Install Packages

In [1]:
```
#pip install opencv-python
```

In [2]:
```
#pip install -U seaborn
```

In [3]:
```
!pip install shap
```

```
Requirement already satisfied: shap in c:\users\peddi\anaconda3\lib\site-packag
es (0.39.0)
Requirement already satisfied: scipy in c:\users\peddi\anaconda3\lib\site-packa
ges (from shap) (1.5.2)
Requirement already satisfied: cloudpickle in c:\users\peddi\anaconda3\lib\site
-packages (from shap) (1.6.0)
Requirement already satisfied: slicer==0.0.7 in c:\users\peddi\anaconda3\lib\si
te-packages (from shap) (0.0.7)
Requirement already satisfied: numba in c:\users\peddi\anaconda3\lib\site-packa
ges (from shap) (0.51.2)
Requirement already satisfied: scikit-learn in c:\users\peddi\anaconda3\lib\sit
e-packages (from shap) (0.22.2)
Requirement already satisfied: pandas in c:\users\peddi\anaconda3\lib\site-pack
ages (from shap) (1.1.3)
Requirement already satisfied: tqdm>4.25.0 in c:\users\peddi\anaconda3\lib\site
-packages (from shap) (4.50.2)
Requirement already satisfied: numpy in c:\users\peddi\anaconda3\lib\site-packa
ges (from shap) (1.19.2)
Requirement already satisfied: llvmlite<0.35,>=0.34.0.dev0 in c:\users\peddi\an
aconda3\lib\site-packages (from numba->shap) (0.34.0)
Requirement already satisfied: setuptools in c:\users\peddi\anaconda3\lib\site-
packages (from numba->shap) (50.3.1.post20201107)
Requirement already satisfied: joblib>=0.11 in c:\users\peddi\anaconda3\lib\sit
e-packages (from scikit-learn->shap) (0.17.0)
Requirement already satisfied: pytz>=2017.2 in c:\users\peddi\anaconda3\lib\sit
e-packages (from pandas->shap) (2020.1)
Requirement already satisfied: python-dateutil>=2.7.3 in c:\users\peddi\anacond
a3\lib\site-packages (from pandas->shap) (2.8.1)
Requirement already satisfied: six>=1.5 in c:\users\peddi\anaconda3\lib\site-pa
ckages (from python-dateutil>=2.7.3->pandas->shap) (1.15.0)
```

In [4]:
```
import shap
```

In [5]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import cv2
import tensorflow as tf
from PIL import Image
import os
from sklearn.model_selection import train_test_split
from keras.utils import to_categorical
from keras.models import Sequential, load_model
from keras.layers import Conv2D, MaxPool2D, Dense, Flatten, Dropout
import matplotlib.image as mpimg
from matplotlib import *

```

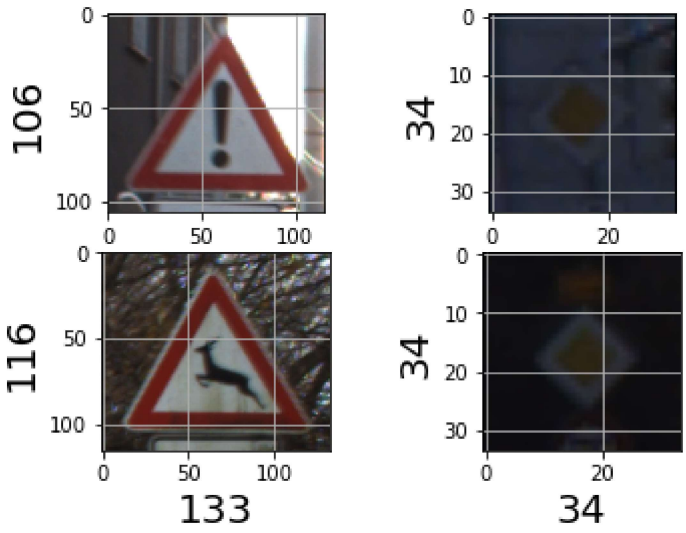
In [165]:
```
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras.models import Sequential
from keras.models import Sequential
from tensorflow.keras.layers import BatchNormalization
from keras.layers import Input,Flatten, Dense, Dropout, Conv2D,concatenate
from tensorflow.keras.activations import relu, softmax
from tensorflow.keras.initializers import he_normal, zeros, glorot_normal, R
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.losses import SparseCategoricalCrossentropy
from tensorflow.keras.regularizers import l1, l2, l1_l2
```

In [7]:
```
# Metrics
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
```

Extract Data from Images

In [28]:

```
import random
from matplotlib.image import imread
dataset_dir = 'C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Fin
meta_info = os.path.join(dataset_dir, 'Meta.csv')
train_csv_path = os.path.join(dataset_dir, 'Train.csv')
test_csv_path = os.path.join(dataset_dir, 'Test.csv')

test = pd.read_csv(dataset_dir + 'Train.csv')
imgs = test["Path"].values
imgs

# Visualizing 25 random images from train data
import random
from matplotlib.image import imread
dataset_dir = 'C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Fin
meta_info = os.path.join(dataset_dir, 'Meta.csv')
train_csv_path = os.path.join(dataset_dir, 'Train.csv')
test_csv_path = os.path.join(dataset_dir, 'Test.csv')

test = pd.read_csv(dataset_dir + 'Train.csv')
imgs = test["Path"].values

#plt.figure(figsize=(25,25))

for i in range(1,5):
    plt.subplot(2,2,i)
    random_img_path = dataset_dir + '/' + random.choice(imgs)
    rand_img = imread(random_img_path)
    plt.imshow(rand_img)
    plt.grid(b=None)
    plt.xlabel(rand_img.shape[1], fontsize = 20)#width of image
    plt.ylabel(rand_img.shape[0], fontsize = 20)#height of image
```



In [29]:

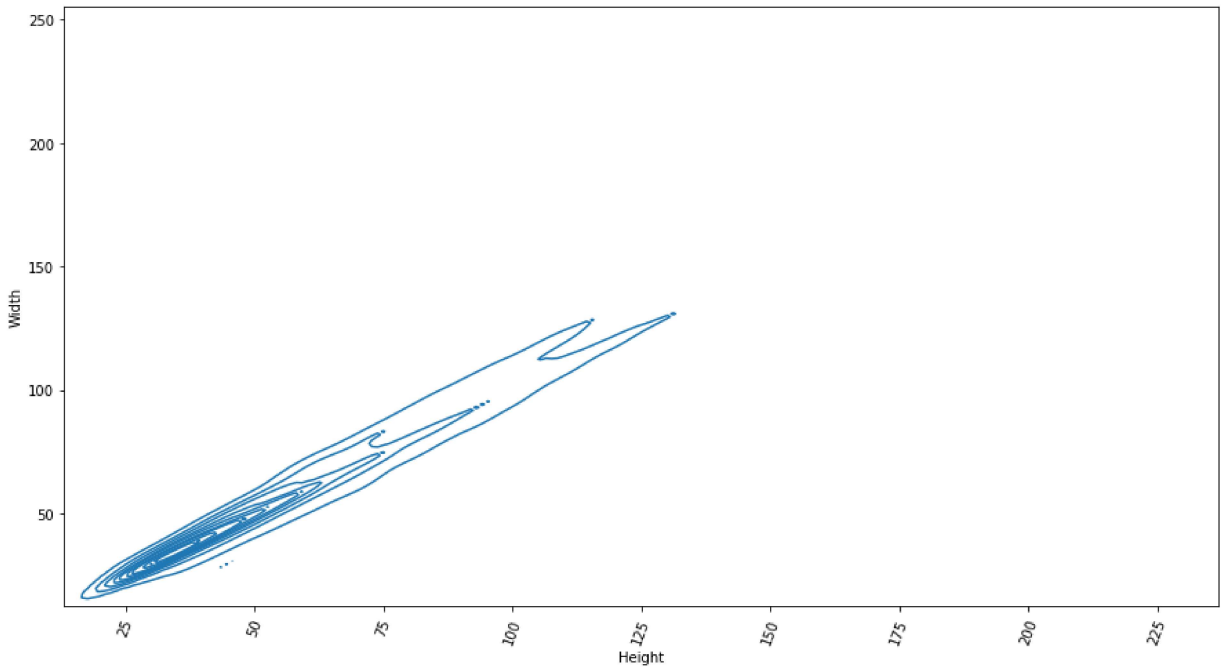
```
train_data_color = '#0f7b8e'
test_data_color = '#630f8e'

df_train = pd.read_csv(train_csv_path)
df_test = pd.read_csv(test_csv_path)
df_meta = pd.read_csv(meta_info)

df_train['Path'] = list(map(lambda x: os.path.join(dataset_dir,x.lower()), d
df_test['Path'] = list(map(lambda x: os.path.join(dataset_dir,x.lower()), df
df_meta['Path'] = list(map(lambda x: os.path.join(dataset_dir,x.lower()), df

df_train.sample(3)
```

Out[29]:

	Width	Height	Roi.X1	Roi.Y1	Roi.X2	Roi.Y2	ClassId	Path
36574	32	32	6	6	27	27	38	C:\Drive\Siri\MSDSBA\4. IE7860 Intelligent Ana...
34811	39	39	6	6	34	34	35	C:\Drive\Siri\MSDSBA\4. IE7860 Intelligent Ana...
35543	46	48	6	6	41	43	36	C:\Drive\Siri\MSDSBA\4. IE7860 Intelligent Ana...

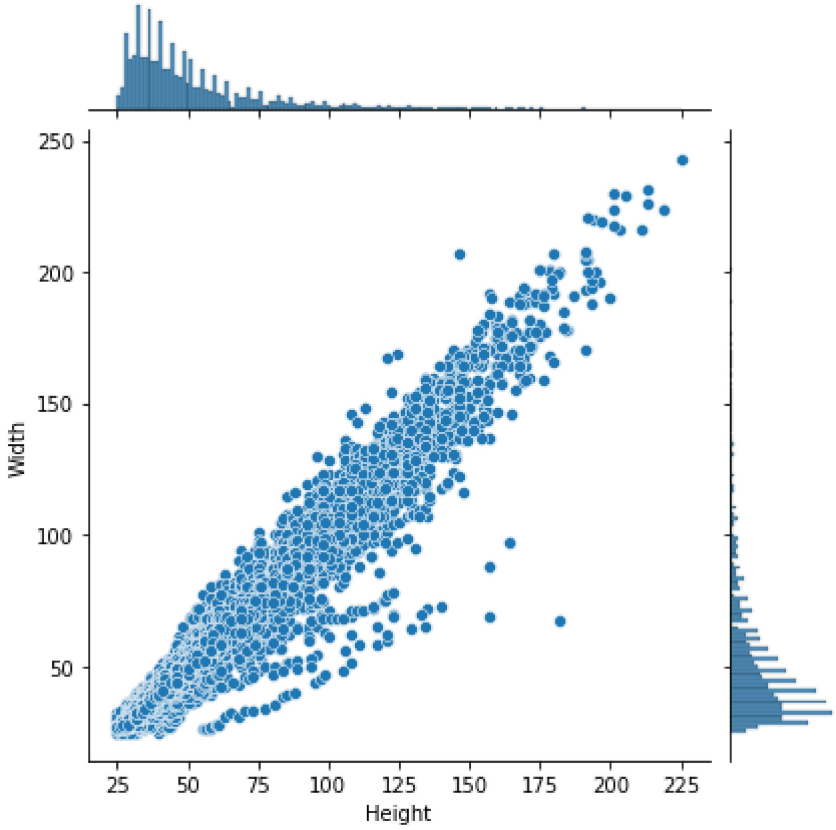
In [30]:

```
plt.figure(figsize=(15,8))
plt.xticks(rotation=70)
plt_box=sns.kdeplot(data=df_train, x="Height", y="Width")
```



In [31]:
```
1 sns.jointplot(data=df_train, x="Height", y="Width")
```

Out[31]:
```
<seaborn.axisgrid.JointGrid at 0x1de6af4dc70>
```



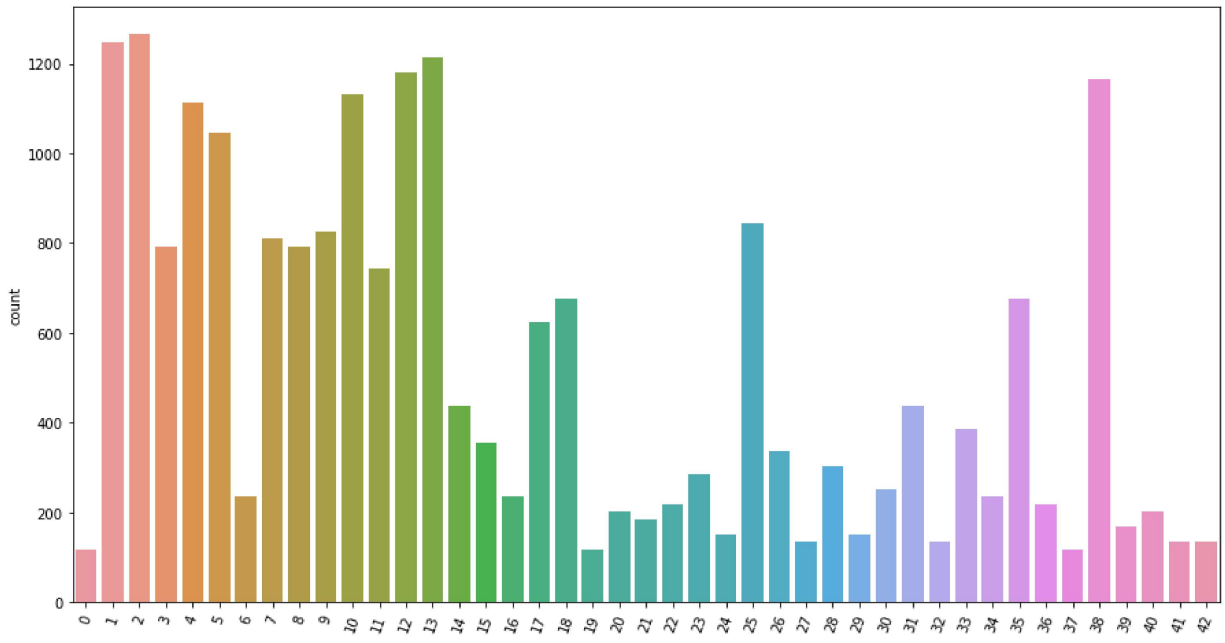
In [32]:
```
1 data = []
2 labels = []
3 classes = 43
4 #cur_path = 'C:\\Users\\adari\\data\\'
5 cur_path = 'C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Final
6 # cur_path = 'C:\\Users\\Triveni\\Desktop\\MSDSBA\\Winter 2021\\IA\\Project\
```

In [33]:
```
1  #Retrieving the images and their labels
2  for i in range(classes):
3      path = os.path.join(cur_path,'Train',str(i))
4      images = os.listdir(path)
5      for a in images:
6          try:
7              image = Image.open(path + '\\'+ a)
8              image = image.resize((30,30))
9              image = np.array(image)
10             #sim = Image.fromarray(image)
11             data.append(image)
12             labels.append(i)
13         except:
14             print("Error loading image")
```

In [34]:
```
#Converting lists into numpy arrays
data = np.array(data)
labels = np.array(labels)
```

In [35]:
```
#Checking for class imbalance in training set
# Below plot shows the class distribution of the training images.

plt.figure(figsize=(15,8))
plt.xticks(rotation=70)
plt_box=sns.countplot(labels)
```

```
Pass the following variable as a keyword arg: x. From version 0.12, the only va
lid positional argument will be `data`, and passing other arguments without an
explicit keyword will result in an error or misinterpretation.
```



Observations :

1. The target classes are clearly not uniformly distributed.
2. This is quite logical since some signs like “Keep speed below 30 K-mph” or “A bump ahead” appears more often then signs like “Road under construction ahead”.
3. Images are unevenly distributed among each class. Some classes have around 2500 images while others have as low as 250 images.
4. Less number of images can undermine the training process. We can use Data-Augmentation to overcome the lack of adequate number of images in some classes.

It’s always a good practice to understand where your model stands without doing any preprocessing as that would help you establish a score for your model, which you could improve upon each iteration. The evaluation metric for our model would be “accuracy” score. Using a fully connected Sequential Neural Netwrok Architecture for Baseline Scores and other testing

ESTABLISHING SCORE WITHOUT ANY

PREPROCESSING

The model = Sequential() statements loads the network. The input shape is 2700 (as images have 3 color channels). The Activation function is “relu”. During hyperparameters optimization we can check with Tanh, Sigmoid and other activation function if they are better suited for the task. For now we stick on to “relu”. There are 4 hidden layers of 128 neurons with relu activation and after each hidden layer except the last one a dropout(50%) function is included. The output layer has the softmax activation since we are dealing with multi class classification and there are 43 classes.

In [36]:
```
#Splitting training and testing dataset
X_train,X_val, y_train, y_val = train_test_split(data, labels, test_size=0.2
```

In [37]:
```
from sklearn.metrics import accuracy_score
# y_test = pd.read_csv('C:\\Users\\Triveni\\Desktop\\MSDSBA\\Winter 2021\\IA
y_test = pd.read_csv('C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analyti
#y_test = pd.read_csv('C:\\Users\\adari\\data\\Test.csv')

labels = y_test["ClassId"].values
imgs = y_test["Path"].values
data=[]
for img in imgs:
#     image = Image.open("C:\\Users\\Triveni\\Desktop\\MSDSBA\\Winter 2021\\
    image = Image.open("C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analy
    #image = Image.open("C:\\Users\\adari\\data\\"+img)
    image = image.resize((30,30))
    data.append(np.array(image))
X_test=np.array(data)
```

In [38]:
```
#Converting the labels into one hot encoding

y_train_cnn = to_categorical(y_train, 43)
y_val_cnn = to_categorical(y_val, 43)
```

In [39]:
```
y_train_cnn.shape
```

Out[39]:
```
(17625, 43)
```

In [40]:
```
X_train=np.array(X_train)
```

In [41]:
```
X_val=np.array(X_val)
```

In [42]:
```
print(X_train.shape)
print(y_train.shape)
```

```
(17625, 30, 30, 3)
(17625,)
```

In [43]:
```
print(X_val.shape)
print(y_val.shape)
```

```
(4407, 30, 30, 3)
(4407,)
```

In [44]:
```
X_test.shape
```

Out[44]:
```
(12630, 30, 30, 3)
```

In [45]:
```
y_test.shape
```

Out[45]:
```
(12630, 8)
```

In [46]:
```
# # Flatten input: Changing dimension of input images from N*30*30*3 to N*27
X_train_rs = X_train.reshape([X_train.shape[0], -1])
X_val_rs = X_val.reshape([X_val.shape[0], -1])
```

In [47]:
```
print(X_train_rs.shape)
print(X_val_rs.shape)
```

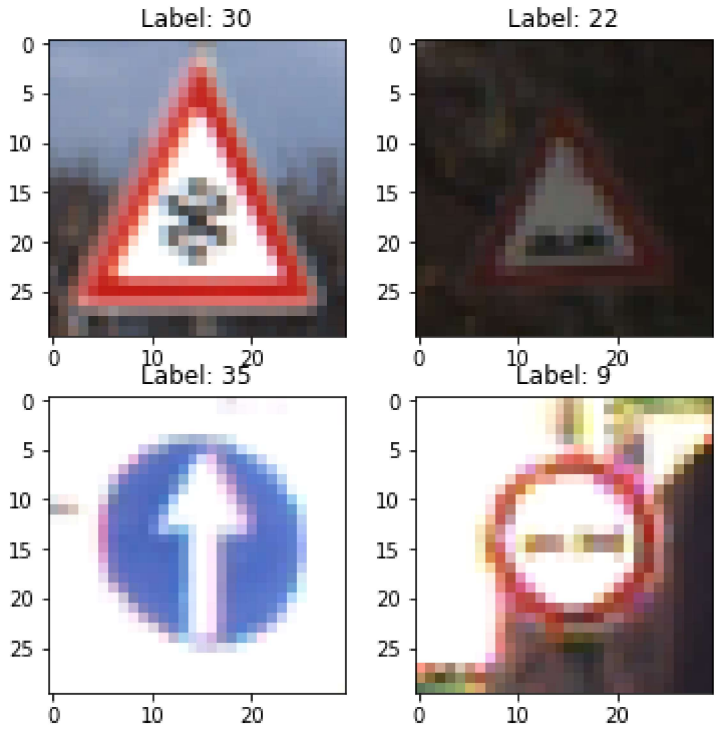
```
(17625, 2700)
(4407, 2700)
```

In [48]:
```
X_test_rs = X_test.reshape([X_test.shape[0], -1])
```

In [49]:
```
print(X_test_rs.shape)
```

```
(12630, 2700)
```

In [50]:
```
plt.figure(figsize=[6,6])
for i in range(4):
    plt.subplot(2,2,i+1)
    plt.title("Label: %i"%y_train[i])
    plt.imshow(X_train_rs[i].reshape([30,30,3]));
```



In [51]:
```
## Changing labels to one-hot encoded vector
from sklearn.preprocessing import LabelBinarizer
lb = LabelBinarizer()
y_train_one_hot = lb.fit_transform(y_train)
y_val_one_hot = lb.transform(y_val)
print('Train labels dimension:');print(y_train_one_hot.shape)
print('Test labels dimension:');print(y_val_one_hot.shape)
```

```
Train labels dimension:
(17625, 43)
Test labels dimension:
(4407, 43)
```

In [52]:
```
from sklearn.preprocessing import LabelBinarizer
lb = LabelBinarizer()
y_test_one_hot = lb.fit_transform(labels)
print('Train labels dimension:');print(y_train_one_hot.shape)
print('Test labels dimension:');print(y_val_one_hot.shape)
```

```
Train labels dimension:
(17625, 43)
Test labels dimension:
(4407, 43)
```

Basic Models

MLP

In [53]:

```
from keras.models import Sequential
from tensorflow.keras.layers import BatchNormalization
n_classes = len(np.unique(labels))
model=tf.keras.Sequential()
model.add(keras.layers.Dense(128,input_dim=2700, activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dense(128,activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.5))
model.add(keras.layers.Dense(128,activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dropout(0.5))
model.add(keras.layers.Dense(128,activation='relu'))
model.add(BatchNormalization())
model.add(keras.layers.Dense(n_classes,activation='softmax'))
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['a
```

In [54]:

```
history = model.fit(X_train_rs, y_train_one_hot, validation_data = (X_val_rs
score_mlp = model.evaluate(X_val_rs, y_val_one_hot,batch_size=1, verbose=0)
print('Test loss:', score_mlp[0], '   Test accuracy:', score_mlp[1])

```

```
Epoch 1/15
138/138 - 3s - loss: 3.2831 - accuracy: 0.1750 - val_loss: 2.7257 - val_accurac
y: 0.2539
Epoch 2/15
138/138 - 1s - loss: 2.0110 - accuracy: 0.4137 - val_loss: 1.9887 - val_accurac
y: 0.4118
Epoch 3/15
138/138 - 1s - loss: 1.4596 - accuracy: 0.5540 - val_loss: 1.3704 - val_accurac
y: 0.6031
Epoch 4/15
138/138 - 1s - loss: 1.1062 - accuracy: 0.6637 - val_loss: 1.0502 - val_accurac
y: 0.6742
Epoch 5/15
138/138 - 1s - loss: 0.9230 - accuracy: 0.7183 - val_loss: 0.8034 - val_accurac
y: 0.7497
Epoch 6/15
138/138 - 1s - loss: 0.8134 - accuracy: 0.7525 - val_loss: 0.6515 - val_accurac
y: 0.8003
Epoch 7/15
138/138 - 1s - loss: 0.7216 - accuracy: 0.7809 - val_loss: 0.6030 - val_accurac
y: 0.8273
Epoch 8/15
138/138 - 1s - loss: 0.6890 - accuracy: 0.7918 - val_loss: 0.6609 - val_accurac
y: 0.8046
Epoch 9/15
138/138 - 1s - loss: 0.5995 - accuracy: 0.8179 - val_loss: 0.5922 - val_accurac
y: 0.8353
Epoch 10/15
138/138 - 1s - loss: 0.5772 - accuracy: 0.8237 - val_loss: 0.6839 - val_accurac
y: 0.7910
Epoch 11/15
138/138 - 1s - loss: 0.5403 - accuracy: 0.8376 - val_loss: 0.5348 - val_accurac
y: 0.8448
Epoch 12/15
138/138 - 1s - loss: 0.5106 - accuracy: 0.8441 - val_loss: 0.9075 - val_accurac
y: 0.7663
Epoch 13/15
138/138 - 1s - loss: 0.4969 - accuracy: 0.8505 - val_loss: 0.5267 - val_accurac
y: 0.8475
Epoch 14/15
138/138 - 1s - loss: 0.4569 - accuracy: 0.8592 - val_loss: 0.3782 - val_accurac
y: 0.8902
Epoch 15/15
138/138 - 1s - loss: 0.4340 - accuracy: 0.8673 - val_loss: 0.5083 - val_accurac
y: 0.8500
Test loss: 0.5083445906639099    Test accuracy: 0.8500113487243652
```

In [55]:
```
predict_mlp = model.predict(X_test_rs, batch_size = 1)
score_test_mlp=model.evaluate(X_test_rs, y_test_one_hot,batch_size=1, verbos

```

In [56]:
```
score_test_mlp[1]
```

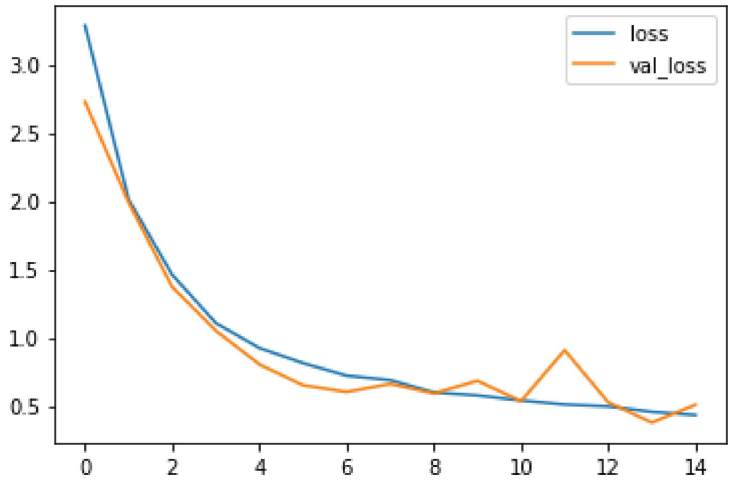
Out[56]: 0.7820269465446472

In [57]:
```

for name, value in zip(model.metrics_names, score_test_mlp):
  print(name, ': ', value)

print()


```

```
loss :  0.8219485878944397
accuracy :  0.7820269465446472
```

In [58]:
```
# Leraning curve MLP
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.legend(['loss','val_loss'])
```

Out[58]: <matplotlib.legend.Legend at 0x1de77a24b50>



In [59]:
```
val_performance = {}
performance = {}
Model={}
```

In [60]:
```
val_performance['MLP']=score_mlp[1]
performance['MLP']=score_test_mlp[1]
Model['MLP']='MLP'
```

The model was able to achieve an accuracy score of 83.61% without any preprocessing.

Base cnn model

In [61]:

```
cnn_model = tf.keras.Sequential([
    keras.layers.Conv2D(filters=32,kernel_size=(5,5),activation='relu',input
    keras.layers.MaxPool2D(pool_size=(2,2)),# down sampling the output inste
    keras.layers.Dropout(0.2),
    keras.layers.Flatten(), # flatten out the layers
    keras.layers.Dense(256,activation='relu'),
    keras.layers.Dense(43,activation = 'softmax')

])
#Compilation of the model
cnn_model.compile(loss='categorical_crossentropy', optimizer='adam', metrics
epochs = 15

```

In [62]:
```
history = cnn_model.fit(X_train, y_train_cnn,  epochs=epochs, validation_dat
```

```
Epoch 1/15
551/551 [==============================] - 14s 24ms/step - loss: 9.8534 - accur
acy: 0.4055 - val_loss: 0.6527 - val_accuracy: 0.8328
Epoch 2/15
551/551 [==============================] - 13s 24ms/step - loss: 0.6735 - accur
acy: 0.8282 - val_loss: 0.6572 - val_accuracy: 0.8514
Epoch 3/15
551/551 [==============================] - 13s 24ms/step - loss: 0.4914 - accur
acy: 0.8728 - val_loss: 0.5357 - val_accuracy: 0.8716
Epoch 4/15
551/551 [==============================] - 14s 25ms/step - loss: 0.5386 - accur
acy: 0.8671 - val_loss: 0.3730 - val_accuracy: 0.9115
Epoch 5/15
551/551 [==============================] - 14s 26ms/step - loss: 0.3917 - accur
acy: 0.8996 - val_loss: 0.4602 - val_accuracy: 0.8981
Epoch 6/15
551/551 [==============================] - 13s 24ms/step - loss: 0.3389 - accur
acy: 0.9139 - val_loss: 0.3993 - val_accuracy: 0.9247
Epoch 7/15
551/551 [==============================] - 13s 24ms/step - loss: 0.4064 - accur
acy: 0.9073 - val_loss: 0.3226 - val_accuracy: 0.9369
Epoch 8/15
551/551 [==============================] - 14s 25ms/step - loss: 0.3210 - accur
acy: 0.9261 - val_loss: 0.3985 - val_accuracy: 0.9238
Epoch 9/15
551/551 [==============================] - 14s 25ms/step - loss: 0.3574 - accur
acy: 0.9224 - val_loss: 0.4729 - val_accuracy: 0.9158
Epoch 10/15
551/551 [==============================] - 14s 26ms/step - loss: 0.2975 - accur
acy: 0.9346 - val_loss: 0.3267 - val_accuracy: 0.9412
Epoch 11/15
551/551 [==============================] - 13s 24ms/step - loss: 0.2475 - accur
acy: 0.9397 - val_loss: 0.7539 - val_accuracy: 0.8834
Epoch 12/15
551/551 [==============================] - 13s 24ms/step - loss: 0.3863 - accur
acy: 0.9184 - val_loss: 0.3818 - val_accuracy: 0.9401
Epoch 13/15
551/551 [==============================] - 14s 25ms/step - loss: 0.2913 - accur
acy: 0.9361 - val_loss: 0.4450 - val_accuracy: 0.9365
Epoch 14/15
551/551 [==============================] - 14s 25ms/step - loss: 0.2408 - accur
acy: 0.9457 - val_loss: 0.4388 - val_accuracy: 0.9310
Epoch 15/15
551/551 [==============================] - 13s 24ms/step - loss: 0.2692 - accur
acy: 0.9425 - val_loss: 0.4241 - val_accuracy: 0.9437
```

In [63]:
```
score_cnn = cnn_model.evaluate(X_val, y_val_cnn,batch_size=1, verbose=0)
print('Test loss:', score_cnn[0], '   Test accuracy:', score_cnn[1])
```

```
Test loss: 0.42412441968917847    Test accuracy: 0.9437258839607239
```

In [64]:
```
pred_cnn = cnn_model.predict_classes(X_test)
#Accuracy with the test data
from sklearn.metrics import accuracy_score
print(accuracy_score(labels, pred_cnn))
```

```
`model.predict_classes()` is deprecated and will be removed after 2021-01-01. P
lease use instead:* `np.argmax(model.predict(x), axis=-1)`,   if your model doe
s multi-class classification   (e.g. if it uses a `softmax` last-layer activati
on).* `(model.predict(x) > 0.5).astype("int32")`,   if your model does binary c
lassification   (e.g. if it uses a `sigmoid` last-layer activation).


0.8524940617577197
```

In [65]:
```
val_performance['CNN']= score_cnn[1]
performance['CNN']=accuracy_score(labels, pred_cnn)
Model['CNN']='CNN'
```

In [66]:
```
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

loss = history.history['loss']
val_loss = history.history['val_loss']


```

In [67]:

```
epochs_range = range(15)

plt.figure(figsize=(8, 8))
plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')
plt.show()
```

SVM

In [68]:

```
#Normalize the data for SVM
from sklearn.preprocessing import StandardScaler
sc = StandardScaler()
X_train_svm = sc.fit_transform(X_train_rs)
X_val_svm= sc.fit_transform(X_val_rs)
X_test_svm = sc.fit_transform(X_test_rs)
```

In [69]:
```
from sklearn.svm import SVC
svclassifier = SVC(kernel='linear',decision_function_shape='ovo')
#svclassifier = SVC(gamma=1,kernel='rbf')
svclassifier.fit(X_train_rs, y_train)
score_train = svclassifier.score(X_val_rs, y_val)
Pred_svm=svclassifier.predict(X_test_rs)    #prediction
```

In [70]:
```
score_train
```

Out[70]:
```
0.9355570683004312
```

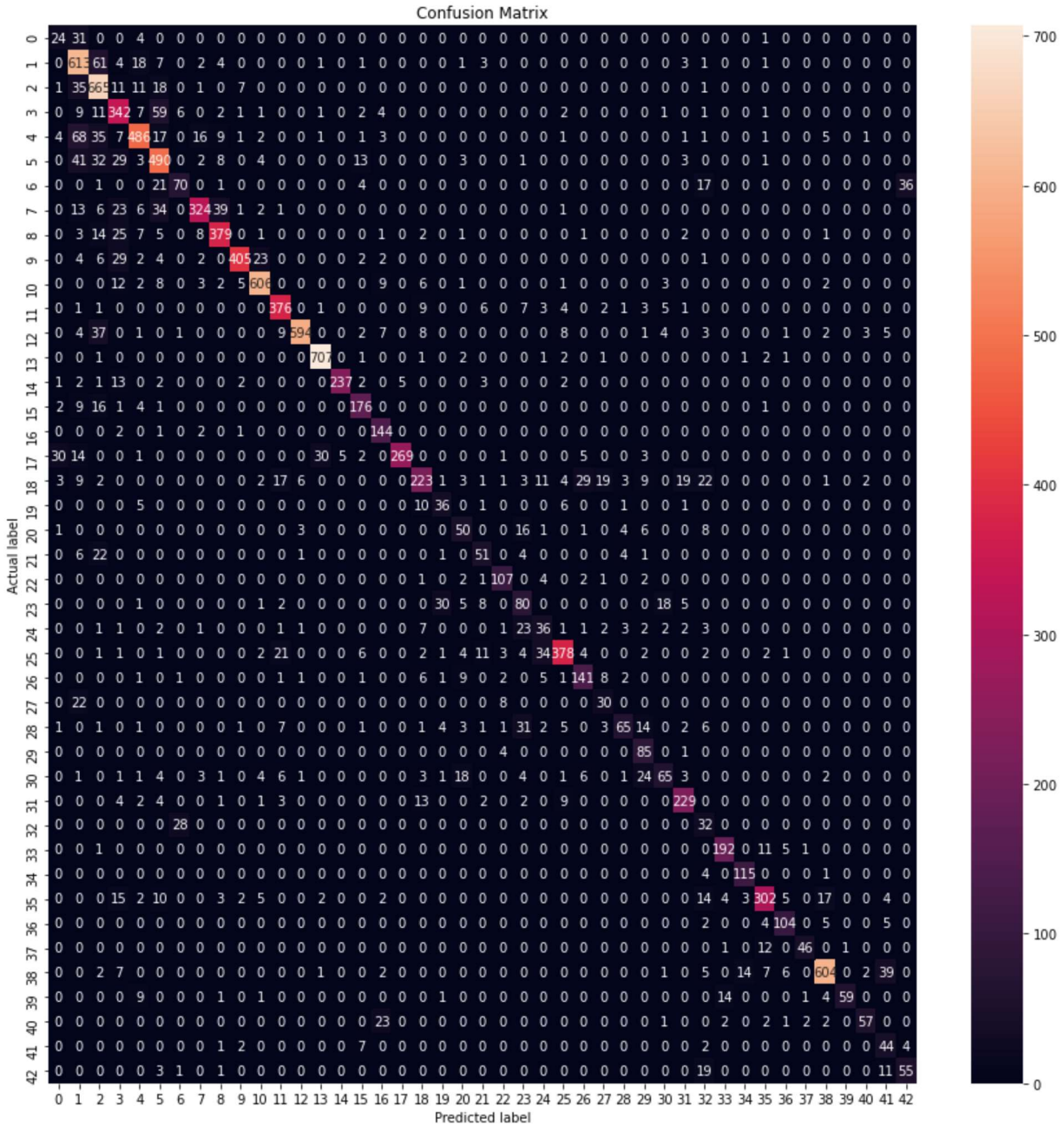
In [71]:

```
# Evaluate predictions
print(accuracy_score(labels, Pred_svm))
print(classification_report(labels, Pred_svm))
```

```
0.7991290577988915
              precision    recall  f1-score   support

           0       0.36      0.40      0.38        60
           1       0.69      0.85      0.76       720
           2       0.73      0.89      0.80       750
           3       0.65      0.76      0.70       450
           4       0.85      0.74      0.79       660
           5       0.71      0.78      0.74       630
           6       0.65      0.47      0.54       150
           7       0.89      0.72      0.80       450
           8       0.84      0.84      0.84       450
           9       0.95      0.84      0.89       480
          10       0.93      0.92      0.92       660
          11       0.85      0.90      0.87       420
          12       0.98      0.86      0.92       690
          13       0.95      0.98      0.97       720
          14       0.98      0.88      0.93       270
          15       0.80      0.84      0.82       210
          16       0.73      0.96      0.83       150
          17       0.98      0.75      0.85       360
          18       0.76      0.57      0.65       390
          19       0.47      0.60      0.53        60
          20       0.49      0.56      0.52        90
          21       0.58      0.57      0.57        90
          22       0.84      0.89      0.86       120
          23       0.46      0.53      0.49       150
          24       0.37      0.40      0.39        90
          25       0.89      0.79      0.83       480
          26       0.74      0.78      0.76       180
          27       0.45      0.50      0.48        60
          28       0.77      0.43      0.56       150
          29       0.56      0.94      0.70        90
          30       0.65      0.43      0.52       150
          31       0.84      0.85      0.85       270
          32       0.22      0.53      0.31        60
          33       0.90      0.91      0.91       210
          34       0.86      0.96      0.91       120
          35       0.87      0.77      0.82       390
          36       0.84      0.87      0.85       120
          37       0.92      0.77      0.84        60
          38       0.93      0.88      0.90       690
          39       0.98      0.66      0.79        90
          40       0.88      0.63      0.74        90
          41       0.41      0.73      0.52        60
          42       0.58      0.61      0.59        90

    accuracy                           0.80     12630
   macro avg       0.74      0.73      0.73     12630
weighted avg       0.82      0.80      0.80     12630
```

In [72]:
```
#plot for confusion matrix
def plot_cm(labels, predictions):
  cm = confusion_matrix(labels, predictions)
  plt.figure(figsize=(15,15))
  sns.heatmap(cm, annot=True, fmt="d")
  plt.title('Confusion Matrix')
  plt.ylabel('Actual label')
  plt.xlabel('Predicted label')
```

In [73]:
```
plot_cm(labels, Pred_svm)
```



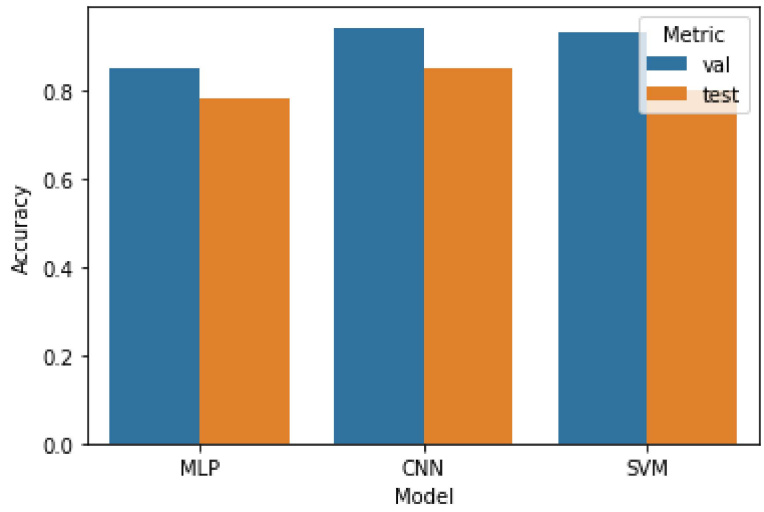
In [74]:
```
val_performance['SVM']= score_train
performance['SVM']=accuracy_score(labels, Pred_svm)
Model['SVM']='SVM'
```

Model Performance

In [75]:
```
Performance = pd.DataFrame(
    {'val': val_performance,
     'test': performance,
     'Model':Model
    })
```

In [76]:
```
df_accuracy = Performance.melt(id_vars=['Model'], var_name='Metric', value_n
```

In [77]:
```
ax = sns.barplot(x="Model", y="Accuracy", hue="Metric", data=df_accuracy)
```



PRE-PROCESSING STEPS

In [78]:
```
print("Number of training examples =", df_train.shape[0])
print("Number of testing examples =", df_test.shape[0])

print("Number of classes =", y_val_one_hot.shape[1])
```

```
Number of training examples = 39209
Number of testing examples = 12630
Number of classes = 43
```

Preprocess the data here. Preprocessing steps could include normalization, converting to grayscale, etc.

Equalize histograms of training samples - by generation of additional, transformed images

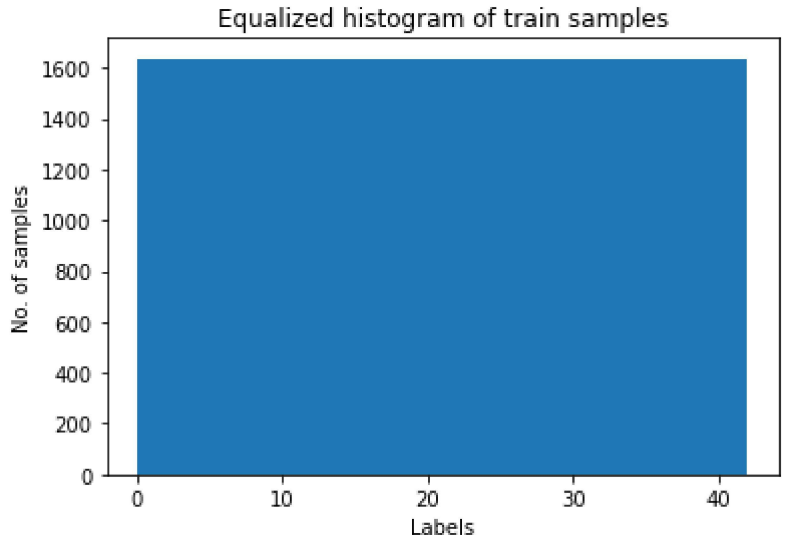
In [79]:

```
from tqdm import tqdm
from scipy import ndimage
import cv2

def augment_brightness_camera_images(image):
    image1 = cv2.cvtColor(image,cv2.COLOR_RGB2HSV)
    random_bright = .25+np.random.uniform()
    image1[:,:,2] = image1[:,:,2]*random_bright
    image1 = cv2.cvtColor(image1,cv2.COLOR_HSV2RGB)
    return image1

def transform_image(img):
    ang_range = 25
    ang_rot = np.random.uniform(ang_range)-ang_range/2
    rows,cols,ch = img.shape
    Rot_M = cv2.getRotationMatrix2D((cols/2,rows/2),ang_rot,1)

    img = cv2.warpAffine(img,Rot_M,(cols,rows))
    img = augment_brightness_camera_images(img)

    return img

def get_random_image_of_given_label(images_set, labels_set, label):
    image_indexes = np.where(labels_set == label)
    rand_index = random.randint(0, np.bincount(labels_set)[label] - 1)
    return images_set[image_indexes][rand_index]

def equalize_samples_set(X_set, y_set):
    labels_count_arr = np.bincount(y_set)
    labels_bins = np.arange(len(labels_count_arr))

    ind = 0

    for label in tqdm(labels_bins):
        labels_no_to_add =  int(np.mean(labels_count_arr)) * 4 - labels_coun

        ind = ind + 1
        X_temp = []
        y_temp = []

        for num in range(labels_no_to_add):
            rand_image = get_random_image_of_given_label(X_set, y_set, label
            X_temp.append(transform_image(rand_image))
            y_temp.append(label)

        X_set = np.append(X_set, np.array(X_temp), axis=0)
        y_set = np.append(y_set, np.array(y_temp), axis=0)

    return X_set, y_set

```

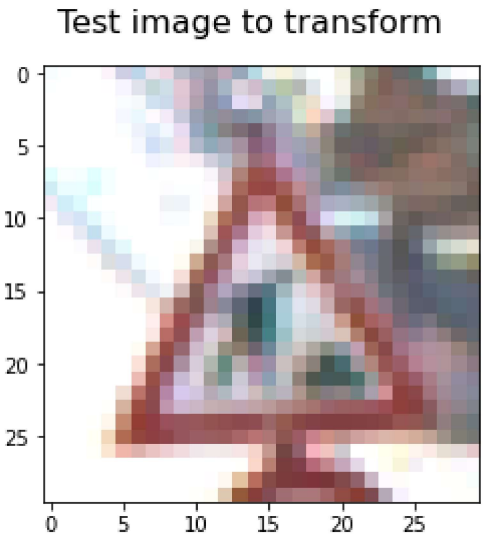
In [80]:

```
n_train = X_train.shape[0]
X_train_eq, y_train_eq = equalize_samples_set(X_train, y_train)


n_classes = len(np.unique(labels))
n, bins, patches = plt.hist(y_train_eq, n_classes)
plt.xlabel('Labels')
plt.ylabel('No. of samples')
plt.title('Equalized histogram of train samples')
plt.show()

print("Train set increased from {} to {}".format(n_train,X_train_eq.shape[0]))

fig=plt.figure()
fig.suptitle('Test image to transform', fontsize=16)
plt.imshow(X_train_eq[1000])

grid_len = 4
fig=plt.figure(figsize=(grid_len,grid_len))
fig.suptitle('Test images after transformation', fontsize=16)

for i in range(1,grid_len*grid_len+1):
    image = transform_image(X_train_eq[1000])
    plt.subplot(grid_len,grid_len,i)
    plt.imshow(image)
```

```
100%|██████████| 43/43 [00:26<00:00,  1.64it/s]
```




```
Train set increased from 17625 to 70348
```



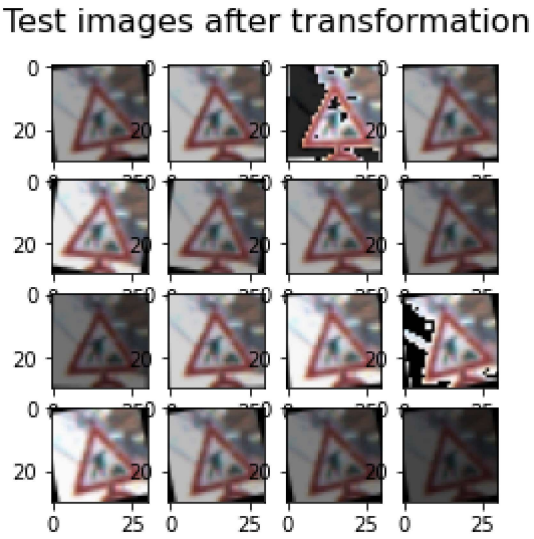


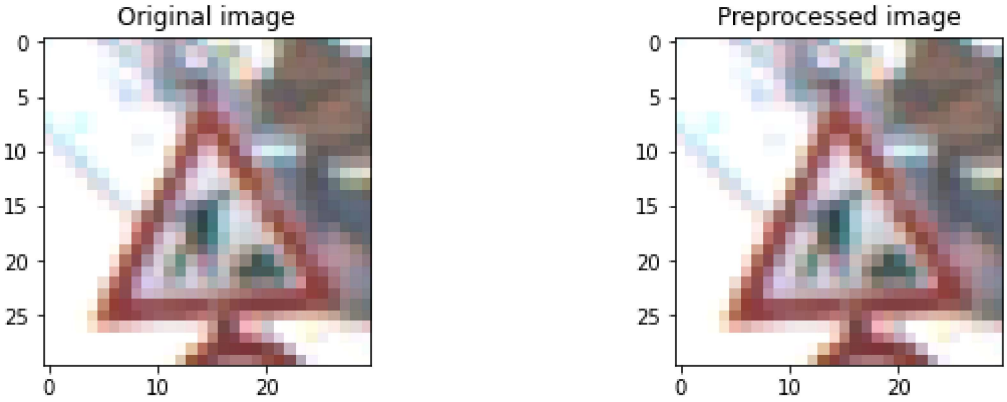
Image normalization and grayscale conversion

In [81]:

```
import cv2
import tensorflow as tf
# from tensorflow.contrib.layers import flatten

def grayscale(img):
    return cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)[:,:,None]

def normalize(value):
    return value / 255

def preprocess_image(image):
    #img = grayscale(image)
    img = normalize(image)
    return img

from tqdm import tqdm
def preprocess_batch(images):
    imgs = np.zeros(shape=images.shape)
    processed_image_depth = preprocess_image(images[0]).shape[2]
    imgs = imgs[:,:,:,0:processed_image_depth]
    for i in tqdm(range(images.shape[0])):
        imgs[i] = preprocess_image(images[i])
    return imgs


# X_train_eq, y_train_eq

X_train_processed = preprocess_batch(X_train_eq)
X_val_processed = preprocess_batch(X_val)

no_test_image = 1000

sample_image = X_train[no_test_image]
sample_image_processed = normalize(X_train_eq[no_test_image])
fig=plt.figure(figsize=(16,3))
sub=plt.subplot(131)
sub.set_title("Original image")
plt.imshow(sample_image)
sub=plt.subplot(132)
sub.set_title("Preprocessed image")
plt.imshow(sample_image_processed.squeeze(), cmap='gray')

print("Sample image dimension BEFORE processing: {}".format(sample_image.sha
print("Sample image dimension AFTER processing: {}".format(sample_image_proc

image_depth = X_train_processed.shape[3]

sample_image = X_train[no_test_image]
dim1 = sample_image.shape[0]
dim2 = sample_image.shape[1]
dim3 = sample_image.shape[2]
sample_image_reshaped = np.reshape(sample_image, dim1*dim2*dim3)
plt.figure(figsize=(16,3))
sub=plt.subplot(131)
sub.set_title("Original image histogram")
n, bins, patches = plt.hist(sample_image_reshaped, 255)
```

```
57
58 sample_image_processed = X_train_processed[no_test_image]
59 dim1 = sample_image_processed.shape[0]
60 dim2 = sample_image_processed.shape[1]
61 dim3 = sample_image_processed.shape[2]
62 sample_image_processed_reshaped = np.reshape(sample_image_processed, dim1*di
63 sub=plt.subplot(132)
64 sub.set_title("Preprocessed image histogram")
65 n, bins, patches = plt.hist(sample_image_processed_reshaped,255)
```

```
100%|██████████████████████████████████████████████████| 70348/70348 [00:00<00:00, 75661.98it/s]
100%|██████████████████████████████████████████████████| 4407/4407 [00:00<00:00, 73640.27it/s]

Sample image dimension BEFORE processing: (30, 30, 3)
Sample image dimension AFTER processing: (30, 30, 3)
```



In [82]:
```
1 # # Flatten input: Changing dimension of input images from N*30*30*3 to N*27
2 X_train_pr = X_train_processed.reshape([X_train_processed.shape[0], -1])
3 X_val_pr = X_val_processed.reshape([X_val_processed.shape[0], -1])
4
5 lb = LabelBinarizer()
6 y_train_eq_one_hot = lb.fit_transform(y_train_eq)
7
```

In [83]:
```
1 X_train_pr.shape
```

Out[83]: (70348, 2700)

In [84]:
```
1 y_train_eq_one_hot.shape
```

Out[84]: (70348, 43)

In [85]:
```
1 y_val_one_hot.shape
```

Out[85]: (4407, 43)

In [86]:
```
1 X_val_pr.shape
```

Out[86]: (4407, 2700)

In [87]:
```
1 X_train_processed.shape
```

Out[87]:
```
(70348, 30, 30, 3)
```

In [88]:
```
1 y_train_eq.shape
```

Out[88]:
```
(70348,)
```

Models Improvement

SVM

In [89]:
```
1 from sklearn.svm import SVC
2 svclassifier_pr = SVC(kernel='linear',decision_function_shape='ovo')
3 #svclassifier = SVC(gamma=1,kernel='rbf')
4 svclassifier_pr.fit(X_train_pr, y_train_eq)
5
6
```

Out[89]:
```
SVC(C=1.0, break_ties=False, cache_size=200, class_weight=None, coef0=0.0,
    decision_function_shape='ovo', degree=3, gamma='scale', kernel='linear',
    max_iter=-1, probability=False, random_state=None, shrinking=True,
    tol=0.001, verbose=False)
```

In [90]:
```
1 score_train_pr = svclassifier_pr.score(X_val_pr, y_val)
```

In [91]:
```
1 Pred_svm_pr=svclassifier_pr.predict(X_test_rs)    #prediction
```

In [92]:
```
1 score_train_pr
```

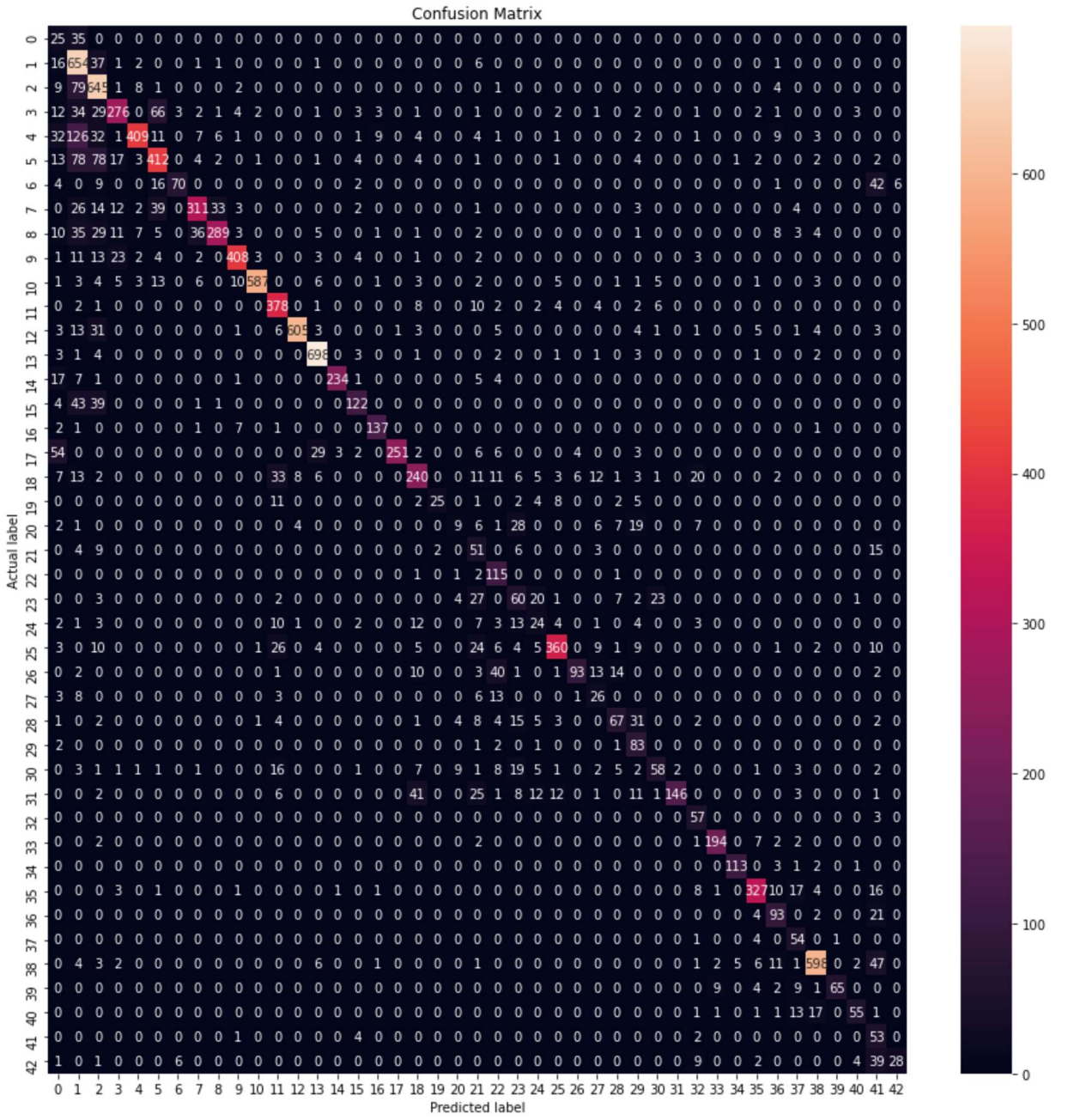
Out[92]:
```
0.9357839800317677
```

In [93]:

```
# Evaluate predictions
print(accuracy_score(labels, Pred_svm_pr))
print(classification_report(labels, Pred_svm_pr))
```

```
0.7525732383214568
              precision    recall  f1-score   support

           0       0.11      0.42      0.17        60
           1       0.55      0.91      0.69       720
           2       0.64      0.86      0.74       750
           3       0.78      0.61      0.69       450
           4       0.94      0.62      0.75       660
           5       0.72      0.65      0.69       630
           6       0.89      0.47      0.61       150
           7       0.84      0.69      0.76       450
           8       0.87      0.64      0.74       450
           9       0.92      0.85      0.89       480
          10       0.99      0.89      0.94       660
          11       0.76      0.90      0.82       420
          12       0.98      0.88      0.93       690
          13       0.91      0.97      0.94       720
          14       0.98      0.87      0.92       270
          15       0.81      0.58      0.68       210
          16       0.90      0.91      0.90       150
          17       1.00      0.70      0.82       360
          18       0.69      0.62      0.65       390
          19       0.93      0.42      0.57        60
          20       0.33      0.10      0.15        90
          21       0.24      0.57      0.33        90
          22       0.51      0.96      0.67       120
          23       0.37      0.40      0.38       150
          24       0.29      0.27      0.28        90
          25       0.88      0.75      0.81       480
          26       0.89      0.52      0.65       180
          27       0.33      0.43      0.37        60
          28       0.63      0.45      0.52       150
          29       0.43      0.92      0.58        90
          30       0.61      0.39      0.47       150
          31       0.99      0.54      0.70       270
          32       0.48      0.95      0.64        60
          33       0.94      0.92      0.93       210
          34       0.95      0.94      0.95       120
          35       0.89      0.84      0.86       390
          36       0.62      0.78      0.69       120
          37       0.49      0.90      0.63        60
          38       0.93      0.87      0.90       690
          39       0.98      0.72      0.83        90
          40       0.83      0.61      0.71        90
          41       0.20      0.88      0.33        60
          42       0.82      0.31      0.45        90

    accuracy                           0.75     12630
   macro avg       0.72      0.69      0.67     12630
weighted avg       0.81      0.75      0.76     12630
```

In [94]:
```
1 plot_cm(labels, Pred_svm_pr)
```



In [95]:
```
1 val_performance_pr = {}
2 performance_pr = {}
3 Model_pr={}
```

In [96]:
```
1 val_performance_pr['SVM']= score_train_pr
2 performance_pr['SVM']=accuracy_score(labels, Pred_svm_pr)
3 Model_pr['SVM']='SVM'
```

CNN_1

In [97]:
```
img_height = 60
img_width = 60
```

In [98]:
```
y_train_prcnn = to_categorical(y_train_eq, 43)
y_val_prcnn = to_categorical(y_val, 43)
```

In [99]:
```
X_train_processed.shape
```

Out[99]:
```
(70348, 30, 30, 3)
```

In [100]:
```
X_train.shape[1:]
```

Out[100]:
```
(30, 30, 3)
```

In [101]:
```
cnn_ag_model = Sequential([

    Conv2D(filters=16,kernel_size=(3,3),activation='relu',input_shape=(30,30
    MaxPool2D(pool_size=(2,2)),# down sampling the output instead of 28*28 i
    Conv2D(32, kernel_size=(4, 4), activation='relu'),
    Conv2D(32, kernel_size=(4, 4), activation='relu'),
    MaxPool2D(pool_size=(2, 2)),
#     Conv2D(64, kernel_size=(3,3), activation='relu'),
#     Conv2D(64, kernel_size=(3,3), activation='relu'),
#     MaxPool2D(pool_size=(2, 2)),
    Dropout(0.3),
    Flatten(), # flatten out the layers
    Dense(256,activation='relu'),
    Dense(43,activation = 'softmax')

])


```

In [102]:
```
cnn_ag_model.compile(loss='categorical_crossentropy', optimizer='adam', metr
```

In [103]:
```
history_ag = cnn_ag_model.fit(X_train_processed, y_train_prcnn,  epochs= 15,
```

```
Epoch 1/15
2199/2199 [==============================] - 43s 19ms/step - loss: 1.5164 - acc
uracy: 0.5836 - val_loss: 0.1213 - val_accuracy: 0.9637
Epoch 2/15
2199/2199 [==============================] - 44s 20ms/step - loss: 0.2086 - acc
uracy: 0.9377 - val_loss: 0.0784 - val_accuracy: 0.9789
Epoch 3/15
2199/2199 [==============================] - 44s 20ms/step - loss: 0.1323 - acc
uracy: 0.9600 - val_loss: 0.0520 - val_accuracy: 0.9850
Epoch 4/15
2199/2199 [==============================] - 44s 20ms/step - loss: 0.0989 - acc
uracy: 0.9693 - val_loss: 0.0449 - val_accuracy: 0.9873
Epoch 5/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0824 - acc
uracy: 0.9751 - val_loss: 0.0429 - val_accuracy: 0.9873
Epoch 6/15
2199/2199 [==============================] - 45s 21ms/step - loss: 0.0740 - acc
uracy: 0.9763 - val_loss: 0.0276 - val_accuracy: 0.9925
Epoch 7/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0580 - acc
uracy: 0.9827 - val_loss: 0.0234 - val_accuracy: 0.9943
Epoch 8/15
2199/2199 [==============================] - 44s 20ms/step - loss: 0.0506 - acc
uracy: 0.9847 - val_loss: 0.0270 - val_accuracy: 0.9932
Epoch 9/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0452 - acc
uracy: 0.9857 - val_loss: 0.0266 - val_accuracy: 0.9932
Epoch 10/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0416 - acc
uracy: 0.9868 - val_loss: 0.0330 - val_accuracy: 0.9905
Epoch 11/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0432 - acc
uracy: 0.9872 - val_loss: 0.0243 - val_accuracy: 0.9946
Epoch 12/15
2199/2199 [==============================] - 44s 20ms/step - loss: 0.0426 - acc
uracy: 0.9874 - val_loss: 0.0234 - val_accuracy: 0.9941
Epoch 13/15
2199/2199 [==============================] - 45s 20ms/step - loss: 0.0400 - acc
uracy: 0.9870 - val_loss: 0.0312 - val_accuracy: 0.9941
Epoch 14/15
2199/2199 [==============================] - 46s 21ms/step - loss: 0.0406 - acc
uracy: 0.9879 - val_loss: 0.0293 - val_accuracy: 0.9925
Epoch 15/15
2199/2199 [==============================] - 45s 21ms/step - loss: 0.0371 - acc
uracy: 0.9893 - val_loss: 0.0243 - val_accuracy: 0.9948
```

In [104]:
```
score_cnn_pr2 = cnn_ag_model.evaluate(X_val, y_val_cnn,batch_size=1, verbose
print('Test loss:', score_cnn_pr2[0], '   Test accuracy:', score_cnn_pr2[1])
```

```
Test loss: 8.642882347106934    Test accuracy: 0.9779895544052124
```

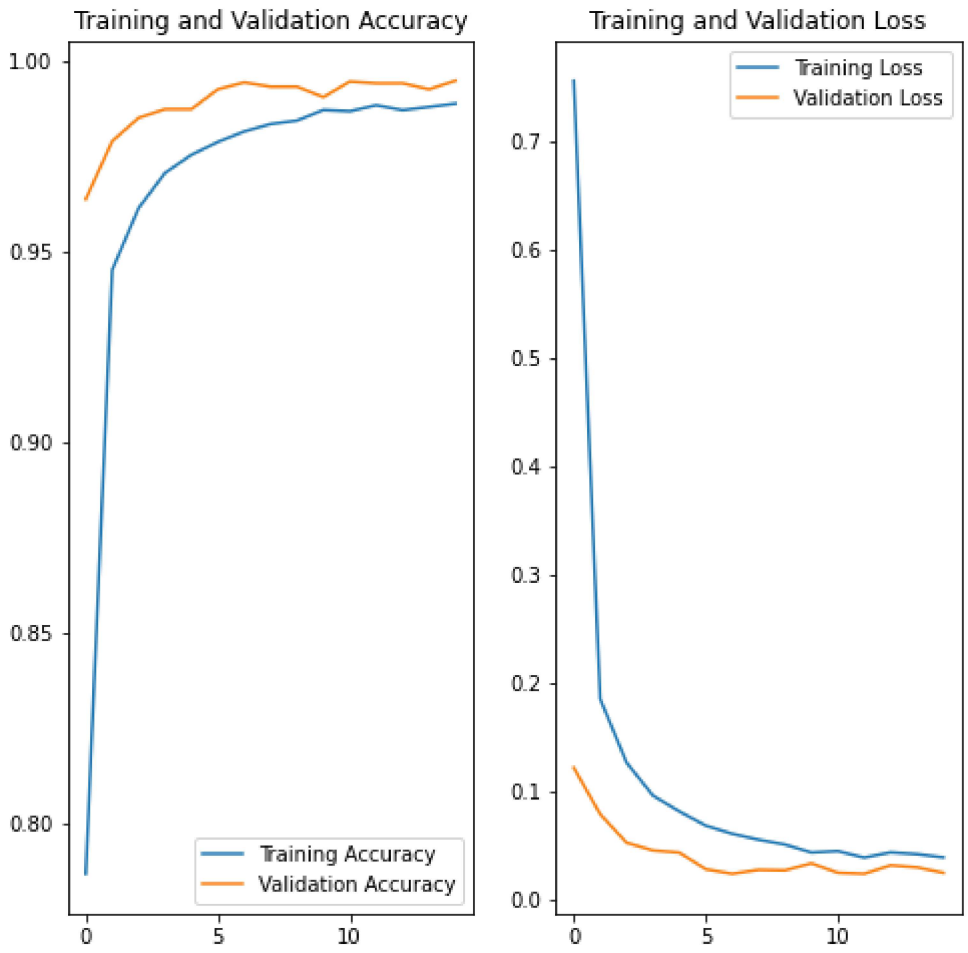
In [105]:

```
pred_cnn_pr2 = cnn_ag_model.predict_classes(X_test)
#Accuracy with the test data
from sklearn.metrics import accuracy_score
print(accuracy_score(labels, pred_cnn_pr2))
```

```
`model.predict_classes()` is deprecated and will be removed after 2021-01-01. P
lease use instead:* `np.argmax(model.predict(x), axis=-1)`,   if your model doe
s multi-class classification   (e.g. if it uses a `softmax` last-layer activati
on).* `(model.predict(x) > 0.5).astype("int32")`,   if your model does binary c
lassification   (e.g. if it uses a `sigmoid` last-layer activation).


0.9277117973079968
```

In [106]:

```
acc = history_ag.history['accuracy']
val_acc = history_ag.history['val_accuracy']

loss = history_ag.history['loss']
val_loss = history_ag.history['val_loss']

epochs_range = range(15)

plt.figure(figsize=(8, 8))
plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')
plt.show()
```



In [107]:

```
val_performance_pr['CNN_1']= score_cnn_pr2[1]
performance_pr['CNN_1']=accuracy_score(labels, pred_cnn_pr2)
Model_pr['CNN_1']='CNN_1'
```

CNN_2

In [108]:
```
img_height = 60
img_width = 60
```

In [109]:
```
cnn_i_model = tf.keras.Sequential(
            [
    keras.layers.Conv2D(filters=32,kernel_size=(4,4),activation='relu',input
    keras.layers.MaxPool2D(pool_size=(2,2)),# down sampling the output inste
    keras.layers.Conv2D(64, kernel_size=(4, 4), activation='relu'),
    keras.layers.Conv2D(64, kernel_size=(4, 4), activation='relu'),
    keras.layers.MaxPool2D(pool_size=(2, 2)),
    keras.layers.Dropout(0.3),
    keras.layers.Flatten(), # flatten out the layers
    keras.layers.Dense(256,activation='relu'),
    keras.layers.Dense(43,activation = 'softmax')



])
cnn_i_model.compile(loss='categorical_crossentropy', optimizer='adam', metri
```

In [110]:
```
X_train_processed.shape[1:]
```

Out[110]: (30, 30, 3)

In [111]:
```
y_train.shape
```

Out[111]: (17625,)

In [112]:
```
X_val_processed.shape
```

Out[112]: (4407, 30, 30, 3)

In [113]:
```
y_val_cnn.shape
```

Out[113]: (4407, 43)

In [114]:
```
y_train_eq.shape
```

Out[114]: (70348,)

In [115]:
```
y_train_prcnn = to_categorical(y_train_eq, 43)
y_val_prcnn = to_categorical(y_val, 43)
```

In [116]:
```
historya = cnn_i_model.fit(X_train_processed, y_train_prcnn,  epochs= 15, va
```

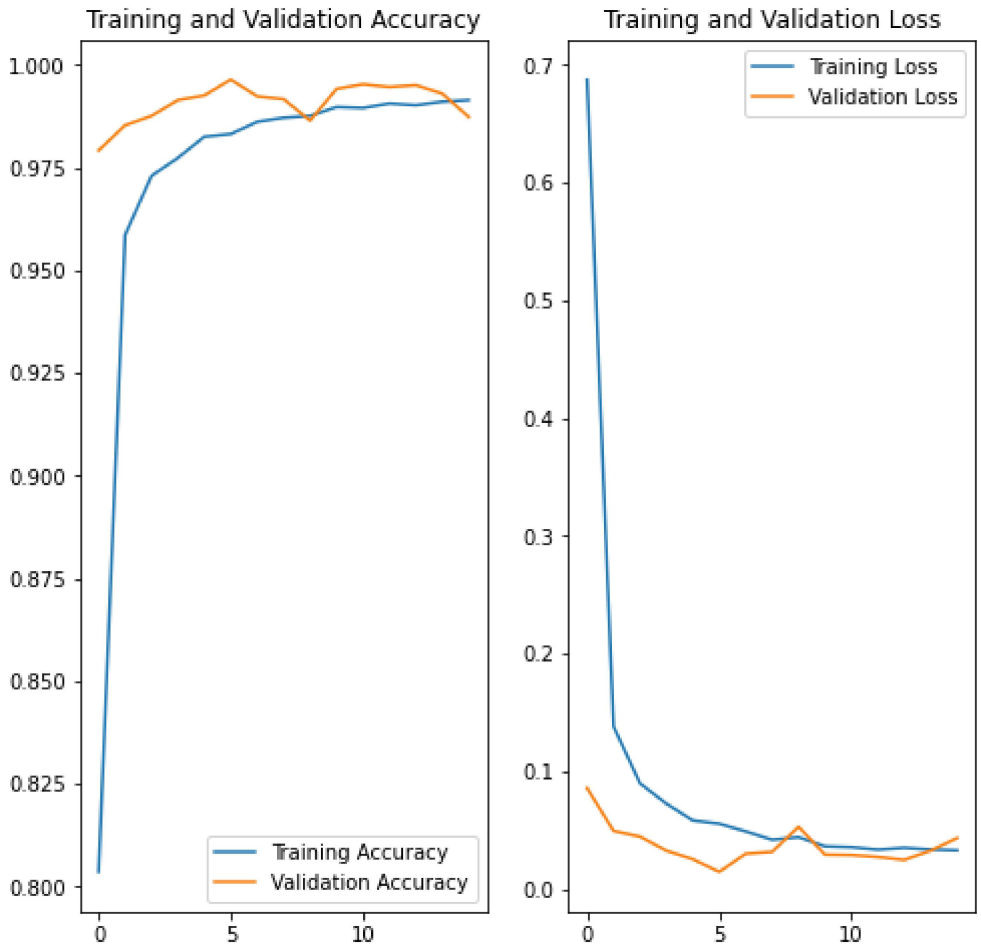
```
Epoch 1/15
2199/2199 [==============================] - 76s 34ms/step - loss: 1.4670 - acc
uracy: 0.5919 - val_loss: 0.0858 - val_accuracy: 0.9791
Epoch 2/15
2199/2199 [==============================] - 76s 35ms/step - loss: 0.1490 - acc
uracy: 0.9547 - val_loss: 0.0495 - val_accuracy: 0.9853
Epoch 3/15
2199/2199 [==============================] - 76s 34ms/step - loss: 0.0951 - acc
uracy: 0.9719 - val_loss: 0.0447 - val_accuracy: 0.9875
Epoch 4/15
2199/2199 [==============================] - 77s 35ms/step - loss: 0.0748 - acc
uracy: 0.9765 - val_loss: 0.0327 - val_accuracy: 0.9914
Epoch 5/15
2199/2199 [==============================] - 76s 34ms/step - loss: 0.0568 - acc
uracy: 0.9832 - val_loss: 0.0255 - val_accuracy: 0.9925
Epoch 6/15
2199/2199 [==============================] - 77s 35ms/step - loss: 0.0569 - acc
uracy: 0.9826 - val_loss: 0.0147 - val_accuracy: 0.9964
Epoch 7/15
2199/2199 [==============================] - 77s 35ms/step - loss: 0.0417 - acc
uracy: 0.9879 - val_loss: 0.0301 - val_accuracy: 0.9923
Epoch 8/15
2199/2199 [==============================] - 76s 34ms/step - loss: 0.0391 - acc
uracy: 0.9878 - val_loss: 0.0318 - val_accuracy: 0.9916
Epoch 9/15
2199/2199 [==============================] - 76s 35ms/step - loss: 0.0393 - acc
uracy: 0.9886 - val_loss: 0.0530 - val_accuracy: 0.9864
Epoch 10/15
2199/2199 [==============================] - 78s 36ms/step - loss: 0.0363 - acc
uracy: 0.9897 - val_loss: 0.0294 - val_accuracy: 0.9941
Epoch 11/15
2199/2199 [==============================] - 79s 36ms/step - loss: 0.0298 - acc
uracy: 0.9911 - val_loss: 0.0290 - val_accuracy: 0.9952
Epoch 12/15
2199/2199 [==============================] - 77s 35ms/step - loss: 0.0305 - acc
uracy: 0.9908 - val_loss: 0.0274 - val_accuracy: 0.9946
Epoch 13/15
2199/2199 [==============================] - 77s 35ms/step - loss: 0.0314 - acc
uracy: 0.9903 - val_loss: 0.0249 - val_accuracy: 0.9950
Epoch 14/15
2199/2199 [==============================] - 76s 35ms/step - loss: 0.0315 - acc
uracy: 0.9917 - val_loss: 0.0328 - val_accuracy: 0.9930
Epoch 15/15
2199/2199 [==============================] - 76s 35ms/step - loss: 0.0333 - acc
uracy: 0.9908 - val_loss: 0.0435 - val_accuracy: 0.9873
```

In [117]:
```
score_cnn_pr1 = cnn_i_model.evaluate(X_val, y_val_cnn,batch_size=1, verbose=
print('Test loss:', score_cnn_pr1[0], '   Test accuracy:', score_cnn_pr1[1])
```

```
Test loss: 30.481815338134766    Test accuracy: 0.9260267615318298
```

In [118]:

```
acc = historya.history['accuracy']
val_acc = historya.history['val_accuracy']

loss = historya.history['loss']
val_loss = historya.history['val_loss']

epochs_range = range(15)

plt.figure(figsize=(8, 8))
plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')
plt.show()
```



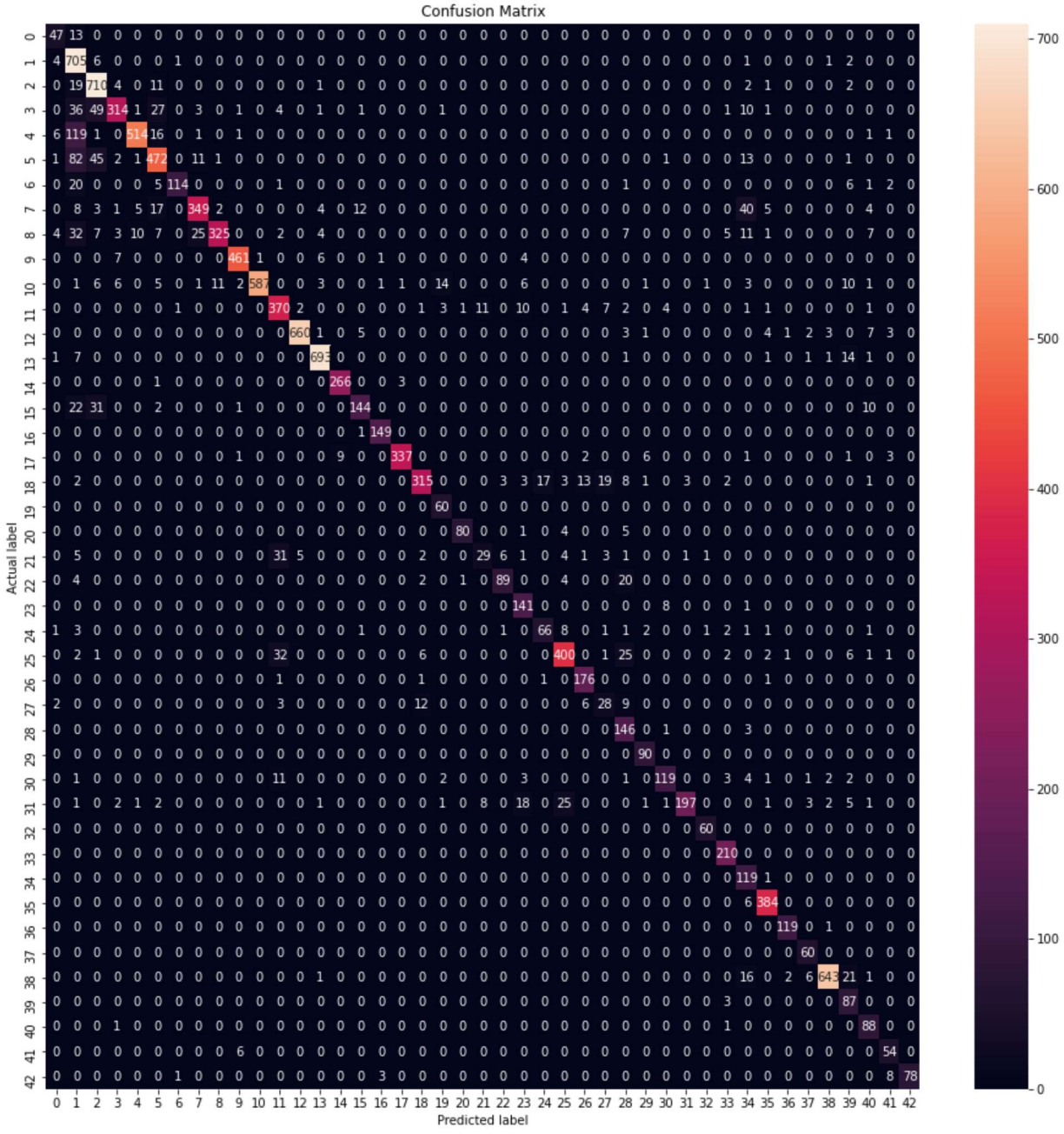
In [119]:

```
pred_cnn_pr1 = cnn_i_model.predict_classes(X_test)
#Accuracy with the test data
from sklearn.metrics import accuracy_score
print(accuracy_score(labels, pred_cnn_pr1))
```

```
0.8752969121140143
```

In [121]:

```
import sklearn
import seaborn as sns
from sklearn.metrics import confusion_matrix
def plot_cm(labels, pred):
  cm = confusion_matrix(labels, pred)
  plt.figure(figsize=(16,16))
  sns.heatmap(cm, annot=True, fmt="d")
  plt.title('Confusion Matrix')
  plt.ylabel('Actual label')
  plt.xlabel('Predicted label')

plot_cm(labels, pred_cnn_pr1)
```



In [122]:

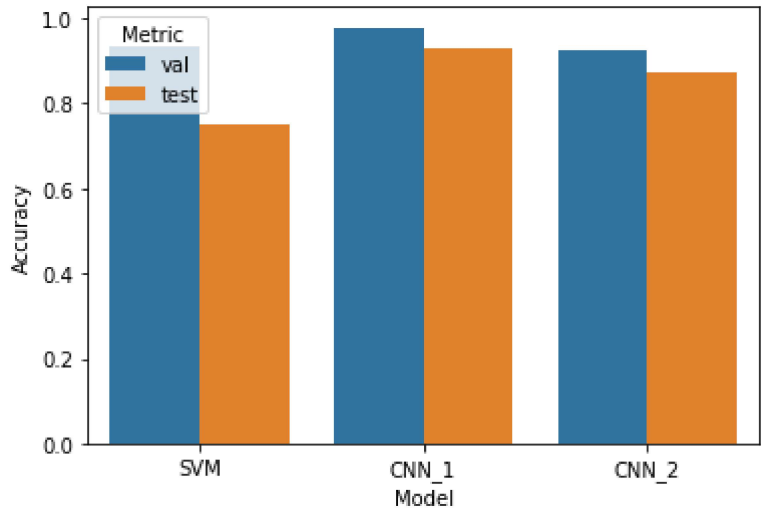
```
val_performance_pr['CNN_2']= score_cnn_pr1[1]
performance_pr['CNN_2']=accuracy_score(labels, pred_cnn_pr1)
Model_pr['CNN_2']='CNN_2'
```

Model Performance

In [123]:
```
Performance_pr = pd.DataFrame(
    {'val': val_performance_pr,
     'test': performance_pr,
     'Model':Model_pr
    })
```

In [124]:
```
df_accuracy_pr = Performance_pr.melt(id_vars=['Model'], var_name='Metric', v
```

In [125]:
```
ax = sns.barplot(x="Model", y="Accuracy", hue="Metric", data=df_accuracy_pr)
```



Explainable AI

In [181]:
```
from sklearn.metrics import accuracy_score
y_test_at = pd.read_csv("C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Anal
labels = y_test_at["ClassId"].values
imgs = y_test_at["Path"].values
data=[]
for img in imgs:
    image = Image.open("C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analy
    image = image.resize((30,30))
    image = np.array(image)
    image = image.astype('float32')
    image /=255.0
    data.append(np.array(image))
X_test_at=np.array(data)
```

In [182]:
```
explainer = shap.GradientExplainer(cnn_ag_model, X_train_processed)
```

In [183]:
```
# we explain the model's predictions on the first three samples of the test
shap_values = explainer.shap_values(X_test_at[:10])
```

```
`tf.keras.backend.set_learning_phase` is deprecated and will be removed after 2
020-10-11. To update it, simply pass a True/False value to the `training` argum
ent of the `__call__` method of your layer or model.
```

In [185]:
```
# here we plot the explanations for all classes for the first input (this is
shap.image_plot([shap_values[i] for i in range(8)], X_test_at[:10])
```

Object Detection

In [142]:

```
from tqdm import tqdm
import math
#Run this only once
#Creating validation directory
val_dir = 'C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Final P
os.mkdir(val_dir)

n_classes = 43
train_dir = 'C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Final

#Moving files from train to validation directory
for n in tqdm(range(n_classes)) :
  path = os.path.join(val_dir, str(n))
  os.mkdir(path)
  src_path = train_dir.format('/' + str(n))
  files = os.listdir(src_path)
  rand_idx = random.sample(range(len(files)), math.ceil(len(files)/4))
  for idx in rand_idx :
    src = src_path + "/" + files[idx]
    shutil.move(src, path)
```

```
100%|████████| 43/43 [00:05<00:00,  7.40it/s]
```

In [143]:

```
#Setting up variables
IMG_WIDTH = 30
IMG_HEIGHT = 30
N_CHANNELS = 3
BATCH_SIZE = 32
N_EPOCHS = 10
VAL_BATCH_SIZE = 32
CLASS_NAMES = list(range(43))
N_CLASSES = 43

train_path = "C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Pro
val_path = "C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analytics\\Final
```

In [144]:

```
import pathlib
import os
import ntpath
#Path to train and validation datasets
data_root_train = pathlib.Path(train_path)
data_root_val = pathlib.Path(val_path)

#Getting paths to all the images in train and validation sets
all_image_paths_train = list(data_root_train.glob('*/*'))
all_image_paths_train = [str(path).replace(os.sep,'/') for path in all_image

all_image_paths_val = list(data_root_val.glob('*/*'))
all_image_paths_val = [str(path).replace(os.sep,'/') for path in all_image_p

#Counting number of images in each sets
image_count_train = len(all_image_paths_train)
image_count_val = len(all_image_paths_val)
all_image_paths_train
```

Out[144]:

```
['C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00001.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00002.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00003.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00005.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00006.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00008.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00009.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00010.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
in/0/00000_00000_00011.png',
 'C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Project/Data/Tra
```

In [145]:

```
#Extracting labels for each image
label_names_train = sorted(int(item.name) for item in data_root_train.glob('
label_names_val = sorted(int(item.name) for item in data_root_val.glob('*/')
label_to_index_train = dict((name, index) for index,name in enumerate(label_
label_to_index_val = dict((name, index) for index,name in enumerate(label_na
all_image_labels_train = [label_to_index_train[int(pathlib.Path(path).parent
all_image_labels_val = [label_to_index_val[int(pathlib.Path(path).parent.nam
```

In [146]:

```
df_train = pd.read_csv("C:\\Drive\\Siri\\MSDSBA\\4. IE7860 Intelligent Analy
for idx, row in df_train.iterrows() :
  w = row['Width']
  h = row['Height']
  if w > IMG_WIDTH :
    diff = w-IMG_WIDTH
    df_train.iloc[idx, 4] = df_train.iloc[idx]['Roi.X2'] - diff
  else :
    diff = IMG_WIDTH-w
    df_train.iloc[idx, 4] = df_train.iloc[idx]['Roi.X2'] + diff
  if h > IMG_HEIGHT :
    diff = h - IMG_HEIGHT
    df_train.iloc[idx, 5] = df_train.iloc[idx]['Roi.Y2'] - diff
  else :
    diff = IMG_HEIGHT - h
    df_train.iloc[idx, 5] = df_train.iloc[idx]['Roi.Y2'] + diff
```

In [147]:

```
df_train
```

Out[147]:

	Width	Height	Roi.X1	Roi.Y1	Roi.X2	Roi.Y2	ClassId	Path
0	27	26	5	5	25	24	20	Train/20/00020_00000_00000.png
1	28	27	5	6	25	25	20	Train/20/00020_00000_00001.png
2	29	26	6	5	25	25	20	Train/20/00020_00000_00002.png
3	28	27	5	6	25	25	20	Train/20/00020_00000_00003.png
4	28	26	5	5	25	25	20	Train/20/00020_00000_00004.png
...	...	...	...	...	...	...	...	...
39204	52	56	5	6	25	25	42	Train/42/00042_00007_00025.png
39205	56	58	5	5	25	25	42	Train/42/00042_00007_00026.png
39206	58	62	5	6	25	25	42	Train/42/00042_00007_00027.png
39207	63	69	5	7	25	24	42	Train/42/00042_00007_00028.png
39208	68	69	7	6	24	24	42	Train/42/00042_00007_00029.png

39209 rows × 8 columns

In [148]:

```
all_image_paths_val[6][83:]
```

Out[148]:

```
'0/00000_00002_00014.png'
```

In [149]:

```
train_idx_list = []
val_idx_list = []

for path_tr in tqdm(all_image_paths_train) :
  train_idx_list.append(df_train[df_train['Path'] == path_tr[72 : ]].index[0
for path_val in tqdm(all_image_paths_val) :
  path_val = "Train/" + path_val[83:]
  val_idx_list.append(df_train[df_train['Path'] == path_val].index[0])
new_df_train = pd.DataFrame()
new_df_val = pd.DataFrame()
new_df_train = new_df_train.append(df_train.iloc[train_idx_list], ignore_ind
new_df_val = new_df_val.append(df_train.iloc[val_idx_list], ignore_index = T
new_df_train = new_df_train.drop(['Height', 'Width', 'ClassId', 'Path'], axi
new_df_val = new_df_val.drop(['Height', 'Width', 'ClassId', 'Path'], axis =
```

```
100%|██████████████████████████████████████████████████████████████████
██| 16509/16509 [00:51<00:00, 319.54it/s]
100%|██████████████████████████████████████████████████████████████████
███| 5523/5523 [00:18<00:00, 299.23it/s]
```

In [150]:

```
new_df_val
```

Out[150]:

	Roi.X1	Roi.Y1	Roi.X2	Roi.Y2
0	5	6	25	24
1	6	6	25	25
2	6	5	25	25
3	10	11	19	19
4	12	13	18	18
...	...	...	...	...
5518	7	7	24	24
5519	6	6	25	24
5520	5	6	25	25
5521	5	6	25	25
5522	5	5	24	24

5523 rows × 4 columns

In [151]:

```
def tfdata_generator(images, labels, df, is_training, batch_size=32):
  '''Construct a data generator using tf.Dataset'''
  def parse_function(filename, labels, df):
    '''Function to preprocess the images'''
    #reading path
    image_string = tf.io.read_file(filename)
    #decoding image
    image = tf.image.decode_png(image_string, channels=N_CHANNELS)
    # This will convert to float values in [0, 1]
    image = tf.image.convert_image_dtype(image, tf.float32)
    #Adjusting contrast and brightness of the image
    if tf.math.reduce_mean(image) < 0.3 :
      image = tf.image.adjust_contrast(image, 5)
      image = tf.image.adjust_brightness(image, 0.2)
    #resize the image
    image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH], method="nearest"
    image = image/255.0
    #one hot coding for label
    #y = tf.one_hot(tf.cast(label, tf.uint8), N_CLASSES)
    return image, {"classification" : labels, "regression" : df}
  ##creating a dataset from tensorslices
  dataset = tf.data.Dataset.from_tensor_slices((images, labels, df))
  if is_training:
    dataset = dataset.shuffle(30000)  # depends on sample size
  # Transform and batch data at the same time
  dataset = dataset.map(parse_function, num_parallel_calls = tf.data.experim
  dataset = dataset.repeat()
  dataset = dataset.batch(batch_size)
  #prefetch the data into CPU/GPU
  dataset = dataset.prefetch(tf.data.experimental.AUTOTUNE)
  return dataset
```

In [152]:

```
tf_image_generator_train = tfdata_generator(all_image_paths_train, all_image
tf_image_generator_val = tfdata_generator(all_image_paths_val, all_image_lab
```

In [153]:

```
steps_per_epoch_train = np.ceil(len(all_image_paths_train)/BATCH_SIZE)
steps_per_epoch_val = np.ceil(len(all_image_paths_val)/BATCH_SIZE)
```

In [154]:

```
class Sharpen(tf.keras.layers.Layer):
    def __init__(self, num_outputs) :
        super(Sharpen, self).__init__()
        self.num_outputs = num_outputs

    def build(self, input_shape) :
        self.kernel = np.array([[-1,-1,-1], [-1,9,-1], [-1,-1,-1]])
        self.kernel = tf.expand_dims(self.kernel, 0)
        self.kernel = tf.expand_dims(self.kernel, 0)
        self.kernel = tf.cast(self.kernel, tf.float32)

    def call(self, input_) :
        return tf.nn.conv2d(input_, self.kernel, strides=[1, 1, 1, 1], paddi
```

In [161]:

```
def get_model() :
  #Input Layer
  input_layer = Input(shape=(IMG_HEIGHT, IMG_WIDTH, N_CHANNELS, ), name="inp
  #Sharpen Layer to sharpen the edges of the image.
  sharp = Sharpen(num_outputs=(IMG_HEIGHT, IMG_WIDTH, N_CHANNELS, ))(input_l
  #Convolution, maxpool and dropout layers
  conv_1 = Conv2D(filters=32, kernel_size=(5,5), activation=relu,
                  kernel_initializer=he_normal(seed=54), bias_initializer=ze
                  name="first_convolutional_layer") (sharp)
  conv_2 = Conv2D(filters=64, kernel_size=(3,3), activation=relu,
                  kernel_initializer=he_normal(seed=55), bias_initializer=ze
                  name="second_convolutional_layer") (conv_1)
  maxpool_1 = MaxPool2D(pool_size=(2,2), name = "first_maxpool_layer")(conv_
  dr1 = Dropout(0.25)(maxpool_1)
  conv_3 = Conv2D(filters=64, kernel_size=(3,3), activation=relu,
                  kernel_initializer=he_normal(seed=56), bias_initializer=ze
                  name="third_convolutional_layer") (dr1)
  maxpool_2 = MaxPool2D(pool_size=(2,2), name = "second_maxpool_layer")(conv
  dr2 = Dropout(0.25)(maxpool_2)
  flat = Flatten(name="flatten_layer")(dr2)

  #Fully connected layers
  d1 = Dense(units=256, activation=relu, kernel_initializer=he_normal(seed=4
             bias_initializer=zeros(), name="first_dense_layer_classificatio
  dr3 = Dropout(0.5)(d1)

  classification = Dense(units = 43, activation=None, name="classification",

  regression = Dense(units = 4, activation = 'linear', name = "regression",
                     kernel_initializer=RandomNormal(seed=43), kernel_regula
  #Model
  model = Model(inputs = input_layer, outputs = [classification, regression]
  model.summary()
  return model
```

In [166]:
```
1 model = get_model()
```

```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_layer (InputLayer)     [(None, 30, 30, 3)]       0
_________________________________________________________________
sharpen_3 (Sharpen)          (None, 30, 30, 3)         0
_________________________________________________________________
first_convolutional_layer (Conv (None, 26, 26, 32)     2432
_________________________________________________________________
second_convolutional_layer (Con (None, 24, 24, 64)     18496
_________________________________________________________________
first_maxpool_layer (MaxPooling (None, 12, 12, 64)     0
_________________________________________________________________
dropout_7 (Dropout)          (None, 12, 12, 64)        0
_________________________________________________________________
third_convolutional_layer (Conv (None, 10, 10, 64)     36928
_________________________________________________________________
second_maxpool_layer (MaxPoolin (None, 5, 5, 64)       0
_________________________________________________________________
dropout_8 (Dropout)          (None, 5, 5, 64)          0
_________________________________________________________________
flatten_layer (Flatten)      (None, 1600)              0
_________________________________________________________________
first_dense_layer_classificatio (None, 256)            409856
_________________________________________________________________
dropout_9 (Dropout)          (None, 256)               0
_________________________________________________________________
classification (Dense)       (None, 43)                11051
_________________________________________________________________
```

```
regression (Dense)              (None, 4)            1028        dropout_9[0]
[0]
==================================================================================
==================
Total params: 479,791
Trainable params: 479,791
Non-trainable params: 0
```

In [167]:

```python
from tensorflow.keras.callbacks import Callback
from sklearn.metrics import f1_score, precision_score, recall_score
class Metrics(Callback) :
  def __init__(self, validation_data_generator) :
    self.validation_data_generator = validation_data_generator

  def on_train_begin(self, logs={}) :
    '''
    This function initializes lists to store AUC and Micro F1 scores
    '''
    self.val_f1s = []
    self.val_precisions = []
    self.val_recalls = []
    self.batches = self.validation_data_generator.as_numpy_iterator()

  def on_epoch_end(self, epoch, logs = {}) :
    '''
    This function calculates the micro f1 and auc scores
    at the end of each epochs
    '''
    current_batch = self.batches.next()
    images = current_batch[0]
    labels = current_batch[1]
    labels = labels["classification"]
    labels = np.array(labels)
    pred = self.model.predict(images)
    pred = pred[0]
    val_predict = (np.asarray(pred)).round()
    idx = np.argmax(val_predict, axis=-1)
    a = np.zeros( val_predict.shape )
    a[ np.arange(a.shape[0]), idx] = 1
    val_predict = [np.where(r==1)[0][0] for r in a]
    val_predict = np.array(val_predict)
    val_targ = labels
    _val_f1 = f1_score(val_targ, val_predict, average = 'weighted')
    _val_precision = precision_score(val_targ, val_predict, average='weighte
    _val_recall = recall_score(val_targ, val_predict, average='weighted')
    print("\nEpoch : {0} -  Precision_Score : {1:.2f} - Recall_Score : {2:.2
    self.val_f1s.append(_val_f1)
    self.val_precisions.append(_val_precision)
    self.val_recalls.append(_val_recall)
    return
```

In [168]:

```
from keras import backend as K
def r2_keras(y_true, y_pred):
  SS_res =  K.sum(K.square(y_true - y_pred))
  SS_tot = K.sum(K.square(y_true - K.mean(y_true)))
  return ( 1 - SS_res/(SS_tot + K.epsilon()) )

loss = SparseCategoricalCrossentropy(from_logits=True)

model.compile(optimizer="adam", loss = {"classification" : loss, "regression
              metrics={"classification" : "acc", "regression" : r2_keras}, l
```

In [169]:

```
from tensorflow.keras.callbacks import ModelCheckpoint, TensorBoard, EarlySt
from sklearn.metrics import f1_score, precision_score, recall_score, auc
import datetime
import time
%load_ext tensorboard
log_dir="/content/drive/My Drive/CaseStudy2/logs/fit/" + datetime.datetime.n
NAME = "TrafficSignRecog-first-cut-{0}".format(int(time.time()))
save_best_model = ModelCheckpoint(filepath='/content/drive/My Drive/CaseStud
                                  save_best_only = True, mode = 'min', save_
tensorboard_callback = TensorBoard(log_dir=log_dir, histogram_freq=1, write_
                                   write_images = True)
early_stop = EarlyStopping(monitor='loss', min_delta=0.0001, patience=5)
metrics = Metrics(tf_image_generator_val)
```

In [170]:

```
history = model.fit_generator(
    generator = tf_image_generator_train, steps_per_epoch = steps_per_epoch_
    epochs = N_EPOCHS,
    validation_data = tf_image_generator_val, validation_steps = steps_per_e
    callbacks = [save_best_model, tensorboard_callback, metrics, early_stop]
)
```

```
WARNING:tensorflow:Model failed to serialize as JSON. Ignoring... Layer Sharp
en has arguments in `__init__` and therefore must override `get_config`.

`Model.fit_generator` is deprecated and will be removed in a future version.
Please use `Model.fit`, which supports generators.
```

In [171]:
```
test_df = pd.read_csv('C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/
for idx, row in test_df.iterrows() :
  w = row['Width']
  h = row['Height']
  if w > IMG_WIDTH :
    diff = w-IMG_WIDTH
    test_df.iloc[idx, 4] = test_df.iloc[idx]['Roi.X2'] - diff
  else :
    diff = IMG_WIDTH-w
    test_df.iloc[idx, 4] = test_df.iloc[idx]['Roi.X2'] + diff
  if h > IMG_HEIGHT :
    diff = h - IMG_HEIGHT
    test_df.iloc[idx, 5] = test_df.iloc[idx]['Roi.Y2'] - diff
  else :
    diff = IMG_HEIGHT - h
    test_df.iloc[idx, 5] = test_df.iloc[idx]['Roi.Y2'] + diff
```

In [173]:
```
def evaluate_test_images(path, model) :
  labels = []
  bbox = []
  all_imgs = os.listdir(path)
  all_imgs.sort()
  for img in tqdm(all_imgs) :
    if '.png' in img :
      image_string = tf.io.read_file(path + '/' + img)
      image = tf.image.decode_png(image_string, channels=N_CHANNELS)
      image = tf.image.convert_image_dtype(image, tf.float32)
      if tf.math.reduce_mean(image) < 0.3 :
        image = tf.image.adjust_contrast(image, 5)
        image = tf.image.adjust_brightness(image, 0.2)
      image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH], method="neares
      image = image/255.0
      image = np.expand_dims(image, axis=0)
      pred = model.predict(image)
      labels.append(np.argmax(pred[0][0]))
      bbox.append(pred[1][0])
  return labels, bbox
```

In [174]:
```
model.compile()
```

In [175]:
```
test_path = "C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Proj
labels, bbox = evaluate_test_images(test_path, model)
```

```
100%|
| 12630/12630 [09:04<00:00, 23.19it/s]
```

In [176]:
```
from sklearn.metrics import f1_score, mean_squared_error, precision_score, r
test_precision = precision_score(test_df['ClassId'], labels, average='weight
test_recall = recall_score(test_df['ClassId'], labels, average='weighted')
test_f1_score = f1_score(test_df['ClassId'], labels, average = 'weighted')
test_mse = mean_squared_error(test_df.iloc[:, 2:6], bbox)
```

In [177]:
```
print("Test Precision : {0:.2f}".format(test_precision))
print("Test Recall : {0:.2f}".format(test_recall))
print("Test f1-score : {0:.2f}".format(test_f1_score))
print("Test Mean squared error : {0:.2f}".format(test_mse))
```

```
Test Precision : 0.89
Test Recall : 0.88
Test f1-score : 0.87
Test Mean squared error : 3.20
```

In [178]:
```
pip install pillow
```

```
Requirement already satisfied: pillow in c:\users\peddi\anaconda3\lib\site-pack
ages (8.0.1)
Note: you may need to restart the kernel to use updated packages.
```

In [179]:

```
#Plotting some correctly classified images :
from PIL import Image
import matplotlib.pyplot as plt
import math
test_df = pd.read_csv('C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/
test_path = "C:/Drive/Siri/MSDSBA/4. IE7860 Intelligent Analytics/Final Proj
fig, ax = plt.subplots(5, 5)
fig.set_size_inches((10, 10))
cnt = 0
i = 0
j = 0
while cnt < 25 :
  idx = random.randint(0, test_df.shape[0])
  if test_df.iloc[idx]['ClassId'] == labels[idx] :
    x1, y1, x2, y2 = test_df.iloc[idx, 2:6]
    img = cv2.imread(test_path + test_df.iloc[idx]['Path'])
    height = img.shape[0]
    width = img.shape[1]
    px1, py1, px2, py2 = bbox[idx][0], bbox[idx][1], bbox[idx][2], bbox[idx]
    if width > IMG_WIDTH :
      diff = width - IMG_WIDTH
      px2 += diff
    elif width < IMG_WIDTH :
      px2 -= diff
    else :
      pass
    if height > IMG_HEIGHT :
      diff = height - IMG_HEIGHT
      py2 += diff
    elif height < IMG_HEIGHT :
      py2 -= diff
    else :
      pass
    img = cv2.rectangle(img, (x1, y1), (x2, y2), (255,0,0), 1) #Actual bound
    img = cv2.rectangle(img, (math.ceil(px1), math.ceil(py1)), (math.ceil(px
    ax[i][j].imshow(img)
    j+=1
    if j == 5 :
      i+=1
      j = 0
    cnt+=1
plt.show()
```