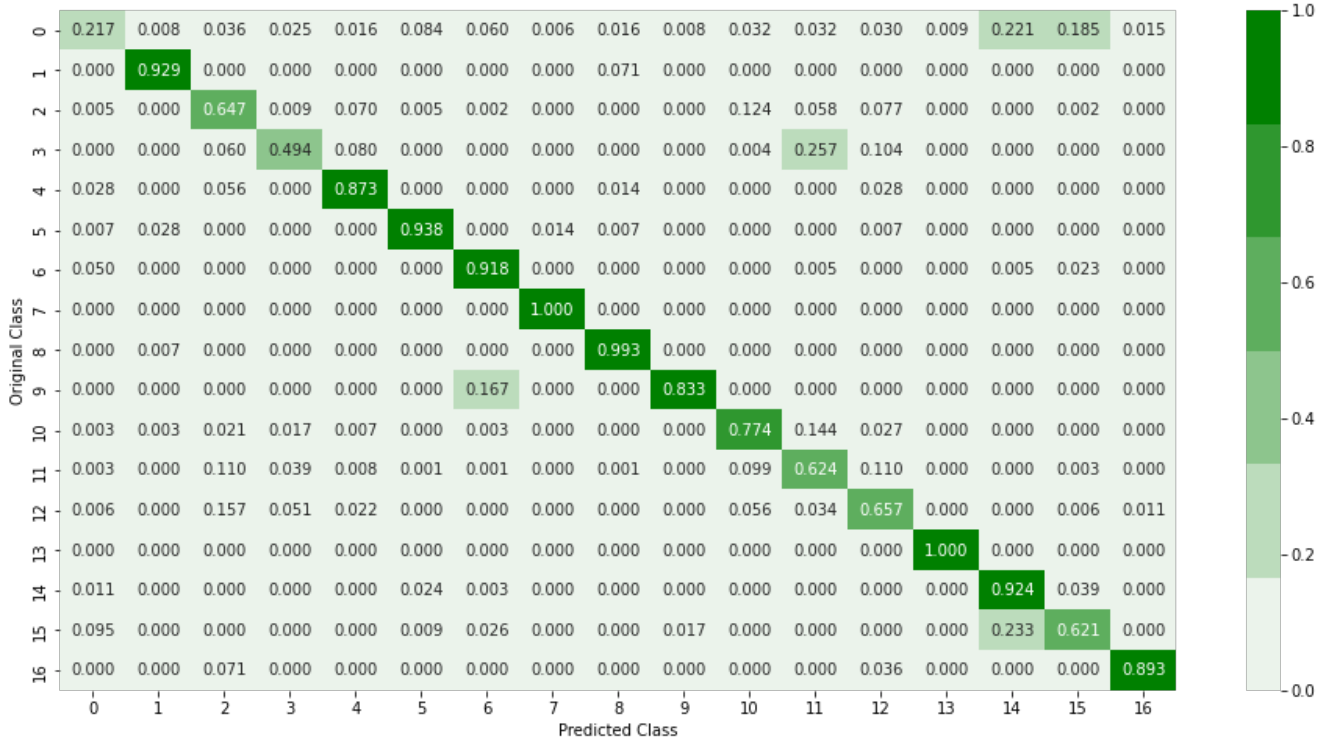
```
Number of misclassified points  52.774254914394426
---------------------------------------------------- Confusion matrix -----------------------------------
---------------
```




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




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




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

- From Recall matrix we can see that most of the classes have been predicted with high recall.
- Precisions are low for most classes except for class 'zero'.
- From precision matrix (first row), we observe that model finds there are similarity among class 'zero' and other classes.

Retrain Model 2

Load saved model weights

Retrain 1

In [ ]:

```
# NeuNet_2.load_weights("/content/m2_weights-65-0.4937.hdf5")
```

In [ ]:

```
# opt = optimizers.Adam(learning_rate=0.0009)
# NeuNet_2.compile(loss='categorical_crossentropy', optimizer = opt, metrics=['accuracy'])
```

logs/20220211-030126 WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback. Epoch 1/50 2/1472 [.....] - ETA: 5:10 - loss: 0.0051 - accuracy: 0.5000 WARNING:tensorflow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0048s vs `on_train_batch_begin` time: 0.0189s). Check your callbacks. WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time: 0.0048s vs `on_train_batch_end` time: 0.0175s). Check your callbacks. 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.4080

micro_F1_train: 0.4197866412991778

micro_F1_val: 0.4085288522511097

Epoch 00001: val_accuracy improved from -inf to 0.40853, saving model to model_5_save/weights-e65+01-0.4085.hdf5 1472/1472 [==============================] - 13s 8ms/step - loss: 0.0045 - accuracy: 0.4080 - val_loss: 1.3893 - val_accuracy: 0.4085 - lr: 9.0000e-04 Epoch 2/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0039 - accuracy: 0.4069

micro_F1_train: 0.43833661751715697

micro_F1_val: 0.42057704502219406

Epoch 00002: val_accuracy improved from 0.40853 to 0.42058, saving model to model_5_save/weights-e65+02-0.4206.hdf5 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0039 - accuracy: 0.4069 - val_loss: 1.3481 - val_accuracy: 0.4206 - lr: 9.0000e-04 Epoch 3/50 1469/1472 [==============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.3920

micro_F1_train: 0.41496228850988653

micro_F1_val: 0.4053582752060875

Epoch 00003: val_accuracy did not improve from 0.42058 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0043 - accuracy: 0.3921 - val_loss: 1.3961 - val_accuracy: 0.4054 - lr: 9.0000e-04 Epoch 4/50 1470/1472 [==============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.3982

micro_F1_train: 0.404566147992118

micro_F1_val: 0.39267596702599866

Epoch 00004: val_accuracy did not improve from 0.42058 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0041 - accuracy: 0.3981 - val_loss: 1.4385 - val_accuracy: 0.3927 - lr: 9.0000e-04 Epoch 5/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0045 - accuracy: 0.3993

micro_F1_train: 0.4146225453557111

micro_F1_val: 0.4036144578313253

Epoch 00005: val_accuracy did not improve from 0.42058 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0045 - accuracy: 0.3993 - val_loss: 1.4889 - val_accuracy: 0.4036 - lr: 8.1000e-04 Epoch 6/50 1464/1472 [==============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4125

micro_F1_train: 0.40612896650132496

micro_F1_val: 0.3979074191502854

Epoch 00006: val_accuracy did not improve from 0.42058 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0040 - accuracy: 0.4127 - val_loss: 1.4660 - val_accuracy: 0.3979 - lr: 8.1000e-04 Epoch 7/50 1463/1472 [==============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4053

micro_F1_train: 0.44900455255826593

micro_F1_val: 0.4437222574508561

Epoch 00007: val_accuracy improved from 0.42058 to 0.44372, saving model to model_5_save/weights-e65+07-0.4437.hdf5 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.4051 - val_loss: 1.3228 - val_accuracy: 0.4437 - lr: 7.2900e-04 Epoch 8/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0041 - accuracy: 0.4098

micro_F1_train: 0.46041992253856084

micro_F1_val: 0.45640456563094484

Epoch 00008: val_accuracy improved from 0.44372 to 0.45640, saving model to model_5_save/weights-e65+08-0.4564.hdf5 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0041 - accuracy: 0.4097 - val_loss: 1.2835 - val_accuracy: 0.4564 - lr: 7.2900e-04 Epoch 9/50 1468/1472 [============================>.] - ETA: 0s - loss: 0.0040 - accuracy: 0.4121

micro_F1_train: 0.4449955833389957

micro_F1_val: 0.4376981610653139

Epoch 00009: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0040 - accuracy: 0.4120 - val_loss: 1.3431 - val_accuracy: 0.4377 - lr: 7.2900e-04 Epoch 10/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4199

micro_F1_train: 0.4498878847591221

micro_F1_val: 0.43864933417882057

Epoch 00010: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 10s 6ms/step - loss: 0.0038 - accuracy: 0.4199 - val_loss: 1.3248 - val_accuracy: 0.4386 - lr: 7.2900e-04 Epoch 11/50 1469/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4151

micro_F1_train: 0.43677379900795

micro_F1_val: 0.4231135066582118

Epoch 00011: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0036 - accuracy: 0.4154 - val_loss: 1.3184 - val_accuracy: 0.4231 - lr: 6.5610e-04 Epoch 12/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0039 - accuracy: 0.4049

micro_F1_train: 0.4566147992117959

micro_F1_val: 0.4495878249841471

Epoch 00012: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0039 - accuracy: 0.4050 - val_loss: 1.2985 - val_accuracy: 0.4496 - lr: 6.5610e-04 Epoch 13/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0043 - accuracy: 0.4118

micro_F1_train: 0.4570224909968064

micro_F1_val: 0.44403931515535827

Epoch 00013: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0043 - accuracy: 0.4118 - val_loss: 1.3001 - val_accuracy: 0.4440 - lr: 5.9049e-04 Epoch 14/50 1467/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4145

micro_F1_train: 0.4394237956105185

micro_F1_val: 0.43024730500951175

Epoch 00014: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0036 - accuracy: 0.4146 - val_loss: 1.3110 - val_accuracy: 0.4302 - lr: 5.9049e-04 Epoch 15/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0045 - accuracy: 0.4161

micro_F1_train: 0.4284161174152341

micro_F1_val: 0.40805326569435635

Epoch 00015: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0045 - accuracy: 0.4160 - val_loss: 1.3578 - val_accuracy: 0.4081 - lr: 5.3144e-04 Epoch 16/50 1462/1472 [============================>.] - ETA: 0s - loss: 0.0034 - accuracy: 0.4142

micro_F1_train: 0.43677379900795

micro_F1_val: 0.42422320862396956

Epoch 00016: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0034 - accuracy: 0.4144 - val_loss: 1.3229 - val_accuracy: 0.4242 - lr: 5.3144e-04 Epoch 17/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4107

micro_F1_train: 0.445267377862336O6

micro_F1_val: 0.4275523145212429

Epoch 00017: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0036 - accuracy: 0.4112 - val_loss: 1.2856 - val_accuracy: 0.4276 - lr: 4.7830e-04 Epoch 18/50 1471/1472 [============================>.] - ETA: 0s - loss: 0.0038 - accuracy: 0.4223

micro_F1_train: 0.4536930080858871

micro_F1_val: 0.4380152187698161

Epoch 00018: val_accuracy did not improve from 0.45640 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0038 - accuracy: 0.4222 - val_loss: 1.2941 - val_accuracy: 0.4380 - lr: 4.7830e-04 Epoch 19/50 1470/1472 [============================>.] - ETA: 0s - loss: 0.0042 - accuracy: 0.4132

micro_F1_train: 0.4732622137663926

micro_F1_val: 0.462428662016487

Epoch 00019: val_accuracy improved from 0.45640 to 0.46243, saving model to model_5_save/weights-e65+19-0.4624.hdf5 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0042 - accuracy: 0.4130 - val_loss: 1.2805 - val_accuracy: 0.4624 - lr: 4.3047e-04 Epoch 20/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0035 - accuracy: 0.4249

micro_F1_train: 0.440035333288034 24

micro_F1_val: 0.4275523145212429

Epoch 00020: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0035 - accuracy: 0.4252 - val_loss: 1.3003 - val_accuracy: 0.4276 - lr: 4.3047e-04 Epoch 21/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0037 - accuracy: 0.4263

micro_F1_train: 0.4439084052456343

micro_F1_val: 0.4329422954977806

Epoch 00021: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0037 - accuracy: 0.4262 - val_loss: 1.3088 - val_accuracy: 0.4329 - lr: 4.3047e-04 Epoch 22/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4255

micro_F1_train: 0.46334171366446963

micro_F1_val: 0.44705136334812934

Epoch 00022: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0033 - accuracy: 0.4258 - val_loss: 1.2816 - val_accuracy: 0.4471 - lr: 3.8742e-04 Epoch 23/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4363

micro_F1_train: 0.43459944282122714

micro_F1_val: 0.42232086239695626

Epoch 00023: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0033 - accuracy: 0.4366 - val_loss: 1.3256 - val_accuracy: 0.4223 - lr: 3.8742e-04 Epoch 24/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4471

micro_F1_train: 0.4411904600122308

micro_F1_val: 0.4272352568167406

Epoch 00024: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4473 - val_loss: 1.2703 - val_accuracy: 0.4272 - lr: 3.4868e-04 Epoch 25/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0034 - accuracy: 0.4360

micro_F1_train: 0.428212271522728 84

micro_F1_val: 0.4128091312618896

Epoch 00025: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0034 - accuracy: 0.4360 - val_loss: 1.3155 - val_accuracy: 0.4128 - lr: 3.4868e-04 Epoch 26/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0034 - accuracy: 0.4376

micro_F1_train: 0.46103146021607666

micro_F1_val: 0.4497463538363982

Epoch 00026: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0034 - accuracy: 0.4370 - val_loss: 1.2471 - val_accuracy: 0.4497 - lr: 3.4868e-04 Epoch 27/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4445

micro_F1_train: 0.4375891825779711

micro_F1_val: 0.4237476220672162

Epoch 00027: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0033 - accuracy: 0.4442 - val_loss: 1.3127 - val_accuracy: 0.4237 - lr: 3.4868e-04 Epoch 28/50 1469/1472 [============================>.] - ETA: 0s - loss: 0.0034 - accuracy: 0.4379

micro_F1_train: 0.46069171706190126

micro_F1_val: 0.4448319594166138

Epoch 00028: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0034 - accuracy: 0.4377 - val_loss: 1.2606 - val_accuracy: 0.4448 - lr: 3.4868e-04 Epoch 29/50 1469/1472 [============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4372

micro_F1_train: 0.44710199089488345

micro_F1_val: 0.43389346861128725

Epoch 00029: val_accuracy did not improve from 0.46243 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0037 - accuracy: 0.4372 - val_loss: 1.2936 - val_accuracy: 0.4339 - lr: 3.1381e-04 Epoch 30/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4435

micro_F1_train: 0.4980634640212

micro_F1_val: 0.48224476854787574

Epoch 00030: val_accuracy improved from 0.46243 to 0.48224, saving model to model_5_save/weights-e65+30-0.4822.hdf5 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0033 - accuracy: 0.4431 - val_loss: 1.2207 - val_accuracy: 0.4822 - lr: 3.1381e-04 Epoch 31/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4563

micro_F1_train: 0.4643609431269 96

micro_F1_val: 0.4497463538363982

Epoch 00031: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0033 - accuracy: 0.4562 - val_loss: 1.2944 - val_accuracy: 0.4497 - lr: 3.1381e-04 Epoch 32/50 1471/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4468

micro_F1_train: 0.46334171366446963

micro_F1_val: 0.45212428662016485

Epoch 00032: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4468 - val_loss: 1.2606 - val_accuracy: 0.4521 - lr: 3.1381e-04 Epoch 33/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0031 - accuracy: 0.4446

micro_F1_train: 0.4678942719304206

micro_F1_val: 0.4573557387444515

Epoch 00033: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4446 - val_loss: 1.2785 - val_accuracy: 0.4574 - lr: 2.8243e-04 Epoch 34/50 1462/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4520

micro_F1_train: 0.4846775837466875

micro_F1_val: 0.47622067216233355

micro_F1_val: 0.4762...

Epoch 00034: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4519 - val_loss: 1.2260 - val_accuracy: 0.4762 - lr: 2.8243e-04 Epoch 35/50 1471/1472 [==============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4525

micro_F1_train: 0.4687776041312768

micro_F1_val: 0.4560875079264426

Epoch 00035: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4526 - val_loss: 1.2522 - val_accuracy: 0.4561 - lr: 2.5419e-04 Epoch 36/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0033 - accuracy: 0.4529

micro_F1_train: 0.4751647754297751

micro_F1_val: 0.4622701331642359

Epoch 00036: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0033 - accuracy: 0.4529 - val_loss: 1.2560 - val_accuracy: 0.4623 - lr: 2.5419e-04 Epoch 37/50 1469/1472 [==============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4481

micro_F1_train: 0.46809811782292593

micro_F1_val: 0.4530754597336715

Epoch 00037: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0033 - accuracy: 0.4482 - val_loss: 1.2611 - val_accuracy: 0.4531 - lr: 2.2877e-04 Epoch 38/50 1466/1472 [==============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4502

micro_F1_train: 0.47468913501392945

micro_F1_val: 0.4619530754597337

Epoch 00038: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0033 - accuracy: 0.4502 - val_loss: 1.2585 - val_accuracy: 0.4620 - lr: 2.2877e-04 Epoch 39/50 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4575

micro_F1_train: 0.4618468437860977

micro_F1_val: 0.4497463538363982

Epoch 00039: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 15s 10ms/step - loss: 0.0031 - accuracy: 0.4575 - val_loss: 1.2697 - val_accuracy: 0.4497 - lr: 2.0589e-04 Epoch 40/50 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4549

micro_F1_train: 0.45790582319766254

micro_F1_val: 0.44419784400760937

Epoch 00040: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 18s 12ms/step - loss: 0.0031 - accuracy: 0.4551 - val_loss: 1.2853 - val_accuracy: 0.4442 - lr: 2.0589e-04 Epoch 41/50 1466/1472 [==============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4499

micro_F1_train: 0.46096351158524157

micro_F1_val: 0.4499048826886493

Epoch 00041: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 16s 11ms/step - loss: 0.0032 - accuracy: 0.4500 - val_loss: 1.2664 - val_accuracy: 0.4499 - lr: 1.8530e-04 Epoch 42/50 1469/1472 [==============================>.] - ETA: 0s - loss: 0.0036 - accuracy: 0.4497

micro_F1_train: 0.44377250798396417

micro_F1_val: 0.42882054533925174

Epoch 00042: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0035 - accuracy: 0.4500 - val_loss: 1.3148 - val_accuracy: 0.4288 - lr: 1.8530e-04 Epoch 43/50 1468/1472 [==============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4501

micro_F1_train: 0.48515322416253315

micro_F1_val: 0.4722574508560558

Epoch 00043: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step

Epoch 00043: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0030 - accuracy: 0.4506 - val_loss: 1.2288 - val_accuracy: 0.4723 - lr: 1.6677e-04 Epoch 44/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4596

micro_F1_train: 0.4733301623972277

micro_F1_val: 0.45719720989220036

Epoch 00044: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0031 - accuracy: 0.4598 - val_loss: 1.2609 - val_accuracy: 0.4572 - lr: 1.6677e-04 Epoch 45/50 1468/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4686

micro_F1_train: 0.47727118298566285

micro_F1_val: 0.46322130627774255

Epoch 00045: val_accuracy did not improve from 0.48224 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0030 - accuracy: 0.4688 - val_loss: 1.2430 - val_accuracy: 0.4632 - lr: 1.5009e-04 Epoch 46/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4684

micro_F1_train: 0.4992865393762316

micro_F1_val: 0.4833544705136335

Epoch 00046: val_accuracy improved from 0.48224 to 0.48335, saving model to model_5_save/weights-e65+46-0.4834.hdf5 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0030 - accuracy: 0.4683 - val_loss: 1.2139 - val_accuracy: 0.4834 - lr: 1.5009e-04 Epoch 47/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4742

micro_F1_train: 0.47557246721478563

micro_F1_val: 0.4613189600507292

Epoch 00047: val_accuracy did not improve from 0.48335 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0031 - accuracy: 0.4743 - val_loss: 1.2461 - val_accuracy: 0.4613 - lr: 1.5009e-04 Epoch 48/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4730

micro_F1_train: 0.4842019433308419

micro_F1_val: 0.47019657577679136

Epoch 00048: val_accuracy did not improve from 0.48335 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0030 - accuracy: 0.4729 - val_loss: 1.2445 - val_accuracy: 0.4702 - lr: 1.5009e-04 Epoch 49/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4715

micro_F1_train: 0.4725147788272066

micro_F1_val: 0.46163601775523144

Epoch 00049: val_accuracy did not improve from 0.48335 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0032 - accuracy: 0.4716 - val_loss: 1.2702 - val_accuracy: 0.4616 - lr: 1.3509e-04 Epoch 50/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4704

micro_F1_train: 0.5028198681796562

micro_F1_val: 0.4889029803424223

Epoch 00050: val_accuracy improved from 0.48335 to 0.48890, saving model to model_5_save/weights-e65+50-0.4889.hdf5 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0032 - accuracy: 0.4705 - val_loss: 1.2075 - val_accuracy: 0.4889 - lr: 1.3509e-04 Time Taken for training (sec): 556.2567737102509

Retrain 2

In [ ]:

```
NeuNet_2.load_weights("/content/model_5_save/weights-e65+50-0.4889.hdf5")
```

In [ ]:

```
opt = optimizers.Adam(learning_rate=0.0001)
NeuNet_2.compile(loss='categorical_crossentropy', optimizer = opt, metrics=['accuracy'])
```

logs/20220211-031907 WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback. Epoch 1/50 2/1472 [..............................] - ETA: 5:17 - loss: 0.0054 - accuracy: 0.5000 WARNING:tensorflow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0040s vs `on_train_batch_begin` time: 0.0199s). Check your callbacks. WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time: 0.0040s vs `on_train_batch_end` time: 0.0176s). Check your callbacks. 1465/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4795

micro_F1_train: 0.4875314262417612

micro_F1_val: 0.4771718452758402

Epoch 00001: val_accuracy improved from -inf to 0.47717, saving model to model_5_save2/weights-e65+50+01-0.4772.hdf5 1472/1472 [==============================] - 13s 8ms/step - loss: 0.0033 - accuracy: 0.4793 - val_loss: 1.2379 - val_accuracy: 0.4772 Epoch 2/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4799

micro_F1_train: 0.4989467962220561

micro_F1_val: 0.4843056436271401

Epoch 00002: val_accuracy improved from 0.47717 to 0.48431, saving model to model_5_save2/weights-e65+50+02-0.4843.hdf5 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4801 - val_loss: 1.2088 - val_accuracy: 0.4843 Epoch 3/50 1470/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4754

micro_F1_train: 0.49038526873683497

micro_F1_val: 0.4771718452758402

Epoch 00003: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4755 - val_loss: 1.2315 - val_accuracy: 0.4772 Epoch 4/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4707

micro_F1_train: 0.47733913161649794

micro_F1_val: 0.45989220038046924

Epoch 00004: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0032 - accuracy: 0.4703 - val_loss: 1.2454 - val_accuracy: 0.4599 Epoch 5/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4696

micro_F1_train: 0.4914044981993613

micro_F1_val: 0.47479391249207353

Epoch 00005: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4701 - val_loss: 1.2199 - val_accuracy: 0.4748 Epoch 6/50 1469/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4725

micro_F1_train: 0.4824352789291296

micro_F1_val: 0.46480659480025366

Epoch 00006: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4724 - val_loss: 1.2432 - val_accuracy: 0.4648 Epoch 7/50 1470/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4752

micro_F1_train: 0.48658014541007

micro_F1_val: 0.47305009511731133

Epoch 00007: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4752 - val_loss: 1.2313 - val_accuracy: 0.4731 Epoch 8/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4645

micro_F1_train: 0.4974519263436842

micro_F1_val: 0.4835129993658846

Epoch 00008: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4650 - val_loss: 1.2218 - val_accuracy: 0.4835 Epoch 9/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4745

micro_F1_train: 0.49058911462934024

micro_F1_val: 0.47463538363982244

Epoch 00009: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4743 - val_loss: 1.2405 - val_accuracy: 0.4746 Epoch 10/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4755

micro_F1_train: 0.48977373105931915

micro_F1_val: 0.4751109701965758

Epoch 00010: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4753 - val_loss: 1.2182 - val_accuracy: 0.4751 Epoch 11/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0030 - accuracy: 0.4618

micro_F1_train: 0.4813481008357682

micro_F1_val: 0.4670259987317692

Epoch 00011: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0030 - accuracy: 0.4618 - val_loss: 1.2397 - val_accuracy: 0.4670 Epoch 12/50 1470/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4756

micro_F1_train: 0.48719168308758576

micro_F1_val: 0.4714648065948003

Epoch 00012: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4758 - val_loss: 1.2198 - val_accuracy: 0.4715 Epoch 13/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0035 - accuracy: 0.4766

micro_F1_train: 0.46932119317795745

micro_F1_val: 0.45339251743817377

Epoch 00013: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0035 - accuracy: 0.4767 - val_loss: 1.2638 - val_accuracy: 0.4534 Epoch 14/50 1467/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4678

micro_F1_train: 0.4769993884623225

micro_F1_val: 0.4643310082435003

Epoch 00014: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0030 - accuracy: 0.4676 - val_loss: 1.2529 - val_accuracy: 0.4643 Epoch 15/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4771

micro_F1_train: 0.4944621865869403

micro_F1_val: 0.47622067216233355

Epoch 00015: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0028 - accuracy: 0.4771 - val_loss: 1.2269 - val_accuracy: 0.4762 Epoch 16/50 1464/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4786

micro_F1_train: 0.49228783040021745

micro_F1_val: 0.4776474318325935

Epoch 00016: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4788 - val_loss: 1.2216 - val_accuracy: 0.4776 Epoch 17/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4754

micro_F1_train: 0.4898416796901543

micro_F1_val: 0.4741597970830691

Epoch 00017: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 13s 9ms/step - loss: 0.0029 - accuracy: 0.4747 - val_loss: 1.2253 - val_accuracy: 0.4742 Epoch 18/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4829

micro_F1_train: 0.4948698783719508

micro_F1_val: 0.47479391249207353

Epoch 00018: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4826 - val_loss: 1.2115 - val_accuracy: 0.4748 Epoch 19/50 1470/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4818

micro_F1_train: 0.4982673099137052

micro_F1_val: 0.478281547241598

Epoch 00019: val_accuracy did not improve from 0.48431 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4815 - val_loss: 1.2206 - val_accuracy: 0.4783 Epoch 20/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0028 - accuracy: 0.4784

micro_F1_train: 0.5096826798940002

micro_F1_val: 0.48922003804692454

Epoch 00020: val_accuracy improved from 0.48431 to 0.48922, saving model to model_5_save2/weights-e65+50+20-0.4892.hdf5 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4784 - val_loss: 1.2064 - val_accuracy: 0.4892 Epoch 21/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0028 - accuracy: 0.4839

micro_F1_train: 0.5008493578854386

micro_F1_val: 0.4803424223208624

Epoch 00021: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4839 - val_loss: 1.2194 - val_accuracy: 0.4803 Epoch 22/50 1463/1472 [==============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4802

micro_F1_train: 0.49276347081606303

micro_F1_val: 0.4733671528218136

Epoch 00022: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0031 - accuracy: 0.4805 - val_loss: 1.2210 - val_accuracy: 0.4734 Epoch 23/50 1469/1472 [==============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4734

micro_F1_train: 0.49235577903105254

micro_F1_val: 0.47400126823081806

Epoch 00023: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0031 - accuracy: 0.4731 - val_loss: 1.2292 - val_accuracy: 0.4740 Epoch 24/50 1465/1472 [==============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4756

micro_F1_train: 0.49636474825032273

micro_F1_val: 0.4785986049461002

Epoch 00024: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0030 - accuracy: 0.4754 - val_loss: 1.2136 - val_accuracy: 0.4786 Epoch 25/50 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4800

micro_F1_train: 0.48868655296595775

micro_F1_val: 0.4724159797083069

Epoch 00025: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4801 - val_loss: 1.2261 - val_accuracy: 0.4724 Epoch 26/50 1464/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4671

micro_F1_train: 0.5055378134130597

micro_F1_val: 0.48652504755865567

Epoch 00026: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0029 - accuracy: 0.4671 - val_loss: 1.1996 - val_accuracy: 0.4865 Epoch 27/50 1463/1472 [==============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4819

micro_F1_train: 0.49949038526873685

micro_F1_val: 0.48161065313887125

Epoch 00027: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4819 - val_loss: 1.2103 - val_accuracy: 0.4816 Epoch 28/50 1465/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4777

micro_F1_train: 0.4991506421145614

micro_F1_val: 0.4784400760938491

Epoch 00028: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4781 - val_loss: 1.2118 - val_accuracy: 0.4784 Epoch 29/50 1466/1472 [==============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4833

micro_F1_train: 0.5079839641231 23

micro_F1_val: 0.4881103360811668

Epoch 00029: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0030 - accuracy: 0.4837 - val_loss: 1.2035 - val_accuracy: 0.4881 Epoch 30/50 1471/1472 [==============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4811

micro_F1_train: 0.5022762791329755

micro_F1_val: 0.48398858592263794

Epoch 00030: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0030 - accuracy: 0.4810 - val_loss: 1.2091 - val_accuracy: 0.4840 Epoch 31/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0028 - accuracy: 0.4966

micro_F1_train: 0.5013249983012842

micro_F1_val: 0.48113506658211797

Epoch 00031: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.4966 - val_loss: 1.2122 - val_accuracy: 0.4811 Epoch 32/50 1471/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4772

micro_F1_train: 0.5030916627029965

micro_F1_val: 0.4808180088776157

Epoch 00032: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4773 - val_loss: 1.1952 - val_accuracy: 0.4808 Epoch 33/50 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4766

micro_F1_train: 0.48630835088672963

micro_F1_val: 0.4678186429930247

Epoch 00033: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4771 - val_loss: 1.2345 - val_accuracy: 0.4678 Epoch 34/50 1464/1472 [==============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4780

micro_F1_train: 0.4917442413535367

micro_F1_val: 0.4749524413443247

Epoch 00034: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4778 - val_loss: 1.2235 - val_accuracy: 0.4750 Epoch 35/50 1465/1472 [==============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4810

micro_F1_train: 0.5003737174695 93

micro_F1_val: 0.4819277108433735

Epoch 00035: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4812 - val_loss: 1.2113 - val_accuracy: 0.4819 Epoch 36/50 1465/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4898

micro_F1_train: 0.5001019229462527

micro_F1_val: 0.4835129993658846

Epoch 00036: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 8ms/step -

loss: 0.0029 - accuracy: 0.4898 - val_loss: 1.2060 - val_accuracy: 0.4835 Epoch 37/50 1470/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4814

micro_F1_train: 0.48963783379764897

micro_F1_val: 0.47130627774254913

Epoch 00037: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0032 - accuracy: 0.4813 - val_loss: 1.2346 - val_accuracy: 0.4713 Epoch 38/50 1468/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4813

micro_F1_train: 0.4980634640212

micro_F1_val: 0.478281547241598

Epoch 00038: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4818 - val_loss: 1.2195 - val_accuracy: 0.4783 Epoch 39/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4797

micro_F1_train: 0.4828429707141401

micro_F1_val: 0.46591629676601143

Epoch 00039: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0031 - accuracy: 0.4794 - val_loss: 1.2459 - val_accuracy: 0.4659 Epoch 40/50 1465/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4752

micro_F1_train: 0.491200652306856

micro_F1_val: 0.47463538363982244

Epoch 00040: val_accuracy did not improve from 0.48922 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4752 - val_loss: 1.2134 - val_accuracy: 0.4746 Epoch 41/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0030 - accuracy: 0.4786

micro_F1_train: 0.511109601141537

micro_F1_val: 0.4930247305009512

Epoch 00041: val_accuracy improved from 0.48922 to 0.49302, saving model to model_5_save2/weights-e65+50+41-0.4930.hdf5 1472/1472 [==============================] - 12s 8ms/step - loss: 0.0030 - accuracy: 0.4786 - val_loss: 1.1793 - val_accuracy: 0.4930 Epoch 42/50 1466/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4854

micro_F1_train: 0.4992185907453965

micro_F1_val: 0.4755865567533291

Epoch 00042: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4853 - val_loss: 1.2086 - val_accuracy: 0.4756 Epoch 43/50 1463/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4815

micro_F1_train: 0.5030237140721614

micro_F1_val: 0.4833544705136335

Epoch 00043: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4816 - val_loss: 1.1886 - val_accuracy: 0.4834 Epoch 44/50 1461/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4875

micro_F1_train: 0.4956173133111368

micro_F1_val: 0.47622067216233355

Epoch 00044: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4871 - val_loss: 1.2170 - val_accuracy: 0.4762 Epoch 45/50 1471/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4838

micro_F1_train: 0.5017326900862947

micro_F1_val: 0.4862079898541535

Epoch 00045: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0030 - accuracy: 0.4839 - val_loss: 1.1929 - val_accuracy: 0.4862 Epoch 46/50 1471/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4954

micro_F1_train: 0.4928993680777332

micro_F1_val: 0.4766962587190869

Epoch 00046: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.4953 - val_loss: 1.2260 - val_accuracy: 0.4767 Epoch 47/50 1470/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4816

micro_F1_train: 0.4875993748725963

micro_F1_val: 0.4724159797083069

Epoch 00047: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4816 - val_loss: 1.2171 - val_accuracy: 0.4724 Epoch 48/50 1472/1472 [==============================] - ETA: 0s - loss: 0.0029 - accuracy: 0.4822

micro_F1_train: 0.500373717469593

micro_F1_val: 0.4825618262523779

Epoch 00048: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4822 - val_loss: 1.1981 - val_accuracy: 0.4826 Epoch 49/50 1470/1472 [==============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4899

micro_F1_train: 0.5107019093565265

micro_F1_val: 0.49286620164870004

Epoch 00049: val_accuracy did not improve from 0.49302 1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4897 - val_loss: 1.1890 - val_accuracy: 0.4929 Epoch 50/50 1467/1472 [==============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4813

micro_F1_train: 0.5160698511924985

micro_F1_val: 0.49603677869372226

Epoch 00050: val_accuracy improved from 0.49302 to 0.49604, saving model to model_5_save2/weights-e65+50+50-0.4960.hdf5 1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4816 - val_loss: 1.1668 - val_accuracy: 0.4960 Time Taken for training (sec): 562.9610755443573

Retrain 3

In [ ]:

```
NeuNet_2.load_weights("/content/m2_weights-e65+50+50-0.4960.hdf5")
```

In [ ]:

```
opt = optimizers.Adam(learning_rate=0.0001)
NeuNet_2.compile(loss='categorical_crossentropy', optimizer = opt, metrics=['accuracy'])
```

In [ ]:

```
logdir = os.path.join("logs", datetime.now().strftime("%Y%m%d-%H%M%S"))
print(logdir)
file_writer = tf.summary.create_file_writer(logdir + "/metrics")
# tensorboard = TensorBoard(log_dir=logdir)
tensorboard = TensorBoard(log_dir=logdir, histogram_freq=1, write_graph=True,write_grads=True)

metric_calc_5 = metric_calc()

# Saving model at every epoch if validation accuracy is improved from previous epoch
filepath_m5="model_5_save3/weights-e65+50+50+{epoch:02d}-{val_accuracy:.4f}.hdf5"
checkpoint_m5 = ModelCheckpoint(filepath=filepath_m5, monitor='val_accuracy',  verbose=1,
                                save_best_only=True,
                                mode='auto')
# earlystop_m5 = EarlyStopping(monitor='val_accuracy', min_delta=0.01, patience=20, verbose=1)
# reduce_lr_m5 = ReduceLROnPlateau(monitor='val_loss', factor=0.9, patience=2, min_lr=0.0001)

callback_list_5 = [metric_calc_5
```

```
callback_list_5 = [metric_calc_5,
                   checkpoint_m5,
                   #earlystop_m5,
                   #reduce_lr_m5,
                   tensorboard]
# fit network
verbose_5, epochs_5, batch_size_5 = 1, 50, 10
start = time.time()
history_5 = NeuNet_2.fit(X_train_std, y_ctg_train,
                         class_weight = class_wts,
                         validation_data=(X_test_std,y_ctg_test),
                         epochs=epochs_5,
                         batch_size=batch_size_5,
                         verbose=verbose_5,
                         callbacks=callback_list_5)

# Passing the F1 score data of each epoch to tensor board
# https://stackoverflow.com/questions/58102016/how-visualize-in-tensorboard-a-metric-callback
for i in range(len(metric_calc_5.metrics['micro_F1_train'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_train', metric_calc_5.metrics['micro_F1_train'][i])
file_writer.flush()

for i in range(len(metric_calc_5.metrics['micro_F1_val'])):
    with file_writer.as_default(step=i+1):
        tf.summary.scalar('micro_F1_val', metric_calc_5.metrics['micro_F1_val'][i])
file_writer.flush()

stop = time.time()
print('Time Taken for training (sec): ',stop-start)
```

```
logs/20220211-113500
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/50
   2/1472 [..............................] - ETA: 5:01 - loss: 0.0036 - accuracy: 0.5000 WARNING:tensor
flow:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0051s vs
`on_train_batch_begin` time: 0.0180s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch time:
0.0051s vs `on_train_batch_end` time: 0.0182s). Check your callbacks.
1463/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4925

micro_F1_train:  0.49582115920364206

micro_F1_val:  0.4819277108433735

Epoch 00001: val_accuracy improved from -inf to 0.48193, saving model to model_5_save3/weights-e65+50+5
0+01-0.4819.hdf5
1472/1472 [==============================] - 12s 7ms/step - loss: 0.0030 - accuracy: 0.4922 - val_loss:
1.2308 - val_accuracy: 0.4819
Epoch 2/50
1467/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4859

micro_F1_train:  0.5053339675205545

micro_F1_val:  0.4903297400126823

Epoch 00002: val_accuracy improved from 0.48193 to 0.49033, saving model to model_5_save3/weights-e65+5
0+50+02-0.4903.hdf5
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0027 - accuracy: 0.4859 - val_loss:
1.1882 - val_accuracy: 0.4903
Epoch 3/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4797

micro_F1_train:  0.4980634640212

micro_F1_val:  0.4809765377298668

Epoch 00003: val_accuracy did not improve from 0.49033
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0030 - accuracy: 0.4796 - val_loss:
1.2130 - val_accuracy: 0.4810
Epoch 4/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4870

micro_F1_train:  0.5104301148331861

micro_F1_val:  0.4906467977171845
```

```
Epoch 00004: val_accuracy improved from 0.49033 to 0.49065, saving model to model_5_save3/weights-e65+5
0+50+04-0.4906.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0027 - accuracy: 0.4871 - val_loss:
1.1850 - val_accuracy: 0.4906
Epoch 5/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4832

micro_F1_train:  0.5033634572263369

micro_F1_val:  0.4836715282181357

Epoch 00005: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4833 - val_loss:
1.1906 - val_accuracy: 0.4837
Epoch 6/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4828

micro_F1_train:  0.5048583271047088

micro_F1_val:  0.48826886493341787

Epoch 00006: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0030 - accuracy: 0.4837 - val_loss:
1.1922 - val_accuracy: 0.4883
Epoch 7/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4876

micro_F1_train:  0.5007814092546036

micro_F1_val:  0.4809765377298668

Epoch 00007: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4877 - val_loss:
1.2134 - val_accuracy: 0.4810
Epoch 8/50
1462/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4866

micro_F1_train:  0.5077121695997826

micro_F1_val:  0.4885859226379201

Epoch 00008: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0028 - accuracy: 0.4866 - val_loss:
1.1988 - val_accuracy: 0.4886
Epoch 9/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4881

micro_F1_train:  0.5051301216280492

micro_F1_val:  0.4881103360811668

Epoch 00009: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4881 - val_loss:
1.1922 - val_accuracy: 0.4881
Epoch 10/50
1470/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4882

micro_F1_train:  0.48345450839165593

micro_F1_val:  0.463855421686747

Epoch 00010: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4884 - val_loss:
1.2326 - val_accuracy: 0.4639
Epoch 11/50
1472/1472 [==============================] - ETA: 0s - loss: 0.0028 - accuracy: 0.4807

micro_F1_train:  0.5090711422164843

micro_F1_val:  0.4881103360811668

Epoch 00011: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.4807 - val_loss:
1.1934 - val_accuracy: 0.4881
Epoch 12/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4854
```

```
micro_F1_train:  0.5015967928246245

micro_F1_val:  0.48319594166138236

Epoch 00012: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4856 - val_loss:
1.2165 - val_accuracy: 0.4832
Epoch 13/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4952

micro_F1_train:  0.506489094244751

micro_F1_val:  0.4868421052631579

Epoch 00013: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0027 - accuracy: 0.4950 - val_loss:
1.2064 - val_accuracy: 0.4868
Epoch 14/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4900

micro_F1_train:  0.5092749881089896

micro_F1_val:  0.49001268230818007

Epoch 00014: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4901 - val_loss:
1.1918 - val_accuracy: 0.4900
Epoch 15/50
1465/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4898

micro_F1_train:  0.5045185839505334

micro_F1_val:  0.487000634115409

Epoch 00015: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4900 - val_loss:
1.1977 - val_accuracy: 0.4870
Epoch 16/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4915

micro_F1_train:  0.5028198681796562

micro_F1_val:  0.4850982878883957

Epoch 00016: val_accuracy did not improve from 0.49065
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0027 - accuracy: 0.4916 - val_loss:
1.2027 - val_accuracy: 0.4851
Epoch 17/50
1467/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4851

micro_F1_train:  0.5108378066181967

micro_F1_val:  0.4914394419784401

Epoch 00017: val_accuracy improved from 0.49065 to 0.49144, saving model to model_5_save3/weights-e65+5
0+50+17-0.4914.hdf5
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0029 - accuracy: 0.4852 - val_loss:
1.1875 - val_accuracy: 0.4914
Epoch 18/50
1472/1472 [==============================] - ETA: 0s - loss: 0.0029 - accuracy: 0.4926

micro_F1_train:  0.5039070462730176

micro_F1_val:  0.48462270133164237

Epoch 00018: val_accuracy did not improve from 0.49144
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4926 - val_loss:
1.2140 - val_accuracy: 0.4846
Epoch 19/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4846

micro_F1_train:  0.4954134674186315

micro_F1_val:  0.47685478757133803

Epoch 00019: val_accuracy did not improve from 0.49144
```

```
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0029 - accuracy: 0.4847 - val_loss:
1.2161 - val_accuracy: 0.4769
Epoch 20/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4913

micro_F1_train:  0.5210980498742951

micro_F1_val:  0.49889029803424223

Epoch 00020: val_accuracy improved from 0.49144 to 0.49889, saving model to model_5_save3/weights-e65+5
0+50+20-0.4989.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4917 - val_loss:
1.1676 - val_accuracy: 0.4989
Epoch 21/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4946

micro_F1_train:  0.5189916423184073

micro_F1_val:  0.49873176918199114

Epoch 00021: val_accuracy did not improve from 0.49889
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4943 - val_loss:
1.1814 - val_accuracy: 0.4987
Epoch 22/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4905

micro_F1_train:  0.5075083237072773

micro_F1_val:  0.48478123018389346

Epoch 00022: val_accuracy did not improve from 0.49889
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4908 - val_loss:
1.1993 - val_accuracy: 0.4848
Epoch 23/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4935

micro_F1_train:  0.49955833389957194

micro_F1_val:  0.48050095117311353

Epoch 00023: val_accuracy did not improve from 0.49889
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4933 - val_loss:
1.2056 - val_accuracy: 0.4805
Epoch 24/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4985

micro_F1_train:  0.5135557518516002

micro_F1_val:  0.49381737476220 67

Epoch 00024: val_accuracy did not improve from 0.49889
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4985 - val_loss:
1.1761 - val_accuracy: 0.4938
Epoch 25/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.5004

micro_F1_train:  0.5155942107766529

micro_F1_val:  0.49429296131896006

Epoch 00025: val_accuracy did not improve from 0.49889
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.5006 - val_loss:
1.1810 - val_accuracy: 0.4943
Epoch 26/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0032 - accuracy: 0.4900

micro_F1_train:  0.5227967656451723

micro_F1_val:  0.49968294229549776

Epoch 00026: val_accuracy improved from 0.49889 to 0.49968, saving model to model_5_save3/weights-e65+5
0+50+26-0.4997.hdf5
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0032 - accuracy: 0.4895 - val_loss:
1.1879 - val_accuracy: 0.4997
Epoch 27/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4939
```

```
micro_F1_train:  0.5266698376027723

micro_F1_val:  0.5031705770450222

Epoch 00027: val_accuracy improved from 0.49968 to 0.50317, saving model to model_5_save3/weights-e65+5
0+50+27-0.5032.hdf5
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.4942 - val_loss:
1.1790 - val_accuracy: 0.5032
Epoch 28/50
1469/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4990

micro_F1_train:  0.5113813956648774

micro_F1_val:  0.4879518072289157

Epoch 00028: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0027 - accuracy: 0.4987 - val_loss:
1.1930 - val_accuracy: 0.4880
Epoch 29/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4925

micro_F1_train:  0.5030916627029965

micro_F1_val:  0.4825618262523779

Epoch 00029: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4924 - val_loss:
1.2150 - val_accuracy: 0.4826
Epoch 30/50
1467/1472 [============================>.] - ETA: 0s - loss: 0.0033 - accuracy: 0.4907

micro_F1_train:  0.5048583271047088

micro_F1_val:  0.48319594166138236

Epoch 00030: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0033 - accuracy: 0.4906 - val_loss:
1.2151 - val_accuracy: 0.4832
Epoch 31/50
1462/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4948

micro_F1_train:  0.5087993476931439

micro_F1_val:  0.48589093214965123

Epoch 00031: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4946 - val_loss:
1.2138 - val_accuracy: 0.4859
Epoch 32/50
1465/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4976

micro_F1_train:  0.5185839505333968

micro_F1_val:  0.4950856055802156

Epoch 00032: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4979 - val_loss:
1.1941 - val_accuracy: 0.4951
Epoch 33/50
1465/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4986

micro_F1_train:  0.5168172861316844

micro_F1_val:  0.4931832593532023

Epoch 00033: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0027 - accuracy: 0.4983 - val_loss:
1.2055 - val_accuracy: 0.4932
Epoch 34/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4892

micro_F1_train:  0.5060134538289054

micro_F1_val:  0.48652504755865567

Epoch 00034: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4894 - val_loss:
```

```
1.2000 - val_accuracy: 0.4865
Epoch 35/50
1467/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4941

micro_F1_train:  0.5085275531698036

micro_F1_val:  0.4879518072289157

Epoch 00035: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0028 - accuracy: 0.4943 - val_loss:
1.2029 - val_accuracy: 0.4880
Epoch 36/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0030 - accuracy: 0.4952

micro_F1_train:  0.49887884759122103

micro_F1_val:  0.4784400760938491

Epoch 00036: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0030 - accuracy: 0.4951 - val_loss:
1.2321 - val_accuracy: 0.4784
Epoch 37/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4917

micro_F1_train:  0.5004416661004281

micro_F1_val:  0.4800253646163602

Epoch 00037: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0029 - accuracy: 0.4918 - val_loss:
1.2241 - val_accuracy: 0.4800
Epoch 38/50
1471/1472 [============================>.] - ETA: 0s - loss: 0.0031 - accuracy: 0.4918

micro_F1_train:  0.5081198613847931

micro_F1_val:  0.48668357641090676

Epoch 00038: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 10s 7ms/step - loss: 0.0031 - accuracy: 0.4919 - val_loss:
1.2062 - val_accuracy: 0.4867
Epoch 39/50
1462/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4960

micro_F1_train:  0.5205544608276144

micro_F1_val:  0.4982561826252378

Epoch 00039: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0027 - accuracy: 0.4962 - val_loss:
1.1810 - val_accuracy: 0.4983
Epoch 40/50
1469/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4989

micro_F1_train:  0.5156621594074879

micro_F1_val:  0.48922003804692454

Epoch 00040: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0028 - accuracy: 0.4988 - val_loss:
1.1953 - val_accuracy: 0.4892
Epoch 41/50
1466/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4937

micro_F1_train:  0.5168852347625196

micro_F1_val:  0.49286620164870004

Epoch 00041: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4941 - val_loss:
1.1772 - val_accuracy: 0.4929
Epoch 42/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4948

micro_F1_train:  0.5077121695997826

micro_F1_val:  0.4825618262523779
```

```
Epoch 00042: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0027 - accuracy: 0.4945 - val_loss:
1.2122 - val_accuracy: 0.4826
Epoch 43/50
1467/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4918

micro_F1_train:  0.5109057552490317

micro_F1_val:  0.48478123018389346

Epoch 00043: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 12s 8ms/step - loss: 0.0028 - accuracy: 0.4919 - val_loss:
1.1918 - val_accuracy: 0.4848
Epoch 44/50
1470/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4978

micro_F1_train:  0.5163416457158388

micro_F1_val:  0.4936588459099556

Epoch 00044: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0027 - accuracy: 0.4976 - val_loss:
1.1886 - val_accuracy: 0.4937
Epoch 45/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4975

micro_F1_train:  0.514914724468302

micro_F1_val:  0.4879518072289157

Epoch 00045: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0028 - accuracy: 0.4977 - val_loss:
1.1950 - val_accuracy: 0.4880
Epoch 46/50
1463/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4928

micro_F1_train:  0.5125365223890739

micro_F1_val:  0.48922003804692454

Epoch 00046: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4930 - val_loss:
1.1919 - val_accuracy: 0.4892
Epoch 47/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.5016

micro_F1_train:  0.5163416457158388

micro_F1_val:  0.4895370957514268

Epoch 00047: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.5016 - val_loss:
1.1825 - val_accuracy: 0.4895
Epoch 48/50
1468/1472 [============================>.] - ETA: 0s - loss: 0.0029 - accuracy: 0.4980

micro_F1_train:  0.5115852415573826

micro_F1_val:  0.48779327837666453

Epoch 00048: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0029 - accuracy: 0.4979 - val_loss:
1.1995 - val_accuracy: 0.4878
Epoch 49/50
1470/1472 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.4980

micro_F1_train:  0.5165454916083441

micro_F1_val:  0.4930247305009512

Epoch 00049: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 8ms/step - loss: 0.0027 - accuracy: 0.4981 - val_loss:
1.1881 - val_accuracy: 0.4930
Epoch 50/50
1469/1472 [============================>.] - ETA: 0s - loss: 0.0028 - accuracy: 0.4948
```

```
micro_F1_train:  0.5219134334443161

micro_F1_val:  0.49698795180722893

Epoch 00050: val_accuracy did not improve from 0.50317
1472/1472 [==============================] - 11s 7ms/step - loss: 0.0028 - accuracy: 0.4951 - val_loss:
1.1838 - val_accuracy: 0.4970
Time Taken for training (sec):  563.025274515152
```

In [ ]:

```
# http://localhost:6006/
%load_ext tensorboard
%tensorboard --logdir logs --host localhost
```

Model 2 Retrain Predictions

In [ ]:

```
NeuNet_2.load_weights("/content/m2_weights-e65+50+50+27-0.5032.hdf5")
```

In [ ]:

```
px_data_std = pd.DataFrame(Scaler.transform(px_data))
px_data_std = px_data_std.drop(feature_correlated,axis=1)
```

In [ ]:

```
# %%timeit
y_pred_5 = NeuNet_2.predict(px_data_std)
```

In [ ]:

```
np.argmax(y_pred_5,axis=1)
```

Out[ ]:

```
array([ 3,  3, 12, ..., 14, 14, 14])
```

In [ ]:

```
y_pred_pd_5 = pd.DataFrame(np.argmax(y_pred_5,axis=1),index=px_data.index)
# y_pred_pd[0] = y_pred_pd[0]+1
```

In [ ]:

```
%%timeit
t = y_pred_pd_5.to_numpy().reshape((145,145))
```

```
The slowest run took 18.32 times longer than the fastest. This could mean that an intermediate result i
s being cached.
100000 loops, best of 5: 4.02 µs per loop
```

In [ ]:

```
# y_pred_pd_5
```

In [ ]:

```
y_pred_pd_5.value_counts()
```

Out[ ]:

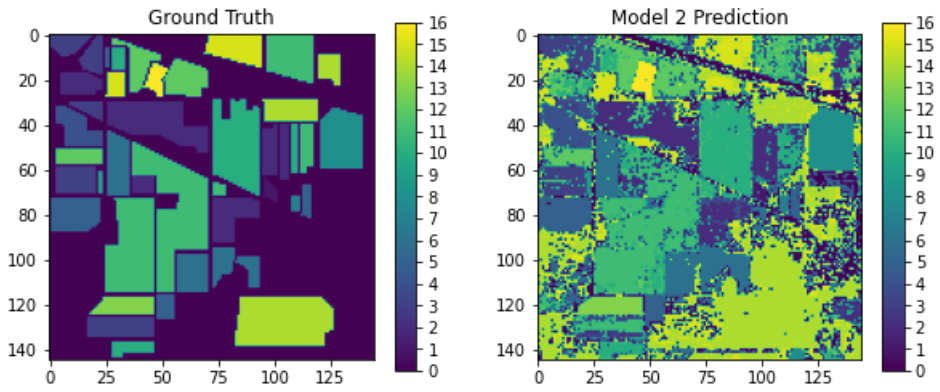
```
14    3394
15    2805
0     2582
11    2144
10    1654
2     1625
12    1409
6     1366
5     1082
3      966
8      644
4      621
13     258
16     218
9      146
1       56
7       55
dtype: int64
```

In [ ]:

```
# px_data.index
```

In [ ]:

```
figr,axis = plt.subplots(1,2,figsize=(10,10))
im0 = axis[0].imshow(mat_gt['indian_pines_gt'])#,cmap='jet')
axis[0].set_title('Ground Truth')
plt.colorbar(im0,ax=axis[0],shrink=0.4,aspect=16, ticks=range(0,17,1))

im1 = axis[1].imshow(y_pred_pd_5.to_numpy().reshape((145,145)))#,cmap='jet')
axis[1].set_title('Model 2 Prediction')
plt.colorbar(im1,ax=axis[1],shrink=0.4,aspect=16, ticks=range(0,17,1))
# plt.savefig('NeuNet_4_e100.png')
plt.show()
```



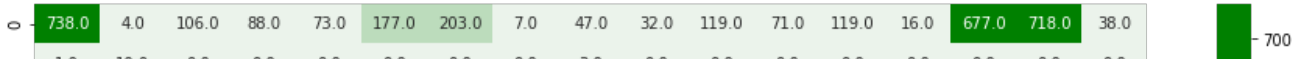
In [ ]:

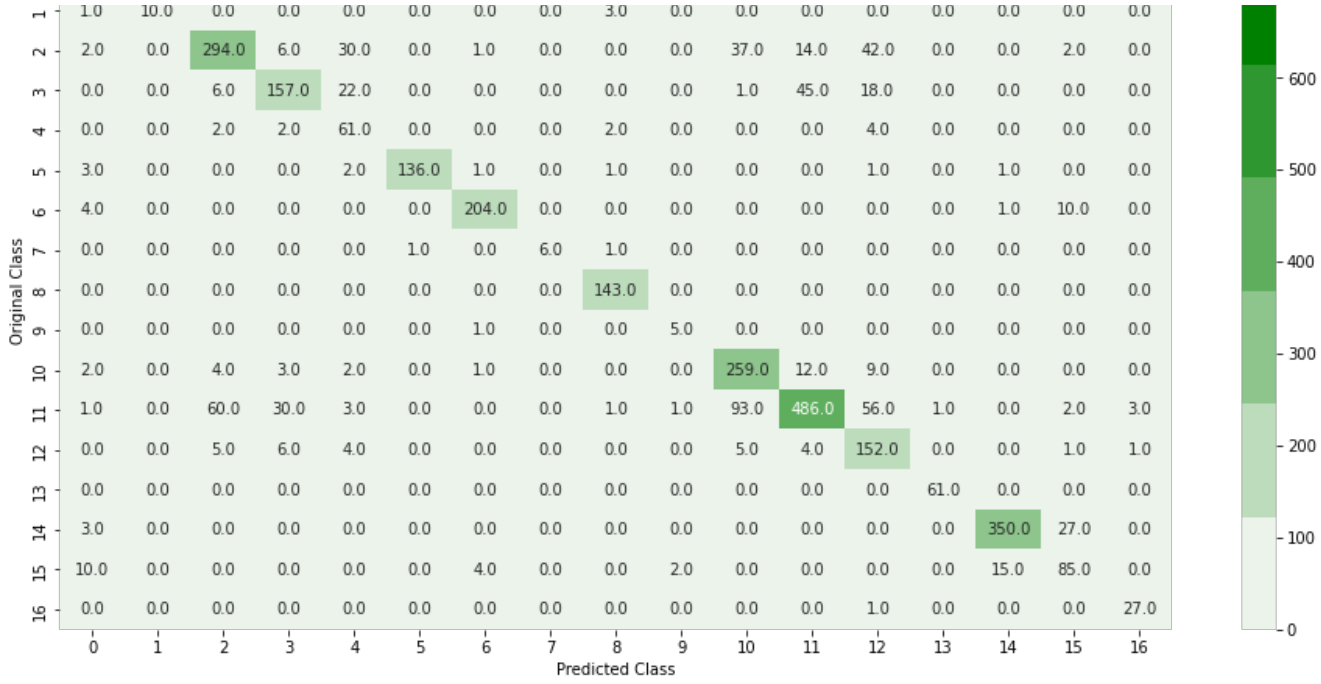
```
y_pred_5_test = NeuNet_2.predict(X_test_std)
y_pred_pd_5_test = pd.DataFrame(np.argmax(y_pred_5_test,axis=1),index=y_test.index)
```

In [ ]:

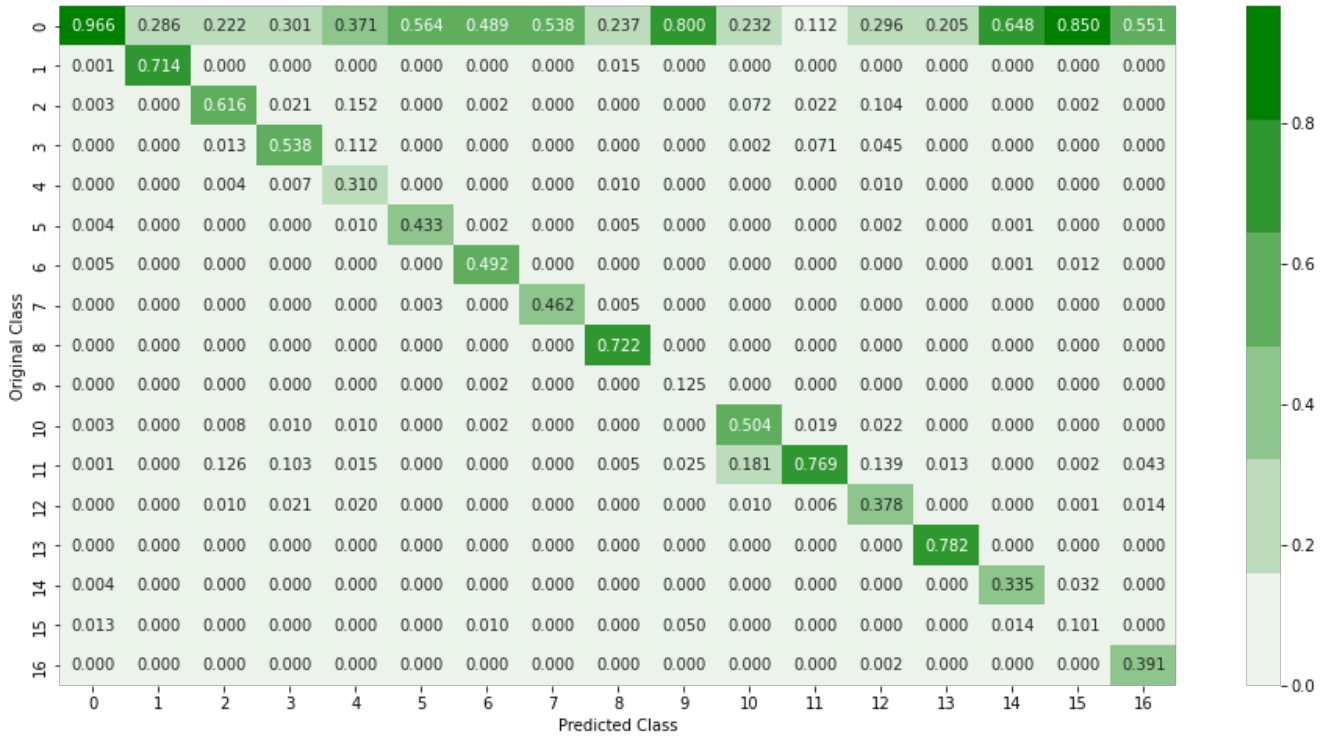
```
# plot_confusion_matrix(px_class,y_pred_pd_5)
plot_confusion_matrix(y_test,y_pred_pd_5_test)
```

```
Number of misclassified points  49.68294229549778
-------------------------------------------------- Confusion matrix ----------------------------------
---------------
```



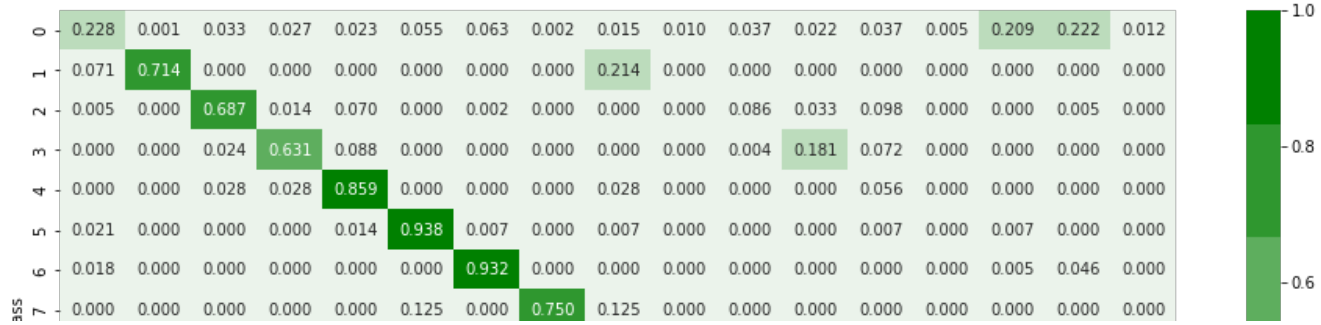


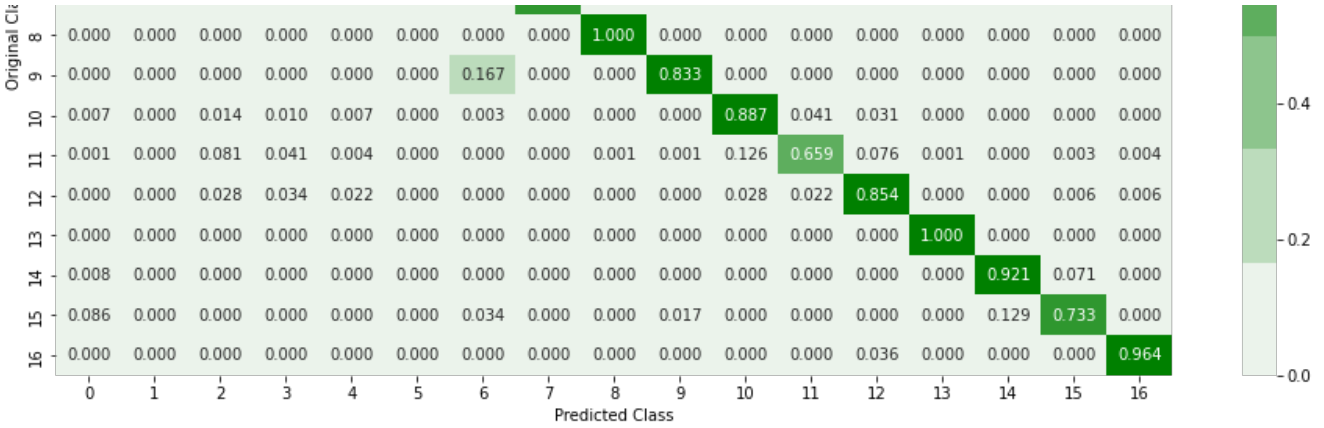
---------- Precision matrix ----------



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

---------- Recall matrix ----------






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

In [ ]:

```
kappa_score = cohen_kappa_score(y_test,y_pred_pd_5_test)
```

In [ ]:

```
print('kappa_score for model 2 (17 classes) = ', kappa_score)
```

```
kappa_score for model 2 (17 classes) =  0.44586439564171576
```

Confusion matrix without class 0

In [ ]:

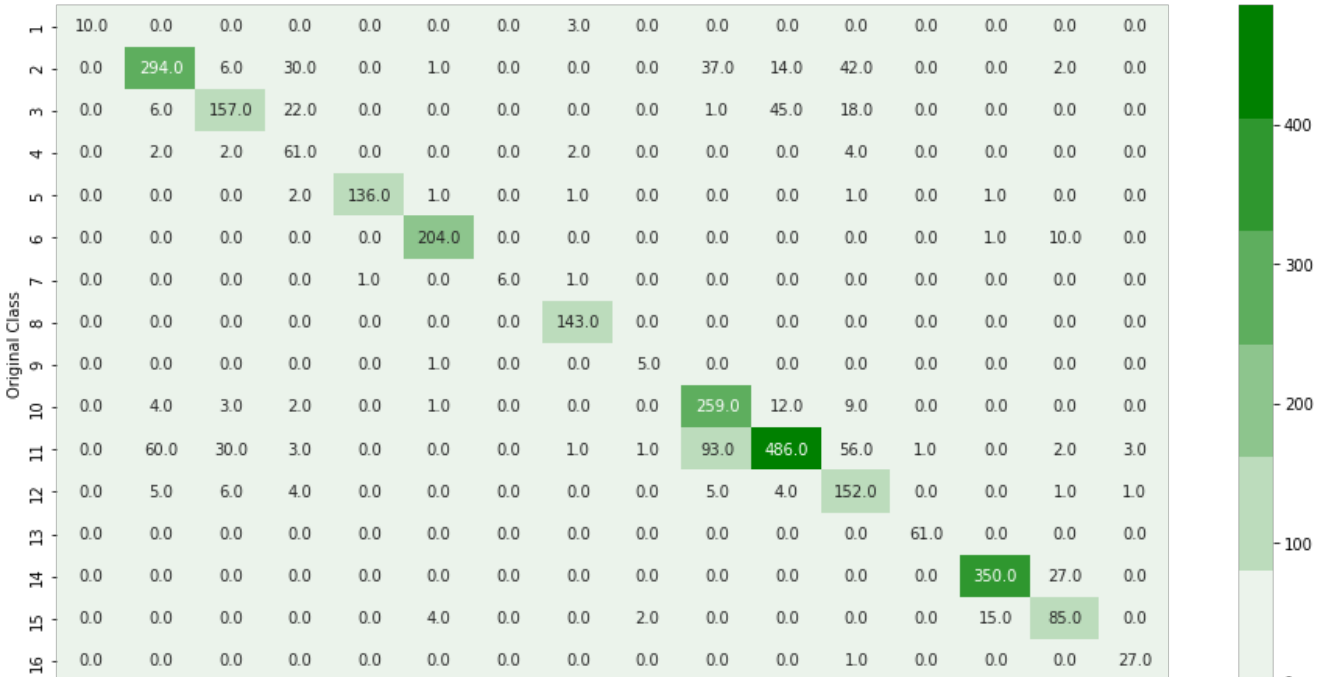
```
# code reference: appliedaicourse.com case studies
def plot_confusion_matrix_1(test_y, predict_y):
    '''
    This function generates the confusion matrix ignoring row and column associated with Class 0.
    Also evaluates the micro and macro F1 score for the above.
    '''
    print('Confusion / Precision / Recall matrix without class 0')
    C = confusion_matrix(test_y, predict_y)
    # print("Number of misclassified points ",(len(test_y)-np.trace(C))/len(test_y)*100)
    print("Number of misclassified points ",(np.sum(C[1:,1:])-np.trace(C[1:,1:]))/np.sum(C[1:,1:])*100)
    # C = 17x17 matrix, each cell (i,j) represents number of points of class i are predicted class j

    #Precision matrix
    A =(C[1:,1:]/C[1:,1:].sum(axis=0))
    #divid each element of the confusion matrix with the sum of elements in that column

    #Recall matrix
    B =(((C[1:,1:].T)/(C[1:,1:].sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in that row

    labels = list(range(0,17,1))
    cmap=sb.light_palette("green")
    # representing C in heatmap format
    print("-"*50, "Confusion matrix", "-"*50)
    plt.figure(figsize=(16,8))
    sb.heatmap(C[1:,1:], annot=True, cmap=cmap, fmt=".1f", xticklabels=labels[1:17], yticklabels=labels
[1:17])
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    # representing B in heatmap format
    print("-"*50, "Precision matrix", "-"*50)
    plt.figure(figsize=(16,8))
    sb.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels[1:17], yticklabels=labels[1:17])
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
```

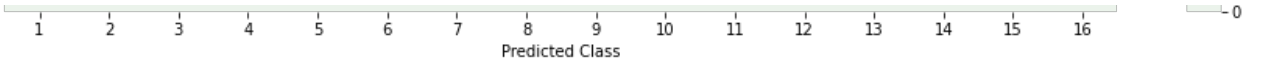
```
    plt.show()
    print("Sum of columns in precision matrix",A.sum(axis=0))

    # representing A in heatmap format
    print("-"*50, "Recall matrix"    , "-"*50)
    plt.figure(figsize=(16,8))
    sb.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels[1:17], yticklabels=labels[1:17])
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in recall matrix",B.sum(axis=1))

    #sum of all True positives
    TP = np.trace(C[1:,1:])

    #sum of all True positives and False Positives
    TP_FP = np.sum(C[1:,1:].sum(axis=1))

    #sum of all True positives and False Negatives
    TP_NP = np.sum(C[1:,1:].sum(axis=0))

    #micro F1 score evaluation
    micro_Pr  = TP / TP_FP
    micro_Re = TP / TP_NP
    micro_F1 = 2 * (micro_Pr * micro_Re)/(micro_Pr + micro_Re)

    print('\n micro F1 score ignoring class 0 : ', micro_F1)

    #macro F1 score evaluation
    macro_Pr = np.trace(B)/16
    macro_Re = np.trace(A)/16

    macro_F1 = 2 * (macro_Pr * macro_Re)/(macro_Pr + macro_Re)

    print('\n macro F1 score ignoring class 0 : ', macro_F1)

    AA = np.trace(B)/16
    print('\n Average Accuracy ignoring class 0 = ',AA)
```

In [ ]:

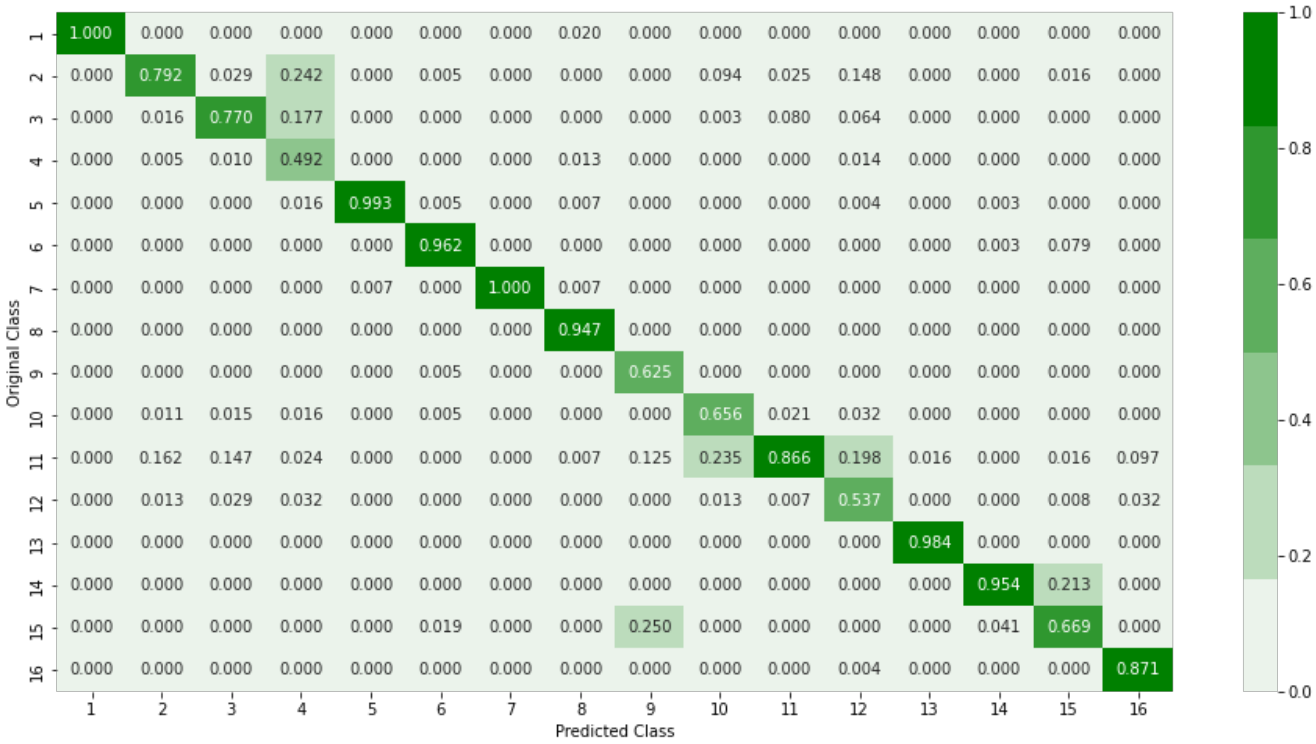
```
# plot_confusion_matrix_1(px_class,y_pred_pd_5)
plot_confusion_matrix_1(y_test,y_pred_pd_5_test)
```

```
Confusion / Precision / Recall matrix without class 0
Number of misclassified points  20.104952443424075
---------------------------------------------------- Confusion matrix ----------------------------------
---------------
```



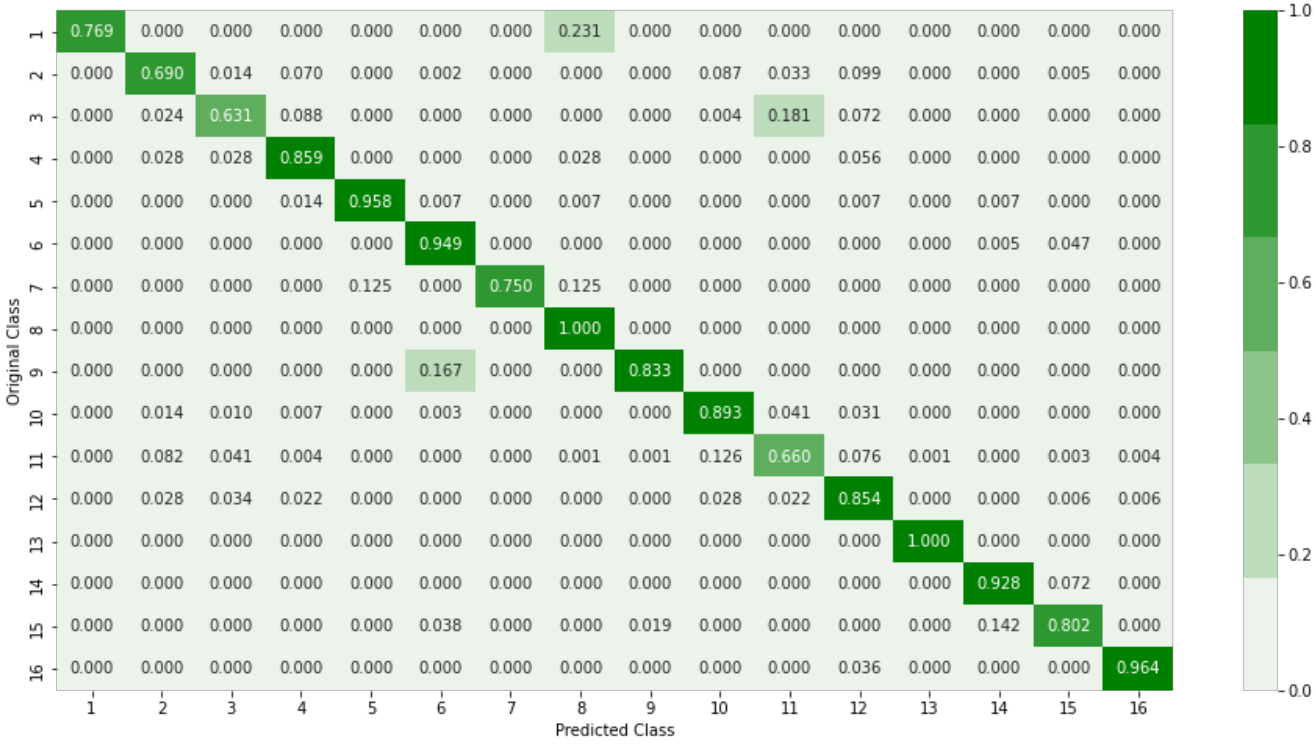


---------- Precision matrix ----------



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

---------- Recall matrix ----------



Sum of rows in recall matrix [1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]

micro F1 score ignoring class 0 : 0.7989504755657593

macro F1 score ignoring class 0 : 0.8328771622914929

```
Average Accuracy ignoring class 0 =  0.8463051401778926
```

In [ ]:

```
y_test[y_test[0]!=0]
```

Out[ ]:

	0
546	11
10878	5
9176	2
5888	10
7486	10
...	...
6908	10
1394	15
8568	3
3658	15
12402	2

3075 rows × 1 columns

In [ ]:

```
kappa_score_16 = cohen_kappa_score(y_test[y_test[0]!=0],y_pred_pd_5_test[y_test[0]!=0])
```

In [ ]:

```
print('kappa_score for model 2 (16 classes ignoring class 0) = ', kappa_score_16)
```

```
kappa_score for model 2 (16 classes ignoring class 0) =  0.7663891128653534
```