In [ ]:
```
import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
import os
import pickle
import matplotlib.patches as patches
import re
import random
from sklearn.model_selection import train_test_split
import cv2
import seaborn as sns
import warnings
warnings.filterwarnings("ignore")
from keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.utils import plot_model
from PIL import Image
import tensorflow as tf
from keras.layers import GlobalAveragePooling2D,Dense,Conv2D,BatchNormalization,Dropout
import keras
from keras import backend as K
from keras.models import Model,load_model
from tensorflow.python.framework.ops import disable_eager_execution
from keras.regularizers import l2
import datetime
%load_ext tensorboard
```

In [ ]:
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

In [ ]:
```
with open('/content/drive//My Drive/Steel_Detection /data.pkl','rb') as f:
    train=pickle.load(f)
```

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

	image_id	rle_1	rle_2	rle_3	rle_4	defect	stratify	defect_1	defect_2	defect_3	defect_4	total_defects
0	0002cc93b.jpg	29102 12 29346 24 29602 24 29858 24 30114 24 3...				1	1	1	0	0	0	1
1	00031f466.jpg					0	0	0	0	0	0	0
2	000418bfc.jpg					0	0	0	0	0	0	0
3	000789191.jpg					0	0	0	0	0	0	0
4	0007a71bf.jpg			18661 28 18863 82 19091 110 19347 110 19603 11...		1	3	0	0	1	0	1

In [ ]:
```
train.shape
```

```
(12568, 12)
```

```
In [ ]: def f1_score(y_true, y_pred):
            #https://aakashgoel12.medium.com/how-to-add-user-defined-function-get-f1-score-in-keras-metric
        s-3013f979ce0d
            #https://stackoverflow.com/questions/43547402/how-to-calculate-f1-macro-in-keras
            true_positives=K.sum(K.round(K.clip(y_true*y_pred,0,1)))   #calculates number of true positive
        s
            possible_positives=K.sum(K.round(K.clip(y_true,0,1)))      #calculates number of actual positi
        ves
            predicted_positives=K.sum(K.round(K.clip(y_pred,0,1)))

            #K.epsilon takes care of non-zero divisions
            #was modified by adding the constant epsilon, in order to avoid division by 0. Thus NaN will n
        ot be computed.
            precision=true_positives/(predicted_positives +K.epsilon())
            recall=true_positives/(possible_positives+K.epsilon())
            f1_val=2*(precision*recall)/(precision+recall+K.epsilon())
            return f1_val
```

- If image have defect than only image considered in data.

```
In [ ]: #https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.train_test_split.html
        train=train[train['defect']==1]
        x_train,x_test=train_test_split(train,test_size=0.10,stratify=train['stratify'],random_state=0)
        x_train,x_val=train_test_split(x_train,test_size=0.20,stratify=x_train['stratify'],random_state=0)
        x_train=x_train[['image_id','defect_1','defect_2','defect_3','defect_4']]
        x_val=x_val[['image_id','defect_1','defect_2','defect_3','defect_4']]
        x_test=x_test[['image_id','defect_1','defect_2','defect_3','defect_4']]
        print("x_train {}".format(x_train.shape),"  x_val {}".format(x_val.shape)," x_test {}".format(x_te
        st.shape))
```

```
x_train (4799, 5)   x_val (1200, 5)  x_test (667, 5)
```

In [ ]:
```
#https://www.analyticsvidhya.com/blog/2020/08/image-augmentation-on-the-fly-using-keras-imagedatag
enerator/
#https://www.tensorflow.org/api_docs/python/tf/keras/preprocessing/image/ImageDataGenerator
train_datagen=ImageDataGenerator(rescale=1./255,
                                 shear_range=0.2,
                                 zoom_range=0.1,
                                 horizontal_flip=True,
                                 vertical_flip=True,
                                 rotation_range=10,
                                 width_shift_range=0.1,
                                 height_shift_range=0.1)

val_datagen=ImageDataGenerator(rescale=1./255)


train_folder_path='/content/drive//My Drive/Steel_Detection /train_images'
col=["defect_1","defect_2","defect_3","defect_4"]
train_image_generator=train_datagen.flow_from_dataframe(dataframe=x_train,
                                                  directory=train_folder_path,
                                                  x_col="image_id",
                                                  y_col=col,
                                                  batch_size=32,
                                                  class_mode="raw",
                                                  target_size=(256,512))

val_image_generator=val_datagen.flow_from_dataframe(dataframe=x_val,
                                                  directory=train_folder_path,
                                                  x_col="image_id",
                                                  y_col=col,
                                                  batch_size=32,
                                                  class_mode="raw",
                                                  target_size=(256,512))
```

```
Found 4799 validated image filenames.
Found 1200 validated image filenames.
```

- Used pre-trained Xception() model as base model by keras without fully-connected layer at the top of the network and later freeze the pre-trained model.

In [ ]:
```
#https://keras.io/api/applications/inceptionresnetv2/
base_model=tf.keras.applications.xception.Xception(input_shape=(256,512,3),include_top=False)
base_model.trainable=False

m=base_model.output
# add a global average pooling layer
#https://stackoverflow.com/questions/49295311/what-is-the-difference-between-flatten-and-globalave
ragepooling2d-in-keras
m=GlobalAveragePooling2D()(m)

# add fully-connected layers
m=Dense(1024,activation='relu')(m)
m=BatchNormalization()(m)   #https://www.analyticsvidhya.com/blog/2021/03/introduction-to-batch-no
rmalization/
m=Dropout(0.4)(m)

#https://machinelearningmastery.com/how-to-reduce-overfitting-in-deep-learning-with-weight-regular
ization/
m=Dense(512,activation='relu')(m)
m=BatchNormalization()(m)
m= Dropout(0.4)(m)

m=Dense(64,activation='relu')(m)

#prediction layer
output=Dense(4,activation='sigmoid')(m)

model=Model(inputs=base_model.input,outputs=output)
model._name="Multi_label_Classification_Model"
model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/xception/xception_weights_tf_dim_ordering_tf_kernels_no
top.h5
83689472/83683744 [==============================] - 1s 0us/step
83697664/83683744 [==============================] - 1s 0us/step
Model: "Multi_label_Classification_Model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 256, 512, 3) 0
__________________________________________________________________________________________________
block1_conv1 (Conv2D)           (None, 127, 255, 32) 864         input_1[0][0]
__________________________________________________________________________________________________
block1_conv1_bn (BatchNormaliza (None, 127, 255, 32) 128         block1_conv1[0][0]
__________________________________________________________________________________________________
block1_conv1_act (Activation)   (None, 127, 255, 32) 0           block1_conv1_bn[0][0]
__________________________________________________________________________________________________
block1_conv2 (Conv2D)           (None, 125, 253, 64) 18432       block1_conv1_act[0][0]
__________________________________________________________________________________________________
block1_conv2_bn (BatchNormaliza (None, 125, 253, 64) 256         block1_conv2[0][0]
__________________________________________________________________________________________________
block1_conv2_act (Activation)   (None, 125, 253, 64) 0           block1_conv2_bn[0][0]
__________________________________________________________________________________________________
block2_sepconv1 (SeparableConv2 (None, 125, 253, 128 8768        block1_conv2_act[0][0]
__________________________________________________________________________________________________
block2_sepconv1_bn (BatchNormal (None, 125, 253, 128 512         block2_sepconv1[0][0]
__________________________________________________________________________________________________
block2_sepconv2_act (Activation (None, 125, 253, 128 0           block2_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block2_sepconv2 (SeparableConv2 (None, 125, 253, 128 17536       block2_sepconv2_act[0][0]
__________________________________________________________________________________________________
block2_sepconv2_bn (BatchNormal (None, 125, 253, 128 512         block2_sepconv2[0][0]
__________________________________________________________________________________________________
conv2d (Conv2D)                 (None, 63, 127, 128) 8192        block1_conv2_act[0][0]
__________________________________________________________________________________________________
block2_pool (MaxPooling2D)      (None, 63, 127, 128) 0           block2_sepconv2_bn[0][0]
__________________________________________________________________________________________________
batch_normalization (BatchNorma (None, 63, 127, 128) 512         conv2d[0][0]
__________________________________________________________________________________________________
add (Add)                       (None, 63, 127, 128) 0           block2_pool[0][0]
                                                                 batch_normalization[0][0]
__________________________________________________________________________________________________
block3_sepconv1_act (Activation (None, 63, 127, 128) 0           add[0][0]
__________________________________________________________________________________________________
```

```
block3_sepconv1 (SeparableConv2 (None, 63, 127, 256) 33920       block3_sepconv1_act[0][0]
__________________________________________________________________________________________________
block3_sepconv1_bn (BatchNormal (None, 63, 127, 256) 1024        block3_sepconv1[0][0]
__________________________________________________________________________________________________
block3_sepconv2_act (Activation (None, 63, 127, 256) 0           block3_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block3_sepconv2 (SeparableConv2 (None, 63, 127, 256) 67840       block3_sepconv2_act[0][0]
__________________________________________________________________________________________________
block3_sepconv2_bn (BatchNormal (None, 63, 127, 256) 1024        block3_sepconv2[0][0]
__________________________________________________________________________________________________
conv2d_1 (Conv2D)               (None, 32, 64, 256)  32768       add[0][0]
__________________________________________________________________________________________________
block3_pool (MaxPooling2D)      (None, 32, 64, 256)  0           block3_sepconv2_bn[0][0]
__________________________________________________________________________________________________
batch_normalization_1 (BatchNor (None, 32, 64, 256)  1024        conv2d_1[0][0]
__________________________________________________________________________________________________
add_1 (Add)                     (None, 32, 64, 256)  0           block3_pool[0][0]
                                                                 batch_normalization_1[0][0]
__________________________________________________________________________________________________
block4_sepconv1_act (Activation (None, 32, 64, 256)  0           add_1[0][0]
__________________________________________________________________________________________________
block4_sepconv1 (SeparableConv2 (None, 32, 64, 728)  188672      block4_sepconv1_act[0][0]
__________________________________________________________________________________________________
block4_sepconv1_bn (BatchNormal (None, 32, 64, 728)  2912        block4_sepconv1[0][0]
__________________________________________________________________________________________________
block4_sepconv2_act (Activation (None, 32, 64, 728)  0           block4_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block4_sepconv2 (SeparableConv2 (None, 32, 64, 728)  536536      block4_sepconv2_act[0][0]
__________________________________________________________________________________________________
block4_sepconv2_bn (BatchNormal (None, 32, 64, 728)  2912        block4_sepconv2[0][0]
__________________________________________________________________________________________________
conv2d_2 (Conv2D)               (None, 16, 32, 728)  186368      add_1[0][0]
__________________________________________________________________________________________________
block4_pool (MaxPooling2D)      (None, 16, 32, 728)  0           block4_sepconv2_bn[0][0]
__________________________________________________________________________________________________
batch_normalization_2 (BatchNor (None, 16, 32, 728)  2912        conv2d_2[0][0]
__________________________________________________________________________________________________
add_2 (Add)                     (None, 16, 32, 728)  0           block4_pool[0][0]
                                                                 batch_normalization_2[0][0]
__________________________________________________________________________________________________
block5_sepconv1_act (Activation (None, 16, 32, 728)  0           add_2[0][0]
__________________________________________________________________________________________________
block5_sepconv1 (SeparableConv2 (None, 16, 32, 728)  536536      block5_sepconv1_act[0][0]
block5_sepconv1_bn (BatchNormal (None, 16, 32, 728)  2912        block5_sepconv1[0][0]
__________________________________________________________________________________________________
block5_sepconv2_act (Activation (None, 16, 32, 728)  0           block5_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block5_sepconv2 (SeparableConv2 (None, 16, 32, 728)  536536      block5_sepconv2_act[0][0]
__________________________________________________________________________________________________
block5_sepconv2_bn (BatchNormal (None, 16, 32, 728)  2912        block5_sepconv2[0][0]
__________________________________________________________________________________________________
block5_sepconv3_act (Activation (None, 16, 32, 728)  0           block5_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block5_sepconv3 (SeparableConv2 (None, 16, 32, 728)  536536      block5_sepconv3_act[0][0]
__________________________________________________________________________________________________
block5_sepconv3_bn (BatchNormal (None, 16, 32, 728)  2912        block5_sepconv3[0][0]
__________________________________________________________________________________________________
add_3 (Add)                     (None, 16, 32, 728)  0           block5_sepconv3_bn[0][0]
                                                                 add_2[0][0]
__________________________________________________________________________________________________
block6_sepconv1_act (Activation (None, 16, 32, 728)  0           add_3[0][0]
__________________________________________________________________________________________________
block6_sepconv1 (SeparableConv2 (None, 16, 32, 728)  536536      block6_sepconv1_act[0][0]
__________________________________________________________________________________________________
block6_sepconv1_bn (BatchNormal (None, 16, 32, 728)  2912        block6_sepconv1[0][0]
__________________________________________________________________________________________________
block6_sepconv2_act (Activation (None, 16, 32, 728)  0           block6_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block6_sepconv2 (SeparableConv2 (None, 16, 32, 728)  536536      block6_sepconv2_act[0][0]
__________________________________________________________________________________________________
block6_sepconv2_bn (BatchNormal (None, 16, 32, 728)  2912        block6_sepconv2[0][0]
__________________________________________________________________________________________________
block6_sepconv3_act (Activation (None, 16, 32, 728)  0           block6_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block6_sepconv3 (SeparableConv2 (None, 16, 32, 728)  536536      block6_sepconv3_act[0][0]
__________________________________________________________________________________________________
block6_sepconv3_bn (BatchNormal (None, 16, 32, 728)  2912        block6_sepconv3[0][0]
__________________________________________________________________________________________________
add_4 (Add)                     (None, 16, 32, 728)  0           block6_sepconv3_bn[0][0]
                                                                 add_3[0][0]
__________________________________________________________________________________________________
block7_sepconv1_act (Activation (None, 16, 32, 728)  0           add_4[0][0]
__________________________________________________________________________________________________
block7_sepconv1 (SeparableConv2 (None, 16, 32, 728)  536536      block7_sepconv1_act[0][0]
__________________________________________________________________________________________________
```

```
block7_sepconv1_bn (BatchNormal (None, 16, 32, 728)  2912        block7_sepconv1[0][0]
__________________________________________________________________________________________________
block7_sepconv2_act (Activation (None, 16, 32, 728)  0           block7_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block7_sepconv2 (SeparableConv2 (None, 16, 32, 728)  536536      block7_sepconv2_act[0][0]
__________________________________________________________________________________________________
block7_sepconv2_bn (BatchNormal (None, 16, 32, 728)  2912        block7_sepconv2[0][0]
__________________________________________________________________________________________________
block7_sepconv3_act (Activation (None, 16, 32, 728)  0           block7_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block7_sepconv3 (SeparableConv2 (None, 16, 32, 728)  536536      block7_sepconv3_act[0][0]
__________________________________________________________________________________________________
block7_sepconv3_bn (BatchNormal (None, 16, 32, 728)  2912        block7_sepconv3[0][0]
__________________________________________________________________________________________________
add_5 (Add)                     (None, 16, 32, 728)  0           block7_sepconv3_bn[0][0]
                                                                 add_4[0][0]
__________________________________________________________________________________________________
block8_sepconv1_act (Activation (None, 16, 32, 728)  0           add_5[0][0]
__________________________________________________________________________________________________
block8_sepconv1 (SeparableConv2 (None, 16, 32, 728)  536536      block8_sepconv1_act[0][0]
__________________________________________________________________________________________________
block8_sepconv1_bn (BatchNormal (None, 16, 32, 728)  2912        block8_sepconv1[0][0]
__________________________________________________________________________________________________
block8_sepconv2_act (Activation (None, 16, 32, 728)  0           block8_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block8_sepconv2 (SeparableConv2 (None, 16, 32, 728)  536536      block8_sepconv2_act[0][0]
__________________________________________________________________________________________________
block8_sepconv2_bn (BatchNormal (None, 16, 32, 728)  2912        block8_sepconv2[0][0]
__________________________________________________________________________________________________
block8_sepconv3_act (Activation (None, 16, 32, 728)  0           block8_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block8_sepconv3 (SeparableConv2 (None, 16, 32, 728)  536536      block8_sepconv3_act[0][0]
__________________________________________________________________________________________________
block8_sepconv3_bn (BatchNormal (None, 16, 32, 728)  2912        block8_sepconv3[0][0]
__________________________________________________________________________________________________
add_6 (Add)                     (None, 16, 32, 728)  0           block8_sepconv3_bn[0][0]
                                                                 add_5[0][0]
__________________________________________________________________________________________________
block9_sepconv1_act (Activation (None, 16, 32, 728)  0           add_6[0][0]
__________________________________________________________________________________________________
block9_sepconv1 (SeparableConv2 (None, 16, 32, 728)  536536      block9_sepconv1_act[0][0]
__________________________________________________________________________________________________
block9_sepconv1_bn (BatchNormal (None, 16, 32, 728)  2912        block9_sepconv1[0][0]
________________________________________________________________________________________________
block9_sepconv2_act (Activation (None, 16, 32, 728)  0           block9_sepconv1_bn[0][0]
________________________________________________________________________________________________
block9_sepconv2 (SeparableConv2 (None, 16, 32, 728)  536536      block9_sepconv2_act[0][0]
________________________________________________________________________________________________
block9_sepconv2_bn (BatchNormal (None, 16, 32, 728)  2912        block9_sepconv2[0][0]
________________________________________________________________________________________________
block9_sepconv3_act (Activation (None, 16, 32, 728)  0           block9_sepconv2_bn[0][0]
________________________________________________________________________________________________
block9_sepconv3 (SeparableConv2 (None, 16, 32, 728)  536536      block9_sepconv3_act[0][0]
________________________________________________________________________________________________
block9_sepconv3_bn (BatchNormal (None, 16, 32, 728)  2912        block9_sepconv3[0][0]
________________________________________________________________________________________________
add_7 (Add)                     (None, 16, 32, 728)  0           block9_sepconv3_bn[0][0]
                                                                 add_6[0][0]
________________________________________________________________________________________________
block10_sepconv1_act (Activatio (None, 16, 32, 728)  0           add_7[0][0]
________________________________________________________________________________________________
block10_sepconv1 (SeparableConv (None, 16, 32, 728)  536536      block10_sepconv1_act[0][0]
________________________________________________________________________________________________
block10_sepconv1_bn (BatchNorma (None, 16, 32, 728)  2912        block10_sepconv1[0][0]
________________________________________________________________________________________________
block10_sepconv2_act (Activatio (None, 16, 32, 728)  0           block10_sepconv1_bn[0][0]
________________________________________________________________________________________________
block10_sepconv2 (SeparableConv (None, 16, 32, 728)  536536      block10_sepconv2_act[0][0]
________________________________________________________________________________________________
block10_sepconv2_bn (BatchNorma (None, 16, 32, 728)  2912        block10_sepconv2[0][0]
________________________________________________________________________________________________
block10_sepconv3_act (Activatio (None, 16, 32, 728)  0           block10_sepconv2_bn[0][0]
________________________________________________________________________________________________
block10_sepconv3 (SeparableConv (None, 16, 32, 728)  536536      block10_sepconv3_act[0][0]
________________________________________________________________________________________________
block10_sepconv3_bn (BatchNorma (None, 16, 32, 728)  2912        block10_sepconv3[0][0]
________________________________________________________________________________________________
add_8 (Add)                     (None, 16, 32, 728)  0           block10_sepconv3_bn[0][0]
                                                                 add_7[0][0]
________________________________________________________________________________________________
block11_sepconv1_act (Activatio (None, 16, 32, 728)  0           add_8[0][0]
________________________________________________________________________________________________
block11_sepconv1 (SeparableConv (None, 16, 32, 728)  536536      block11_sepconv1_act[0][0]
________________________________________________________________________________________________
block11_sepconv1_bn (BatchNorma (None, 16, 32, 728)  2912        block11_sepconv1[0][0]
________________________________________________________________________________________________
```

```
block11_sepconv2_act (Activatio (None, 16, 32, 728)  0           block11_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block11_sepconv2 (SeparableConv (None, 16, 32, 728)  536536      block11_sepconv2_act[0][0]
__________________________________________________________________________________________________
block11_sepconv2_bn (BatchNorma (None, 16, 32, 728)  2912        block11_sepconv2[0][0]
__________________________________________________________________________________________________
block11_sepconv3_act (Activatio (None, 16, 32, 728)  0           block11_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block11_sepconv3 (SeparableConv (None, 16, 32, 728)  536536      block11_sepconv3_act[0][0]
__________________________________________________________________________________________________
block11_sepconv3_bn (BatchNorma (None, 16, 32, 728)  2912        block11_sepconv3[0][0]
__________________________________________________________________________________________________
add_9 (Add)                     (None, 16, 32, 728)  0           block11_sepconv3_bn[0][0]
                                                                 add_8[0][0]
__________________________________________________________________________________________________
block12_sepconv1_act (Activatio (None, 16, 32, 728)  0           add_9[0][0]
__________________________________________________________________________________________________
block12_sepconv1 (SeparableConv (None, 16, 32, 728)  536536      block12_sepconv1_act[0][0]
__________________________________________________________________________________________________
block12_sepconv1_bn (BatchNorma (None, 16, 32, 728)  2912        block12_sepconv1[0][0]
__________________________________________________________________________________________________
block12_sepconv2_act (Activatio (None, 16, 32, 728)  0           block12_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block12_sepconv2 (SeparableConv (None, 16, 32, 728)  536536      block12_sepconv2_act[0][0]
__________________________________________________________________________________________________
block12_sepconv2_bn (BatchNorma (None, 16, 32, 728)  2912        block12_sepconv2[0][0]
__________________________________________________________________________________________________
block12_sepconv3_act (Activatio (None, 16, 32, 728)  0           block12_sepconv2_bn[0][0]
__________________________________________________________________________________________________
block12_sepconv3 (SeparableConv (None, 16, 32, 728)  536536      block12_sepconv3_act[0][0]
__________________________________________________________________________________________________
block12_sepconv3_bn (BatchNorma (None, 16, 32, 728)  2912        block12_sepconv3[0][0]
__________________________________________________________________________________________________
add_10 (Add)                    (None, 16, 32, 728)  0           block12_sepconv3_bn[0][0]
                                                                 add_9[0][0]
__________________________________________________________________________________________________
block13_sepconv1_act (Activatio (None, 16, 32, 728)  0           add_10[0][0]
__________________________________________________________________________________________________
block13_sepconv1 (SeparableConv (None, 16, 32, 728)  536536      block13_sepconv1_act[0][0]
__________________________________________________________________________________________________
block13_sepconv1_bn (BatchNorma (None, 16, 32, 728)  2912        block13_sepconv1[0][0]
__________________________________________________________________________________________________
block13_sepconv2_act (Activatio (None, 16, 32, 728)  0           block13_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block13_sepconv2 (SeparableConv (None, 16, 32, 1024) 752024      block13_sepconv2_act[0][0]
__________________________________________________________________________________________________
block13_sepconv2_bn (BatchNorma (None, 16, 32, 1024) 4096        block13_sepconv2[0][0]
__________________________________________________________________________________________________
conv2d_3 (Conv2D)               (None, 8, 16, 1024)  745472      add_10[0][0]
__________________________________________________________________________________________________
block13_pool (MaxPooling2D)     (None, 8, 16, 1024)  0           block13_sepconv2_bn[0][0]
__________________________________________________________________________________________________
batch_normalization_3 (BatchNor (None, 8, 16, 1024)  4096        conv2d_3[0][0]
__________________________________________________________________________________________________
add_11 (Add)                    (None, 8, 16, 1024)  0           block13_pool[0][0]
                                                                 batch_normalization_3[0][0]
__________________________________________________________________________________________________
block14_sepconv1 (SeparableConv (None, 8, 16, 1536)  1582080     add_11[0][0]
__________________________________________________________________________________________________
block14_sepconv1_bn (BatchNorma (None, 8, 16, 1536)  6144        block14_sepconv1[0][0]
__________________________________________________________________________________________________
block14_sepconv1_act (Activatio (None, 8, 16, 1536)  0           block14_sepconv1_bn[0][0]
__________________________________________________________________________________________________
block14_sepconv2 (SeparableConv (None, 8, 16, 2048)  3159552     block14_sepconv1_act[0][0]
__________________________________________________________________________________________________
block14_sepconv2_bn (BatchNorma (None, 8, 16, 2048)  8192        block14_sepconv2[0][0]
__________________________________________________________________________________________________
block14_sepconv2_act (Activatio (None, 8, 16, 2048)  0           block14_sepconv2_bn[0][0]
__________________________________________________________________________________________________
global_average_pooling2d (Globa (None, 2048)         0           block14_sepconv2_act[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 1024)         2098176     global_average_pooling2d[0][0]
__________________________________________________________________________________________________
batch_normalization_4 (BatchNor (None, 1024)         4096        dense[0][0]
__________________________________________________________________________________________________
dropout (Dropout)               (None, 1024)         0           batch_normalization_4[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 512)          524800      dropout[0][0]
__________________________________________________________________________________________________
batch_normalization_5 (BatchNor (None, 512)          2048        dense_1[0][0]
__________________________________________________________________________________________________
dropout_1 (Dropout)             (None, 512)          0           batch_normalization_5[0][0]
__________________________________________________________________________________________________
dense_2 (Dense)                 (None, 64)           32832       dropout_1[0][0]
__________________________________________________________________________________________________
dense_3 (Dense)                 (None, 4)            260         dense_2[0][0]
```

```
==================================================================================================
Total params: 23,523,692
Trainable params: 2,659,140
Non-trainable params: 20,864,552
__________________________________________________________________________________________________
```

In [ ]:
```
log_dir=os.path.join("logs",datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard=tf.keras.callbacks.TensorBoard(log_dir=log_dir,histogram_freq=1,write_graph=True,write
_grads=True)

checkpoint_filepath='/content/drive//My Drive/Steel_Detection /multi_label.h5'
model_checkpoint_callback=tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_filepath,monitor=
'val_f1_score',mode='max',save_best_only=True)
#https://keras.io/api/metrics/
#https://keras.io/api/losses/probabilistic_losses/#categorical_crossentropy-function
model.compile(optimizer='Adam',loss='binary_crossentropy',metrics=["acc",f1_score])
callback=[model_checkpoint_callback,tensorboard]
#https://datascience.stackexchange.com/questions/34444/what-is-the-difference-between-fit-and-fit-
generator-in-keras
history=model.fit_generator(train_image_generator,validation_data=val_image_generator,epochs=20,ve
rbose=1,callbacks=callback)
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
Epoch 1/20
150/150 [==============================] - 2474s 16s/step - loss: 0.3016 - acc: 0.7647 - f1_score: 0.7640 - val_loss: 0.2212 - val_acc: 0.
8008 - val_f1_score: 0.8246
Epoch 2/20
150/150 [==============================] - 178s 1s/step - loss: 0.2332 - acc: 0.8087 - f1_score: 0.8120 - val_loss: 0.1843 - val_acc: 0.84
50 - val_f1_score: 0.8628
Epoch 3/20
150/150 [==============================] - 182s 1s/step - loss: 0.2066 - acc: 0.8310 - f1_score: 0.8408 - val_loss: 0.1967 - val_acc: 0.83
58 - val_f1_score: 0.8525
Epoch 4/20
150/150 [==============================] - 179s 1s/step - loss: 0.1998 - acc: 0.8362 - f1_score: 0.8460 - val_loss: 0.1849 - val_acc: 0.82
67 - val_f1_score: 0.8536
Epoch 5/20
150/150 [==============================] - 176s 1s/step - loss: 0.1869 - acc: 0.8441 - f1_score: 0.8530 - val_loss: 0.2130 - val_acc: 0.81
83 - val_f1_score: 0.8384
Epoch 6/20
150/150 [==============================] - 180s 1s/step - loss: 0.1848 - acc: 0.8456 - f1_score: 0.8537 - val_loss: 0.1733 - val_acc: 0.84
50 - val_f1_score: 0.8705
Epoch 7/20
150/150 [==============================] - 181s 1s/step - loss: 0.1779 - acc: 0.8489 - f1_score: 0.8590 - val_loss: 0.1759 - val_acc: 0.83
75 - val_f1_score: 0.8610
Epoch 8/20
150/150 [==============================] - 176s 1s/step - loss: 0.1756 - acc: 0.8543 - f1_score: 0.8640 - val_loss: 0.1740 - val_acc: 0.83
75 - val_f1_score: 0.8614
Epoch 9/20
150/150 [==============================] - 175s 1s/step - loss: 0.1681 - acc: 0.8521 - f1_score: 0.8641 - val_loss: 0.1634 - val_acc: 0.85
00 - val_f1_score: 0.8746
Epoch 10/20
150/150 [==============================] - 176s 1s/step - loss: 0.1682 - acc: 0.8546 - f1_score: 0.8663 - val_loss: 0.1592 - val_acc: 0.85
83 - val_f1_score: 0.8800
Epoch 11/20
150/150 [==============================] - 175s 1s/step - loss: 0.1604 - acc: 0.8558 - f1_score: 0.8698 - val_loss: 0.1621 - val_acc: 0.85
42 - val_f1_score: 0.8758
Epoch 12/20
150/150 [==============================] - 175s 1s/step - loss: 0.1645 - acc: 0.8554 - f1_score: 0.8683 - val_loss: 0.1766 - val_acc: 0.82
75 - val_f1_score: 0.8558
Epoch 13/20
150/150 [==============================] - 175s 1s/step - loss: 0.1657 - acc: 0.8521 - f1_score: 0.8677 - val_loss: 0.1596 - val_acc: 0.85
08 - val_f1_score: 0.8727
Epoch 14/20
150/150 [==============================] - 176s 1s/step - loss: 0.1546 - acc: 0.8704 - f1_score: 0.8794 - val_loss: 0.1585 - val_acc: 0.86
42 - val_f1_score: 0.8866
```

```
Epoch 15/20
150/150 [==============================] - 174s 1s/step - loss: 0.1544 - acc: 0.8598 - f1_score: 0.8757 - val_loss: 0.1545 - val_acc: 0.85
33 - val_f1_score: 0.8820
Epoch 16/20
150/150 [==============================] - 174s 1s/step - loss: 0.1536 - acc: 0.8668 - f1_score: 0.8761 - val_loss: 0.1618 - val_acc: 0.85
92 - val_f1_score: 0.8823
Epoch 17/20
150/150 [==============================] - 175s 1s/step - loss: 0.1532 - acc: 0.8664 - f1_score: 0.8790 - val_loss: 0.1546 - val_acc: 0.86
00 - val_f1_score: 0.8816
Epoch 18/20
150/150 [==============================] - 174s 1s/step - loss: 0.1516 - acc: 0.8656 - f1_score: 0.8764 - val_loss: 0.1546 - val_acc: 0.86
00 - val_f1_score: 0.8789
Epoch 19/20
150/150 [==============================] - 174s 1s/step - loss: 0.1504 - acc: 0.8664 - f1_score: 0.8837 - val_loss: 0.1552 - val_acc: 0.86
33 - val_f1_score: 0.8834
Epoch 20/20
150/150 [==============================] - 174s 1s/step - loss: 0.1448 - acc: 0.8735 - f1_score: 0.8849 - val_loss: 0.1497 - val_acc: 0.86
75 - val_f1_score: 0.8841
```

```
In [ ]: %tensorboard --logdir logs
```

In [ ]:
```
train_image_generator=val_datagen.flow_from_dataframe(dataframe=x_train,
                                                  directory=train_folder_path,
                                                  x_col="image_id",
                                                  y_col=col,
                                                  batch_size=32,
                                                  shuffle=False,
                                                  class_mode="raw",
                                                  target_size=(256,512))


val_image_generator=val_datagen.flow_from_dataframe(dataframe=x_val,
                                                  directory=train_folder_path,
                                                  x_col="image_id",
                                                  y_col=col,
                                                  batch_size=32,
                                                  shuffle=False,
                                                  class_mode="raw",
                                                  target_size=(256,512))

test_image_generator=val_datagen.flow_from_dataframe(dataframe=x_test,
                                                  directory=train_folder_path,
                                                  x_col="image_id",
                                                  y_col=col,
                                                  batch_size=32,
                                                  shuffle=False,
                                                  class_mode="raw",
                                                  target_size=(256,512))
```

```
Found 4799 validated image filenames.
Found 1200 validated image filenames.
Found 667 validated image filenames.
```

In [ ]:
```
print('Training Dataset:\n')
print(model.evaluate(train_image_generator,verbose=1))
print("="*100)
print('\nValidation Dataset:\n')
print(model.evaluate(val_image_generator,verbose=1))
print("="*100)
print('\nTest Dataset:\n')
print(model.evaluate(test_image_generator,verbose=1))
```

```
Training Dataset:

150/150 [==============================] - 52s 348ms/step - loss: 0.1153 - acc: 0.8960 - f1_score: 0.9109
[0.11531050503253937, 0.8960199952125549, 0.9108885526657104]
====================================================================================================

Validation Dataset:

38/38 [==============================] - 13s 342ms/step - loss: 0.1497 - acc: 0.8675 - f1_score: 0.8840
[0.14966358244419098, 0.8675000071525574, 0.8840486407279968]
====================================================================================================

Test Dataset:

21/21 [==============================] - 241s 12s/step - loss: 0.1459 - acc: 0.8711 - f1_score: 0.8915
[0.14590173959732056, 0.8710644841194153, 0.891469419002533]
```

- For validation,test datasets loss increases as compared to train but still as one move from validation to test slight decrease in loss and similar with metrics where validation,test datasets accuracy, f1_score decreases as compared to train but still as one move from validation to test increase in accuracy, f1_score can be observed which shows model works better on unseen data.

In [ ]: