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Task 2. Deep Learning-based Quark-Gluon Classification

> **Datasets:** https://cernbox.cern.ch/index.php/s/hqz8zE7oxyPjvsL
>
> **Description 125x125 matrices (three channel images) for two classes of particles quarks and gluons impinging on a calorimeter. For a description of 1st dataset please refer to the link provided for the dataset.**
>
> **Please use a Convolutional Neural Network (CNN) architecture of your choice to achieve the highest possible classification on this dataset. The framework used in this solution is Tesorflow.**

In [2]:

```
import numpy as np
import tensorflow as tf
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import gc
import os
from pyarrow.parquet import ParquetFile
import pyarrow as pa
import pyarrow.parquet as pq
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report
from sklearn.metrics import roc_auc_score, auc, roc_curve
from itertools import cycle
!pip install fastparquet
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/publi
c/simple/
Requirement already satisfied: fastparquet in /usr/local/lib/python3.9/dist-packages (202
3.2.0)
Requirement already satisfied: pandas>=1.5.0 in /usr/local/lib/python3.9/dist-packages (f
rom fastparquet) (1.5.3)
Requirement already satisfied: fsspec in /usr/local/lib/python3.9/dist-packages (from fas
tparquet) (2023.3.0)
Requirement already satisfied: packaging in /usr/local/lib/python3.9/dist-packages (from
fastparquet) (23.0)
Requirement already satisfied: cramjam>=2.3 in /usr/local/lib/python3.9/dist-packages (fr
om fastparquet) (2.6.2)
Requirement already satisfied: numpy>=1.20.3 in /usr/local/lib/python3.9/dist-packages (f
rom fastparquet) (1.22.4)
Requirement already satisfied: python-dateutil>=2.8.1 in /usr/local/lib/python3.9/dist-pa
ckages (from pandas>=1.5.0->fastparquet) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.9/dist-packages (fr
om pandas>=1.5.0->fastparquet) (2022.7.1)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.9/dist-packages (from p
ython-dateutil>=2.8.1->pandas>=1.5.0->fastparquet) (1.16.0)
```

In [3]:

```
!wget https://cernbox.cern.ch/index.php/s/hqz8zE7oxyPjvsL/download
!mkdir data
!7z x -o/content/data download
```

```
--2023-04-01 16:02:10--  https://cernbox.cern.ch/index.php/s/hqz8zE7oxyPjvsL/download
Resolving cernbox.cern.ch (cernbox.cern.ch)... 128.142.170.17, 137.138.120.151, 128.142.5
3.28, ...
Connecting to cernbox.cern.ch (cernbox.cern.ch)|128.142.170.17|:443... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
```

```
Location: https://cernbox.cern.ch/s/hqz8zE7oxyPjvsL/download [following]
--2023-04-01 16:02:11--  https://cernbox.cern.ch/s/hqz8zE7oxyPjvsL/download
Reusing existing connection to cernbox.cern.ch:443.
HTTP request sent, awaiting response... 200 OK
Length: unspecified [application/octet-stream]
Saving to: 'download'

download                [     <=>            ] 690.93M  12.5MB/s    in 63s

2023-04-01 16:03:17 (10.9 MB/s) - 'download' saved [724495872]


7-Zip [64] 16.02 : Copyright (c) 1999-2016 Igor Pavlov : 2016-05-21
p7zip Version 16.02 (locale=en_US.UTF-8,Utf16=on,HugeFiles=on,64 bits,2 CPUs Intel(R) Xeo
n(R) CPU @ 2.00GHz (50653),ASM,AES-NI)

Scanning the drive for archives:
  0M Scan         1 file, 724495872 bytes (691 MiB)

Extracting archive: download
--
Path = download
Type = tar
Physical Size = 724495872
Headers Size = 3072
Code Page = UTF-8

  0%     19% 1 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run0_n36272.test.snappy.parquet
 29% 2 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run1_n47540.test.snappy.parquet
 41% 2 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run1_n47540.test.snappy.parquet
 47% 2 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run1_n47540.test.snappy.parquet
 50% 2 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run1_n47540.test.snappy.parquet
 62% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
 69% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
 73% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
 84% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
 91% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
 96% 3 - hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_ . t0_run2_n55494.test.snappy.parquet
Everything is Ok

Folders: 1
Files: 3
Size:       724492307
Compressed: 724495872
```

In [4]:

```
files=os.listdir("/content/data")
print(files)
```

```
['hqz8zE7oxyPjvsL']
```

In [5]:

```
pf = ParquetFile('/content/data/hqz8zE7oxyPjvsL/QCDToGGQQ_IMGjet_RH1all_jet0_run0_n36272.
test.snappy.parquet')
first_rows = next(pf.iter_batches(batch_size = 12000, columns=['X_jets', 'y']))
df = pa.Table.from_batches([first_rows]).to_pandas()
del (first_rows)
```

In [6]:

```
X_dataset = np.array(np.array(np.array(df['X_jets'].tolist()).tolist()).tolist())
y_dataset = df['y'].to_numpy()
print(X_dataset.shape, y_dataset.shape)
del (df)
```

```
(12000, 3, 125, 125) (12000,)
```

In [7]:

```
X_train, X_test, y_train, y_test = train_test_split(X_dataset, y_dataset, test_size = 0.
```

```
2, random_state=9)
X_train = np.moveaxis(X_train, 1, -1)
X_test = np.moveaxis(X_test, 1, -1)
gc.collect()
del (X_dataset, y_dataset)
X_train.shape, y_train.shape, X_test.shape, y_test.shape
```

Out[7]:

```
((9600, 125, 125, 3), (9600,), (2400, 125, 125, 3), (2400,))
```

In [8]:

```
num_classes = 1
input_shape = (125, 125, 3)
model = tf.keras.applications.ResNet101V2(
          include_top=True,
          weights=None,
          input_shape=input_shape,
          classes=1,
          classifier_activation='sigmoid'
)
model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=0.001),loss='binary_crosse
ntropy',metrics=['accuracy'])
model.summary()
```

```
Model: "resnet101v2"
__________________________________________________________________________________________
_________
 Layer (type)                    Output Shape         Param #     Connected to

==========================================================================================
=========
 input_1 (InputLayer)            [(None, 125, 125, 3  0           []

                                 )]


 conv1_pad (ZeroPadding2D)       (None, 131, 131, 3)  0           ['input_1[0][0]']


 conv1_conv (Conv2D)             (None, 63, 63, 64)   9472        ['conv1_pad[0][0]']


 pool1_pad (ZeroPadding2D)       (None, 65, 65, 64)   0           ['conv1_conv[0][0]']


 pool1_pool (MaxPooling2D)       (None, 32, 32, 64)   0           ['pool1_pad[0][0]']


 conv2_block1_preact_bn (BatchN  (None, 32, 32, 64)  256         ['pool1_pool[0][0]']

 ormalization)


 conv2_block1_preact_relu (Acti  (None, 32, 32, 64)  0           ['conv2_block1_preact_bn
[0][0]']
 vation)


 conv2_block1_1_conv (Conv2D)    (None, 32, 32, 64)   4096        ['conv2_block1_preact_re
lu[0][0]'
                                                                 ]
```

```
 conv2_block1_1_bn (BatchNormal  (None, 32, 32, 64)  256         ['conv2_block1_1_conv[0]
[0]']
 ization)


 conv2_block1_1_relu (Activatio  (None, 32, 32, 64)  0           ['conv2_block1_1_bn[0][0
]']
 n)


 conv2_block1_2_pad (ZeroPaddin  (None, 34, 34, 64)  0           ['conv2_block1_1_relu[0]
[0]']
 g2D)


 conv2_block1_2_conv (Conv2D)   (None, 32, 32, 64)   36864       ['conv2_block1_2_pad[0][
0]']


 conv2_block1_2_bn (BatchNormal  (None, 32, 32, 64)  256         ['conv2_block1_2_conv[0]
[0]']
 ization)


 conv2_block1_2_relu (Activatio  (None, 32, 32, 64)  0           ['conv2_block1_2_bn[0][0
]']
 n)


 conv2_block1_0_conv (Conv2D)   (None, 32, 32, 256)  16640       ['conv2_block1_preact_re
lu[0][0]'
                                                                 ]


 conv2_block1_3_conv (Conv2D)   (None, 32, 32, 256)  16640       ['conv2_block1_2_relu[0]
[0]']


 conv2_block1_out (Add)         (None, 32, 32, 256)  0           ['conv2_block1_0_conv[0
][0]',
                                                                  'conv2_block1_3_conv[
0][0]']


 conv2_block2_preact_bn (BatchN  (None, 32, 32, 256)  1024       ['conv2_block1_out[0][0]
']
 ormalization)


 conv2_block2_preact_relu (Acti  (None, 32, 32, 256)  0          ['conv2_block2_preact_bn
[0][0]']
 vation)


 conv2_block2_1_conv (Conv2D)   (None, 32, 32, 64)   16384       ['conv2_block2_preact_re
lu[0][0]'
                                                                 ]


 conv2_block2_1_bn (BatchNormal  (None, 32, 32, 64)  256         ['conv2_block2_1_conv[0]
[0]']
 ization)
```

```
 conv2_block2_1_relu (Activatio  (None, 32, 32, 64)  0           ['conv2_block2_1_bn[0][0
]']
 n)


 conv2_block2_2_pad (ZeroPaddin  (None, 34, 34, 64)  0           ['conv2_block2_1_relu[0]
[0]']
 g2D)


 conv2_block2_2_conv (Conv2D)   (None, 32, 32, 64)   36864       ['conv2_block2_2_pad[0][
0]']


 conv2_block2_2_bn (BatchNormal  (None, 32, 32, 64)  256         ['conv2_block2_2_conv[0]
[0]']
 ization)


 conv2_block2_2_relu (Activatio  (None, 32, 32, 64)  0           ['conv2_block2_2_bn[0][0
]']
 n)


 conv2_block2_3_conv (Conv2D)   (None, 32, 32, 256)  16640       ['conv2_block2_2_relu[0]
[0]']


 conv2_block2_out (Add)         (None, 32, 32, 256)  0           ['conv2_block1_out[0][0
]',
                                                                  'conv2_block2_3_conv[
0][0]']


 conv2_block3_preact_bn (BatchN  (None, 32, 32, 256)  1024       ['conv2_block2_out[0][0]
']
 ormalization)


 conv2_block3_preact_relu (Acti  (None, 32, 32, 256)  0          ['conv2_block3_preact_bn
[0][0]']
 vation)


 conv2_block3_1_conv (Conv2D)   (None, 32, 32, 64)   16384       ['conv2_block3_preact_re
lu[0][0]'
                                                                 ]


 conv2_block3_1_bn (BatchNormal  (None, 32, 32, 64)  256         ['conv2_block3_1_conv[0]
[0]']
 ization)


 conv2_block3_1_relu (Activatio  (None, 32, 32, 64)  0           ['conv2_block3_1_bn[0][0
]']
 n)


 conv2_block3_2_pad (ZeroPaddin  (None, 34, 34, 64)  0           ['conv2_block3_1_relu[0]
[0]']
```

```
[0]']
 g2D)

 conv2_block3_2_conv (Conv2D)   (None, 16, 16, 64)   36864       ['conv2_block3_2_pad[0][
0]']

 conv2_block3_2_bn (BatchNormal  (None, 16, 16, 64)  256         ['conv2_block3_2_conv[0]
[0]']
 ization)

 conv2_block3_2_relu (Activatio  (None, 16, 16, 64)  0           ['conv2_block3_2_bn[0][0
]']
 n)

 max_pooling2d (MaxPooling2D)   (None, 16, 16, 256)  0           ['conv2_block2_out[0][0]
']

 conv2_block3_3_conv (Conv2D)   (None, 16, 16, 256)  16640       ['conv2_block3_2_relu[0]
[0]']

 conv2_block3_out (Add)         (None, 16, 16, 256)  0           ['max_pooling2d[0][0]',

                                                                  'conv2_block3_3_conv[
0][0]']

 conv3_block1_preact_bn (BatchN  (None, 16, 16, 256)  1024       ['conv2_block3_out[0][0]
']
 ormalization)

 conv3_block1_preact_relu (Acti  (None, 16, 16, 256)  0          ['conv3_block1_preact_bn
[0][0]']
 vation)

 conv3_block1_1_conv (Conv2D)   (None, 16, 16, 128)  32768       ['conv3_block1_preact_re
lu[0][0]'
                                                                 ]

 conv3_block1_1_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block1_1_conv[0]
[0]']
 ization)

 conv3_block1_1_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block1_1_bn[0][0
]']
 n)

 conv3_block1_2_pad (ZeroPaddin  (None, 18, 18, 128)  0          ['conv3_block1_1_relu[0]
[0]']
 g2D)

 conv3_block1_2_conv (Conv2D)   (None, 16, 16, 128)  147456      ['conv3_block1_2_pad[0][
```

```
0][0]']

 conv3_block1_2_bn (BatchNormal  (None, 16, 16, 128)  512         ['conv3_block1_2_conv[0]
[0]']
 ization)

 conv3_block1_2_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block1_2_bn[0][0
]']
 n)

 conv3_block1_0_conv (Conv2D)   (None, 16, 16, 512)  131584      ['conv3_block1_preact_re
lu[0][0]'
                                                                 ]

 conv3_block1_3_conv (Conv2D)   (None, 16, 16, 512)  66048       ['conv3_block1_2_relu[0]
[0]']

 conv3_block1_out (Add)         (None, 16, 16, 512)  0           ['conv3_block1_0_conv[0
][0]',
                                                                  'conv3_block1_3_conv[
0][0]']

 conv3_block2_preact_bn (BatchN  (None, 16, 16, 512)  2048       ['conv3_block1_out[0][0]
']
 ormalization)

 conv3_block2_preact_relu (Acti  (None, 16, 16, 512)  0          ['conv3_block2_preact_bn
[0][0]']
 vation)

 conv3_block2_1_conv (Conv2D)   (None, 16, 16, 128)  65536       ['conv3_block2_preact_re
lu[0][0]'
                                                                 ]

 conv3_block2_1_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block2_1_conv[0]
[0]']
 ization)

 conv3_block2_1_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block2_1_bn[0][0
]']
 n)

 conv3_block2_2_pad (ZeroPaddin  (None, 18, 18, 128)  0          ['conv3_block2_1_relu[0]
[0]']
 g2D)

 conv3_block2_2_conv (Conv2D)   (None, 16, 16, 128)  147456      ['conv3_block2_2_pad[0][
0]']

 conv3_block2_2_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block2_2_conv[0]
[0]']
```

```
[0]']
 ization)


 conv3_block2_2_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block2_2_bn[0][0
]']
 n)


 conv3_block2_3_conv (Conv2D)   (None, 16, 16, 512)  66048       ['conv3_block2_2_relu[0]
[0]']


 conv3_block2_out (Add)         (None, 16, 16, 512)  0           ['conv3_block1_out[0][0
]',
                                                                  'conv3_block2_3_conv[
0][0]']


 conv3_block3_preact_bn (BatchN  (None, 16, 16, 512)  2048       ['conv3_block2_out[0][0]
']
 ormalization)


 conv3_block3_preact_relu (Acti  (None, 16, 16, 512)  0          ['conv3_block3_preact_bn
[0][0]']
 vation)


 conv3_block3_1_conv (Conv2D)   (None, 16, 16, 128)  65536       ['conv3_block3_preact_re
lu[0][0]'
                                                                 ]


 conv3_block3_1_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block3_1_conv[0]
[0]']
 ization)


 conv3_block3_1_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block3_1_bn[0][0
]']
 n)


 conv3_block3_2_pad (ZeroPaddin  (None, 18, 18, 128)  0          ['conv3_block3_1_relu[0]
[0]']
 g2D)


 conv3_block3_2_conv (Conv2D)   (None, 16, 16, 128)  147456      ['conv3_block3_2_pad[0][
0]']


 conv3_block3_2_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block3_2_conv[0]
[0]']
 ization)


 conv3_block3_2_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block3_2_bn[0][0
]']
 n)
```

```
 conv3_block3_3_conv (Conv2D)   (None, 16, 16, 512)  66048       ['conv3_block3_2_relu[0]
[0]']

 conv3_block3_out (Add)         (None, 16, 16, 512)  0           ['conv3_block2_out[0][0
]',
                                                                  'conv3_block3_3_conv[
0][0]']

 conv3_block4_preact_bn (BatchN  (None, 16, 16, 512)  2048       ['conv3_block3_out[0][0]
']
 ormalization)

 conv3_block4_preact_relu (Acti  (None, 16, 16, 512)  0          ['conv3_block4_preact_bn
[0][0]']
 vation)

 conv3_block4_1_conv (Conv2D)   (None, 16, 16, 128)  65536       ['conv3_block4_preact_re
lu[0][0]'
                                                                 ]

 conv3_block4_1_bn (BatchNormal  (None, 16, 16, 128)  512        ['conv3_block4_1_conv[0]
[0]']
 ization)

 conv3_block4_1_relu (Activatio  (None, 16, 16, 128)  0          ['conv3_block4_1_bn[0][0
]']
 n)

 conv3_block4_2_pad (ZeroPaddin  (None, 18, 18, 128)  0          ['conv3_block4_1_relu[0]
[0]']
 g2D)

 conv3_block4_2_conv (Conv2D)   (None, 8, 8, 128)    147456      ['conv3_block4_2_pad[0][
0]']

 conv3_block4_2_bn (BatchNormal  (None, 8, 8, 128)   512         ['conv3_block4_2_conv[0]
[0]']
 ization)

 conv3_block4_2_relu (Activatio  (None, 8, 8, 128)   0           ['conv3_block4_2_bn[0][0
]']
 n)

 max_pooling2d_1 (MaxPooling2D)  (None, 8, 8, 512)   0           ['conv3_block3_out[0][0]
']

 conv3_block4_3_conv (Conv2D)   (None, 8, 8, 512)    66048       ['conv3_block4_2_relu[0]
[0]']

 conv3_block4_out (Add)         (None, 8, 8, 512)    0           ['max_pooling2d_1[0][0]
'
```

```
',                                                                  'conv3_block4_3_conv[
0][0]']

 conv4_block1_preact_bn (BatchN  (None, 8, 8, 512)   2048        ['conv3_block4_out[0][0]
']
 ormalization)

 conv4_block1_preact_relu (Acti  (None, 8, 8, 512)   0           ['conv4_block1_preact_bn
[0][0]']
 vation)

 conv4_block1_1_conv (Conv2D)   (None, 8, 8, 256)    131072      ['conv4_block1_preact_re
lu[0][0]'
                                                                 ]

 conv4_block1_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block1_1_conv[0]
[0]']
 ization)

 conv4_block1_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block1_1_bn[0][0
]']
 n)

 conv4_block1_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block1_1_relu[0]
[0]']
 g2D)

 conv4_block1_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block1_2_pad[0][
0]']

 conv4_block1_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block1_2_conv[0]
[0]']
 ization)

 conv4_block1_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block1_2_bn[0][0
]']
 n)

 conv4_block1_0_conv (Conv2D)   (None, 8, 8, 1024)   525312      ['conv4_block1_preact_re
lu[0][0]'
                                                                 ]

 conv4_block1_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block1_2_relu[0]
[0]']

 conv4_block1_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block1_0_conv[0
][0]',
                                                                  'conv4_block1_3_conv[
0][0]']
```

```
 conv4_block2_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block1_out[0][0]
']
 ormalization)


 conv4_block2_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block2_preact_bn
[0][0]']
 vation)


 conv4_block2_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block2_preact_re
lu[0][0]'
                                                                 ]


 conv4_block2_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block2_1_conv[0]
[0]']
 ization)


 conv4_block2_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block2_1_bn[0][0
]']
 n)


 conv4_block2_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block2_1_relu[0]
[0]']
 g2D)


 conv4_block2_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block2_2_pad[0][
0]']

 conv4_block2_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block2_2_conv[0]
[0]']
 ization)


 conv4_block2_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block2_2_bn[0][0
]']
 n)


 conv4_block2_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block2_2_relu[0]
[0]']

 conv4_block2_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block1_out[0][0
]',
                                                                  'conv4_block2_3_conv[
0][0]']

 conv4_block3_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block2_out[0][0]
']
 ormalization)


 conv4_block3_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block3_preact_bn
[0][0]']
 vation)
```

```
 conv4_block3_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block3_preact_re
lu[0][0]'
                                                                 ]

 conv4_block3_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block3_1_conv[0]
[0]']
 ization)

 conv4_block3_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block3_1_bn[0][0
]']
 n)

 conv4_block3_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block3_1_relu[0]
[0]']
 g2D)

 conv4_block3_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block3_2_pad[0][
0]']

 conv4_block3_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block3_2_conv[0]
[0]']
 ization)

 conv4_block3_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block3_2_bn[0][0
]']
 n)

 conv4_block3_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block3_2_relu[0]
[0]']

 conv4_block3_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block2_out[0][0
]',
                                                                  'conv4_block3_3_conv[
0][0]']

 conv4_block4_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block3_out[0][0]
']
 ormalization)

 conv4_block4_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block4_preact_bn
[0][0]']
 vation)

 conv4_block4_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block4_preact_re
lu[0][0]'
                                                                 ]

 conv4_block4_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block4_1_conv[0]
[0]']
```

```
[0]']
 ization)


 conv4_block4_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block4_1_bn[0][0
]']
 n)


 conv4_block4_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block4_1_relu[0]
[0]']
 g2D)


 conv4_block4_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block4_2_pad[0][
0]']


 conv4_block4_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block4_2_conv[0]
[0]']
 ization)


 conv4_block4_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block4_2_bn[0][0
]']
 n)


 conv4_block4_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block4_2_relu[0]
[0]']


 conv4_block4_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block3_out[0][0
]',
                                                                  'conv4_block4_3_conv[
0][0]']


 conv4_block5_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block4_out[0][0]
']
 ormalization)


 conv4_block5_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block5_preact_bn
[0][0]']
 vation)


 conv4_block5_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block5_preact_re
lu[0][0]'
                                                                 ]


 conv4_block5_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block5_1_conv[0]
[0]']
 ization)


 conv4_block5_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block5_1_bn[0][0
]']
 n)
```

```
 conv4_block5_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block5_1_relu[0]
[0]']
 g2D)


 conv4_block5_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block5_2_pad[0][
0]']


 conv4_block5_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block5_2_conv[0]
[0]']
 ization)


 conv4_block5_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block5_2_bn[0][0
]']
 n)


 conv4_block5_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block5_2_relu[0]
[0]']


 conv4_block5_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block4_out[0][0
]',
                                                                  'conv4_block5_3_conv[
0][0]']


 conv4_block6_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block5_out[0][0]
']
 ormalization)


 conv4_block6_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block6_preact_bn
[0][0]']
 vation)


 conv4_block6_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block6_preact_re
lu[0][0]'
                                                                 ]


 conv4_block6_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block6_1_conv[0]
[0]']
 ization)


 conv4_block6_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block6_1_bn[0][0
]']
 n)


 conv4_block6_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block6_1_relu[0]
[0]']
 g2D)


 conv4_block6_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block6_2_pad[0][
0]']
```

```
 conv4_block6_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block6_2_conv[0]
 ization)                                                        [0]']

 conv4_block6_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block6_2_bn[0][0
 n)                                                              ]']

 conv4_block6_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block6_2_relu[0]
                                                                 [0]']

 conv4_block6_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block5_out[0][0
                                                                 ]',
                                                                  'conv4_block6_3_conv[
                                                                 0][0]']

 conv4_block7_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block6_out[0][0]
 ormalization)                                                   ']

 conv4_block7_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block7_preact_bn
 vation)                                                         [0][0]']

 conv4_block7_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block7_preact_re
                                                                 lu[0][0]'
                                                                 ]

 conv4_block7_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block7_1_conv[0]
 ization)                                                        [0]']

 conv4_block7_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block7_1_bn[0][0
 n)                                                              ]']

 conv4_block7_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block7_1_relu[0]
 g2D)                                                            [0]']

 conv4_block7_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block7_2_pad[0][
                                                                 0]']

 conv4_block7_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block7_2_conv[0]
 ization)                                                        [0]']

 conv4_block7_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block7_2_bn[0][0
 n)                                                              ]']
```

```
 conv4_block7_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block7_2_relu[0]
[0]']

 conv4_block7_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block6_out[0][0
]',
                                                                  'conv4_block7_3_conv[
0][0]']

 conv4_block8_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block7_out[0][0]
']
 ormalization)

 conv4_block8_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block8_preact_bn
[0][0]']
 vation)

 conv4_block8_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block8_preact_re
lu[0][0]'
                                                                 ]

 conv4_block8_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block8_1_conv[0]
[0]']
 ization)

 conv4_block8_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block8_1_bn[0][0
]']
 n)

 conv4_block8_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block8_1_relu[0]
[0]']
 g2D)

 conv4_block8_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block8_2_pad[0][
0]']

 conv4_block8_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block8_2_conv[0]
[0]']
 ization)

 conv4_block8_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block8_2_bn[0][0
]']
 n)

 conv4_block8_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block8_2_relu[0]
[0]']

 conv4_block8_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block7_out[0][0
]',
                                                                  'conv4_block8_3_conv[
0][0]']
```

```
0][0]']

 conv4_block9_preact_bn (BatchN  (None, 8, 8, 1024)  4096        ['conv4_block8_out[0][0]
']
 ormalization)

 conv4_block9_preact_relu (Acti  (None, 8, 8, 1024)  0           ['conv4_block9_preact_bn
[0][0]']
 vation)

 conv4_block9_1_conv (Conv2D)   (None, 8, 8, 256)    262144      ['conv4_block9_preact_re
lu[0][0]'
                                                                 ]

 conv4_block9_1_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block9_1_conv[0]
[0]']
 ization)

 conv4_block9_1_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block9_1_bn[0][0
]']
 n)

 conv4_block9_2_pad (ZeroPaddin  (None, 10, 10, 256)  0          ['conv4_block9_1_relu[0]
[0]']
 g2D)

 conv4_block9_2_conv (Conv2D)   (None, 8, 8, 256)    589824      ['conv4_block9_2_pad[0][
0]']

 conv4_block9_2_bn (BatchNormal  (None, 8, 8, 256)   1024        ['conv4_block9_2_conv[0]
[0]']
 ization)

 conv4_block9_2_relu (Activatio  (None, 8, 8, 256)   0           ['conv4_block9_2_bn[0][0
]']
 n)

 conv4_block9_3_conv (Conv2D)   (None, 8, 8, 1024)   263168      ['conv4_block9_2_relu[0]
[0]']

 conv4_block9_out (Add)         (None, 8, 8, 1024)   0           ['conv4_block8_out[0][0
]',
                                                                  'conv4_block9_3_conv[
0][0]']

 conv4_block10_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block9_out[0][0]
']
 Normalization)

 conv4_block10_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block10_preact_b
```

```
n[0][0]']
 ivation)


 conv4_block10_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block10_preact_r
elu[0][0]
                                                                 ']


 conv4_block10_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block10_1_conv[0
][0]']
 lization)


 conv4_block10_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block10_1_bn[0][
0]']
 on)


 conv4_block10_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block10_1_relu[0
][0]']
 ng2D)


 conv4_block10_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block10_2_pad[0]
[0]']

 conv4_block10_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block10_2_conv[0
][0]']
 lization)


 conv4_block10_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block10_2_bn[0][
0]']
 on)


 conv4_block10_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block10_2_relu[0
][0]']

 conv4_block10_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block9_out[0][0]
',
                                                                  'conv4_block10_3_conv
[0][0]']

 conv4_block11_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block10_out[0][0
]']
 Normalization)


 conv4_block11_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block11_preact_b
n[0][0]']
 ivation)


 conv4_block11_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block11_preact_r
elu[0][0]
                                                                 ']
```

```
 conv4_block11_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block11_1_conv[0
 lization)                                                       ][0]']

 conv4_block11_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block11_1_bn[0][
 on)                                                             0]']

 conv4_block11_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block11_1_relu[0
 ng2D)                                                           ][0]']

 conv4_block11_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block11_2_pad[0]
                                                                 [0]']

 conv4_block11_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block11_2_conv[0
 lization)                                                       ][0]']

 conv4_block11_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block11_2_bn[0][
 on)                                                             0]']

 conv4_block11_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block11_2_relu[0
                                                                 ][0]']

 conv4_block11_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block10_out[0][0
                                                                 ]',
                                                                  'conv4_block11_3_conv
                                                                 [0][0]']

 conv4_block12_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block11_out[0][0
 Normalization)                                                  ]']

 conv4_block12_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block12_preact_b
 ivation)                                                        n[0][0]']

 conv4_block12_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block12_preact_r
                                                                 elu[0][0]
                                                                 ']

 conv4_block12_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block12_1_conv[0
 lization)                                                       ][0]']

 conv4_block12_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block12_1_bn[0][
 on)                                                             0]']
```

```
 conv4_block12_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block12_1_relu[0
][0]']
 ng2D)

 conv4_block12_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block12_2_pad[0]
[0]']

 conv4_block12_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block12_2_conv[0
][0]']
 lization)

 conv4_block12_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block12_2_bn[0][
0]']
 on)

 conv4_block12_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block12_2_relu[0
][0]']

 conv4_block12_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block11_out[0][0
]',
                                                                  'conv4_block12_3_conv
[0][0]']

 conv4_block13_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block12_out[0][0
]']
 Normalization)

 conv4_block13_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block13_preact_b
n[0][0]']
 ivation)

 conv4_block13_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block13_preact_r
elu[0][0]
                                                                 ']

 conv4_block13_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block13_1_conv[0
][0]']
 lization)

 conv4_block13_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block13_1_bn[0][
0]']
 on)

 conv4_block13_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block13_1_relu[0
][0]']
 ng2D)

 conv4_block13_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block13_2_pad[0]
[0]']
```

```
[0]']

 conv4_block13_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block13_2_conv[0
 lization)                                                       ][0]']

 conv4_block13_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block13_2_bn[0][
 on)                                                             0]']

 conv4_block13_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block13_2_relu[0
                                                                 ][0]']

 conv4_block13_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block12_out[0][0
                                                                 ]',
                                                                  'conv4_block13_3_conv
                                                                 [0][0]']

 conv4_block14_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block13_out[0][0
 Normalization)                                                  ]']

 conv4_block14_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block14_preact_b
 ivation)                                                        n[0][0]']

 conv4_block14_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block14_preact_r
                                                                 elu[0][0]
                                                                 ']

 conv4_block14_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block14_1_conv[0
 lization)                                                       ][0]']

 conv4_block14_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block14_1_bn[0][
 on)                                                             0]']

 conv4_block14_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block14_1_relu[0
 ng2D)                                                           ][0]']

 conv4_block14_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block14_2_pad[0]
                                                                 [0]']

 conv4_block14_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block14_2_conv[0
 lization)                                                       ][0]']

 conv4_block14_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block14_2_bn[0][
 0]']
```

```
0]']
 on)


 conv4_block14_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block14_2_relu[0
][0]']

 conv4_block14_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block13_out[0][0
]',
                                                                  'conv4_block14_3_conv
[0][0]']

 conv4_block15_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block14_out[0][0
]']
 Normalization)


 conv4_block15_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block15_preact_b
n[0][0]']
 ivation)


 conv4_block15_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block15_preact_r
elu[0][0]
                                                                 ']


 conv4_block15_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block15_1_conv[0
][0]']
 lization)


 conv4_block15_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block15_1_bn[0][
0]']
 on)


 conv4_block15_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block15_1_relu[0
][0]']
 ng2D)


 conv4_block15_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block15_2_pad[0]
[0]']

 conv4_block15_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block15_2_conv[0
][0]']
 lization)


 conv4_block15_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block15_2_bn[0][
0]']
 on)


 conv4_block15_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block15_2_relu[0
][0]']

 conv4_block15_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block14_out[0][0
]']
```

```
]',
                                                                 'conv4_block15_3_conv
[0][0]']

 conv4_block16_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block15_out[0][0
]']
 Normalization)

 conv4_block16_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block16_preact_b
n[0][0]']
 ivation)

 conv4_block16_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block16_preact_r
elu[0][0]
                                                                 ']

 conv4_block16_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block16_1_conv[0
][0]']
 lization)

 conv4_block16_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block16_1_bn[0][
0]']
 on)

 conv4_block16_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block16_1_relu[0
][0]']
 ng2D)

 conv4_block16_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block16_2_pad[0]
[0]']

 conv4_block16_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block16_2_conv[0
][0]']
 lization)

 conv4_block16_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block16_2_bn[0][
0]']
 on)

 conv4_block16_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block16_2_relu[0
][0]']

 conv4_block16_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block15_out[0][0
]',
                                                                 'conv4_block16_3_conv
[0][0]']

 conv4_block17_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block16_out[0][0
]']
 Normalization)
```

```
 conv4_block17_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block17_preact_b
n[0][0]']
 ivation)


 conv4_block17_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block17_preact_r
elu[0][0]
                                                                 ']


 conv4_block17_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block17_1_conv[0
][0]']
 lization)


 conv4_block17_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block17_1_bn[0][
0]']
 on)


 conv4_block17_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block17_1_relu[0
][0]']
 ng2D)


 conv4_block17_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block17_2_pad[0]
[0]']

 conv4_block17_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block17_2_conv[0
][0]']
 lization)


 conv4_block17_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block17_2_bn[0][
0]']
 on)


 conv4_block17_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block17_2_relu[0
][0]']


 conv4_block17_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block16_out[0][0
]',
                                                                  'conv4_block17_3_conv
[0][0]']

 conv4_block18_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block17_out[0][0
]']
 Normalization)


 conv4_block18_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block18_preact_b
n[0][0]']
 ivation)


 conv4_block18_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block18_preact_r
elu[0][0]
                                                                 ']
```

```
 conv4_block18_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block18_1_conv[0
 lization)                                                       ][0]']

 conv4_block18_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block18_1_bn[0][
 on)                                                             0]']

 conv4_block18_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block18_1_relu[0
 ng2D)                                                           ][0]']

 conv4_block18_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block18_2_pad[0]
                                                                 [0]']

 conv4_block18_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block18_2_conv[0
 lization)                                                       ][0]']

 conv4_block18_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block18_2_bn[0][
 on)                                                             0]']

 conv4_block18_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block18_2_relu[0
                                                                 ][0]']

 conv4_block18_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block17_out[0][0
                                                                 ]',
                                                                  'conv4_block18_3_conv
                                                                 [0][0]']

 conv4_block19_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block18_out[0][0
 Normalization)                                                  ]']

 conv4_block19_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block19_preact_b
 ivation)                                                        n[0][0]']

 conv4_block19_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block19_preact_r
                                                                 elu[0][0]
                                                                 ']

 conv4_block19_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block19_1_conv[0
 lization)                                                       ][0]']

 conv4_block19_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block19_1_bn[0][
```

```
0]']
 on)


 conv4_block19_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block19_1_relu[0
][0]']
 ng2D)


 conv4_block19_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block19_2_pad[0]
[0]']


 conv4_block19_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block19_2_conv[0
][0]']
 lization)


 conv4_block19_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block19_2_bn[0][
0]']
 on)


 conv4_block19_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block19_2_relu[0
][0]']


 conv4_block19_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block18_out[0][0
]',
                                                                  'conv4_block19_3_conv
[0][0]']


 conv4_block20_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block19_out[0][0
]']
 Normalization)


 conv4_block20_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block20_preact_b
n[0][0]']
 ivation)


 conv4_block20_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block20_preact_r
elu[0][0]
                                                                 ']


 conv4_block20_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block20_1_conv[0
][0]']
 lization)


 conv4_block20_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block20_1_bn[0][
0]']
 on)


 conv4_block20_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block20_1_relu[0
][0]']
 ng2D)
```

```
 conv4_block20_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block20_2_pad[0]
[0]']

 conv4_block20_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block20_2_conv[0
][0]']
 lization)

 conv4_block20_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block20_2_bn[0][
0]']
 on)

 conv4_block20_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block20_2_relu[0
][0]']

 conv4_block20_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block19_out[0][0
]',
                                                                  'conv4_block20_3_conv
[0][0]']

 conv4_block21_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block20_out[0][0
]']
 Normalization)

 conv4_block21_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block21_preact_b
n[0][0]']
 ivation)

 conv4_block21_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block21_preact_r
elu[0][0]
                                                                 ']

 conv4_block21_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block21_1_conv[0
][0]']
 lization)

 conv4_block21_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block21_1_bn[0][
0]']
 on)

 conv4_block21_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block21_1_relu[0
][0]']
 ng2D)

 conv4_block21_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block21_2_pad[0]
[0]']

 conv4_block21_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block21_2_conv[0
][0]']
 lization)
```

```
 conv4_block21_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block21_2_bn[0][[
 on)                                                             0]']


 conv4_block21_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block21_2_relu[0
                                                                 ][0]']


 conv4_block21_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block20_out[0][0
                                                                 ]',
                                                                  'conv4_block21_3_conv
                                                                 [0][0]']


 conv4_block22_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block21_out[0][0
 Normalization)                                                  ]']


 conv4_block22_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block22_preact_b
 ivation)                                                        n[0][0]']


 conv4_block22_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block22_preact_r
                                                                 elu[0][0]
                                                                 ']


 conv4_block22_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block22_1_conv[0
 lization)                                                       ][0]']


 conv4_block22_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block22_1_bn[0][[
 on)                                                             0]']


 conv4_block22_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block22_1_relu[0
 ng2D)                                                           ][0]']


 conv4_block22_2_conv (Conv2D)  (None, 8, 8, 256)    589824      ['conv4_block22_2_pad[0]
                                                                 [0]']

 conv4_block22_2_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block22_2_conv[0
 lization)                                                       ][0]']


 conv4_block22_2_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block22_2_bn[0][[
 on)                                                             0]']


 conv4_block22_3_conv (Conv2D)  (None, 8, 8, 1024)   263168      ['conv4_block22_2_relu[0
                                                                 ][0]']
```

```
 conv4_block22_out (Add)        (None, 8, 8, 1024)   0           ['conv4_block21_out[0][0
]',
                                                                  'conv4_block22_3_conv
[0][0]']

 conv4_block23_preact_bn (Batch  (None, 8, 8, 1024)  4096        ['conv4_block22_out[0][0
]']
 Normalization)

 conv4_block23_preact_relu (Act  (None, 8, 8, 1024)  0           ['conv4_block23_preact_b
n[0][0]']
 ivation)

 conv4_block23_1_conv (Conv2D)  (None, 8, 8, 256)    262144      ['conv4_block23_preact_r
elu[0][0]
                                                                 ']

 conv4_block23_1_bn (BatchNorma  (None, 8, 8, 256)   1024        ['conv4_block23_1_conv[0
][0]']
 lization)

 conv4_block23_1_relu (Activati  (None, 8, 8, 256)   0           ['conv4_block23_1_bn[0][
0]']
 on)

 conv4_block23_2_pad (ZeroPaddi  (None, 10, 10, 256)  0          ['conv4_block23_1_relu[0
][0]']
 ng2D)

 conv4_block23_2_conv (Conv2D)  (None, 4, 4, 256)    589824      ['conv4_block23_2_pad[0]
[0]']

 conv4_block23_2_bn (BatchNorma  (None, 4, 4, 256)   1024        ['conv4_block23_2_conv[0
][0]']
 lization)

 conv4_block23_2_relu (Activati  (None, 4, 4, 256)   0           ['conv4_block23_2_bn[0][
0]']
 on)

 max_pooling2d_2 (MaxPooling2D)  (None, 4, 4, 1024)  0           ['conv4_block22_out[0][0
]']

 conv4_block23_3_conv (Conv2D)  (None, 4, 4, 1024)   263168      ['conv4_block23_2_relu[0
][0]']

 conv4_block23_out (Add)        (None, 4, 4, 1024)   0           ['max_pooling2d_2[0][0]'
,
                                                                  'conv4_block23_3_conv
[0][0]']
```

```
 conv5_block1_preact_bn (BatchN  (None, 4, 4, 1024)  4096        ['conv4_block23_out[0][0
 ormalization)                                                   ]']

 conv5_block1_preact_relu (Acti  (None, 4, 4, 1024)  0           ['conv5_block1_preact_bn
 vation)                                                         [0][0]']

 conv5_block1_1_conv (Conv2D)   (None, 4, 4, 512)    524288      ['conv5_block1_preact_re
                                                                 lu[0][0]'
                                                                 ]

 conv5_block1_1_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block1_1_conv[0]
 ization)                                                        [0]']

 conv5_block1_1_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block1_1_bn[0][0
 n)                                                              ]']

 conv5_block1_2_pad (ZeroPaddin  (None, 6, 6, 512)   0           ['conv5_block1_1_relu[0]
 g2D)                                                            [0]']

 conv5_block1_2_conv (Conv2D)   (None, 4, 4, 512)    2359296     ['conv5_block1_2_pad[0][
                                                                 0]']

 conv5_block1_2_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block1_2_conv[0]
 ization)                                                        [0]']

 conv5_block1_2_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block1_2_bn[0][0
 n)                                                              ]']

 conv5_block1_0_conv (Conv2D)   (None, 4, 4, 2048)   2099200     ['conv5_block1_preact_re
                                                                 lu[0][0]'
                                                                 ]

 conv5_block1_3_conv (Conv2D)   (None, 4, 4, 2048)   1050624     ['conv5_block1_2_relu[0]
                                                                 [0]']

 conv5_block1_out (Add)         (None, 4, 4, 2048)   0           ['conv5_block1_0_conv[0
                                                                 ][0]',
                                                                  'conv5_block1_3_conv[
                                                                 0][0]']

 conv5_block2_preact_bn (BatchN  (None, 4, 4, 2048)  8192        ['conv5_block1_out[0][0]
 ']
 ormalization)
```

```
 conv5_block2_preact_relu (Acti  (None, 4, 4, 2048)  0           ['conv5_block2_preact_bn
[0][0]']
 vation)

 conv5_block2_1_conv (Conv2D)   (None, 4, 4, 512)    1048576     ['conv5_block2_preact_re
lu[0][0]'
                                                                 ]

 conv5_block2_1_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block2_1_conv[0]
[0]']
 ization)

 conv5_block2_1_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block2_1_bn[0][0
]']
 n)

 conv5_block2_2_pad (ZeroPaddin  (None, 6, 6, 512)   0           ['conv5_block2_1_relu[0]
[0]']
 g2D)

 conv5_block2_2_conv (Conv2D)   (None, 4, 4, 512)    2359296     ['conv5_block2_2_pad[0][
0]']

 conv5_block2_2_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block2_2_conv[0]
[0]']
 ization)

 conv5_block2_2_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block2_2_bn[0][0
]']
 n)

 conv5_block2_3_conv (Conv2D)   (None, 4, 4, 2048)   1050624     ['conv5_block2_2_relu[0]
[0]']

 conv5_block2_out (Add)         (None, 4, 4, 2048)   0           ['conv5_block1_out[0][0
]',
                                                                  'conv5_block2_3_conv[
0][0]']

 conv5_block3_preact_bn (BatchN  (None, 4, 4, 2048)  8192        ['conv5_block2_out[0][0]
']
 ormalization)

 conv5_block3_preact_relu (Acti  (None, 4, 4, 2048)  0           ['conv5_block3_preact_bn
[0][0]']
 vation)

 conv5_block3_1_conv (Conv2D)   (None, 4, 4, 512)    1048576     ['conv5_block3_preact_re
```

```
1u[0][0]'
                                                                  ]

 conv5_block3_1_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block3_1_conv[0]
[0]']
 ization)

 conv5_block3_1_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block3_1_bn[0][0
]']
 n)

 conv5_block3_2_pad (ZeroPaddin  (None, 6, 6, 512)   0           ['conv5_block3_1_relu[0]
[0]']
 g2D)

 conv5_block3_2_conv (Conv2D)   (None, 4, 4, 512)    2359296     ['conv5_block3_2_pad[0][
0]']

 conv5_block3_2_bn (BatchNormal  (None, 4, 4, 512)   2048        ['conv5_block3_2_conv[0]
[0]']
 ization)

 conv5_block3_2_relu (Activatio  (None, 4, 4, 512)   0           ['conv5_block3_2_bn[0][0
]']
 n)

 conv5_block3_3_conv (Conv2D)   (None, 4, 4, 2048)   1050624     ['conv5_block3_2_relu[0]
[0]']

 conv5_block3_out (Add)         (None, 4, 4, 2048)   0           ['conv5_block2_out[0][0
]',
                                                                  'conv5_block3_3_conv[
0][0]']

 post_bn (BatchNormalization)   (None, 4, 4, 2048)   8192        ['conv5_block3_out[0][0]
']

 post_relu (Activation)         (None, 4, 4, 2048)   0           ['post_bn[0][0]']

 avg_pool (GlobalAveragePooling  (None, 2048)        0           ['post_relu[0][0]']
 2D)

 predictions (Dense)            (None, 1)            2049        ['avg_pool[0][0]']

==================================================================================
=========
Total params: 42,628,609
Trainable params: 42,530,945
Non-trainable params: 97,664
```

In [9]:

```
filepath="classifier_weights2-improvement-{epoch:02d}-{val_accuracy:.2f}.hdf5"
checkpoint1 = tf.keras.callbacks.ModelCheckpoint(filepath, monitor='val_accuracy', verbo
se=1, save_best_only=True, mode='max')
callbacks_list = [checkpoint1]
del(checkpoint1)
```

In [10]:

```
history = model.fit(X_train,
                    y_train,
                    epochs=15,
                    callbacks=callbacks_list,
                    validation_data = (X_test, y_test))
```

```
Epoch 1/15
300/300 [==============================] - ETA: 0s - loss: 0.6336 - accuracy: 0.6751
Epoch 1: val_accuracy improved from -inf to 0.62375, saving model to classifier_weights2-
improvement-01-0.62.hdf5
300/300 [==============================] - 144s 226ms/step - loss: 0.6336 - accuracy: 0.6
751 - val_loss: 0.8299 - val_accuracy: 0.6237
Epoch 2/15
300/300 [==============================] - ETA: 0s - loss: 0.5806 - accuracy: 0.7098
Epoch 2: val_accuracy improved from 0.62375 to 0.67500, saving model to classifier_weight
s2-improvement-02-0.68.hdf5
300/300 [==============================] - 66s 220ms/step - loss: 0.5806 - accuracy: 0.70
98 - val_loss: 0.7019 - val_accuracy: 0.6750
Epoch 3/15
300/300 [==============================] - ETA: 0s - loss: 0.5677 - accuracy: 0.7182
Epoch 3: val_accuracy did not improve from 0.67500
300/300 [==============================] - 62s 207ms/step - loss: 0.5677 - accuracy: 0.71
82 - val_loss: 0.7276 - val_accuracy: 0.6146
Epoch 4/15
300/300 [==============================] - ETA: 0s - loss: 0.5587 - accuracy: 0.7284
Epoch 4: val_accuracy improved from 0.67500 to 0.71292, saving model to classifier_weight
s2-improvement-04-0.71.hdf5
300/300 [==============================] - 66s 220ms/step - loss: 0.5587 - accuracy: 0.72
84 - val_loss: 0.5838 - val_accuracy: 0.7129
Epoch 5/15
300/300 [==============================] - ETA: 0s - loss: 0.5485 - accuracy: 0.7355
Epoch 5: val_accuracy did not improve from 0.71292
300/300 [==============================] - 62s 207ms/step - loss: 0.5485 - accuracy: 0.73
55 - val_loss: 1.0337 - val_accuracy: 0.6488
Epoch 6/15
300/300 [==============================] - ETA: 0s - loss: 0.5417 - accuracy: 0.7403
Epoch 6: val_accuracy improved from 0.71292 to 0.73083, saving model to classifier_weight
s2-improvement-06-0.73.hdf5
300/300 [==============================] - 65s 216ms/step - loss: 0.5417 - accuracy: 0.74
03 - val_loss: 0.5532 - val_accuracy: 0.7308
Epoch 7/15
300/300 [==============================] - ETA: 0s - loss: 0.5326 - accuracy: 0.7473
Epoch 7: val_accuracy did not improve from 0.73083
300/300 [==============================] - 63s 210ms/step - loss: 0.5326 - accuracy: 0.74
73 - val_loss: 0.6239 - val_accuracy: 0.6621
Epoch 8/15
300/300 [==============================] - ETA: 0s - loss: 0.5214 - accuracy: 0.7559
Epoch 8: val_accuracy did not improve from 0.73083
300/300 [==============================] - 63s 210ms/step - loss: 0.5214 - accuracy: 0.75
59 - val_loss: 1.4939 - val_accuracy: 0.5025
Epoch 9/15
300/300 [==============================] - ETA: 0s - loss: 0.5151 - accuracy: 0.7610
Epoch 9: val_accuracy did not improve from 0.73083
300/300 [==============================] - 62s 207ms/step - loss: 0.5151 - accuracy: 0.76
10 - val_loss: 0.9007 - val_accuracy: 0.6954
Epoch 10/15
300/300 [==============================] - ETA: 0s - loss: 0.4942 - accuracy: 0.7710
Epoch 10: val_accuracy did not improve from 0.73083
300/300 [==============================] - 62s 207ms/step - loss: 0.4942 - accuracy: 0.77
```

```
10 - val_loss: 0.6585 - val_accuracy: 0.6383
Epoch 11/15
300/300 [==============================] - ETA: 0s - loss: 0.4685 - accuracy: 0.7861
Epoch 11: val_accuracy did not improve from 0.73083
300/300 [==============================] - 62s 207ms/step - loss: 0.4685 - accuracy: 0.78
61 - val_loss: 0.6216 - val_accuracy: 0.6929
Epoch 12/15
300/300 [==============================] - ETA: 0s - loss: 0.4476 - accuracy: 0.7997
Epoch 12: val_accuracy did not improve from 0.73083
300/300 [==============================] - 63s 210ms/step - loss: 0.4476 - accuracy: 0.79
97 - val_loss: 0.6467 - val_accuracy: 0.6775
Epoch 13/15
300/300 [==============================] - ETA: 0s - loss: 0.4229 - accuracy: 0.8136
Epoch 13: val_accuracy did not improve from 0.73083
300/300 [==============================] - 63s 211ms/step - loss: 0.4229 - accuracy: 0.81
36 - val_loss: 0.9171 - val_accuracy: 0.6433
Epoch 14/15
300/300 [==============================] - ETA: 0s - loss: 0.3905 - accuracy: 0.8259
Epoch 14: val_accuracy did not improve from 0.73083
300/300 [==============================] - 62s 208ms/step - loss: 0.3905 - accuracy: 0.82
59 - val_loss: 0.9912 - val_accuracy: 0.6808
Epoch 15/15
300/300 [==============================] - ETA: 0s - loss: 0.3659 - accuracy: 0.8427
Epoch 15: val_accuracy did not improve from 0.73083
300/300 [==============================] - 62s 207ms/step - loss: 0.3659 - accuracy: 0.84
27 - val_loss: 1.2377 - val_accuracy: 0.6746
```

In [15]:

```
best_epoch=np.argmax(history.history['val_accuracy'])
best_acc=np.max(history.history['val_accuracy'])
del(X_train,y_train)
```

In [16]:

```
model.load_weights('./classifier_weights2-improvement-06-0.73.hdf5')
```

In [17]:

```
# Classification Report and ROC AUC score on test data:
predictions = model.predict(X_test)
bin =[0 if p<0.5 else 1 for p in predictions]
print(classification_report(y_test,bin))
```

```
75/75 [==============================] - 7s 53ms/step
              precision    recall  f1-score   support

         0.0       0.75      0.71      0.73      1231
         1.0       0.71      0.75      0.73      1169

    accuracy                           0.73      2400
   macro avg       0.73      0.73      0.73      2400
weighted avg       0.73      0.73      0.73      2400
```

In [18]:

```
print("ROC AUC:")
roc_auc_score(y_test, bin)
```

```
ROC AUC:
```

Out[18]:

```
0.731256762325413
```

In [19]:

```
fpr, tpr, thresh = roc_curve(y_test, bin, pos_label=1)
sns.set_style("darkgrid")
plt.figure(figsize=(7.5,5));
plt.plot(fpr, tpr,'--r');
```

```
plt.title('ROC curve');
plt.xlabel('False Positive Rate');
plt.ylabel('True Positive rate');
plt.savefig('ROC',dpi=300);
plt.show();
```