A - Overview and Objective

Objective:

The objective of this analysis is to develop a convolutional neural network capabale of classifying images with cracked concrete from images with no surface defects. Through transfer learning, MobileNetV2 and Inception V3 CNNs will be utilized for classifying the concrete images and have their performance compared to the developed CNN. The models' classification decisions will be explained using class activation maps.

Dataset overview:

The dataset contains concrete images having cracks. The data is collected from various METU Campus Buildings. The dataset is divided into two as negative and positive crack images for image classification. Each class has 20000images with a total of 40000 images with 227 x 227 pixels with RGB channels. The dataset is generated from 458 high-resolution images (4032x3024 pixel) with the method proposed by Zhang et al (2016). High-resolution images have variance in terms of surface finish and illumination conditions. No data augmentation in terms of random rotation or flipping is applied.

data source link: https://www.kaggle.com/datasets/arnavr10880/concrete-crack-images-for-classification (https://www.kaggle.com/datasets/arnavr10880/concrete-crack-images-for-classification)

Citations:

- 2018 – Özgenel, Ç.F., Gönenç Sorguç, A. “Performance Comparison of Pretrained Convolutional Neural Networks on Crack Detection in Buildings”, ISARC 2018, Berlin.
- Lei Zhang , Fan Yang , Yimin Daniel Zhang, and Y. J. Z., Zhang, L., Yang, F., Zhang, Y. D., & Zhu, Y. J. (2016). Road Crack Detection Using Deep Convolutional Neural Network. In 2016 IEEE International Conference on Image Processing (ICIP). http://doi.org/10.1109/ICIP.2016.7533052 (http://doi.org/10.1109/ICIP.2016.7533052)

B - Setup

1.0 Import Libraries

In [1]:
```
import pandas as pd
import numpy as np
import PIL
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
import seaborn as sns
import tensorflow as tf
from tensorflow.keras import datasets, layers, models

from sklearn.metrics import accuracy_score
from keras.models import Sequential
from keras.layers import Dense, Conv2D , MaxPool2D , Flatten , Dropout
from keras.preprocessing.image import ImageDataGenerator
from keras.layers import BatchNormalization
from sklearn.metrics import classification_report,confusion_matrix
from tensorflow.keras.regularizers import l2

from PIL import Image
from numpy import asarray
from pathlib import Path

import keras
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import RandomizedSearchCV
from keras.wrappers.scikit_learn import KerasClassifier
from keras.layers import Dropout
from tensorflow.keras.optimizers import Adam
import joblib
import sys
sys.modules['sklearn.externals.joblib'] = joblib
from sklearn.externals.joblib import parallel_backend


#from tensorflow import keras
from tensorflow.keras import Model,layers
#from IPython.display import Image, display
import matplotlib.cm as cm
```

In [2]:
```
import IPython
import IPython.display
```

2.0 Read Dataset

Connect to Google Drive to get Kaggle credentials and download data from Kaggle

In [3]:
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from google.colab import drive
drive.mount('/content/drive')
```

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Mounted at /content/drive
```

In [4]:
```
! pip install kaggle
```

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Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.8/dist-packages (from requests->kaggle) (2.10)
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In [5]:
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! mkdir ~/.kaggle
```

In [6]:
```
! ! cp /content/drive/MyDrive/Datasets/Concrete_Crack_Detection/kaggle.json ~/.kaggle/
```

In [7]:
```
! chmod 600 ~/.kaggle/kaggle.json
```

In [8]:
```
! kaggle datasets download arunrk7/surface-crack-detection
```

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Downloading surface-crack-detection.zip to /content
 91% 212M/233M [00:01<00:00, 164MB/s]
100% 233M/233M [00:01<00:00, 143MB/s]
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In [9]:
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! unzip surface-crack-detection.zip
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  inflating: Positive/19868.jpg
  inflating: Positive/19869.jpg
  inflating: Positive/19870.jpg
  inflating: Positive/19871.jpg
  inflating: Positive/19872.jpg
  inflating: Positive/19873.jpg
  inflating: Positive/19874.jpg
  inflating: Positive/19875.jpg
  inflating: Positive/19876.jpg
  inflating: Positive/19877.jpg
  inflating: Positive/19878.jpg
  inflating: Positive/19879.jpg
  inflating: Positive/19880.jpg
  inflating: Positive/19881.jpg
  inflating: Positive/19882.jpg
  inflating: Positive/19883.jpg
  inflating: Positive/19884.jpg
  inflating: Positive/19885.jpg
  inflating: Positive/19886.jpg
  inflating: Positive/19887.jpg
  inflating: Positive/19888.jpg
  inflating: Positive/19889.jpg
  inflating: Positive/19890.jpg
  inflating: Positive/19891.jpg
  inflating: Positive/19892.jpg
  inflating: Positive/19893.jpg
  inflating: Positive/19894.jpg
  inflating: Positive/19895.jpg
  inflating: Positive/19896.jpg
  inflating: Positive/19897.jpg
  inflating: Positive/19898.jpg
  inflating: Positive/19899.jpg
  inflating: Positive/19900.jpg
  inflating: Positive/19901.jpg
```

```
  inflating: Positive/19902.jpg
  inflating: Positive/19903.jpg
  inflating: Positive/19904.jpg
  inflating: Positive/19905.jpg
  inflating: Positive/19906.jpg
  inflating: Positive/19907.jpg
  inflating: Positive/19908.jpg
  inflating: Positive/19909.jpg
  inflating: Positive/19910.jpg
  inflating: Positive/19911.jpg
  inflating: Positive/19912.jpg
  inflating: Positive/19913.jpg
  inflating: Positive/19914.jpg
  inflating: Positive/19915.jpg
  inflating: Positive/19916.jpg
  inflating: Positive/19917.jpg
  inflating: Positive/19918.jpg
  inflating: Positive/19919.jpg
  inflating: Positive/19920.jpg
  inflating: Positive/19921.jpg
  inflating: Positive/19922.jpg
  inflating: Positive/19923.jpg
  inflating: Positive/19924.jpg
  inflating: Positive/19925.jpg
  inflating: Positive/19926.jpg
  inflating: Positive/19927.jpg
  inflating: Positive/19928.jpg
  inflating: Positive/19929.jpg
  inflating: Positive/19930.jpg
  inflating: Positive/19931.jpg
  inflating: Positive/19932.jpg
  inflating: Positive/19933.jpg
  inflating: Positive/19934.jpg
  inflating: Positive/19935.jpg
  inflating: Positive/19936.jpg
  inflating: Positive/19937.jpg
  inflating: Positive/19938.jpg
  inflating: Positive/19939.jpg
  inflating: Positive/19940.jpg
  inflating: Positive/19941.jpg
  inflating: Positive/19942.jpg
  inflating: Positive/19943.jpg
  inflating: Positive/19944.jpg
  inflating: Positive/19945.jpg
  inflating: Positive/19946.jpg
  inflating: Positive/19947.jpg
  inflating: Positive/19948.jpg
  inflating: Positive/19949.jpg
  inflating: Positive/19950.jpg
  inflating: Positive/19951.jpg
  inflating: Positive/19952.jpg
  inflating: Positive/19953.jpg
  inflating: Positive/19954.jpg
  inflating: Positive/19955.jpg
  inflating: Positive/19956.jpg
  inflating: Positive/19957.jpg
  inflating: Positive/19958.jpg
```

```
inflating: Positive/19959.jpg
inflating: Positive/19960.jpg
inflating: Positive/19961.jpg
inflating: Positive/19962.jpg
inflating: Positive/19963.jpg
inflating: Positive/19964.jpg
inflating: Positive/19965.jpg
inflating: Positive/19966.jpg
inflating: Positive/19967.jpg
inflating: Positive/19968.jpg
inflating: Positive/19969.jpg
inflating: Positive/19970.jpg
inflating: Positive/19971.jpg
inflating: Positive/19972.jpg
inflating: Positive/19973.jpg
inflating: Positive/19974.jpg
inflating: Positive/19975.jpg
inflating: Positive/19976.jpg
inflating: Positive/19977.jpg
inflating: Positive/19978.jpg
inflating: Positive/19979.jpg
inflating: Positive/19980.jpg
inflating: Positive/19981.jpg
inflating: Positive/19982.jpg
inflating: Positive/19983.jpg
inflating: Positive/19984.jpg
inflating: Positive/19985.jpg
inflating: Positive/19986.jpg
inflating: Positive/19987.jpg
inflating: Positive/19988.jpg
inflating: Positive/19989.jpg
inflating: Positive/19990.jpg
inflating: Positive/19991.jpg
inflating: Positive/19992.jpg
inflating: Positive/19993.jpg
inflating: Positive/19994.jpg
inflating: Positive/19995.jpg
inflating: Positive/19996.jpg
inflating: Positive/19997.jpg
inflating: Positive/19998.jpg
inflating: Positive/19999.jpg
inflating: Positive/20000.jpg
```

2.1 Open Image of Each Class

Opening a JPEG File and getting an idea of shape

In [10]:
```
img = Image.open('Positive/19425.jpg') #open image

numpydata = asarray(img) #put image into an array

# <class 'numpy.ndarray'>
print(type(numpydata))

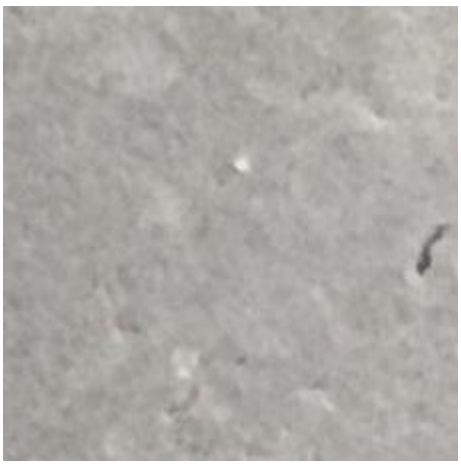
#  shape
print(numpydata.shape)
```

```
<class 'numpy.ndarray'>
(227, 227, 3)
```

In [11]:
```
pil_im = Image.open('Positive/19425.jpg')
display(pil_im)
```

Example of image classified as 'Positive' with crack.

In [12]:
```
pil_im = Image.open('Negative/00001.jpg')
display(pil_im)
```



Example image with no crack, classified as 'Negative'

C - Pre-processing

1.0 Create dataframe with image filepath and label

In [13]:
```
#Define image directory path
positive_dir=Path("../content/Positive")
negative_dir=Path("../content/Negative")
```

In [14]:
```
#Function to create dataframe with image filepath and labels
def DataFrame_create(image_dir,label):
    filepaths=pd.Series(list(image_dir.glob(r"*.jpg")),name="Filepath").astype
(str)
    labels=pd.Series(label,name="label",index=filepaths.index)
    dataframe=pd.concat([filepaths,labels],axis=1)

    return dataframe
```

In [15]:
```
#create positive and negative image dataframes
positive_df=DataFrame_create(positive_dir,label='positive')
negative_df=DataFrame_create(negative_dir,label='negative')
```

In [16]:
```
#Combine positive and negative dataframe into single dataframe. Frac = 5% of d
ata is put into df (5% of 40,000 images)
df=pd.concat([positive_df,negative_df],axis=0).sample(frac=.05, random_state=
1).reset_index(drop=True)
df.head()
```

Out[16]:

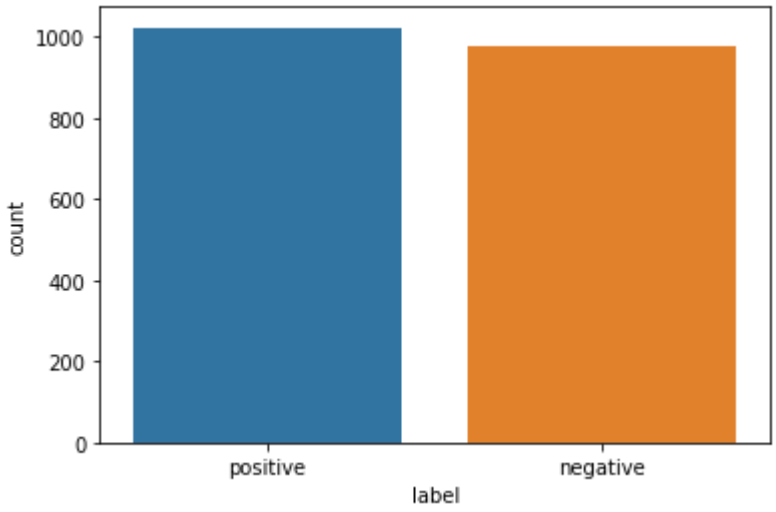
	Filepath	label
0	../content/Positive/06692.jpg	positive
1	../content/Positive/04918.jpg	positive
2	../content/Positive/15978_1.jpg	positive
3	../content/Negative/04106.jpg	negative
4	../content/Positive/03594.jpg	positive

2.0 Check for Class Imbalance

In [17]:
```
ax = sns.countplot(df.label,label="Count") ;
positive, negative = df.label.value_counts();
print('Number positive : ', positive);
print('Number negative : ', negative);
```

```
/usr/local/lib/python3.8/dist-packages/seaborn/_decorators.py:36: FutureWarni
ng: Pass the following variable as a keyword arg: x. From version 0.12, the o
nly valid positional argument will be `data`, and passing other arguments wit
hout an explicit keyword will result in an error or misinterpretation.
  warnings.warn(

Number positive :  1022
Number negative :  978
```



The classes are well balanced

3.0 Train/Validation/Test Split

In [18]:
```
#Train/Test Split
train_df,test_df=train_test_split(df,train_size=0.8,shuffle=True)
```

In [19]:
```
#Number of images in train dataframe
train_df['label'].value_counts()
```

Out[19]:
```
positive    815
negative    785
Name: label, dtype: int64
```

In [20]:
```
#Number of images in test dataframe
test_df['label'].value_counts()
```

Out[20]:
```
positive    207
negative    193
Name: label, dtype: int64
```

In [21]:
```
test_df.head(10)
```

Out[21]:

	Filepath	label
1155	../content/Negative/08975.jpg	negative
314	../content/Negative/09250.jpg	negative
1665	../content/Positive/01223.jpg	positive
467	../content/Positive/07183.jpg	positive
15	../content/Negative/13099.jpg	negative
1842	../content/Positive/15435_1.jpg	positive
1017	../content/Positive/11034_1.jpg	positive
1678	../content/Negative/03234.jpg	negative
954	../content/Negative/10738.jpg	negative
488	../content/Positive/11443_1.jpg	positive

In [22]:
```
#Generate batches of tensor image data with real-time data augmentation.

train_gen = tf.keras.preprocessing.image.ImageDataGenerator(
    rescale=1./255, #pixel values down into a range of between 0 and 1
    validation_split=0.2
)

test_gen = tf.keras.preprocessing.image.ImageDataGenerator(
    rescale=1./255
)
```

In [23]:
```
#Takes the dataframe and the path to a directory + generates batches. The gene
rated batches contain augmented/normalized data.

train_data = train_gen.flow_from_dataframe(
    train_df,
    x_col='Filepath',
    y_col='label',
    target_size=(128,128),
    color_mode='rgb',
    class_mode='binary',
    batch_size=128,
    shuffle=True,
    subset='training'
)

val_data = train_gen.flow_from_dataframe(
    train_df,
    x_col='Filepath',
    y_col='label',
    target_size=(128,128),
    color_mode='rgb',
    class_mode='binary',
    batch_size=128,
    shuffle=True,
    subset='validation'
)

test_data = test_gen.flow_from_dataframe(
    test_df,
    x_col='Filepath',
    y_col='label',
    target_size=(128,128),
    color_mode='rgb',
    class_mode='binary',
    batch_size=128,
    shuffle=False,
)
```

```
Found 1280 validated image filenames belonging to 2 classes.
Found 320 validated image filenames belonging to 2 classes.
Found 400 validated image filenames belonging to 2 classes.
```

D - Modeling

1.0 Baseline CNN Model

The Baseline CNN model was loosely based the popular VGG (Visual Geometry Group) model architecture. VGG is a very deep network (VGG16 consists of 16 convoluional layers) and uses 3x3 kernal sizes. All VGG hidden layers use an RELU activation function. This model consists of 4 convolutional layers, 2 maxpooling layers, 1 flattening layer, and 2 dense layers. The filter size also doubles through each convolutional layer stack, which is a key principle of VGG architecture.

https://viso.ai/deep-learning/vgg-very-deep-convolutional-networks/ (https://viso.ai/deep-learning/vgg-very-deep-convolutional-networks/)

1.1 Create Model

In [24]:
```
#Baseline

baseline_model = Sequential()
baseline_model.add(Conv2D(16,1,padding="same", activation="relu", strides=2, i
nput_shape = (128,128,3)))
baseline_model.add(Conv2D(16,1, padding="same", strides=2, activation="relu"))
baseline_model.add(MaxPool2D())

baseline_model.add(Conv2D(32, 3, padding="same", strides=2, activation="rel
u"))
baseline_model.add(Conv2D(32, 3, padding="same", strides=2, activation="rel
u"))
baseline_model.add(MaxPool2D())

baseline_model.add(Flatten())
baseline_model.add(Dense(64,activation="relu"))
baseline_model.add(Dropout(0.5))

baseline_model.add(Dense(2, activation="softmax"))

baseline_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 64, 64, 16)        64

 conv2d_1 (Conv2D)           (None, 32, 32, 16)        272

 max_pooling2d (MaxPooling2D  (None, 16, 16, 16)       0
 )

 conv2d_2 (Conv2D)           (None, 8, 8, 32)          4640

 conv2d_3 (Conv2D)           (None, 4, 4, 32)          9248

 max_pooling2d_1 (MaxPooling  (None, 2, 2, 32)         0
 2D)

 flatten (Flatten)           (None, 128)               0

 dense (Dense)               (None, 64)                8256

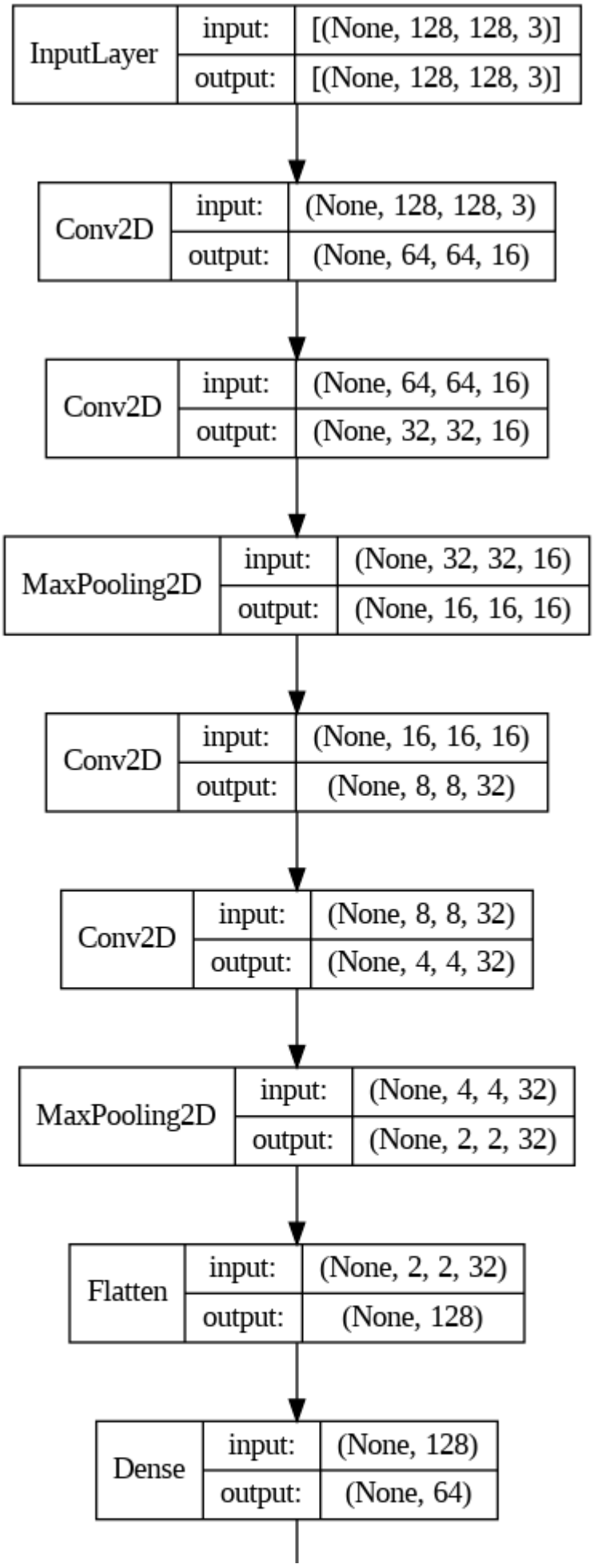
 dropout (Dropout)           (None, 64)                0

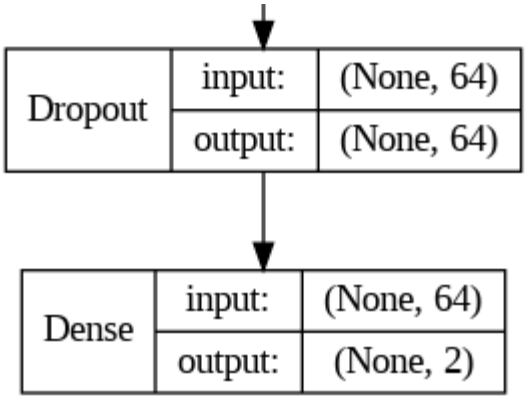
 dense_1 (Dense)             (None, 2)                 130

=================================================================
Total params: 22,610
Trainable params: 22,610
Non-trainable params: 0
_________________________________________________________________
```

In [25]:
```
tf.keras.utils.plot_model(baseline_model, to_file='baseline_model.png', show_s
hapes=True, show_layer_names=False)
```

Out[25]:


InputLayer
input: [(None, 128, 128, 3)]
output: [(None, 128, 128, 3)]
Conv2D
input: (None, 128, 128, 3)
output: (None, 64, 64, 16)
Conv2D
input: (None, 64, 64, 16)
output: (None, 32, 32, 16)
MaxPooling2D
input: (None, 32, 32, 16)
output: (None, 16, 16, 16)
Conv2D
input: (None, 16, 16, 16)
output: (None, 8, 8, 32)
Conv2D
input: (None, 8, 8, 32)
output: (None, 4, 4, 32)
MaxPooling2D
input: (None, 4, 4, 32)
output: (None, 2, 2, 32)
Flatten
input: (None, 2, 2, 32)
output: (None, 128)
Dense
input: (None, 128)
output: (None, 64)


Dropout
input:
(None, 64)
output:
(None, 64)
Dense
input:
(None, 64)
output:
(None, 2)

1.2 Baseline Model Results

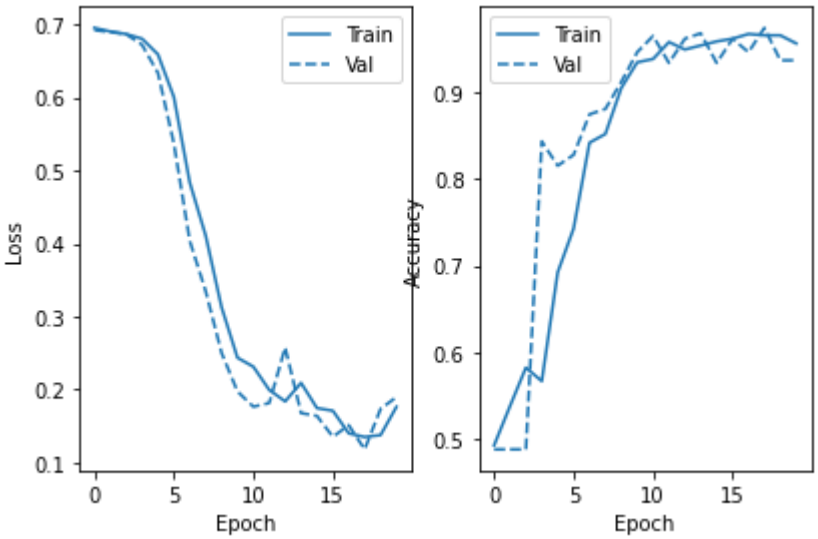
In [26]:
```
baseline_model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',metrics=['accuracy'] )
baseline_history = baseline_model.fit(train_data, validation_data=val_data, epochs=20, callbacks=[tf.keras.callbacks.EarlyStopping(monitor='val_loss',patience=3)])
```

```
Epoch 1/20
10/10 [==============================] - 8s 655ms/step - loss: 0.6955 - accur
acy: 0.4922 - val_loss: 0.6925 - val_accuracy: 0.4875
Epoch 2/20
10/10 [==============================] - 7s 677ms/step - loss: 0.6906 - accur
acy: 0.5375 - val_loss: 0.6898 - val_accuracy: 0.4875
Epoch 3/20
10/10 [==============================] - 6s 635ms/step - loss: 0.6870 - accur
acy: 0.5820 - val_loss: 0.6870 - val_accuracy: 0.4875
Epoch 4/20
10/10 [==============================] - 4s 367ms/step - loss: 0.6807 - accur
acy: 0.5664 - val_loss: 0.6724 - val_accuracy: 0.8438
Epoch 5/20
10/10 [==============================] - 3s 340ms/step - loss: 0.6592 - accur
acy: 0.6922 - val_loss: 0.6338 - val_accuracy: 0.8156
Epoch 6/20
10/10 [==============================] - 3s 334ms/step - loss: 0.6008 - accur
acy: 0.7430 - val_loss: 0.5371 - val_accuracy: 0.8281
Epoch 7/20
10/10 [==============================] - 3s 339ms/step - loss: 0.4836 - accur
acy: 0.8422 - val_loss: 0.4035 - val_accuracy: 0.8750
Epoch 8/20
10/10 [==============================] - 3s 331ms/step - loss: 0.4109 - accur
acy: 0.8523 - val_loss: 0.3347 - val_accuracy: 0.8813
Epoch 9/20
10/10 [==============================] - 4s 352ms/step - loss: 0.3126 - accur
acy: 0.9055 - val_loss: 0.2500 - val_accuracy: 0.9125
Epoch 10/20
10/10 [==============================] - 3s 338ms/step - loss: 0.2433 - accur
acy: 0.9352 - val_loss: 0.1971 - val_accuracy: 0.9469
Epoch 11/20
10/10 [==============================] - 3s 332ms/step - loss: 0.2310 - accur
acy: 0.9391 - val_loss: 0.1762 - val_accuracy: 0.9656
Epoch 12/20
10/10 [==============================] - 3s 334ms/step - loss: 0.1991 - accur
acy: 0.9586 - val_loss: 0.1812 - val_accuracy: 0.9344
Epoch 13/20
10/10 [==============================] - 4s 347ms/step - loss: 0.1835 - accur
acy: 0.9500 - val_loss: 0.2573 - val_accuracy: 0.9625
Epoch 14/20
10/10 [==============================] - 3s 342ms/step - loss: 0.2088 - accur
acy: 0.9547 - val_loss: 0.1675 - val_accuracy: 0.9688
Epoch 15/20
10/10 [==============================] - 3s 336ms/step - loss: 0.1743 - accur
acy: 0.9594 - val_loss: 0.1635 - val_accuracy: 0.9344
Epoch 16/20
10/10 [==============================] - 3s 339ms/step - loss: 0.1706 - accur
acy: 0.9625 - val_loss: 0.1349 - val_accuracy: 0.9625
Epoch 17/20
10/10 [==============================] - 3s 336ms/step - loss: 0.1397 - accur
acy: 0.9680 - val_loss: 0.1507 - val_accuracy: 0.9469
Epoch 18/20
10/10 [==============================] - 3s 334ms/step - loss: 0.1347 - accur
acy: 0.9664 - val_loss: 0.1177 - val_accuracy: 0.9750
Epoch 19/20
10/10 [==============================] - 3s 331ms/step - loss: 0.1372 - accur
acy: 0.9664 - val_loss: 0.1732 - val_accuracy: 0.9375
```

```
Epoch 20/20
10/10 [==============================] - 3s 333ms/step - loss: 0.1760 - accur
acy: 0.9570 - val_loss: 0.1894 - val_accuracy: 0.9375
```

In [27]:
```
import matplotlib.pyplot as plt
def plot_metrics(baseline_history):
  metrics =  ['loss','accuracy']
  for n, metric in enumerate(metrics):
    name = metric.replace("_"," ").capitalize()
    plt.subplot(1,2,n+1)
    plt.tight_layout()
    plt.plot(baseline_history.epoch,  baseline_history.history[metric], color=
colors[0], label='Train')
    plt.plot(baseline_history.epoch, baseline_history.history['val_'+metric],
             color=colors[0], linestyle="--", label='Val')
    plt.xlabel('Epoch')
    plt.ylabel(name)
    plt.legend()
```

In [28]:
```
colors = plt.rcParams['axes.prop_cycle'].by_key()['color']
plot_metrics(baseline_history)
```

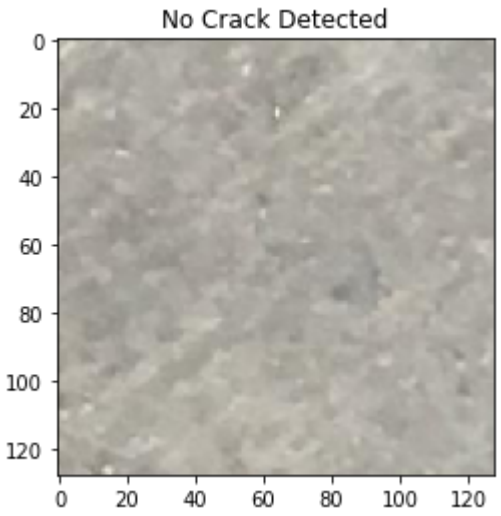


In [29]:
```
#Test model on an image
image = tf.keras.preprocessing.image.load_img("../content/Negative/08693.jpg",
target_size=(128,128))
input_arr = np.array([tf.keras.preprocessing.image.img_to_array(image)]).astyp
e('float32') / 255
predictions = baseline_model.predict(input_arr)

plt.figure()
plt.imshow(image)

if(predictions[0][1]>=0.5):
    plt.title("Crack Detected")
else:
    plt.title("No Crack Detected")
```

```
1/1 [==============================] - 0s 138ms/step
```

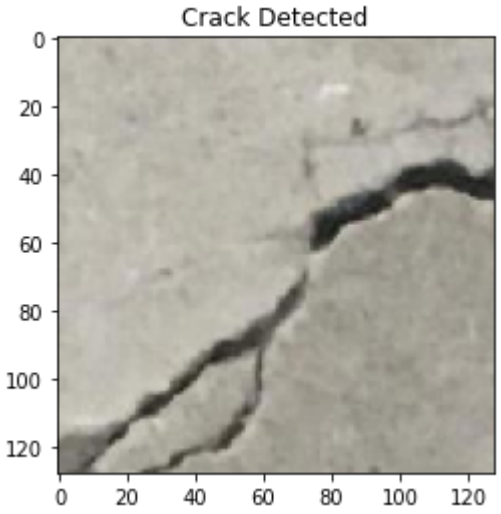


In [30]:
```
#Test model on an image
image = tf.keras.preprocessing.image.load_img("../content/Positive/04092.jpg",
target_size=(128,128))
input_arr = np.array([tf.keras.preprocessing.image.img_to_array(image)]).astyp
e('float32') / 255
predictions = baseline_model.predict(input_arr)

plt.figure()
plt.imshow(image)

if(predictions[0][1]>=0.5):
    plt.title("Crack Detected")
else:
    plt.title("No Crack Detected")
```

```
1/1 [==============================] - 0s 19ms/step
```



In [31]:
```
baseline_results = baseline_model.evaluate(test_data, verbose = 0)
baseline_loss = baseline_results[0]
baseline_acc = baseline_results[1]

print('Baseline Test loss:', baseline_loss)
print('Baseline Test accuracy:', baseline_acc)
```

```
Baseline Test loss: 0.17325277626514435
Baseline Test accuracy: 0.9474999904632568
```

2.0 Hyperparameter Tuning

2.1 Tune Baseline Model

In [32]:
```
# define a grid of the hyperparameter search space
hiddenLayerOne = [16, 32, 64]
hiddenLayerTwo = [16, 32, 64]
hiddenLayerThree = [16, 32, 64]
```

```
hiddenLayerFour = [16, 32, 64]
learnRate = [1e-2, 1e-3, 1e-4]
hiddenDense = [64, 128, 256]
kernel_size = [1,3]
strides = [1,2,3]
dropout_rate = [0.3, 0.4, 0.5]
#batchSize = [32,64,128]

# create a dictionary from the hyperparameter grid
param_grid = dict(
  hiddenLayerOne=hiddenLayerOne,
  hiddenLayerTwo=hiddenLayerTwo,
  hiddenLayerThree=hiddenLayerThree,
  hiddenLayerFour=hiddenLayerFour,
  kernel_size=kernel_size,
  hiddenDense=hiddenDense,
  learnRate=learnRate,
  strides=strides,
  #batch_size=batchSize,
  dropout_rate = dropout_rate,
)
```

In [33]:

```
# Function to create model
def create_model(hiddenLayerOne=16, hiddenLayerTwo=16, hiddenLayerThree=32, hi
ddenLayerFour=32, hiddenDense=64, learnRate=0.01, strides=2, dropout_rate=.3,
kernel_size=1):
        # create model
  model = Sequential()
  model.add(Conv2D(hiddenLayerOne, kernel_size=kernel_size, padding="same", ac
tivation='relu', strides=strides, kernel_regularizer=keras.regularizers.l2(),
input_shape = (128,128,3)))
  model.add(Conv2D(hiddenLayerTwo, kernel_size=kernel_size, padding="same", st
rides=strides, kernel_regularizer=keras.regularizers.l2(), activation="relu"))
  model.add(MaxPool2D())

  model.add(Conv2D(hiddenLayerThree, kernel_size=kernel_size, padding="same",
strides=strides, kernel_regularizer=keras.regularizers.l2(), activation="rel
u"))
  model.add(Conv2D(hiddenLayerFour, kernel_size=kernel_size, padding="same", s
trides=strides, kernel_regularizer=keras.regularizers.l2(), activation="rel
u"))
  model.add(MaxPool2D())

  model.add(Flatten())
  model.add(Dense(hiddenDense, activation="relu"))
  model.add(layers.Dropout(dropout_rate))
  model.add(Dense(2, activation='softmax'))

        # Compile model
  model.compile(loss='sparse_categorical_crossentropy', optimizer=Adam(learnin
g_rate=learnRate), metrics=['accuracy'])
  return model
```

In [34]:
```
# Random Grid Search
# fix random seed for reproducibility
seed = 7
np.random.seed(seed)

# create model
model = KerasClassifier(build_fn=create_model, verbose=1)

clf = RandomizedSearchCV(estimator=model, param_distributions=param_grid, n_jo
bs=-1, cv=3, scoring='accuracy')

with parallel_backend('threading'):
  tuned_baseline_model = clf.fit(train_data[0][0], train_data[0][1], epochs=5,
validation_data=val_data, callbacks=[tf.keras.callbacks.EarlyStopping(monitor
='val_loss',patience=3)])

# summarize results
print(tuned_baseline_model.best_params_)
```

```
<ipython-input-34-3ef578c0fe7b>:7: DeprecationWarning: KerasClassifier is dep
recated, use Sci-Keras (https://github.com/adriangb/scikeras) instead. See ht
tps://www.adriangb.com/scikeras/stable/migration.html for help migrating.
  model = KerasClassifier(build_fn=create_model, verbose=1)
```

```
Epoch 1/5
Epoch 1/5
3/3 [==============================] - 4s 1s/step - loss: 1.5321 - accuracy:
0.5647 - val_loss: 1.5201 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 4s 1s/step - loss: 1.5119 - accuracy:
0.5059 - val_loss: 1.4947 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 2s 714ms/step - loss: 1.5094 - accurac
y: 0.5059 - val_loss: 1.4992 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 2s 746ms/step - loss: 1.4828 - accurac
y: 0.6000 - val_loss: 1.4724 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 2s 705ms/step - loss: 1.4886 - accurac
y: 0.4941 - val_loss: 1.4790 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 2s 707ms/step - loss: 1.4668 - accurac
y: 0.4706 - val_loss: 1.4502 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 2s 731ms/step - loss: 1.4644 - accurac
y: 0.5294 - val_loss: 1.4568 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 2s 697ms/step - loss: 1.4454 - accurac
y: 0.4588 - val_loss: 1.4287 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 2s 702ms/step - loss: 1.4182 - accurac
y: 0.5176 - val_loss: 1.4077 - val_accuracy: 0.4875
3/3 [==============================] - 2s 735ms/step - loss: 1.4401 - accurac
y: 0.5412 - val_loss: 1.4360 - val_accuracy: 0.4875
2/2 [==============================] - 0s 32ms/step
2/2 [==============================] - 0s 29ms/step
Epoch 1/5
Epoch 1/5
3/3 [==============================] - 8s 2s/step - loss: 1.5611 - accuracy:
0.6047 - val_loss: 1.5452 - val_accuracy: 0.5125
Epoch 2/5
3/3 [==============================] - 3s 1s/step - loss: 1.5393 - accuracy:
0.4651 - val_loss: 1.5216 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 4s 2s/step - loss: 1.5126 - accuracy:
0.5465 - val_loss: 1.4985 - val_accuracy: 0.5125
Epoch 4/5
3/3 [==============================] - 3s 1s/step - loss: 1.4893 - accuracy:
0.5349 - val_loss: 1.4760 - val_accuracy: 0.5125
Epoch 5/5
3/3 [==============================] - 3s 2s/step - loss: 1.4665 - accuracy:
0.5349 - val_loss: 1.4541 - val_accuracy: 0.5125
2/2 [==============================] - 1s 363ms/step
Epoch 1/5
3/3 [==============================] - 28s 11s/step - loss: 2.2273 - accurac
y: 0.5882 - val_loss: 2.2172 - val_accuracy: 0.4969
Epoch 2/5
3/3 [==============================] - 50s 22s/step - loss: 2.2360 - accurac
y: 0.4824 - val_loss: 2.2005 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 55s 23s/step - loss: 2.2579 - accurac
```

```
y: 0.5176 - val_loss: 2.2300 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 50s 20s/step - loss: 2.2082 - accurac
y: 0.5176 - val_loss: 2.2011 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 50s 19s/step - loss: 2.2136 - accurac
y: 0.5529 - val_loss: 2.2048 - val_accuracy: 0.5125
3/3 [==============================] - 26s 9s/step - loss: 2.2147 - accuracy:
0.5529 - val_loss: 2.2046 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 18s 7s/step - loss: 2.1541 - accuracy:
0.5765 - val_loss: 2.1574 - val_accuracy: 0.4875

WARNING:tensorflow:5 out of the last 9 calls to <function Model.make_predict_
function.<locals>.predict_function at 0x7feb3a5574c0> triggered tf.function r
etracing. Tracing is expensive and the excessive number of tracings could be
due to (1) creating @tf.function repeatedly in a loop, (2) passing tensors wi
th different shapes, (3) passing Python objects instead of tensors. For (1),
please define your @tf.function outside of the loop. For (2), @tf.function ha
s reduce_retracing=True option that can avoid unnecessary retracing. For (3),
please refer to https://www.tensorflow.org/guide/function#controlling_retraci
ng and https://www.tensorflow.org/api_docs/python/tf/function for  more detai
ls.

2/2 [==============================] - 3s 269ms/step
Epoch 1/5
3/3 [==============================] - 18s 7s/step - loss: 2.2421 - accuracy:
0.5233 - val_loss: 2.2261 - val_accuracy: 0.5125
Epoch 2/5
3/3 [==============================] - ETA: 0s - loss: 2.2406 - accuracy: 0.5
465

WARNING:tensorflow:6 out of the last 11 calls to <function Model.make_predict
_function.<locals>.predict_function at 0x7feb3a5d61f0> triggered tf.function
retracing. Tracing is expensive and the excessive number of tracings could be
due to (1) creating @tf.function repeatedly in a loop, (2) passing tensors wi
th different shapes, (3) passing Python objects instead of tensors. For (1),
please define your @tf.function outside of the loop. For (2), @tf.function ha
s reduce_retracing=True option that can avoid unnecessary retracing. For (3),
please refer to https://www.tensorflow.org/guide/function#controlling_retraci
ng and https://www.tensorflow.org/api_docs/python/tf/function for  more detai
ls.
```

```
2/2 [==============================] - 3s 640ms/step
3/3 [==============================] - 18s 7s/step - loss: 2.2406 - accuracy:
0.5465 - val_loss: 2.2088 - val_accuracy: 0.5125
Epoch 3/5
Epoch 1/5
3/3 [==============================] - 23s 9s/step - loss: 2.5395 - accuracy:
0.5059 - val_loss: 2.9253 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 36s 15s/step - loss: 2.2108 - accurac
y: 0.5698 - val_loss: 2.1935 - val_accuracy: 0.5000
Epoch 4/5
3/3 [==============================] - 13s 5s/step - loss: 2.4586 - accuracy:
0.5529 - val_loss: 1.9779 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 7s 3s/step - loss: 1.8305 - accuracy:
0.5059 - val_loss: 1.6785 - val_accuracy: 0.5125
Epoch 4/5
3/3 [==============================] - 7s 3s/step - loss: 1.6917 - accuracy:
0.4706 - val_loss: 1.6643 - val_accuracy: 0.5125
Epoch 5/5
3/3 [==============================] - 8s 3s/step - loss: 1.7189 - accuracy:
0.4118 - val_loss: 1.6242 - val_accuracy: 0.5125
2/2 [==============================] - 1s 258ms/step
Epoch 1/5
3/3 [==============================] - 26s 10s/step - loss: 2.1929 - accurac
y: 0.5349 - val_loss: 2.1808 - val_accuracy: 0.4969
Epoch 5/5
3/3 [==============================] - 9s 3s/step - loss: 2.9056 - accuracy:
0.4588 - val_loss: 1.6915 - val_accuracy: 0.5125
Epoch 2/5
3/3 [==============================] - 9s 3s/step - loss: 1.6988 - accuracy:
0.4706 - val_loss: 1.6617 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 24s 9s/step - loss: 2.1610 - accuracy:
0.5814 - val_loss: 2.1590 - val_accuracy: 0.5250
2/2 [==============================] - 2s 419ms/step
3/3 [==============================] - 9s 3s/step - loss: 1.6676 - accuracy:
0.4353 - val_loss: 1.6383 - val_accuracy: 0.4938
Epoch 4/5
1/3 [=========>....................] - ETA: 1s - loss: 1.6443 - accuracy: 0.5
312Epoch 1/5
3/3 [==============================] - 4s 2s/step - loss: 1.6378 - accuracy:
0.5529 - val_loss: 1.6428 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 9s 3s/step - loss: 1.8299 - accuracy:
0.5116 - val_loss: 2.6154 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 5s 2s/step - loss: 1.6297 - accuracy:
0.5176 - val_loss: 1.5922 - val_accuracy: 0.4875
3/3 [==============================] - 3s 1s/step - loss: 2.1445 - accuracy:
0.5116 - val_loss: 1.9684 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 3s 1s/step - loss: 1.8926 - accuracy:
0.5116 - val_loss: 1.6441 - val_accuracy: 0.4875
Epoch 4/5
2/2 [==============================] - 1s 128ms/step
Epoch 1/5
```

```
3/3 [==============================] - 4s 2s/step - loss: 1.7233 - accuracy:
0.4302 - val_loss: 1.6112 - val_accuracy: 0.5469
Epoch 5/5
3/3 [==============================] - 5s 2s/step - loss: 1.5175 - accuracy:
0.5294 - val_loss: 1.1883 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 2s 1s/step - loss: 1.0556 - accuracy:
0.5529 - val_loss: 0.8863 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 5s 2s/step - loss: 1.5954 - accuracy:
0.5465 - val_loss: 1.5966 - val_accuracy: 0.5344
2/2 [==============================] - 1s 107ms/step
Epoch 1/5
3/3 [==============================] - 3s 1s/step - loss: 0.8324 - accuracy:
0.5529 - val_loss: 0.8039 - val_accuracy: 0.4969
Epoch 4/5
3/3 [==============================] - 2s 1s/step - loss: 0.7974 - accuracy:
0.5529 - val_loss: 0.7987 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 2s 941ms/step - loss: 0.7974 - accurac
y: 0.5412 - val_loss: 0.7991 - val_accuracy: 0.4875
3/3 [==============================] - 5s 1s/step - loss: 1.8712 - accuracy:
0.6353 - val_loss: 1.2370 - val_accuracy: 0.4875
Epoch 2/5
2/2 [==============================] - 0s 28ms/step
2/3 [===================>..........] - ETA: 0s - loss: 1.1563 - accuracy: 0.5
312Epoch 1/5
3/3 [==============================] - 3s 1s/step - loss: 1.1256 - accuracy:
0.5176 - val_loss: 0.9764 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 5s 1s/step - loss: 1.5728 - accuracy:
0.4884 - val_loss: 1.1837 - val_accuracy: 0.5125
Epoch 2/5
3/3 [==============================] - 3s 2s/step - loss: 0.9530 - accuracy:
0.4706 - val_loss: 0.8985 - val_accuracy: 0.5188
Epoch 4/5
3/3 [==============================] - 4s 1s/step - loss: 1.0980 - accuracy:
0.5349 - val_loss: 0.9168 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 3s 937ms/step - loss: 0.8999 - accurac
y: 0.4235 - val_loss: 0.8893 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 2s 943ms/step - loss: 0.8784 - accurac
y: 0.5349 - val_loss: 0.8323 - val_accuracy: 0.5125
Epoch 4/5
3/3 [==============================] - 2s 966ms/step - loss: 0.8879 - accurac
y: 0.5882 - val_loss: 0.8893 - val_accuracy: 0.4875
2/2 [==============================] - 0s 24ms/step
Epoch 1/5
3/3 [==============================] - 3s 2s/step - loss: 0.8267 - accuracy:
0.5349 - val_loss: 0.8240 - val_accuracy: 0.5125
Epoch 5/5
3/3 [==============================] - 2s 1s/step - loss: 0.8256 - accuracy:
0.5581 - val_loss: 0.8242 - val_accuracy: 0.5125
3/3 [==============================] - 9s 3s/step - loss: 2.2904 - accuracy:
0.4941 - val_loss: 1.9189 - val_accuracy: 0.4875
Epoch 2/5
```

```
2/2 [==============================] - 0s 29ms/step
Epoch 1/5
3/3 [==============================] - 7s 3s/step - loss: 1.4474 - accuracy:
0.6235 - val_loss: 1.3778 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 10s 4s/step - loss: 1.3071 - accuracy:
0.5412 - val_loss: 1.5072 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 15s 5s/step - loss: 5.1702 - accuracy:
0.4118 - val_loss: 1.8920 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 11s 4s/step - loss: 1.3442 - accuracy:
0.5529 - val_loss: 1.1923 - val_accuracy: 0.5219
Epoch 5/5
3/3 [==============================] - 10s 4s/step - loss: 1.7325 - accuracy:
0.5294 - val_loss: 1.4012 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 11s 4s/step - loss: 1.1980 - accuracy:
0.5059 - val_loss: 1.1786 - val_accuracy: 0.5125
3/3 [==============================] - 11s 4s/step - loss: 1.3240 - accuracy:
0.5294 - val_loss: 1.2290 - val_accuracy: 0.4875
Epoch 4/5
2/2 [==============================] - 1s 168ms/step
Epoch 1/5
3/3 [==============================] - 8s 3s/step - loss: 1.2042 - accuracy:
0.5294 - val_loss: 1.2005 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 14s 5s/step - loss: 2.7157 - accuracy:
0.4419 - val_loss: 1.9514 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 10s 4s/step - loss: 1.1712 - accuracy:
0.5412 - val_loss: 1.1704 - val_accuracy: 0.4719
2/2 [==============================] - 1s 199ms/step
Epoch 1/5
3/3 [==============================] - 9s 3s/step - loss: 1.8537 - accuracy:
0.4651 - val_loss: 1.2428 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 7s 2s/step - loss: 1.3162 - accuracy:
0.4706 - val_loss: 1.0206 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 3s 1s/step - loss: 0.9518 - accuracy:
0.5529 - val_loss: 0.8332 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 8s 4s/step - loss: 1.2397 - accuracy:
0.5698 - val_loss: 1.2135 - val_accuracy: 0.5094
Epoch 4/5
3/3 [==============================] - 4s 1s/step - loss: 0.8049 - accuracy:
0.5529 - val_loss: 0.7753 - val_accuracy: 0.4906
Epoch 4/5
3/3 [==============================] - 3s 1s/step - loss: 0.7644 - accuracy:
0.5529 - val_loss: 0.7706 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 3s 1s/step - loss: 0.7559 - accuracy:
0.5529 - val_loss: 0.7702 - val_accuracy: 0.4875
3/3 [==============================] - 8s 3s/step - loss: 1.1871 - accuracy:
0.6279 - val_loss: 1.1792 - val_accuracy: 0.5125
Epoch 5/5
```

```
2/2 [==============================] - 1s 96ms/step
Epoch 1/5
3/3 [==============================] - 8s 3s/step - loss: 1.1497 - accuracy:
0.7093 - val_loss: 1.1470 - val_accuracy: 0.6687
3/3 [==============================] - 6s 2s/step - loss: 1.5011 - accuracy:
0.4706 - val_loss: 1.0678 - val_accuracy: 0.5031
Epoch 2/5
3/3 [==============================] - 1s 601ms/step - loss: 1.0113 - accurac
y: 0.4588 - val_loss: 0.9121 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 1s 597ms/step - loss: 0.8834 - accurac
y: 0.5176 - val_loss: 0.8586 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 2s 902ms/step - loss: 0.8836 - accurac
y: 0.5294 - val_loss: 0.8638 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 1s 595ms/step - loss: 0.8532 - accurac
y: 0.5412 - val_loss: 0.8504 - val_accuracy: 0.4875
2/2 [==============================] - 0s 29ms/step
Epoch 1/5
3/3 [==============================] - 2s 777ms/step - loss: 1.3548 - accurac
y: 0.4302 - val_loss: 1.0960 - val_accuracy: 0.5750
Epoch 2/5
3/3 [==============================] - 1s 599ms/step - loss: 1.0289 - accurac
y: 0.5349 - val_loss: 1.0745 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 1s 603ms/step - loss: 0.9294 - accurac
y: 0.4884 - val_loss: 0.8466 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 1s 608ms/step - loss: 0.8380 - accurac
y: 0.4884 - val_loss: 0.8216 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 1s 606ms/step - loss: 0.8198 - accurac
y: 0.4651 - val_loss: 0.8086 - val_accuracy: 0.5125
2/2 [==============================] - 0s 21ms/step
Epoch 1/5
3/3 [==============================] - 2s 668ms/step - loss: 1.6135 - accurac
y: 0.5176 - val_loss: 1.5526 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 1s 483ms/step - loss: 1.5294 - accurac
y: 0.5059 - val_loss: 1.4773 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 1s 474ms/step - loss: 1.4529 - accurac
y: 0.5647 - val_loss: 1.4091 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 1s 489ms/step - loss: 1.3840 - accurac
y: 0.5529 - val_loss: 1.3444 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 1s 492ms/step - loss: 1.3197 - accurac
y: 0.5529 - val_loss: 1.2838 - val_accuracy: 0.4875
2/2 [==============================] - 0s 24ms/step
Epoch 1/5
2/2 [==============================] - 1s 157ms/step
Epoch 1/5
3/3 [==============================] - 4s 1s/step - loss: 1.6047 - accuracy:
0.5294 - val_loss: 1.5582 - val_accuracy: 0.4875
Epoch 2/5
```

```
3/3 [==============================] - 4s 1s/step - loss: 1.6199 - accuracy:
0.5116 - val_loss: 1.5639 - val_accuracy: 0.5125
Epoch 2/5
3/3 [==============================] - 2s 898ms/step - loss: 1.5438 - accurac
y: 0.5176 - val_loss: 1.4856 - val_accuracy: 0.5063
Epoch 3/5
3/3 [==============================] - 2s 1s/step - loss: 1.5456 - accuracy:
0.5233 - val_loss: 1.4941 - val_accuracy: 0.5125
Epoch 3/5
3/3 [==============================] - 2s 882ms/step - loss: 1.4577 - accurac
y: 0.5294 - val_loss: 1.4231 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 2s 900ms/step - loss: 1.4696 - accurac
y: 0.5349 - val_loss: 1.4303 - val_accuracy: 0.5125
Epoch 4/5
3/3 [==============================] - 2s 880ms/step - loss: 1.4061 - accurac
y: 0.5294 - val_loss: 1.3633 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 2s 916ms/step - loss: 1.4058 - accurac
y: 0.5233 - val_loss: 1.3717 - val_accuracy: 0.5125
Epoch 5/5
3/3 [==============================] - 2s 895ms/step - loss: 1.3511 - accurac
y: 0.5294 - val_loss: 1.3079 - val_accuracy: 0.4875
2/2 [==============================] - 0s 39ms/step
3/3 [==============================] - ETA: 0s - loss: 1.3443 - accuracy: 0.5
349Epoch 1/5
3/3 [==============================] - 2s 1s/step - loss: 1.3443 - accuracy:
0.5349 - val_loss: 1.3135 - val_accuracy: 0.5125
3/3 [==============================] - 3s 515ms/step - loss: 1.4840 - accurac
y: 0.5529 - val_loss: 1.3236 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 1s 346ms/step - loss: 1.2708 - accurac
y: 0.5529 - val_loss: 1.1540 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 1s 345ms/step - loss: 1.1109 - accurac
y: 0.5529 - val_loss: 1.0275 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 1s 348ms/step - loss: 0.9816 - accurac
y: 0.5529 - val_loss: 0.9274 - val_accuracy: 0.4875
Epoch 5/5
3/3 [==============================] - 1s 339ms/step - loss: 0.8893 - accurac
y: 0.5529 - val_loss: 0.8561 - val_accuracy: 0.4875
2/2 [==============================] - 0s 15ms/step
Epoch 1/5
3/3 [==============================] - 2s 528ms/step - loss: 1.4914 - accurac
y: 0.4588 - val_loss: 1.3374 - val_accuracy: 0.4875
Epoch 2/5
3/3 [==============================] - 1s 358ms/step - loss: 1.2839 - accurac
y: 0.4824 - val_loss: 1.1606 - val_accuracy: 0.4875
Epoch 3/5
2/2 [==============================] - 0s 28ms/step
Epoch 1/5
3/3 [==============================] - 1s 684ms/step - loss: 1.1211 - accurac
y: 0.4941 - val_loss: 1.0250 - val_accuracy: 0.4875
Epoch 4/5
3/3 [==============================] - 1s 596ms/step - loss: 0.9899 - accurac
y: 0.5294 - val_loss: 0.9194 - val_accuracy: 0.4875
```

```
Epoch 5/5
3/3 [==============================] - 1s 616ms/step - loss: 0.8943 - accurac
y: 0.5294 - val_loss: 0.8448 - val_accuracy: 0.4875
2/2 [==============================] - 0s 25ms/step
3/3 [==============================] - 3s 1s/step - loss: 1.5186 - accuracy:
0.4767 - val_loss: 1.3460 - val_accuracy: 0.4781
Epoch 2/5
3/3 [==============================] - 1s 355ms/step - loss: 1.3030 - accurac
y: 0.4535 - val_loss: 1.1849 - val_accuracy: 0.4875
Epoch 3/5
3/3 [==============================] - 1s 353ms/step - loss: 1.1437 - accurac
y: 0.5349 - val_loss: 1.0549 - val_accuracy: 0.5125
2/2 [==============================] - 0s 13ms/step
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_validation.p
y:372: FitFailedWarning:
6 fits failed out of a total of 30.
The score on these train-test partitions for these parameters will be set to
nan.
If these failures are not expected, you can try to debug them by setting erro
r_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
---
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tra
cking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.p
y", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/op
s.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_3" (type
MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_poolin
g2d_3/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=
[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)'
with input shapes: [?,1,1,32].

Call arguments received by layer "max_pooling2d_3" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 32), dtype=float32)

--------------------------------------------------------------------------------
---
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
```

```
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tra
cking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.p
y", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/op
s.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_5" (type
MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_poolin
g2d_5/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=
[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)'
with input shapes: [?,1,1,32].

Call arguments received by layer "max_pooling2d_5" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 32), dtype=float32)

--------------------------------------------------------------------------------
---
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tra
cking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.p
y", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/op
s.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_7" (type
MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_poolin
g2d_7/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=
[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)'
with input shapes: [?,1,1,32].

Call arguments received by layer "max_pooling2d_7" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 32), dtype=float32)
```

```
--------------------------------------------------------------------------------
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.py", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.py", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tracking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.py", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/ops.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_21" (type MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_pooling2d_21/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)' with input shapes: [?,1,1,16].

Call arguments received by layer "max_pooling2d_21" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 16), dtype=float32)

--------------------------------------------------------------------------------
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.py", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.py", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tracking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.py", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/op
```

```
s.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_23" (type
MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_poolin
g2d_23/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=
[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)'
with input shapes: [?,1,1,16].

Call arguments received by layer "max_pooling2d_23" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 16), dtype=float32)

--------------------------------------------------------------------------
---
1 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 236, in fit
    return super(KerasClassifier, self).fit(x, y, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/wrappers/scikit_learn.p
y", line 155, in fit
    self.model = self.build_fn(**self.filter_sk_params(self.build_fn))
  File "<ipython-input-33-11153232267f>", line 11, in create_model
    model.add(MaxPool2D())
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/training/tra
cking/base.py", line 587, in _method_wrapper
    result = method(self, *args, **kwargs)
  File "/usr/local/lib/python3.8/dist-packages/keras/utils/traceback_utils.p
y", line 67, in error_handler
    raise e.with_traceback(filtered_tb) from None
  File "/usr/local/lib/python3.8/dist-packages/tensorflow/python/framework/op
s.py", line 1963, in _create_c_op
    raise ValueError(e.message)
ValueError: Exception encountered when calling layer "max_pooling2d_25" (type
MaxPooling2D).

Negative dimension size caused by subtracting 2 from 1 for '{{node max_poolin
g2d_25/MaxPool}} = MaxPool[T=DT_FLOAT, data_format="NHWC", explicit_paddings=
[], ksize=[1, 2, 2, 1], padding="VALID", strides=[1, 2, 2, 1]](Placeholder)'
with input shapes: [?,1,1,16].

Call arguments received by layer "max_pooling2d_25" (type MaxPooling2D):
  • inputs=tf.Tensor(shape=(None, 1, 1, 16), dtype=float32)

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/usr/local/lib/python3.8/dist-packages/sklearn/model_selection/_search.py:96
9: UserWarning: One or more of the test scores are non-finite: [0.43706165
nan 0.44481358 0.47582134 0.43706165 0.50756737
        nan 0.43706165 0.43706165 0.43706165]
  warnings.warn(
```

```
Epoch 1/5
4/4 [==============================] - 8s 2s/step - loss: 2.3490 - accuracy:
0.4688 - val_loss: 1.2994 - val_accuracy: 0.4875
Epoch 2/5
4/4 [==============================] - 8s 2s/step - loss: 1.4687 - accuracy:
0.5000 - val_loss: 1.2208 - val_accuracy: 0.4875
Epoch 3/5
4/4 [==============================] - 7s 2s/step - loss: 1.1951 - accuracy:
0.5703 - val_loss: 1.1833 - val_accuracy: 0.5125
Epoch 4/5
4/4 [==============================] - 7s 2s/step - loss: 1.1727 - accuracy:
0.5312 - val_loss: 1.1518 - val_accuracy: 0.4875
Epoch 5/5
4/4 [==============================] - 7s 2s/step - loss: 1.1407 - accuracy:
0.5312 - val_loss: 1.1132 - val_accuracy: 0.8062
{'strides': 1, 'learnRate': 0.001, 'kernel_size': 3, 'hiddenLayerTwo': 16, 'h
iddenLayerThree': 16, 'hiddenLayerOne': 16, 'hiddenLayerFour': 32, 'hiddenDen
se': 256, 'dropout_rate': 0.5}
```

2.2 Best Hyperparameters

In [35]:
```
print(clf.best_params_)
```

```
{'strides': 1, 'learnRate': 0.001, 'kernel_size': 3, 'hiddenLayerTwo': 16, 'h
iddenLayerThree': 16, 'hiddenLayerOne': 16, 'hiddenLayerFour': 32, 'hiddenDen
se': 256, 'dropout_rate': 0.5}
```

2.3 Tuned Model Results

In [36]:
```
# Create model with best parameters

model_tuned = Sequential()
model_tuned.add(Conv2D(16,3,padding="same", kernel_regularizer=keras.regularizers.l2(), activation="relu", strides=2, input_shape = (128,128,3)))
model_tuned.add(Conv2D(16,3, padding="same", kernel_regularizer=keras.regularizers.l2(), strides=1, activation="relu"))
model_tuned.add(MaxPool2D())

model_tuned.add(Conv2D(16, 3, padding="same", kernel_regularizer=keras.regularizers.l2(), strides=1, activation="relu"))
model_tuned.add(Conv2D(32, 3, padding="same", kernel_regularizer=keras.regularizers.l2(), strides=1, activation="relu"))
model_tuned.add(MaxPool2D())

model_tuned.add(Flatten())
model_tuned.add(Dense(256,activation="relu"))
model_tuned.add(Dropout(0.5))
model_tuned.add(Dense(2, activation="softmax"))

model_tuned.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8 (Conv2D)           (None, 64, 64, 16)        448

 conv2d_9 (Conv2D)           (None, 64, 64, 16)        2320

 max_pooling2d_4 (MaxPooling  (None, 32, 32, 16)       0
 2D)

 conv2d_10 (Conv2D)          (None, 32, 32, 16)        2320

 conv2d_11 (Conv2D)          (None, 32, 32, 32)        4640

 max_pooling2d_5 (MaxPooling  (None, 16, 16, 32)       0
 2D)

 flatten_2 (Flatten)         (None, 8192)              0

 dense_4 (Dense)             (None, 256)               2097408

 dropout_2 (Dropout)         (None, 256)               0

 dense_5 (Dense)             (None, 2)                 514

=================================================================
Total params: 2,107,650
Trainable params: 2,107,650
Non-trainable params: 0
_________________________________________________________________
```

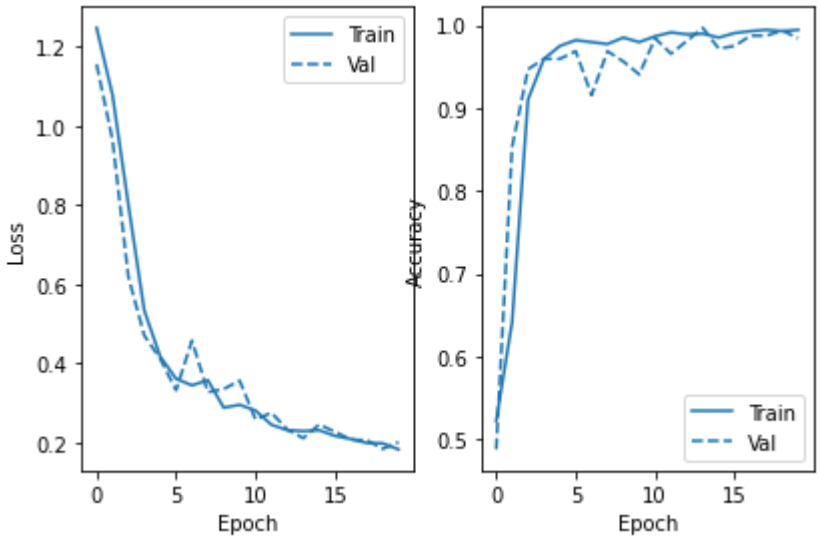
In [37]:
```
model_tuned.compile(loss='sparse_categorical_crossentropy', optimizer=Adam(lea
rning_rate=.001), metrics=['accuracy'])
tuned_history = model_tuned.fit(train_data, validation_data=val_data, epochs=2
0, callbacks=[tf.keras.callbacks.EarlyStopping(monitor='val_loss',patience=
3)])
```

```
Epoch 1/20
10/10 [==============================] - 14s 1s/step - loss: 1.2478 - accurac
y: 0.5219 - val_loss: 1.1557 - val_accuracy: 0.4875
Epoch 2/20
10/10 [==============================] - 13s 1s/step - loss: 1.0786 - accurac
y: 0.6414 - val_loss: 0.9647 - val_accuracy: 0.8531
Epoch 3/20
10/10 [==============================] - 13s 1s/step - loss: 0.8004 - accurac
y: 0.9102 - val_loss: 0.6184 - val_accuracy: 0.9469
Epoch 4/20
10/10 [==============================] - 13s 1s/step - loss: 0.5332 - accurac
y: 0.9594 - val_loss: 0.4702 - val_accuracy: 0.9594
Epoch 5/20
10/10 [==============================] - 13s 1s/step - loss: 0.4170 - accurac
y: 0.9750 - val_loss: 0.4112 - val_accuracy: 0.9594
Epoch 6/20
10/10 [==============================] - 13s 1s/step - loss: 0.3606 - accurac
y: 0.9820 - val_loss: 0.3318 - val_accuracy: 0.9688
Epoch 7/20
10/10 [==============================] - 14s 1s/step - loss: 0.3441 - accurac
y: 0.9797 - val_loss: 0.4571 - val_accuracy: 0.9156
Epoch 8/20
10/10 [==============================] - 13s 1s/step - loss: 0.3570 - accurac
y: 0.9773 - val_loss: 0.3266 - val_accuracy: 0.9688
Epoch 9/20
10/10 [==============================] - 13s 1s/step - loss: 0.2875 - accurac
y: 0.9852 - val_loss: 0.3347 - val_accuracy: 0.9563
Epoch 10/20
10/10 [==============================] - 13s 1s/step - loss: 0.2949 - accurac
y: 0.9797 - val_loss: 0.3560 - val_accuracy: 0.9406
Epoch 11/20
10/10 [==============================] - 13s 1s/step - loss: 0.2801 - accurac
y: 0.9867 - val_loss: 0.2576 - val_accuracy: 0.9844
Epoch 12/20
10/10 [==============================] - 13s 1s/step - loss: 0.2445 - accurac
y: 0.9914 - val_loss: 0.2749 - val_accuracy: 0.9656
Epoch 13/20
10/10 [==============================] - 13s 1s/step - loss: 0.2307 - accurac
y: 0.9891 - val_loss: 0.2323 - val_accuracy: 0.9812
Epoch 14/20
10/10 [==============================] - 12s 1s/step - loss: 0.2284 - accurac
y: 0.9898 - val_loss: 0.2104 - val_accuracy: 0.9969
Epoch 15/20
10/10 [==============================] - 13s 1s/step - loss: 0.2306 - accurac
y: 0.9852 - val_loss: 0.2449 - val_accuracy: 0.9719
Epoch 16/20
10/10 [==============================] - 13s 1s/step - loss: 0.2162 - accurac
y: 0.9906 - val_loss: 0.2265 - val_accuracy: 0.9750
Epoch 17/20
10/10 [==============================] - 12s 1s/step - loss: 0.2083 - accurac
y: 0.9930 - val_loss: 0.2067 - val_accuracy: 0.9875
Epoch 18/20
10/10 [==============================] - 12s 1s/step - loss: 0.1984 - accurac
y: 0.9945 - val_loss: 0.2054 - val_accuracy: 0.9875
Epoch 19/20
10/10 [==============================] - 12s 1s/step - loss: 0.1974 - accurac
y: 0.9930 - val_loss: 0.1834 - val_accuracy: 0.9937
```

```
Epoch 20/20
10/10 [==============================] - 13s 1s/step - loss: 0.1822 - accurac
y: 0.9945 - val_loss: 0.2004 - val_accuracy: 0.9844
```

In [38]:
```
import matplotlib.pyplot as plt
def plot_metrics(tuned_history):
  metrics =  ['loss','accuracy']
  for n, metric in enumerate(metrics):
    name = metric.replace("_"," ").capitalize()
    plt.subplot(1,2,n+1)
    plt.tight_layout()
    plt.plot(tuned_history.epoch,  tuned_history.history[metric], color=colors
[0], label='Train')
    plt.plot(tuned_history.epoch, tuned_history.history['val_'+metric],
             color=colors[0], linestyle="--", label='Val')
    plt.xlabel('Epoch')
    plt.ylabel(name)
    plt.legend()
```

In [39]:
```
colors = plt.rcParams['axes.prop_cycle'].by_key()['color']
plot_metrics(tuned_history)
```

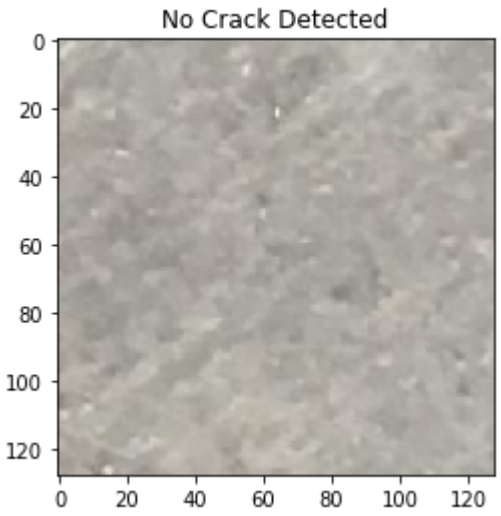


In [40]:
```
#Test model on an image
image = tf.keras.preprocessing.image.load_img("../content/Negative/08693.jpg",
target_size=(128,128))
input_arr = np.array([tf.keras.preprocessing.image.img_to_array(image)]).astyp
e('float32') / 255
predictions = model_tuned.predict(input_arr)

plt.figure()
plt.imshow(image)

if(predictions[0][1]>=0.5):
    plt.title("Crack Detected")
else:
    plt.title("No Crack Detected")
```

```
1/1 [==============================] - 0s 101ms/step
```

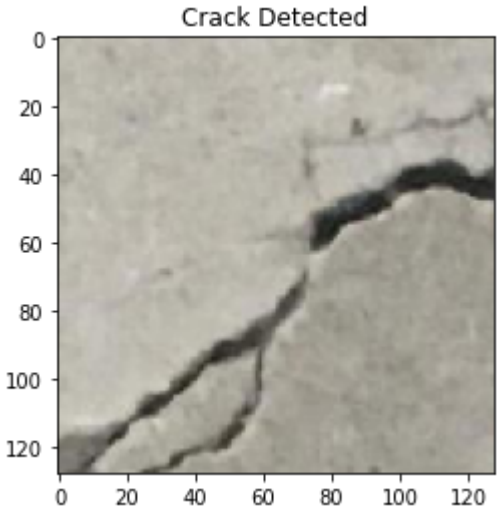


In [41]:
```
#Test model on an image
image = tf.keras.preprocessing.image.load_img("../content/Positive/04092.jpg",
target_size=(128,128))
input_arr = np.array([tf.keras.preprocessing.image.img_to_array(image)]).astyp
e('float32') / 255
predictions = model_tuned.predict(input_arr)

plt.figure()
plt.imshow(image)

if(predictions[0][1]>=0.5):
    plt.title("Crack Detected")
else:
    plt.title("No Crack Detected")
```

```
1/1 [==============================] - 0s 22ms/step
```



In [42]:
```
tuned_results = model_tuned.evaluate(test_data, verbose = 0)
tuned_loss = tuned_results[0]
tuned_acc = tuned_results[1]

print('Tuned Test loss:', tuned_loss)
print('Tuned Test accuracy:', tuned_acc)
```

```
Tuned Test loss: 0.19944778084754944
Tuned Test accuracy: 0.9850000143051147
```

3.0 - Transfer Learning

3.1 MobileNetV2

A base model created by Google, originally trained on an image set with 1000 classes

In [43]:
```
pre_trained_model = tf.keras.applications.MobileNetV2(input_shape=(128, 128,
3), include_top=False, weights='imagenet')

for layer in pre_trained_model.layers:
     layer.trainable = False

pre_trained_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applica
tions/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_128_no
_top.h5
9406464/9406464 [==============================] - 0s 0us/step
Model: "mobilenetv2_1.00_128"
__________________________________________________________________________________
_________________
 Layer (type)                Output Shape              Param #     Connected to
==================================================================================
==================
 input_1 (InputLayer)        [(None, 128, 128, 3       0           []
                             )]

 Conv1 (Conv2D)              (None, 64, 64, 32)        864         ['input_1[0]
[0]']

 bn_Conv1 (BatchNormalization)  (None, 64, 64, 32)     128         ['Conv1[0]
[0]']

 Conv1_relu (ReLU)           (None, 64, 64, 32)        0           ['bn_Conv1
[0][0]']

 expanded_conv_depthwise (Depth  (None, 64, 64, 32)    288         ['Conv1_relu
[0][0]']
 wiseConv2D)

 expanded_conv_depthwise_BN (Ba  (None, 64, 64, 32)    128         ['expanded_c
onv_depthwise[0][0]']
 tchNormalization)

 expanded_conv_depthwise_relu (  (None, 64, 64, 32)    0           ['expanded_c
onv_depthwise_BN[0][0
 ReLU)                                                            ]']

 expanded_conv_project (Conv2D)  (None, 64, 64, 16)    512         ['expanded_c
onv_depthwise_relu[0]
                                                                  [0]']

 expanded_conv_project_BN (Batc  (None, 64, 64, 16)    64          ['expanded_c
onv_project[0][0]']
 hNormalization)

 block_1_expand (Conv2D)        (None, 64, 64, 96)     1536        ['expanded_c
onv_project_BN[0][0]'
                                                                  ]

 block_1_expand_BN (BatchNormal  (None, 64, 64, 96)    384         ['block_1_ex
pand[0][0]']
 ization)

 block_1_expand_relu (ReLU)     (None, 64, 64, 96)     0           ['block_1_ex
pand_BN[0][0]']

 block_1_pad (ZeroPadding2D)    (None, 65, 65, 96)     0           ['block_1_ex
pand_relu[0][0]']

 block_1_depthwise (DepthwiseCo  (None, 32, 32, 96)    864         ['block_1_pa
```

```
d[0][0]']
 nv2D)

 block_1_depthwise_BN (BatchNor  (None, 32, 32, 96)  384         ['block_1_de
pthwise[0][0]']
 malization)

 block_1_depthwise_relu (ReLU)  (None, 32, 32, 96)   0           ['block_1_de
pthwise_BN[0][0]']

 block_1_project (Conv2D)       (None, 32, 32, 24)   2304        ['block_1_de
pthwise_relu[0][0]']

 block_1_project_BN (BatchNorma  (None, 32, 32, 24)  96          ['block_1_pr
oject[0][0]']
 lization)

 block_2_expand (Conv2D)        (None, 32, 32, 144)  3456        ['block_1_pr
oject_BN[0][0]']

 block_2_expand_BN (BatchNormal  (None, 32, 32, 144)  576        ['block_2_ex
pand[0][0]']
 ization)

 block_2_expand_relu (ReLU)     (None, 32, 32, 144)  0           ['block_2_ex
pand_BN[0][0]']

 block_2_depthwise (DepthwiseCo  (None, 32, 32, 144)  1296       ['block_2_ex
pand_relu[0][0]']
 nv2D)

 block_2_depthwise_BN (BatchNor  (None, 32, 32, 144)  576        ['block_2_de
pthwise[0][0]']
 malization)

 block_2_depthwise_relu (ReLU)  (None, 32, 32, 144)  0           ['block_2_de
pthwise_BN[0][0]']

 block_2_project (Conv2D)       (None, 32, 32, 24)   3456        ['block_2_de
pthwise_relu[0][0]']

 block_2_project_BN (BatchNorma  (None, 32, 32, 24)  96          ['block_2_pr
oject[0][0]']
 lization)

 block_2_add (Add)              (None, 32, 32, 24)   0           ['block_1_pr
oject_BN[0][0]',
                                                                  'block_2_pr
oject_BN[0][0]']

 block_3_expand (Conv2D)        (None, 32, 32, 144)  3456        ['block_2_ad
d[0][0]']

 block_3_expand_BN (BatchNormal  (None, 32, 32, 144)  576        ['block_3_ex
pand[0][0]']
 ization)
```

```
 block_3_expand_relu (ReLU)     (None, 32, 32, 144)  0           ['block_3_ex
pand_BN[0][0]']

 block_3_pad (ZeroPadding2D)    (None, 33, 33, 144)  0           ['block_3_ex
pand_relu[0][0]']

 block_3_depthwise (DepthwiseCo  (None, 16, 16, 144)  1296       ['block_3_pa
d[0][0]']
 nv2D)

 block_3_depthwise_BN (BatchNor  (None, 16, 16, 144)  576        ['block_3_de
pthwise[0][0]']
 malization)

 block_3_depthwise_relu (ReLU)  (None, 16, 16, 144)  0           ['block_3_de
pthwise_BN[0][0]']

 block_3_project (Conv2D)       (None, 16, 16, 32)   4608        ['block_3_de
pthwise_relu[0][0]']

 block_3_project_BN (BatchNorma  (None, 16, 16, 32)  128         ['block_3_pr
oject[0][0]']
 lization)

 block_4_expand (Conv2D)        (None, 16, 16, 192)  6144        ['block_3_pr
oject_BN[0][0]']

 block_4_expand_BN (BatchNormal  (None, 16, 16, 192)  768        ['block_4_ex
pand[0][0]']
 ization)

 block_4_expand_relu (ReLU)     (None, 16, 16, 192)  0           ['block_4_ex
pand_BN[0][0]']

 block_4_depthwise (DepthwiseCo  (None, 16, 16, 192)  1728       ['block_4_ex
pand_relu[0][0]']
 nv2D)

 block_4_depthwise_BN (BatchNor  (None, 16, 16, 192)  768        ['block_4_de
pthwise[0][0]']
 malization)

 block_4_depthwise_relu (ReLU)  (None, 16, 16, 192)  0           ['block_4_de
pthwise_BN[0][0]']

 block_4_project (Conv2D)       (None, 16, 16, 32)   6144        ['block_4_de
pthwise_relu[0][0]']

 block_4_project_BN (BatchNorma  (None, 16, 16, 32)  128         ['block_4_pr
oject[0][0]']
 lization)

 block_4_add (Add)              (None, 16, 16, 32)   0           ['block_3_pr
oject_BN[0][0]',
                                                                  'block_4_pr
oject_BN[0][0]']
```

```
 block_5_expand (Conv2D)        (None, 16, 16, 192)  6144        ['block_4_ad
d[0][0]']

 block_5_expand_BN (BatchNormal  (None, 16, 16, 192)  768        ['block_5_ex
pand[0][0]']
 ization)

 block_5_expand_relu (ReLU)     (None, 16, 16, 192)  0          ['block_5_ex
pand_BN[0][0]']

 block_5_depthwise (DepthwiseCo  (None, 16, 16, 192)  1728       ['block_5_ex
pand_relu[0][0]']
 nv2D)

 block_5_depthwise_BN (BatchNor  (None, 16, 16, 192)  768        ['block_5_de
pthwise[0][0]']
 malization)

 block_5_depthwise_relu (ReLU)  (None, 16, 16, 192)  0          ['block_5_de
pthwise_BN[0][0]']

 block_5_project (Conv2D)       (None, 16, 16, 32)   6144        ['block_5_de
pthwise_relu[0][0]']

 block_5_project_BN (BatchNorma  (None, 16, 16, 32)  128         ['block_5_pr
oject[0][0]']
 lization)

 block_5_add (Add)              (None, 16, 16, 32)   0          ['block_4_ad
d[0][0]',
                                                                 'block_5_pr
oject_BN[0][0]']

 block_6_expand (Conv2D)        (None, 16, 16, 192)  6144        ['block_5_ad
d[0][0]']

 block_6_expand_BN (BatchNormal  (None, 16, 16, 192)  768        ['block_6_ex
pand[0][0]']
 ization)

 block_6_expand_relu (ReLU)     (None, 16, 16, 192)  0          ['block_6_ex
pand_BN[0][0]']

 block_6_pad (ZeroPadding2D)    (None, 17, 17, 192)  0          ['block_6_ex
pand_relu[0][0]']

 block_6_depthwise (DepthwiseCo  (None, 8, 8, 192)   1728        ['block_6_pa
d[0][0]']
 nv2D)

 block_6_depthwise_BN (BatchNor  (None, 8, 8, 192)   768         ['block_6_de
pthwise[0][0]']
 malization)

 block_6_depthwise_relu (ReLU)  (None, 8, 8, 192)    0          ['block_6_de
pthwise_BN[0][0]']
```

```
 block_6_project (Conv2D)       (None, 8, 8, 64)     12288       ['block_6_de
pthwise_relu[0][0]']

 block_6_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_6_pr
oject[0][0]']
 lization)

 block_7_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_6_pr
oject_BN[0][0]']

 block_7_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_7_ex
pand[0][0]']
 ization)

 block_7_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_7_ex
pand_BN[0][0]']

 block_7_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_7_ex
pand_relu[0][0]']
 nv2D)

 block_7_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_7_de
pthwise[0][0]']
 malization)

 block_7_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_7_de
pthwise_BN[0][0]']

 block_7_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_7_de
pthwise_relu[0][0]']

 block_7_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_7_pr
oject[0][0]']
 lization)

 block_7_add (Add)              (None, 8, 8, 64)     0           ['block_6_pr
oject_BN[0][0]',
                                                                  'block_7_pr
oject_BN[0][0]']

 block_8_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_7_ad
d[0][0]']

 block_8_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_8_ex
pand[0][0]']
 ization)

 block_8_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_8_ex
pand_BN[0][0]']

 block_8_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_8_ex
pand_relu[0][0]']
 nv2D)

 block_8_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_8_de
pthwise[0][0]']
 malization)
```

```
 block_8_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_8_de
pthwise_BN[0][0]']

 block_8_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_8_de
pthwise_relu[0][0]']

 block_8_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_8_pr
oject[0][0]']
 lization)

 block_8_add (Add)              (None, 8, 8, 64)     0           ['block_7_ad
d[0][0]',
                                                                  'block_8_pr
oject_BN[0][0]']

 block_9_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_8_ad
d[0][0]']

 block_9_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_9_ex
pand[0][0]']
 ization)

 block_9_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_9_ex
pand_BN[0][0]']

 block_9_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_9_ex
pand_relu[0][0]']
 nv2D)

 block_9_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_9_de
pthwise[0][0]']
 malization)

 block_9_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_9_de
pthwise_BN[0][0]']

 block_9_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_9_de
pthwise_relu[0][0]']

 block_9_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_9_pr
oject[0][0]']
 lization)

 block_9_add (Add)              (None, 8, 8, 64)     0           ['block_8_ad
d[0][0]',
                                                                  'block_9_pr
oject_BN[0][0]']

 block_10_expand (Conv2D)       (None, 8, 8, 384)    24576       ['block_9_ad
d[0][0]']

 block_10_expand_BN (BatchNorma  (None, 8, 8, 384)   1536        ['block_10_e
xpand[0][0]']
 lization)

 block_10_expand_relu (ReLU)    (None, 8, 8, 384)    0           ['block_10_e
```

```
xpand_BN[0][0]']

 block_10_depthwise (DepthwiseC  (None, 8, 8, 384)   3456        ['block_10_e
xpand_relu[0][0]']
 onv2D)

 block_10_depthwise_BN (BatchNo  (None, 8, 8, 384)   1536        ['block_10_d
epthwise[0][0]']
 rmalization)

 block_10_depthwise_relu (ReLU)  (None, 8, 8, 384)   0           ['block_10_d
epthwise_BN[0][0]']

 block_10_project (Conv2D)      (None, 8, 8, 96)     36864       ['block_10_d
epthwise_relu[0][0]']

 block_10_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_10_p
roject[0][0]']
 alization)

 block_11_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_10_p
roject_BN[0][0]']

 block_11_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_11_e
xpand[0][0]']
 lization)

 block_11_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_11_e
xpand_BN[0][0]']

 block_11_depthwise (DepthwiseC  (None, 8, 8, 576)   5184        ['block_11_e
xpand_relu[0][0]']
 onv2D)

 block_11_depthwise_BN (BatchNo  (None, 8, 8, 576)   2304        ['block_11_d
epthwise[0][0]']
 rmalization)

 block_11_depthwise_relu (ReLU)  (None, 8, 8, 576)   0           ['block_11_d
epthwise_BN[0][0]']

 block_11_project (Conv2D)      (None, 8, 8, 96)     55296       ['block_11_d
epthwise_relu[0][0]']

 block_11_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_11_p
roject[0][0]']
 alization)

 block_11_add (Add)             (None, 8, 8, 96)     0           ['block_10_p
roject_BN[0][0]',
                                                                  'block_11_p
roject_BN[0][0]']

 block_12_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_11_a
dd[0][0]']

 block_12_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_12_e
```

```
xpand[0][0]']
 lization)

 block_12_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_12_e
xpand_BN[0][0]']

 block_12_depthwise (DepthwiseC  (None, 8, 8, 576)   5184        ['block_12_e
xpand_relu[0][0]']
 onv2D)

 block_12_depthwise_BN (BatchNo  (None, 8, 8, 576)   2304        ['block_12_d
epthwise[0][0]']
 rmalization)

 block_12_depthwise_relu (ReLU)  (None, 8, 8, 576)   0           ['block_12_d
epthwise_BN[0][0]']

 block_12_project (Conv2D)      (None, 8, 8, 96)     55296       ['block_12_d
epthwise_relu[0][0]']

 block_12_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_12_p
roject[0][0]']
 alization)

 block_12_add (Add)             (None, 8, 8, 96)     0           ['block_11_a
dd[0][0]',
                                                                  'block_12_p
roject_BN[0][0]']

 block_13_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_12_a
dd[0][0]']

 block_13_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_13_e
xpand[0][0]']
 lization)

 block_13_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_13_e
xpand_BN[0][0]']

 block_13_pad (ZeroPadding2D)   (None, 9, 9, 576)    0           ['block_13_e
xpand_relu[0][0]']

 block_13_depthwise (DepthwiseC  (None, 4, 4, 576)   5184        ['block_13_p
ad[0][0]']
 onv2D)

 block_13_depthwise_BN (BatchNo  (None, 4, 4, 576)   2304        ['block_13_d
epthwise[0][0]']
 rmalization)

 block_13_depthwise_relu (ReLU)  (None, 4, 4, 576)   0           ['block_13_d
epthwise_BN[0][0]']

 block_13_project (Conv2D)      (None, 4, 4, 160)    92160       ['block_13_d
epthwise_relu[0][0]']

 block_13_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_13_p
```

```
roject[0][0]']
 alization)

 block_14_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_13_p
roject_BN[0][0]']

 block_14_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_14_e
xpand[0][0]']
 lization)

 block_14_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_14_e
xpand_BN[0][0]']

 block_14_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_14_e
xpand_relu[0][0]']
 onv2D)

 block_14_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_14_d
epthwise[0][0]']
 rmalization)

 block_14_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_14_d
epthwise_BN[0][0]']

 block_14_project (Conv2D)      (None, 4, 4, 160)    153600      ['block_14_d
epthwise_relu[0][0]']

 block_14_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_14_p
roject[0][0]']
 alization)

 block_14_add (Add)             (None, 4, 4, 160)    0           ['block_13_p
roject_BN[0][0]',
                                                                  'block_14_p
roject_BN[0][0]']

 block_15_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_14_a
dd[0][0]']

 block_15_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_15_e
xpand[0][0]']
 lization)

 block_15_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_15_e
xpand_BN[0][0]']

 block_15_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_15_e
xpand_relu[0][0]']
 onv2D)

 block_15_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_15_d
epthwise[0][0]']
 rmalization)

 block_15_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_15_d
epthwise_BN[0][0]']
```

```
 block_15_project (Conv2D)      (None, 4, 4, 160)    153600      ['block_15_d
epthwise_relu[0][0]']

 block_15_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_15_p
roject[0][0]']
 alization)

 block_15_add (Add)             (None, 4, 4, 160)    0           ['block_14_a
dd[0][0]',
                                                                  'block_15_p
roject_BN[0][0]']

 block_16_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_15_a
dd[0][0]']

 block_16_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_16_e
xpand[0][0]']
 lization)

 block_16_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_16_e
xpand_BN[0][0]']

 block_16_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_16_e
xpand_relu[0][0]']
 onv2D)

 block_16_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_16_d
epthwise[0][0]']
 rmalization)

 block_16_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_16_d
epthwise_BN[0][0]']

 block_16_project (Conv2D)      (None, 4, 4, 320)    307200      ['block_16_d
epthwise_relu[0][0]']

 block_16_project_BN (BatchNorm  (None, 4, 4, 320)   1280        ['block_16_p
roject[0][0]']
 alization)

 Conv_1 (Conv2D)                (None, 4, 4, 1280)   409600      ['block_16_p
roject_BN[0][0]']

 Conv_1_bn (BatchNormalization)  (None, 4, 4, 1280)  5120        ['Conv_1[0]
[0]']

 out_relu (ReLU)                (None, 4, 4, 1280)   0           ['Conv_1_bn
[0][0]']

==================================================================================
====================
Total params: 2,257,984
Trainable params: 0
Non-trainable params: 2,257,984
__________________________________________________________________________________
_____________________
```

In [44]:
```
last_layer = pre_trained_model.get_layer('out_relu')
last_output = last_layer.output

# Flatten the output layer to 1 dimension
x = layers.Flatten()(last_output)
# Add a fully connected layer with 512 hidden units and ReLU activation
x = layers.Dense(512, activation='relu')(x)
# Add a dropout layer to prevent overfitting
x = layers.Dropout(0.5)(x)
# Add a final softmax layer for classification
x = layers.Dense  (2, activation='softmax')(x)
```

In [45]:
```
from tensorflow.keras import Model,layers

model = Model(pre_trained_model.input, x)
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',metrics
=['accuracy'])

model.summary()
```

```
Model: "model"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_1 (InputLayer)           [(None, 128, 128, 3  0           []
                                )]

 Conv1 (Conv2D)                 (None, 64, 64, 32)   864         ['input_1[0]
[0]']

 bn_Conv1 (BatchNormalization)  (None, 64, 64, 32)   128         ['Conv1[0]
[0]']

 Conv1_relu (ReLU)              (None, 64, 64, 32)   0           ['bn_Conv1
[0][0]']

 expanded_conv_depthwise (Depth  (None, 64, 64, 32)  288         ['Conv1_relu
[0][0]']
 wiseConv2D)

 expanded_conv_depthwise_BN (Ba  (None, 64, 64, 32)  128         ['expanded_c
onv_depthwise[0][0]']
 tchNormalization)

 expanded_conv_depthwise_relu (  (None, 64, 64, 32)  0           ['expanded_c
onv_depthwise_BN[0][0
 ReLU)                                                           ]']

 expanded_conv_project (Conv2D)  (None, 64, 64, 16)  512         ['expanded_c
onv_depthwise_relu[0]
                                                                 [0]']

 expanded_conv_project_BN (Batc  (None, 64, 64, 16)  64          ['expanded_c
onv_project[0][0]']
 hNormalization)

 block_1_expand (Conv2D)        (None, 64, 64, 96)   1536        ['expanded_c
onv_project_BN[0][0]'
                                                                 ]

 block_1_expand_BN (BatchNormal  (None, 64, 64, 96)  384         ['block_1_ex
pand[0][0]']
 ization)

 block_1_expand_relu (ReLU)     (None, 64, 64, 96)   0           ['block_1_ex
pand_BN[0][0]']

 block_1_pad (ZeroPadding2D)    (None, 65, 65, 96)   0           ['block_1_ex
pand_relu[0][0]']

 block_1_depthwise (DepthwiseCo  (None, 32, 32, 96)  864         ['block_1_pa
d[0][0]']
 nv2D)

 block_1_depthwise_BN (BatchNor  (None, 32, 32, 96)  384         ['block_1_de
```

```
pthwise[0][0]']
 malization)

 block_1_depthwise_relu (ReLU)  (None, 32, 32, 96)   0           ['block_1_de
pthwise_BN[0][0]']

 block_1_project (Conv2D)       (None, 32, 32, 24)   2304        ['block_1_de
pthwise_relu[0][0]']

 block_1_project_BN (BatchNorma  (None, 32, 32, 24)  96          ['block_1_pr
oject[0][0]']
 lization)

 block_2_expand (Conv2D)        (None, 32, 32, 144)  3456        ['block_1_pr
oject_BN[0][0]']

 block_2_expand_BN (BatchNormal  (None, 32, 32, 144)  576        ['block_2_ex
pand[0][0]']
 ization)

 block_2_expand_relu (ReLU)     (None, 32, 32, 144)  0           ['block_2_ex
pand_BN[0][0]']

 block_2_depthwise (DepthwiseCo  (None, 32, 32, 144)  1296       ['block_2_ex
pand_relu[0][0]']
 nv2D)

 block_2_depthwise_BN (BatchNor  (None, 32, 32, 144)  576        ['block_2_de
pthwise[0][0]']
 malization)

 block_2_depthwise_relu (ReLU)  (None, 32, 32, 144)  0           ['block_2_de
pthwise_BN[0][0]']

 block_2_project (Conv2D)       (None, 32, 32, 24)   3456        ['block_2_de
pthwise_relu[0][0]']

 block_2_project_BN (BatchNorma  (None, 32, 32, 24)  96          ['block_2_pr
oject[0][0]']
 lization)

 block_2_add (Add)              (None, 32, 32, 24)   0           ['block_1_pr
oject_BN[0][0]',
                                                                  'block_2_pr
oject_BN[0][0]']

 block_3_expand (Conv2D)        (None, 32, 32, 144)  3456        ['block_2_ad
d[0][0]']

 block_3_expand_BN (BatchNormal  (None, 32, 32, 144)  576        ['block_3_ex
pand[0][0]']
 ization)

 block_3_expand_relu (ReLU)     (None, 32, 32, 144)  0           ['block_3_ex
pand_BN[0][0]']

 block_3_pad (ZeroPadding2D)    (None, 33, 33, 144)  0           ['block_3_ex
```

```
pand_relu[0][0]']

 block_3_depthwise (DepthwiseCo  (None, 16, 16, 144)  1296       ['block_3_pa
d[0][0]']
 nv2D)

 block_3_depthwise_BN (BatchNor  (None, 16, 16, 144)  576        ['block_3_de
pthwise[0][0]']
 malization)

 block_3_depthwise_relu (ReLU)  (None, 16, 16, 144)  0          ['block_3_de
pthwise_BN[0][0]']

 block_3_project (Conv2D)       (None, 16, 16, 32)   4608       ['block_3_de
pthwise_relu[0][0]']

 block_3_project_BN (BatchNorma  (None, 16, 16, 32)  128        ['block_3_pr
oject[0][0]']
 lization)

 block_4_expand (Conv2D)        (None, 16, 16, 192)  6144       ['block_3_pr
oject_BN[0][0]']

 block_4_expand_BN (BatchNormal  (None, 16, 16, 192)  768       ['block_4_ex
pand[0][0]']
 ization)

 block_4_expand_relu (ReLU)     (None, 16, 16, 192)  0          ['block_4_ex
pand_BN[0][0]']

 block_4_depthwise (DepthwiseCo  (None, 16, 16, 192)  1728       ['block_4_ex
pand_relu[0][0]']
 nv2D)

 block_4_depthwise_BN (BatchNor  (None, 16, 16, 192)  768       ['block_4_de
pthwise[0][0]']
 malization)

 block_4_depthwise_relu (ReLU)  (None, 16, 16, 192)  0          ['block_4_de
pthwise_BN[0][0]']

 block_4_project (Conv2D)       (None, 16, 16, 32)   6144       ['block_4_de
pthwise_relu[0][0]']

 block_4_project_BN (BatchNorma  (None, 16, 16, 32)  128        ['block_4_pr
oject[0][0]']
 lization)

 block_4_add (Add)              (None, 16, 16, 32)   0          ['block_3_pr
oject_BN[0][0]',
                                                                 'block_4_pr
oject_BN[0][0]']

 block_5_expand (Conv2D)        (None, 16, 16, 192)  6144       ['block_4_ad
d[0][0]']

 block_5_expand_BN (BatchNormal  (None, 16, 16, 192)  768       ['block_5_ex
```

```
pand[0][0]']
 ization)

 block_5_expand_relu (ReLU)     (None, 16, 16, 192)  0           ['block_5_ex
pand_BN[0][0]']

 block_5_depthwise (DepthwiseCo  (None, 16, 16, 192)  1728       ['block_5_ex
pand_relu[0][0]']
 nv2D)

 block_5_depthwise_BN (BatchNor  (None, 16, 16, 192)  768        ['block_5_de
pthwise[0][0]']
 malization)

 block_5_depthwise_relu (ReLU)  (None, 16, 16, 192)  0           ['block_5_de
pthwise_BN[0][0]']

 block_5_project (Conv2D)       (None, 16, 16, 32)   6144        ['block_5_de
pthwise_relu[0][0]']

 block_5_project_BN (BatchNorma  (None, 16, 16, 32)  128         ['block_5_pr
oject[0][0]']
 lization)

 block_5_add (Add)              (None, 16, 16, 32)   0           ['block_4_ad
d[0][0]',
                                                                  'block_5_pr
oject_BN[0][0]']

 block_6_expand (Conv2D)        (None, 16, 16, 192)  6144        ['block_5_ad
d[0][0]']

 block_6_expand_BN (BatchNormal  (None, 16, 16, 192)  768        ['block_6_ex
pand[0][0]']
 ization)

 block_6_expand_relu (ReLU)     (None, 16, 16, 192)  0           ['block_6_ex
pand_BN[0][0]']

 block_6_pad (ZeroPadding2D)    (None, 17, 17, 192)  0           ['block_6_ex
pand_relu[0][0]']

 block_6_depthwise (DepthwiseCo  (None, 8, 8, 192)   1728        ['block_6_pa
d[0][0]']
 nv2D)

 block_6_depthwise_BN (BatchNor  (None, 8, 8, 192)   768         ['block_6_de
pthwise[0][0]']
 malization)

 block_6_depthwise_relu (ReLU)  (None, 8, 8, 192)    0           ['block_6_de
pthwise_BN[0][0]']

 block_6_project (Conv2D)       (None, 8, 8, 64)     12288       ['block_6_de
pthwise_relu[0][0]']

 block_6_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_6_pr
```

```
oject[0][0]']
 lization)

 block_7_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_6_pr
oject_BN[0][0]']

 block_7_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_7_ex
pand[0][0]']
 ization)

 block_7_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_7_ex
pand_BN[0][0]']

 block_7_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_7_ex
pand_relu[0][0]']
 nv2D)

 block_7_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_7_de
pthwise[0][0]']
 malization)

 block_7_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_7_de
pthwise_BN[0][0]']

 block_7_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_7_de
pthwise_relu[0][0]']

 block_7_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_7_pr
oject[0][0]']
 lization)

 block_7_add (Add)              (None, 8, 8, 64)     0           ['block_6_pr
oject_BN[0][0]',
                                                                  'block_7_pr
oject_BN[0][0]']

 block_8_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_7_ad
d[0][0]']

 block_8_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_8_ex
pand[0][0]']
 ization)

 block_8_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_8_ex
pand_BN[0][0]']

 block_8_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_8_ex
pand_relu[0][0]']
 nv2D)

 block_8_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_8_de
pthwise[0][0]']
 malization)

 block_8_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_8_de
pthwise_BN[0][0]']
```

```
 block_8_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_8_de
pthwise_relu[0][0]']

 block_8_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_8_pr
oject[0][0]']
 lization)

 block_8_add (Add)              (None, 8, 8, 64)     0           ['block_7_ad
d[0][0]',
                                                                  'block_8_pr
oject_BN[0][0]']

 block_9_expand (Conv2D)        (None, 8, 8, 384)    24576       ['block_8_ad
d[0][0]']

 block_9_expand_BN (BatchNormal  (None, 8, 8, 384)   1536        ['block_9_ex
pand[0][0]']
 ization)

 block_9_expand_relu (ReLU)     (None, 8, 8, 384)    0           ['block_9_ex
pand_BN[0][0]']

 block_9_depthwise (DepthwiseCo  (None, 8, 8, 384)   3456        ['block_9_ex
pand_relu[0][0]']
 nv2D)

 block_9_depthwise_BN (BatchNor  (None, 8, 8, 384)   1536        ['block_9_de
pthwise[0][0]']
 malization)

 block_9_depthwise_relu (ReLU)  (None, 8, 8, 384)    0           ['block_9_de
pthwise_BN[0][0]']

 block_9_project (Conv2D)       (None, 8, 8, 64)     24576       ['block_9_de
pthwise_relu[0][0]']

 block_9_project_BN (BatchNorma  (None, 8, 8, 64)    256         ['block_9_pr
oject[0][0]']
 lization)

 block_9_add (Add)              (None, 8, 8, 64)     0           ['block_8_ad
d[0][0]',
                                                                  'block_9_pr
oject_BN[0][0]']

 block_10_expand (Conv2D)       (None, 8, 8, 384)    24576       ['block_9_ad
d[0][0]']

 block_10_expand_BN (BatchNorma  (None, 8, 8, 384)   1536        ['block_10_e
xpand[0][0]']
 lization)

 block_10_expand_relu (ReLU)    (None, 8, 8, 384)    0           ['block_10_e
xpand_BN[0][0]']

 block_10_depthwise (DepthwiseC  (None, 8, 8, 384)   3456        ['block_10_e
xpand_relu[0][0]']
```

```
 onv2D)

 block_10_depthwise_BN (BatchNo  (None, 8, 8, 384)   1536        ['block_10_d
epthwise[0][0]']
 rmalization)

 block_10_depthwise_relu (ReLU)  (None, 8, 8, 384)   0           ['block_10_d
epthwise_BN[0][0]']

 block_10_project (Conv2D)      (None, 8, 8, 96)     36864       ['block_10_d
epthwise_relu[0][0]']

 block_10_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_10_p
roject[0][0]']
 alization)

 block_11_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_10_p
roject_BN[0][0]']

 block_11_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_11_e
xpand[0][0]']
 lization)

 block_11_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_11_e
xpand_BN[0][0]']

 block_11_depthwise (DepthwiseC  (None, 8, 8, 576)   5184        ['block_11_e
xpand_relu[0][0]']
 onv2D)

 block_11_depthwise_BN (BatchNo  (None, 8, 8, 576)   2304        ['block_11_d
epthwise[0][0]']
 rmalization)

 block_11_depthwise_relu (ReLU)  (None, 8, 8, 576)   0           ['block_11_d
epthwise_BN[0][0]']

 block_11_project (Conv2D)      (None, 8, 8, 96)     55296       ['block_11_d
epthwise_relu[0][0]']

 block_11_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_11_p
roject[0][0]']
 alization)

 block_11_add (Add)             (None, 8, 8, 96)     0           ['block_10_p
roject_BN[0][0]',
                                                                  'block_11_p
roject_BN[0][0]']

 block_12_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_11_a
dd[0][0]']

 block_12_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_12_e
xpand[0][0]']
 lization)

 block_12_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_12_e
```

```
xpand_BN[0][0]']

 block_12_depthwise (DepthwiseC  (None, 8, 8, 576)   5184        ['block_12_e
xpand_relu[0][0]']
 onv2D)

 block_12_depthwise_BN (BatchNo  (None, 8, 8, 576)   2304        ['block_12_d
epthwise[0][0]']
 rmalization)

 block_12_depthwise_relu (ReLU)  (None, 8, 8, 576)   0           ['block_12_d
epthwise_BN[0][0]']

 block_12_project (Conv2D)      (None, 8, 8, 96)     55296       ['block_12_d
epthwise_relu[0][0]']

 block_12_project_BN (BatchNorm  (None, 8, 8, 96)    384         ['block_12_p
roject[0][0]']
 alization)

 block_12_add (Add)             (None, 8, 8, 96)     0           ['block_11_a
dd[0][0]',
                                                                  'block_12_p
roject_BN[0][0]']

 block_13_expand (Conv2D)       (None, 8, 8, 576)    55296       ['block_12_a
dd[0][0]']

 block_13_expand_BN (BatchNorma  (None, 8, 8, 576)   2304        ['block_13_e
xpand[0][0]']
 lization)

 block_13_expand_relu (ReLU)    (None, 8, 8, 576)    0           ['block_13_e
xpand_BN[0][0]']

 block_13_pad (ZeroPadding2D)   (None, 9, 9, 576)    0           ['block_13_e
xpand_relu[0][0]']

 block_13_depthwise (DepthwiseC  (None, 4, 4, 576)   5184        ['block_13_p
ad[0][0]']
 onv2D)

 block_13_depthwise_BN (BatchNo  (None, 4, 4, 576)   2304        ['block_13_d
epthwise[0][0]']
 rmalization)

 block_13_depthwise_relu (ReLU)  (None, 4, 4, 576)   0           ['block_13_d
epthwise_BN[0][0]']

 block_13_project (Conv2D)      (None, 4, 4, 160)    92160       ['block_13_d
epthwise_relu[0][0]']

 block_13_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_13_p
roject[0][0]']
 alization)

 block_14_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_13_p
```

```
roject_BN[0][0]']

 block_14_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_14_e
xpand[0][0]']
 lization)

 block_14_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_14_e
xpand_BN[0][0]']

 block_14_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_14_e
xpand_relu[0][0]']
 onv2D)

 block_14_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_14_d
epthwise[0][0]']
 rmalization)

 block_14_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_14_d
epthwise_BN[0][0]']

 block_14_project (Conv2D)      (None, 4, 4, 160)    153600      ['block_14_d
epthwise_relu[0][0]']

 block_14_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_14_p
roject[0][0]']
 alization)

 block_14_add (Add)             (None, 4, 4, 160)    0           ['block_13_p
roject_BN[0][0]',
                                                                  'block_14_p
roject_BN[0][0]']

 block_15_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_14_a
dd[0][0]']

 block_15_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_15_e
xpand[0][0]']
 lization)

 block_15_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_15_e
xpand_BN[0][0]']

 block_15_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_15_e
xpand_relu[0][0]']
 onv2D)

 block_15_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_15_d
epthwise[0][0]']
 rmalization)

 block_15_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_15_d
epthwise_BN[0][0]']

 block_15_project (Conv2D)      (None, 4, 4, 160)    153600      ['block_15_d
epthwise_relu[0][0]']

 block_15_project_BN (BatchNorm  (None, 4, 4, 160)   640         ['block_15_p
```

```
roject[0][0']
 alization)

 block_15_add (Add)             (None, 4, 4, 160)    0           ['block_14_a
dd[0][0]',
                                                                  'block_15_p
roject_BN[0][0']

 block_16_expand (Conv2D)       (None, 4, 4, 960)    153600      ['block_15_a
dd[0][0]']

 block_16_expand_BN (BatchNorma  (None, 4, 4, 960)   3840        ['block_16_e
xpand[0][0]']
 lization)

 block_16_expand_relu (ReLU)    (None, 4, 4, 960)    0           ['block_16_e
xpand_BN[0][0]']

 block_16_depthwise (DepthwiseC  (None, 4, 4, 960)   8640        ['block_16_e
xpand_relu[0][0]']
 onv2D)

 block_16_depthwise_BN (BatchNo  (None, 4, 4, 960)   3840        ['block_16_d
epthwise[0][0]']
 rmalization)

 block_16_depthwise_relu (ReLU)  (None, 4, 4, 960)   0           ['block_16_d
epthwise_BN[0][0]']

 block_16_project (Conv2D)      (None, 4, 4, 320)    307200      ['block_16_d
epthwise_relu[0][0]']

 block_16_project_BN (BatchNorm  (None, 4, 4, 320)   1280        ['block_16_p
roject[0][0]']
 alization)

 Conv_1 (Conv2D)                (None, 4, 4, 1280)   409600      ['block_16_p
roject_BN[0][0]']

 Conv_1_bn (BatchNormalization)  (None, 4, 4, 1280)  5120        ['Conv_1[0]
[0]']

 out_relu (ReLU)                (None, 4, 4, 1280)   0           ['Conv_1_bn
[0][0]']

 flatten_3 (Flatten)            (None, 20480)        0           ['out_relu
[0][0]']

 dense_6 (Dense)                (None, 512)          10486272    ['flatten_3
[0][0]']

 dropout_3 (Dropout)            (None, 512)          0           ['dense_6[0]
[0]']

 dense_7 (Dense)                (None, 2)            1026        ['dropout_3
[0][0]']
```

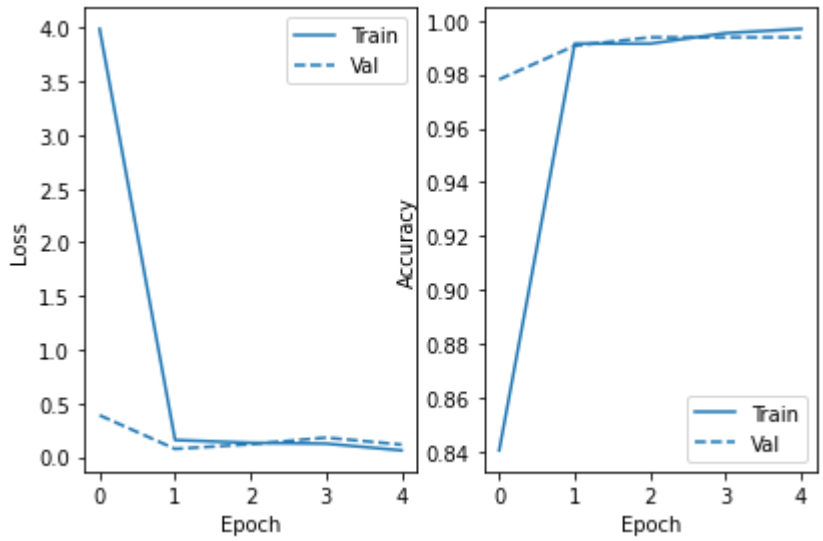
```
=================================================================
=====================
Total params: 12,745,282
Trainable params: 10,487,298
Non-trainable params: 2,257,984
_________________________________________________________________
_____________________
```

In [46]:
```
history = model.fit(train_data, validation_data=val_data, epochs=20, callbacks
=[tf.keras.callbacks.EarlyStopping(monitor='val_loss',patience=3)])
```

```
Epoch 1/20
10/10 [==============================] - 22s 2s/step - loss: 3.9914 - accurac
y: 0.8406 - val_loss: 0.3880 - val_accuracy: 0.9781
Epoch 2/20
10/10 [==============================] - 18s 2s/step - loss: 0.1573 - accurac
y: 0.9914 - val_loss: 0.0748 - val_accuracy: 0.9906
Epoch 3/20
10/10 [==============================] - 17s 2s/step - loss: 0.1312 - accurac
y: 0.9914 - val_loss: 0.1182 - val_accuracy: 0.9937
Epoch 4/20
10/10 [==============================] - 17s 2s/step - loss: 0.1238 - accurac
y: 0.9953 - val_loss: 0.1798 - val_accuracy: 0.9937
Epoch 5/20
10/10 [==============================] - 17s 2s/step - loss: 0.0607 - accurac
y: 0.9969 - val_loss: 0.1147 - val_accuracy: 0.9937
```

In [47]:
```
import matplotlib.pyplot as plt
def plot_metrics(history):
  metrics =  ['loss','accuracy']
  for n, metric in enumerate(metrics):
    name = metric.replace("_"," ").capitalize()
    plt.subplot(1,2,n+1)
    plt.tight_layout()
    plt.plot(history.epoch,  history.history[metric], color=colors[0], label
='Train')
    plt.plot(history.epoch, history.history['val_'+metric],
             color=colors[0], linestyle="--", label='Val')
    plt.xlabel('Epoch')
    plt.ylabel(name)
    plt.legend()
```

In [48]:
```
# Plot the training/validation history of our Keras model
colors = plt.rcParams['axes.prop_cycle'].by_key()['color']
plot_metrics(history)
```



In [49]:
```
mobilev2_results = model.evaluate(test_data, verbose = 0)
mobilev2_loss = mobilev2_results[0]
mobilev2_acc = mobilev2_results[1]

print('MobileV2 Test loss:', mobilev2_loss)
print('MobileV2 Test accuracy:', mobilev2_acc)
```

```
MobileV2 Test loss: 7.659079415134329e-08
MobileV2 Test accuracy: 1.0
```

3.2 InceptionV3

In [50]:
```
pre_trained_model = tf.keras.applications.InceptionV3(input_shape=(128, 128,
3), include_top=False, weights='imagenet')

for layer in pre_trained_model.layers:
     layer.trainable = False

pre_trained_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applica
tions/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
87910968/87910968 [==============================] - 1s 0us/step
Model: "inception_v3"
__________________________________________________________________________________
_________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================
==================
 input_2 (InputLayer)           [(None, 128, 128, 3  0           []
                                )]

 conv2d_12 (Conv2D)             (None, 63, 63, 32)   864         ['input_2[0]
[0]']

 batch_normalization (BatchNorm  (None, 63, 63, 32)  96          ['conv2d_12
[0][0]']
 alization)

 activation (Activation)        (None, 63, 63, 32)   0           ['batch_norm
alization[0][0]']

 conv2d_13 (Conv2D)             (None, 61, 61, 32)   9216        ['activation
[0][0]']

 batch_normalization_1 (BatchNo  (None, 61, 61, 32)  96          ['conv2d_13
[0][0]']
 rmalization)

 activation_1 (Activation)      (None, 61, 61, 32)   0           ['batch_norm
alization_1[0][0]']

 conv2d_14 (Conv2D)             (None, 61, 61, 64)   18432       ['activation
_1[0][0]']

 batch_normalization_2 (BatchNo  (None, 61, 61, 64)  192         ['conv2d_14
[0][0]']
 rmalization)

 activation_2 (Activation)      (None, 61, 61, 64)   0           ['batch_norm
alization_2[0][0]']

 max_pooling2d_6 (MaxPooling2D)  (None, 30, 30, 64)  0           ['activation
_2[0][0]']

 conv2d_15 (Conv2D)             (None, 30, 30, 80)   5120        ['max_poolin
g2d_6[0][0]']

 batch_normalization_3 (BatchNo  (None, 30, 30, 80)  240         ['conv2d_15
[0][0]']
 rmalization)

 activation_3 (Activation)      (None, 30, 30, 80)   0           ['batch_norm
alization_3[0][0]']

 conv2d_16 (Conv2D)             (None, 28, 28, 192)  138240      ['activation
_3[0][0]']
```

```
 batch_normalization_4 (BatchNo  (None, 28, 28, 192)  576        ['conv2d_16
[0][0]']
 rmalization)

 activation_4 (Activation)      (None, 28, 28, 192)  0          ['batch_norm
alization_4[0][0]']

 max_pooling2d_7 (MaxPooling2D)  (None, 13, 13, 192)  0         ['activation
_4[0][0]']

 conv2d_20 (Conv2D)             (None, 13, 13, 64)   12288      ['max_poolin
g2d_7[0][0]']

 batch_normalization_8 (BatchNo  (None, 13, 13, 64)  192        ['conv2d_20
[0][0]']
 rmalization)

 activation_8 (Activation)      (None, 13, 13, 64)   0          ['batch_norm
alization_8[0][0]']

 conv2d_18 (Conv2D)             (None, 13, 13, 48)   9216       ['max_poolin
g2d_7[0][0]']

 conv2d_21 (Conv2D)             (None, 13, 13, 96)   55296      ['activation
_8[0][0]']

 batch_normalization_6 (BatchNo  (None, 13, 13, 48)  144        ['conv2d_18
[0][0]']
 rmalization)

 batch_normalization_9 (BatchNo  (None, 13, 13, 96)  288        ['conv2d_21
[0][0]']
 rmalization)

 activation_6 (Activation)      (None, 13, 13, 48)   0          ['batch_norm
alization_6[0][0]']

 activation_9 (Activation)      (None, 13, 13, 96)   0          ['batch_norm
alization_9[0][0]']

 average_pooling2d (AveragePool  (None, 13, 13, 192)  0         ['max_poolin
g2d_7[0][0]']
 ing2D)

 conv2d_17 (Conv2D)             (None, 13, 13, 64)   12288      ['max_poolin
g2d_7[0][0]']

 conv2d_19 (Conv2D)             (None, 13, 13, 64)   76800      ['activation
_6[0][0]']

 conv2d_22 (Conv2D)             (None, 13, 13, 96)   82944      ['activation
_9[0][0]']

 conv2d_23 (Conv2D)             (None, 13, 13, 32)   6144       ['average_po
oling2d[0][0]']
```

```
 batch_normalization_5 (BatchNo  (None, 13, 13, 64)  192         ['conv2d_17
[0][0]']
 rmalization)

 batch_normalization_7 (BatchNo  (None, 13, 13, 64)  192         ['conv2d_19
[0][0]']
 rmalization)

 batch_normalization_10 (BatchN  (None, 13, 13, 96)  288         ['conv2d_22
[0][0]']
 ormalization)

 batch_normalization_11 (BatchN  (None, 13, 13, 32)  96          ['conv2d_23
[0][0]']
 ormalization)

 activation_5 (Activation)      (None, 13, 13, 64)   0           ['batch_norm
alization_5[0][0]']

 activation_7 (Activation)      (None, 13, 13, 64)   0           ['batch_norm
alization_7[0][0]']

 activation_10 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_10[0][0]']

 activation_11 (Activation)     (None, 13, 13, 32)   0           ['batch_norm
alization_11[0][0]']

 mixed0 (Concatenate)           (None, 13, 13, 256)  0           ['activation
_5[0][0]',
                                                                  'activation
_7[0][0]',
                                                                  'activation
_10[0][0]',
                                                                  'activation
_11[0][0]']

 conv2d_27 (Conv2D)             (None, 13, 13, 64)   16384       ['mixed0[0]
[0]']

 batch_normalization_15 (BatchN  (None, 13, 13, 64)  192         ['conv2d_27
[0][0]']
 ormalization)

 activation_15 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_15[0][0]']

 conv2d_25 (Conv2D)             (None, 13, 13, 48)   12288       ['mixed0[0]
[0]']

 conv2d_28 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_15[0][0]']

 batch_normalization_13 (BatchN  (None, 13, 13, 48)  144         ['conv2d_25
[0][0]']
 ormalization)
```

```
 batch_normalization_16 (BatchN  (None, 13, 13, 96)  288         ['conv2d_28
[0][0]']
 ormalization)

 activation_13 (Activation)     (None, 13, 13, 48)   0           ['batch_norm
alization_13[0][0]']

 activation_16 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_16[0][0]']

 average_pooling2d_1 (AveragePo  (None, 13, 13, 256)  0          ['mixed0[0]
[0]']
 oling2D)

 conv2d_24 (Conv2D)             (None, 13, 13, 64)   16384       ['mixed0[0]
[0]']

 conv2d_26 (Conv2D)             (None, 13, 13, 64)   76800       ['activation
_13[0][0]']

 conv2d_29 (Conv2D)             (None, 13, 13, 96)   82944       ['activation
_16[0][0]']

 conv2d_30 (Conv2D)             (None, 13, 13, 64)   16384       ['average_po
oling2d_1[0][0]']

 batch_normalization_12 (BatchN  (None, 13, 13, 64)  192         ['conv2d_24
[0][0]']
 ormalization)

 batch_normalization_14 (BatchN  (None, 13, 13, 64)  192         ['conv2d_26
[0][0]']
 ormalization)

 batch_normalization_17 (BatchN  (None, 13, 13, 96)  288         ['conv2d_29
[0][0]']
 ormalization)

 batch_normalization_18 (BatchN  (None, 13, 13, 64)  192         ['conv2d_30
[0][0]']
 ormalization)

 activation_12 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_12[0][0]']

 activation_14 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_14[0][0]']

 activation_17 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_17[0][0]']

 activation_18 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_18[0][0]']

 mixed1 (Concatenate)           (None, 13, 13, 288)  0           ['activation
_12[0][0]',
                                                                  'activation
```

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_14[0][0]',
                                                                 'activation
_17[0][0]',
                                                                 'activation
_18[0][0]']

 conv2d_34 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed1[0]
[0]']

 batch_normalization_22 (BatchN  (None, 13, 13, 64)  192         ['conv2d_34
[0][0]']
 ormalization)

 activation_22 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_22[0][0]']

 conv2d_32 (Conv2D)             (None, 13, 13, 48)   13824       ['mixed1[0]
[0]']

 conv2d_35 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_22[0][0]']

 batch_normalization_20 (BatchN  (None, 13, 13, 48)  144         ['conv2d_32
[0][0]']
 ormalization)

 batch_normalization_23 (BatchN  (None, 13, 13, 96)  288         ['conv2d_35
[0][0]']
 ormalization)

 activation_20 (Activation)     (None, 13, 13, 48)   0           ['batch_norm
alization_20[0][0]']

 activation_23 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_23[0][0]']

 average_pooling2d_2 (AveragePo  (None, 13, 13, 288)  0         ['mixed1[0]
[0]']
 oling2D)

 conv2d_31 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed1[0]
[0]']

 conv2d_33 (Conv2D)             (None, 13, 13, 64)   76800       ['activation
_20[0][0]']

 conv2d_36 (Conv2D)             (None, 13, 13, 96)   82944       ['activation
_23[0][0]']

 conv2d_37 (Conv2D)             (None, 13, 13, 64)   18432       ['average_po
oling2d_2[0][0]']

 batch_normalization_19 (BatchN  (None, 13, 13, 64)  192         ['conv2d_31
[0][0]']
 ormalization)

 batch_normalization_21 (BatchN  (None, 13, 13, 64)  192         ['conv2d_33
```

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[0][0]']
 ormalization)

 batch_normalization_24 (BatchN  (None, 13, 13, 96)  288         ['conv2d_36
[0][0]']
 ormalization)

 batch_normalization_25 (BatchN  (None, 13, 13, 64)  192         ['conv2d_37
[0][0]']
 ormalization)

 activation_19 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_19[0][0]']

 activation_21 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_21[0][0]']

 activation_24 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_24[0][0]']

 activation_25 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_25[0][0]']

 mixed2 (Concatenate)           (None, 13, 13, 288)  0           ['activation
_19[0][0]',
                                                                  'activation
_21[0][0]',
                                                                  'activation
_24[0][0]',
                                                                  'activation
_25[0][0]']

 conv2d_39 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed2[0]
[0]']

 batch_normalization_27 (BatchN  (None, 13, 13, 64)  192         ['conv2d_39
[0][0]']
 ormalization)

 activation_27 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_27[0][0]']

 conv2d_40 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_27[0][0]']

 batch_normalization_28 (BatchN  (None, 13, 13, 96)  288         ['conv2d_40
[0][0]']
 ormalization)

 activation_28 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_28[0][0]']

 conv2d_38 (Conv2D)             (None, 6, 6, 384)    995328      ['mixed2[0]
[0]']

 conv2d_41 (Conv2D)             (None, 6, 6, 96)     82944       ['activation
_28[0][0]']
```

```
 batch_normalization_26 (BatchN  (None, 6, 6, 384)   1152        ['conv2d_38
[0][0]']
 ormalization)

 batch_normalization_29 (BatchN  (None, 6, 6, 96)    288         ['conv2d_41
[0][0]']
 ormalization)

 activation_26 (Activation)     (None, 6, 6, 384)    0           ['batch_norm
alization_26[0][0]']

 activation_29 (Activation)     (None, 6, 6, 96)     0           ['batch_norm
alization_29[0][0]']

 max_pooling2d_8 (MaxPooling2D)  (None, 6, 6, 288)   0           ['mixed2[0]
[0]']

 mixed3 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_26[0][0]',
                                                                 'activation
_29[0][0]',
                                                                 'max_poolin
g2d_8[0][0]']

 conv2d_46 (Conv2D)             (None, 6, 6, 128)    98304       ['mixed3[0]
[0]']

 batch_normalization_34 (BatchN  (None, 6, 6, 128)   384         ['conv2d_46
[0][0]']
 ormalization)

 activation_34 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_34[0][0]']

 conv2d_47 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_34[0][0]']

 batch_normalization_35 (BatchN  (None, 6, 6, 128)   384         ['conv2d_47
[0][0]']
 ormalization)

 activation_35 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_35[0][0]']

 conv2d_43 (Conv2D)             (None, 6, 6, 128)    98304       ['mixed3[0]
[0]']

 conv2d_48 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_35[0][0]']

 batch_normalization_31 (BatchN  (None, 6, 6, 128)   384         ['conv2d_43
[0][0]']
 ormalization)

 batch_normalization_36 (BatchN  (None, 6, 6, 128)   384         ['conv2d_48
[0][0]']
```

```
 ormalization)

 activation_31 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_31[0][0]']

 activation_36 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_36[0][0]']

 conv2d_44 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_31[0][0]']

 conv2d_49 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_36[0][0]']

 batch_normalization_32 (BatchN  (None, 6, 6, 128)   384         ['conv2d_44
[0][0]']
 ormalization)

 batch_normalization_37 (BatchN  (None, 6, 6, 128)   384         ['conv2d_49
[0][0]']
 ormalization)

 activation_32 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_32[0][0]']

 activation_37 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_37[0][0]']

 average_pooling2d_3 (AveragePo  (None, 6, 6, 768)   0           ['mixed3[0]
[0]']
 oling2D)

 conv2d_42 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed3[0]
[0]']

 conv2d_45 (Conv2D)             (None, 6, 6, 192)    172032      ['activation
_32[0][0]']

 conv2d_50 (Conv2D)             (None, 6, 6, 192)    172032      ['activation
_37[0][0]']

 conv2d_51 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_3[0][0]']

 batch_normalization_30 (BatchN  (None, 6, 6, 192)   576         ['conv2d_42
[0][0]']
 ormalization)

 batch_normalization_33 (BatchN  (None, 6, 6, 192)   576         ['conv2d_45
[0][0]']
 ormalization)

 batch_normalization_38 (BatchN  (None, 6, 6, 192)   576         ['conv2d_50
[0][0]']
 ormalization)

 batch_normalization_39 (BatchN  (None, 6, 6, 192)   576         ['conv2d_51
```

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[0][0]']
 ormalization)

 activation_30 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_30[0][0]']

 activation_33 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_33[0][0]']

 activation_38 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_38[0][0]']

 activation_39 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_39[0][0]']

 mixed4 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_30[0][0]',
                                                                  'activation
_33[0][0]',
                                                                  'activation
_38[0][0]',
                                                                  'activation
_39[0][0]']

 conv2d_56 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed4[0]
[0]']

 batch_normalization_44 (BatchN  (None, 6, 6, 160)   480         ['conv2d_56
[0][0]']
 ormalization)

 activation_44 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_44[0][0]']

 conv2d_57 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_44[0][0]']

 batch_normalization_45 (BatchN  (None, 6, 6, 160)   480         ['conv2d_57
[0][0]']
 ormalization)

 activation_45 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_45[0][0]']

 conv2d_53 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed4[0]
[0]']

 conv2d_58 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_45[0][0]']

 batch_normalization_41 (BatchN  (None, 6, 6, 160)   480         ['conv2d_53
[0][0]']
 ormalization)

 batch_normalization_46 (BatchN  (None, 6, 6, 160)   480         ['conv2d_58
[0][0]']
 ormalization)
```

```
 activation_41 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_41[0][0]']

 activation_46 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_46[0][0]']

 conv2d_54 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_41[0][0]']

 conv2d_59 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_46[0][0]']

 batch_normalization_42 (BatchN  (None, 6, 6, 160)   480         ['conv2d_54
[0][0]']
 ormalization)

 batch_normalization_47 (BatchN  (None, 6, 6, 160)   480         ['conv2d_59
[0][0]']
 ormalization)

 activation_42 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_42[0][0]']

 activation_47 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_47[0][0]']

 average_pooling2d_4 (AveragePo  (None, 6, 6, 768)   0           ['mixed4[0]
[0]']
 oling2D)

 conv2d_52 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed4[0]
[0]']

 conv2d_55 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_42[0][0]']

 conv2d_60 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_47[0][0]']

 conv2d_61 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_4[0][0]']

 batch_normalization_40 (BatchN  (None, 6, 6, 192)   576         ['conv2d_52
[0][0]']
 ormalization)

 batch_normalization_43 (BatchN  (None, 6, 6, 192)   576         ['conv2d_55
[0][0]']
 ormalization)

 batch_normalization_48 (BatchN  (None, 6, 6, 192)   576         ['conv2d_60
[0][0]']
 ormalization)

 batch_normalization_49 (BatchN  (None, 6, 6, 192)   576         ['conv2d_61
[0][0]']
```

```
 ormalization)

 activation_40 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_40[0][0]']

 activation_43 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_43[0][0]']

 activation_48 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_48[0][0]']

 activation_49 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_49[0][0]']

 mixed5 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_40[0][0]',
                                                                  'activation
_43[0][0]',
                                                                  'activation
_48[0][0]',
                                                                  'activation
_49[0][0]']

 conv2d_66 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed5[0]
[0]']

 batch_normalization_54 (BatchN  (None, 6, 6, 160)   480         ['conv2d_66
[0][0]']
 ormalization)

 activation_54 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_54[0][0]']

 conv2d_67 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_54[0][0]']

 batch_normalization_55 (BatchN  (None, 6, 6, 160)   480         ['conv2d_67
[0][0]']
 ormalization)

 activation_55 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_55[0][0]']

 conv2d_63 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed5[0]
[0]']

 conv2d_68 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_55[0][0]']

 batch_normalization_51 (BatchN  (None, 6, 6, 160)   480         ['conv2d_63
[0][0]']
 ormalization)

 batch_normalization_56 (BatchN  (None, 6, 6, 160)   480         ['conv2d_68
[0][0]']
 ormalization)
```

```
 activation_51 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_51[0][0]']

 activation_56 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_56[0][0]']

 conv2d_64 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_51[0][0]']

 conv2d_69 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_56[0][0]']

 batch_normalization_52 (BatchN  (None, 6, 6, 160)   480         ['conv2d_64
[0][0]']
 ormalization)

 batch_normalization_57 (BatchN  (None, 6, 6, 160)   480         ['conv2d_69
[0][0]']
 ormalization)

 activation_52 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_52[0][0]']

 activation_57 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_57[0][0]']

 average_pooling2d_5 (AveragePo  (None, 6, 6, 768)   0           ['mixed5[0]
[0]']
 oling2D)

 conv2d_62 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed5[0]
[0]']

 conv2d_65 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_52[0][0]']

 conv2d_70 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_57[0][0]']

 conv2d_71 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_5[0][0]']

 batch_normalization_50 (BatchN  (None, 6, 6, 192)   576         ['conv2d_62
[0][0]']
 ormalization)

 batch_normalization_53 (BatchN  (None, 6, 6, 192)   576         ['conv2d_65
[0][0]']
 ormalization)

 batch_normalization_58 (BatchN  (None, 6, 6, 192)   576         ['conv2d_70
[0][0]']
 ormalization)

 batch_normalization_59 (BatchN  (None, 6, 6, 192)   576         ['conv2d_71
[0][0]']
 ormalization)
```

```
 activation_50 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_50[0][0]']

 activation_53 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_53[0][0]']

 activation_58 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_58[0][0]']

 activation_59 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_59[0][0]']

 mixed6 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_50[0][0]',
                                                                  'activation
_53[0][0]',
                                                                  'activation
_58[0][0]',
                                                                  'activation
_59[0][0]']

 conv2d_76 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 batch_normalization_64 (BatchN  (None, 6, 6, 192)   576         ['conv2d_76
[0][0]']
 ormalization)

 activation_64 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_64[0][0]']

 conv2d_77 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_64[0][0]']

 batch_normalization_65 (BatchN  (None, 6, 6, 192)   576         ['conv2d_77
[0][0]']
 ormalization)

 activation_65 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_65[0][0]']

 conv2d_73 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 conv2d_78 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_65[0][0]']

 batch_normalization_61 (BatchN  (None, 6, 6, 192)   576         ['conv2d_73
[0][0]']
 ormalization)

 batch_normalization_66 (BatchN  (None, 6, 6, 192)   576         ['conv2d_78
[0][0]']
 ormalization)

 activation_61 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
```

```
alization_61[0][0]']

 activation_66 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_66[0][0]']

 conv2d_74 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_61[0][0]']

 conv2d_79 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_66[0][0]']

 batch_normalization_62 (BatchN  (None, 6, 6, 192)   576         ['conv2d_74
[0][0]']
 ormalization)

 batch_normalization_67 (BatchN  (None, 6, 6, 192)   576         ['conv2d_79
[0][0]']
 ormalization)

 activation_62 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_62[0][0]']

 activation_67 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_67[0][0]']

 average_pooling2d_6 (AveragePo  (None, 6, 6, 768)   0           ['mixed6[0]
[0]']
 oling2D)

 conv2d_72 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 conv2d_75 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_62[0][0]']

 conv2d_80 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_67[0][0]']

 conv2d_81 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_6[0][0]']

 batch_normalization_60 (BatchN  (None, 6, 6, 192)   576         ['conv2d_72
[0][0]']
 ormalization)

 batch_normalization_63 (BatchN  (None, 6, 6, 192)   576         ['conv2d_75
[0][0]']
 ormalization)

 batch_normalization_68 (BatchN  (None, 6, 6, 192)   576         ['conv2d_80
[0][0]']
 ormalization)

 batch_normalization_69 (BatchN  (None, 6, 6, 192)   576         ['conv2d_81
[0][0]']
 ormalization)
```

```
 activation_60 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_60[0][0]']

 activation_63 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_63[0][0]']

 activation_68 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_68[0][0]']

 activation_69 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_69[0][0]']

 mixed7 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_60[0][0]',
                                                                  'activation
_63[0][0]',
                                                                  'activation
_68[0][0]',
                                                                  'activation
_69[0][0]']

 conv2d_84 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed7[0]
[0]']

 batch_normalization_72 (BatchN  (None, 6, 6, 192)   576         ['conv2d_84
[0][0]']
 ormalization)

 activation_72 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_72[0][0]']

 conv2d_85 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_72[0][0]']

 batch_normalization_73 (BatchN  (None, 6, 6, 192)   576         ['conv2d_85
[0][0]']
 ormalization)

 activation_73 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_73[0][0]']

 conv2d_82 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed7[0]
[0]']

 conv2d_86 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_73[0][0]']

 batch_normalization_70 (BatchN  (None, 6, 6, 192)   576         ['conv2d_82
[0][0]']
 ormalization)

 batch_normalization_74 (BatchN  (None, 6, 6, 192)   576         ['conv2d_86
[0][0]']
 ormalization)

 activation_70 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_70[0][0]']
```

```
 activation_74 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_74[0][0]']

 conv2d_83 (Conv2D)             (None, 2, 2, 320)    552960      ['activation
_70[0][0]']

 conv2d_87 (Conv2D)             (None, 2, 2, 192)    331776      ['activation
_74[0][0]']

 batch_normalization_71 (BatchN  (None, 2, 2, 320)   960         ['conv2d_83
[0][0]']
 ormalization)

 batch_normalization_75 (BatchN  (None, 2, 2, 192)   576         ['conv2d_87
[0][0]']
 ormalization)

 activation_71 (Activation)     (None, 2, 2, 320)    0           ['batch_norm
alization_71[0][0]']

 activation_75 (Activation)     (None, 2, 2, 192)    0           ['batch_norm
alization_75[0][0]']

 max_pooling2d_9 (MaxPooling2D)  (None, 2, 2, 768)   0           ['mixed7[0]
[0]']

 mixed8 (Concatenate)           (None, 2, 2, 1280)   0           ['activation
_71[0][0]',
                                                                  'activation
_75[0][0]',
                                                                  'max_poolin
g2d_9[0][0]']

 conv2d_92 (Conv2D)             (None, 2, 2, 448)    573440      ['mixed8[0]
[0]']

 batch_normalization_80 (BatchN  (None, 2, 2, 448)   1344        ['conv2d_92
[0][0]']
 ormalization)

 activation_80 (Activation)     (None, 2, 2, 448)    0           ['batch_norm
alization_80[0][0]']

 conv2d_89 (Conv2D)             (None, 2, 2, 384)    491520      ['mixed8[0]
[0]']

 conv2d_93 (Conv2D)             (None, 2, 2, 384)    1548288     ['activation
_80[0][0]']

 batch_normalization_77 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_89
[0][0]']
 ormalization)

 batch_normalization_81 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_93
[0][0]']
 ormalization)
```

```
 activation_77 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_77[0][0]']

 activation_81 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_81[0][0]']

 conv2d_90 (Conv2D)             (None, 2, 2, 384)    442368      ['activation
_77[0][0]']

 conv2d_91 (Conv2D)             (None, 2, 2, 384)    442368      ['activation
_77[0][0]']

 conv2d_94 (Conv2D)             (None, 2, 2, 384)    442368      ['activation
_81[0][0]']

 conv2d_95 (Conv2D)             (None, 2, 2, 384)    442368      ['activation
_81[0][0]']

 average_pooling2d_7 (AveragePo  (None, 2, 2, 1280)  0           ['mixed8[0]
[0]']
 oling2D)

 conv2d_88 (Conv2D)             (None, 2, 2, 320)    409600      ['mixed8[0]
[0]']

 batch_normalization_78 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_90
[0][0]']
 ormalization)

 batch_normalization_79 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_91
[0][0]']
 ormalization)

 batch_normalization_82 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_94
[0][0]']
 ormalization)

 batch_normalization_83 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_95
[0][0]']
 ormalization)

 conv2d_96 (Conv2D)             (None, 2, 2, 192)    245760      ['average_po
oling2d_7[0][0]']

 batch_normalization_76 (BatchN  (None, 2, 2, 320)   960         ['conv2d_88
[0][0]']
 ormalization)

 activation_78 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_78[0][0]']

 activation_79 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_79[0][0]']

 activation_82 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_82[0][0]']
```

```
 activation_83 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_83[0][0]']

 batch_normalization_84 (BatchN  (None, 2, 2, 192)   576         ['conv2d_96
[0][0]']
 ormalization)

 activation_76 (Activation)     (None, 2, 2, 320)    0           ['batch_norm
alization_76[0][0]']

 mixed9_0 (Concatenate)         (None, 2, 2, 768)    0           ['activation
_78[0][0]',
                                                                  'activation
_79[0][0]']

 concatenate (Concatenate)      (None, 2, 2, 768)    0           ['activation
_82[0][0]',
                                                                  'activation
_83[0][0]']

 activation_84 (Activation)     (None, 2, 2, 192)    0           ['batch_norm
alization_84[0][0]']

 mixed9 (Concatenate)           (None, 2, 2, 2048)   0           ['activation
_76[0][0]',
                                                                  'mixed9_0
[0][0]',
                                                                  'concatenat
e[0][0]',
                                                                  'activation
_84[0][0]']

 conv2d_101 (Conv2D)            (None, 2, 2, 448)    917504      ['mixed9[0]
[0]']

 batch_normalization_89 (BatchN  (None, 2, 2, 448)   1344        ['conv2d_101
[0][0]']
 ormalization)

 activation_89 (Activation)     (None, 2, 2, 448)    0           ['batch_norm
alization_89[0][0]']

 conv2d_98 (Conv2D)             (None, 2, 2, 384)    786432      ['mixed9[0]
[0]']

 conv2d_102 (Conv2D)            (None, 2, 2, 384)    1548288     ['activation
_89[0][0]']

 batch_normalization_86 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_98
[0][0]']
 ormalization)

 batch_normalization_90 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_102
[0][0]']
 ormalization)
```

```
 activation_86 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_86[0][0]']

 activation_90 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_90[0][0]']

 conv2d_99 (Conv2D)             (None, 2, 2, 384)    442368      ['activation
_86[0][0]']

 conv2d_100 (Conv2D)            (None, 2, 2, 384)    442368      ['activation
_86[0][0]']

 conv2d_103 (Conv2D)            (None, 2, 2, 384)    442368      ['activation
_90[0][0]']

 conv2d_104 (Conv2D)            (None, 2, 2, 384)    442368      ['activation
_90[0][0]']

 average_pooling2d_8 (AveragePo  (None, 2, 2, 2048)  0           ['mixed9[0]
[0]']
 oling2D)

 conv2d_97 (Conv2D)             (None, 2, 2, 320)    655360      ['mixed9[0]
[0]']

 batch_normalization_87 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_99
[0][0]']
 ormalization)

 batch_normalization_88 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_100
[0][0]']
 ormalization)

 batch_normalization_91 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_103
[0][0]']
 ormalization)

 batch_normalization_92 (BatchN  (None, 2, 2, 384)   1152        ['conv2d_104
[0][0]']
 ormalization)

 conv2d_105 (Conv2D)            (None, 2, 2, 192)    393216      ['average_po
oling2d_8[0][0]']

 batch_normalization_85 (BatchN  (None, 2, 2, 320)   960         ['conv2d_97
[0][0]']
 ormalization)

 activation_87 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_87[0][0]']

 activation_88 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_88[0][0]']

 activation_91 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_91[0][0]']
```

```
 activation_92 (Activation)     (None, 2, 2, 384)    0           ['batch_norm
alization_92[0][0]']

 batch_normalization_93 (BatchN  (None, 2, 2, 192)   576         ['conv2d_105
[0][0]']
 ormalization)

 activation_85 (Activation)     (None, 2, 2, 320)    0           ['batch_norm
alization_85[0][0]']

 mixed9_1 (Concatenate)         (None, 2, 2, 768)    0           ['activation
_87[0][0]',
                                                                  'activation
_88[0][0]']

 concatenate_1 (Concatenate)    (None, 2, 2, 768)    0           ['activation
_91[0][0]',
                                                                  'activation
_92[0][0]']

 activation_93 (Activation)     (None, 2, 2, 192)    0           ['batch_norm
alization_93[0][0]']

 mixed10 (Concatenate)          (None, 2, 2, 2048)   0           ['activation
_85[0][0]',
                                                                  'mixed9_1
[0][0]',
                                                                  'concatenat
e_1[0][0]',
                                                                  'activation
_93[0][0]']

==================================================================================
Total params: 21,802,784
Trainable params: 0
Non-trainable params: 21,802,784
__________________________________________________________________________________
```

In [51]:

```
last_layer = pre_trained_model.get_layer('mixed7')
last_output = last_layer.output

# Flatten the output layer to 1 dimension
x = layers.Flatten()(last_output)
# Add a fully connected layer with 512 hidden units and ReLU activation
x = layers.Dense(512, activation='relu')(x)
# Add a dropout layer to prevent overfitting
x = layers.Dropout(0.5)(x)
# Add a final softmax layer for classification
x = layers.Dense  (2, activation='softmax')(x)
```

In [52]:
```
from tensorflow.keras import Model,layers

model = Model(pre_trained_model.input, x)
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',metrics
=['accuracy'])

model.summary()
```

```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 128, 128, 3)]     0

 conv2d_12 (Conv2D)          (None, 63, 63, 32)        864

 batch_normalization (BatchNorm  (None, 63, 63, 32)    96
 alization)

 activation (Activation)     (None, 63, 63, 32)        0

 conv2d_13 (Conv2D)          (None, 61, 61, 32)        9216

 batch_normalization_1 (BatchNo  (None, 61, 61, 32)    96
 rmalization)

 activation_1 (Activation)   (None, 61, 61, 32)        0

 conv2d_14 (Conv2D)          (None, 61, 61, 64)        18432

 batch_normalization_2 (BatchNo  (None, 61, 61, 64)    192
 rmalization)

 activation_2 (Activation)   (None, 61, 61, 64)        0

 max_pooling2d_6 (MaxPooling2D)  (None, 30, 30, 64)    0

 conv2d_15 (Conv2D)          (None, 30, 30, 80)        5120

 batch_normalization_3 (BatchNo  (None, 30, 30, 80)    240
 rmalization)

 activation_3 (Activation)   (None, 30, 30, 80)        0

 conv2d_16 (Conv2D)          (None, 28, 28, 192)       138240

 batch_normalization_4 (BatchNo  (None, 28, 28, 192)   576
```

```
 rmalization)

 activation_4 (Activation)      (None, 28, 28, 192)  0           ['batch_norm
alization_4[0][0]']

 max_pooling2d_7 (MaxPooling2D)  (None, 13, 13, 192)  0          ['activation
_4[0][0]']

 conv2d_20 (Conv2D)             (None, 13, 13, 64)   12288       ['max_poolin
g2d_7[0][0]']

 batch_normalization_8 (BatchNo  (None, 13, 13, 64)  192         ['conv2d_20
[0][0]']
 rmalization)

 activation_8 (Activation)      (None, 13, 13, 64)   0           ['batch_norm
alization_8[0][0]']

 conv2d_18 (Conv2D)             (None, 13, 13, 48)   9216        ['max_poolin
g2d_7[0][0]']

 conv2d_21 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_8[0][0]']

 batch_normalization_6 (BatchNo  (None, 13, 13, 48)  144         ['conv2d_18
[0][0]']
 rmalization)

 batch_normalization_9 (BatchNo  (None, 13, 13, 96)  288         ['conv2d_21
[0][0]']
 rmalization)

 activation_6 (Activation)      (None, 13, 13, 48)   0           ['batch_norm
alization_6[0][0]']

 activation_9 (Activation)      (None, 13, 13, 96)   0           ['batch_norm
alization_9[0][0]']

 average_pooling2d (AveragePool  (None, 13, 13, 192)  0          ['max_poolin
g2d_7[0][0]']
 ing2D)

 conv2d_17 (Conv2D)             (None, 13, 13, 64)   12288       ['max_poolin
g2d_7[0][0]']

 conv2d_19 (Conv2D)             (None, 13, 13, 64)   76800       ['activation
_6[0][0]']

 conv2d_22 (Conv2D)             (None, 13, 13, 96)   82944       ['activation
_9[0][0]']

 conv2d_23 (Conv2D)             (None, 13, 13, 32)   6144        ['average_po
oling2d[0][0]']

 batch_normalization_5 (BatchNo  (None, 13, 13, 64)  192         ['conv2d_17
[0][0]']
 rmalization)
```

```
 batch_normalization_7 (BatchNo  (None, 13, 13, 64)  192         ['conv2d_19
[0][0]']
 rmalization)

 batch_normalization_10 (BatchN  (None, 13, 13, 96)  288         ['conv2d_22
[0][0]']
 ormalization)

 batch_normalization_11 (BatchN  (None, 13, 13, 32)  96          ['conv2d_23
[0][0]']
 ormalization)

 activation_5 (Activation)      (None, 13, 13, 64)   0           ['batch_norm
alization_5[0][0]']

 activation_7 (Activation)      (None, 13, 13, 64)   0           ['batch_norm
alization_7[0][0]']

 activation_10 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_10[0][0]']

 activation_11 (Activation)     (None, 13, 13, 32)   0           ['batch_norm
alization_11[0][0]']

 mixed0 (Concatenate)           (None, 13, 13, 256)  0           ['activation
_5[0][0]',
                                                                  'activation
_7[0][0]',
                                                                  'activation
_10[0][0]',
                                                                  'activation
_11[0][0]']

 conv2d_27 (Conv2D)             (None, 13, 13, 64)   16384       ['mixed0[0]
[0]']

 batch_normalization_15 (BatchN  (None, 13, 13, 64)  192         ['conv2d_27
[0][0]']
 ormalization)

 activation_15 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_15[0][0]']

 conv2d_25 (Conv2D)             (None, 13, 13, 48)   12288       ['mixed0[0]
[0]']

 conv2d_28 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_15[0][0]']

 batch_normalization_13 (BatchN  (None, 13, 13, 48)  144         ['conv2d_25
[0][0]']
 ormalization)

 batch_normalization_16 (BatchN  (None, 13, 13, 96)  288         ['conv2d_28
[0][0]']
 ormalization)
```

```
 activation_13 (Activation)     (None, 13, 13, 48)   0           ['batch_norm
alization_13[0][0]']

 activation_16 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_16[0][0]']

 average_pooling2d_1 (AveragePo  (None, 13, 13, 256)  0          ['mixed0[0]
[0]']
 oling2D)

 conv2d_24 (Conv2D)             (None, 13, 13, 64)   16384       ['mixed0[0]
[0]']

 conv2d_26 (Conv2D)             (None, 13, 13, 64)   76800       ['activation
_13[0][0]']

 conv2d_29 (Conv2D)             (None, 13, 13, 96)   82944       ['activation
_16[0][0]']

 conv2d_30 (Conv2D)             (None, 13, 13, 64)   16384       ['average_po
oling2d_1[0][0]']

 batch_normalization_12 (BatchN  (None, 13, 13, 64)  192         ['conv2d_24
[0][0]']
 ormalization)

 batch_normalization_14 (BatchN  (None, 13, 13, 64)  192         ['conv2d_26
[0][0]']
 ormalization)

 batch_normalization_17 (BatchN  (None, 13, 13, 96)  288         ['conv2d_29
[0][0]']
 ormalization)

 batch_normalization_18 (BatchN  (None, 13, 13, 64)  192         ['conv2d_30
[0][0]']
 ormalization)

 activation_12 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_12[0][0]']

 activation_14 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_14[0][0]']

 activation_17 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_17[0][0]']

 activation_18 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_18[0][0]']

 mixed1 (Concatenate)           (None, 13, 13, 288)  0           ['activation
_12[0][0]',
                                                                  'activation
_14[0][0]',
                                                                  'activation
_17[0][0]',
```

```
                                                                  'activation
_18[0][0]']

 conv2d_34 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed1[0]
[0]']

 batch_normalization_22 (BatchN  (None, 13, 13, 64)  192         ['conv2d_34
[0][0]']
 ormalization)

 activation_22 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_22[0][0]']

 conv2d_32 (Conv2D)             (None, 13, 13, 48)   13824       ['mixed1[0]
[0]']

 conv2d_35 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_22[0][0]']

 batch_normalization_20 (BatchN  (None, 13, 13, 48)  144         ['conv2d_32
[0][0]']
 ormalization)

 batch_normalization_23 (BatchN  (None, 13, 13, 96)  288         ['conv2d_35
[0][0]']
 ormalization)

 activation_20 (Activation)     (None, 13, 13, 48)   0           ['batch_norm
alization_20[0][0]']

 activation_23 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_23[0][0]']

 average_pooling2d_2 (AveragePo  (None, 13, 13, 288)  0         ['mixed1[0]
[0]']
 oling2D)

 conv2d_31 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed1[0]
[0]']

 conv2d_33 (Conv2D)             (None, 13, 13, 64)   76800       ['activation
_20[0][0]']

 conv2d_36 (Conv2D)             (None, 13, 13, 96)   82944       ['activation
_23[0][0]']

 conv2d_37 (Conv2D)             (None, 13, 13, 64)   18432       ['average_po
oling2d_2[0][0]']

 batch_normalization_19 (BatchN  (None, 13, 13, 64)  192         ['conv2d_31
[0][0]']
 ormalization)

 batch_normalization_21 (BatchN  (None, 13, 13, 64)  192         ['conv2d_33
[0][0]']
 ormalization)
```

```
 batch_normalization_24 (BatchN  (None, 13, 13, 96)  288         ['conv2d_36
[0][0]']
 ormalization)

 batch_normalization_25 (BatchN  (None, 13, 13, 64)  192         ['conv2d_37
[0][0]']
 ormalization)

 activation_19 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_19[0][0]']

 activation_21 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_21[0][0]']

 activation_24 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_24[0][0]']

 activation_25 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_25[0][0]']

 mixed2 (Concatenate)           (None, 13, 13, 288)  0           ['activation
_19[0][0]',
                                                                  'activation
_21[0][0]',
                                                                  'activation
_24[0][0]',
                                                                  'activation
_25[0][0]']

 conv2d_39 (Conv2D)             (None, 13, 13, 64)   18432       ['mixed2[0]
[0]']

 batch_normalization_27 (BatchN  (None, 13, 13, 64)  192         ['conv2d_39
[0][0]']
 ormalization)

 activation_27 (Activation)     (None, 13, 13, 64)   0           ['batch_norm
alization_27[0][0]']

 conv2d_40 (Conv2D)             (None, 13, 13, 96)   55296       ['activation
_27[0][0]']

 batch_normalization_28 (BatchN  (None, 13, 13, 96)  288         ['conv2d_40
[0][0]']
 ormalization)

 activation_28 (Activation)     (None, 13, 13, 96)   0           ['batch_norm
alization_28[0][0]']

 conv2d_38 (Conv2D)             (None, 6, 6, 384)    995328      ['mixed2[0]
[0]']

 conv2d_41 (Conv2D)             (None, 6, 6, 96)     82944       ['activation
_28[0][0]']

 batch_normalization_26 (BatchN  (None, 6, 6, 384)   1152        ['conv2d_38
[0][0]']
```

```
 ormalization)

 batch_normalization_29 (BatchN  (None, 6, 6, 96)    288         ['conv2d_41
[0][0]']
 ormalization)

 activation_26 (Activation)     (None, 6, 6, 384)    0           ['batch_norm
alization_26[0][0]']

 activation_29 (Activation)     (None, 6, 6, 96)     0           ['batch_norm
alization_29[0][0]']

 max_pooling2d_8 (MaxPooling2D)  (None, 6, 6, 288)   0           ['mixed2[0]
[0]']

 mixed3 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_26[0][0]',
                                                                  'activation
_29[0][0]',
                                                                  'max_poolin
g2d_8[0][0]']

 conv2d_46 (Conv2D)             (None, 6, 6, 128)    98304       ['mixed3[0]
[0]']

 batch_normalization_34 (BatchN  (None, 6, 6, 128)   384         ['conv2d_46
[0][0]']
 ormalization)

 activation_34 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_34[0][0]']

 conv2d_47 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_34[0][0]']

 batch_normalization_35 (BatchN  (None, 6, 6, 128)   384         ['conv2d_47
[0][0]']
 ormalization)

 activation_35 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_35[0][0]']

 conv2d_43 (Conv2D)             (None, 6, 6, 128)    98304       ['mixed3[0]
[0]']

 conv2d_48 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_35[0][0]']

 batch_normalization_31 (BatchN  (None, 6, 6, 128)   384         ['conv2d_43
[0][0]']
 ormalization)

 batch_normalization_36 (BatchN  (None, 6, 6, 128)   384         ['conv2d_48
[0][0]']
 ormalization)

 activation_31 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
```

```
alization_31[0][0]']

 activation_36 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_36[0][0]']

 conv2d_44 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_31[0][0]']

 conv2d_49 (Conv2D)             (None, 6, 6, 128)    114688      ['activation
_36[0][0]']

 batch_normalization_32 (BatchN  (None, 6, 6, 128)   384         ['conv2d_44
[0][0]']
 ormalization)

 batch_normalization_37 (BatchN  (None, 6, 6, 128)   384         ['conv2d_49
[0][0]']
 ormalization)

 activation_32 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_32[0][0]']

 activation_37 (Activation)     (None, 6, 6, 128)    0           ['batch_norm
alization_37[0][0]']

 average_pooling2d_3 (AveragePo  (None, 6, 6, 768)   0           ['mixed3[0]
[0]']
 oling2D)

 conv2d_42 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed3[0]
[0]']

 conv2d_45 (Conv2D)             (None, 6, 6, 192)    172032      ['activation
_32[0][0]']

 conv2d_50 (Conv2D)             (None, 6, 6, 192)    172032      ['activation
_37[0][0]']

 conv2d_51 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_3[0][0]']

 batch_normalization_30 (BatchN  (None, 6, 6, 192)   576         ['conv2d_42
[0][0]']
 ormalization)

 batch_normalization_33 (BatchN  (None, 6, 6, 192)   576         ['conv2d_45
[0][0]']
 ormalization)

 batch_normalization_38 (BatchN  (None, 6, 6, 192)   576         ['conv2d_50
[0][0]']
 ormalization)

 batch_normalization_39 (BatchN  (None, 6, 6, 192)   576         ['conv2d_51
[0][0]']
 ormalization)
```

```
 activation_30 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_30[0][0]']

 activation_33 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_33[0][0]']

 activation_38 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_38[0][0]']

 activation_39 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_39[0][0]']

 mixed4 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_30[0][0]',
                                                                  'activation
_33[0][0]',
                                                                  'activation
_38[0][0]',
                                                                  'activation
_39[0][0]']

 conv2d_56 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed4[0]
[0]']

 batch_normalization_44 (BatchN  (None, 6, 6, 160)   480         ['conv2d_56
[0][0]']
 ormalization)

 activation_44 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_44[0][0]']

 conv2d_57 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_44[0][0]']

 batch_normalization_45 (BatchN  (None, 6, 6, 160)   480         ['conv2d_57
[0][0]']
 ormalization)

 activation_45 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_45[0][0]']

 conv2d_53 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed4[0]
[0]']

 conv2d_58 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_45[0][0]']

 batch_normalization_41 (BatchN  (None, 6, 6, 160)   480         ['conv2d_53
[0][0]']
 ormalization)

 batch_normalization_46 (BatchN  (None, 6, 6, 160)   480         ['conv2d_58
[0][0]']
 ormalization)

 activation_41 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_41[0][0]']
```

```
 activation_46 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_46[0][0]']

 conv2d_54 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_41[0][0]']

 conv2d_59 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_46[0][0]']

 batch_normalization_42 (BatchN  (None, 6, 6, 160)   480         ['conv2d_54
[0][0]']
 ormalization)

 batch_normalization_47 (BatchN  (None, 6, 6, 160)   480         ['conv2d_59
[0][0]']
 ormalization)

 activation_42 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_42[0][0]']

 activation_47 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_47[0][0]']

 average_pooling2d_4 (AveragePo  (None, 6, 6, 768)   0           ['mixed4[0]
[0]']
 oling2D)

 conv2d_52 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed4[0]
[0]']

 conv2d_55 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_42[0][0]']

 conv2d_60 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_47[0][0]']

 conv2d_61 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_4[0][0]']

 batch_normalization_40 (BatchN  (None, 6, 6, 192)   576         ['conv2d_52
[0][0]']
 ormalization)

 batch_normalization_43 (BatchN  (None, 6, 6, 192)   576         ['conv2d_55
[0][0]']
 ormalization)

 batch_normalization_48 (BatchN  (None, 6, 6, 192)   576         ['conv2d_60
[0][0]']
 ormalization)

 batch_normalization_49 (BatchN  (None, 6, 6, 192)   576         ['conv2d_61
[0][0]']
 ormalization)

 activation_40 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
```

```
alization_40[0][0]']

 activation_43 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_43[0][0]']

 activation_48 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_48[0][0]']

 activation_49 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_49[0][0]']

 mixed5 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_40[0][0]',
                                                                  'activation
_43[0][0]',
                                                                  'activation
_48[0][0]',
                                                                  'activation
_49[0][0]']

 conv2d_66 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed5[0]
[0]']

 batch_normalization_54 (BatchN  (None, 6, 6, 160)   480         ['conv2d_66
[0][0]']
 ormalization)

 activation_54 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_54[0][0]']

 conv2d_67 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_54[0][0]']

 batch_normalization_55 (BatchN  (None, 6, 6, 160)   480         ['conv2d_67
[0][0]']
 ormalization)

 activation_55 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_55[0][0]']

 conv2d_63 (Conv2D)             (None, 6, 6, 160)    122880      ['mixed5[0]
[0]']

 conv2d_68 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_55[0][0]']

 batch_normalization_51 (BatchN  (None, 6, 6, 160)   480         ['conv2d_63
[0][0]']
 ormalization)

 batch_normalization_56 (BatchN  (None, 6, 6, 160)   480         ['conv2d_68
[0][0]']
 ormalization)

 activation_51 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_51[0][0]']
```

```
 activation_56 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_56[0][0]']

 conv2d_64 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_51[0][0]']

 conv2d_69 (Conv2D)             (None, 6, 6, 160)    179200      ['activation
_56[0][0]']

 batch_normalization_52 (BatchN  (None, 6, 6, 160)   480         ['conv2d_64
[0][0]']
 ormalization)

 batch_normalization_57 (BatchN  (None, 6, 6, 160)   480         ['conv2d_69
[0][0]']
 ormalization)

 activation_52 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_52[0][0]']

 activation_57 (Activation)     (None, 6, 6, 160)    0           ['batch_norm
alization_57[0][0]']

 average_pooling2d_5 (AveragePo  (None, 6, 6, 768)   0           ['mixed5[0]
[0]']
 oling2D)

 conv2d_62 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed5[0]
[0]']

 conv2d_65 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_52[0][0]']

 conv2d_70 (Conv2D)             (None, 6, 6, 192)    215040      ['activation
_57[0][0]']

 conv2d_71 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_5[0][0]']

 batch_normalization_50 (BatchN  (None, 6, 6, 192)   576         ['conv2d_62
[0][0]']
 ormalization)

 batch_normalization_53 (BatchN  (None, 6, 6, 192)   576         ['conv2d_65
[0][0]']
 ormalization)

 batch_normalization_58 (BatchN  (None, 6, 6, 192)   576         ['conv2d_70
[0][0]']
 ormalization)

 batch_normalization_59 (BatchN  (None, 6, 6, 192)   576         ['conv2d_71
[0][0]']
 ormalization)

 activation_50 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_50[0][0]']
```

```
 activation_53 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_53[0][0]']

 activation_58 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_58[0][0]']

 activation_59 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_59[0][0]']

 mixed6 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_50[0][0]',
                                                                  'activation
_53[0][0]',
                                                                  'activation
_58[0][0]',
                                                                  'activation
_59[0][0]']

 conv2d_76 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 batch_normalization_64 (BatchN  (None, 6, 6, 192)   576         ['conv2d_76
[0][0]']
 ormalization)

 activation_64 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_64[0][0]']

 conv2d_77 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_64[0][0]']

 batch_normalization_65 (BatchN  (None, 6, 6, 192)   576         ['conv2d_77
[0][0]']
 ormalization)

 activation_65 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_65[0][0]']

 conv2d_73 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 conv2d_78 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_65[0][0]']

 batch_normalization_61 (BatchN  (None, 6, 6, 192)   576         ['conv2d_73
[0][0]']
 ormalization)

 batch_normalization_66 (BatchN  (None, 6, 6, 192)   576         ['conv2d_78
[0][0]']
 ormalization)

 activation_61 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_61[0][0]']

 activation_66 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
```

```
alization_66[0][0]']

 conv2d_74 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_61[0][0]']

 conv2d_79 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_66[0][0]']

 batch_normalization_62 (BatchN  (None, 6, 6, 192)   576         ['conv2d_74
[0][0]']
 ormalization)

 batch_normalization_67 (BatchN  (None, 6, 6, 192)   576         ['conv2d_79
[0][0]']
 ormalization)

 activation_62 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_62[0][0]']

 activation_67 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_67[0][0]']

 average_pooling2d_6 (AveragePo  (None, 6, 6, 768)   0           ['mixed6[0]
[0]']
 oling2D)

 conv2d_72 (Conv2D)             (None, 6, 6, 192)    147456      ['mixed6[0]
[0]']

 conv2d_75 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_62[0][0]']

 conv2d_80 (Conv2D)             (None, 6, 6, 192)    258048      ['activation
_67[0][0]']

 conv2d_81 (Conv2D)             (None, 6, 6, 192)    147456      ['average_po
oling2d_6[0][0]']

 batch_normalization_60 (BatchN  (None, 6, 6, 192)   576         ['conv2d_72
[0][0]']
 ormalization)

 batch_normalization_63 (BatchN  (None, 6, 6, 192)   576         ['conv2d_75
[0][0]']
 ormalization)

 batch_normalization_68 (BatchN  (None, 6, 6, 192)   576         ['conv2d_80
[0][0]']
 ormalization)

 batch_normalization_69 (BatchN  (None, 6, 6, 192)   576         ['conv2d_81
[0][0]']
 ormalization)

 activation_60 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_60[0][0]']
```

```
 activation_63 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_63[0][0]']

 activation_68 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_68[0][0]']

 activation_69 (Activation)     (None, 6, 6, 192)    0           ['batch_norm
alization_69[0][0]']

 mixed7 (Concatenate)           (None, 6, 6, 768)    0           ['activation
_60[0][0]',
                                                                  'activation
_63[0][0]',
                                                                  'activation
_68[0][0]',
                                                                  'activation
_69[0][0]']

 flatten_4 (Flatten)            (None, 27648)        0           ['mixed7[0]
[0]']

 dense_8 (Dense)                (None, 512)          14156288    ['flatten_4
[0][0]']

 dropout_4 (Dropout)            (None, 512)          0           ['dense_8[0]
[0]']

 dense_9 (Dense)                (None, 2)            1026        ['dropout_4
[0][0]']

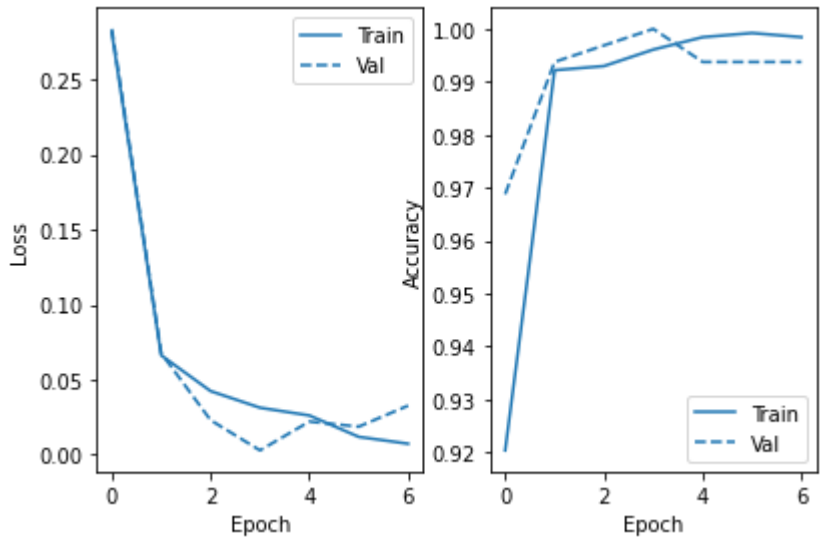
==================================================================================
====================
Total params: 23,132,578
Trainable params: 14,157,314
Non-trainable params: 8,975,264
__________________________________________________________________________________
____________________
```

In [53]:
```
history = model.fit(train_data, validation_data=val_data, epochs=20, callbacks
=[tf.keras.callbacks.EarlyStopping(monitor='val_loss',patience=3)])
```

```
Epoch 1/20
10/10 [==============================] - 49s 4s/step - loss: 0.2811 - accurac
y: 0.9203 - val_loss: 0.2836 - val_accuracy: 0.9688
Epoch 2/20
10/10 [==============================] - 42s 4s/step - loss: 0.0662 - accurac
y: 0.9922 - val_loss: 0.0676 - val_accuracy: 0.9937
Epoch 3/20
10/10 [==============================] - 42s 4s/step - loss: 0.0424 - accurac
y: 0.9930 - val_loss: 0.0230 - val_accuracy: 0.9969
Epoch 4/20
10/10 [==============================] - 41s 4s/step - loss: 0.0313 - accurac
y: 0.9961 - val_loss: 0.0029 - val_accuracy: 1.0000
Epoch 5/20
10/10 [==============================] - 41s 4s/step - loss: 0.0261 - accurac
y: 0.9984 - val_loss: 0.0221 - val_accuracy: 0.9937
Epoch 6/20
10/10 [==============================] - 41s 4s/step - loss: 0.0119 - accurac
y: 0.9992 - val_loss: 0.0187 - val_accuracy: 0.9937
Epoch 7/20
10/10 [==============================] - 41s 4s/step - loss: 0.0073 - accurac
y: 0.9984 - val_loss: 0.0327 - val_accuracy: 0.9937
```

In [54]:
```
import matplotlib.pyplot as plt
def plot_metrics(history):
  metrics =  ['loss','accuracy']
  for n, metric in enumerate(metrics):
    name = metric.replace("_"," ").capitalize()
    plt.subplot(1,2,n+1)
    plt.tight_layout()
    plt.plot(history.epoch,  history.history[metric], color=colors[0], label
='Train')
    plt.plot(history.epoch, history.history['val_'+metric],
             color=colors[0], linestyle="--", label='Val')
    plt.xlabel('Epoch')
    plt.ylabel(name)
    plt.legend()
```

In [55]:
```
# Plot the training/validation history of our Keras model
colors = plt.rcParams['axes.prop_cycle'].by_key()['color']
plot_metrics(history)
```



In [56]:
```
inceptionv3_results = model.evaluate(test_data, verbose = 0)
inceptionv3_loss = inceptionv3_results[0]
inceptionv3_acc = inceptionv3_results[1]

print('InceptionV3 Test loss:', inceptionv3_loss)
print('InceptionV3 Test accuracy:', inceptionv3_acc)
```

```
InceptionV3 Test loss: 0.016351589933037758
InceptionV3 Test accuracy: 0.9950000047683716
```

F - Model Comparison

In [57]:
```
#store metrics in respective lists
models = ['baseline','tuned baseline','mobilenetv2', 'inceptionv3']
accuracies = [baseline_acc, tuned_acc, mobilev2_acc, inceptionv3_acc]
loss = [baseline_loss, tuned_loss, mobilev2_loss, inceptionv3_loss]

#create dataframe with metrics for comparison
df__final_evaluate = pd.DataFrame()
df__final_evaluate['Model'] = models
df__final_evaluate['Loss'] = loss
df__final_evaluate['Accuracy'] = accuracies

df_evaluate = df__final_evaluate.sort_values(by=['Accuracy'], ascending=False)
df_evaluate
```

Out[57]:

	Model	Loss	Accuracy
2	mobilenetv2	7.659079e-08	1.0000
3	inceptionv3	1.635159e-02	0.9950
1	tuned baseline	1.994478e-01	0.9850
0	baseline	1.732528e-01	0.9475

In [ ]:
```

```

Observing the model results, all models perform extremely well at classifying the two classes of image. It was possible to create a baseline model that performs comparably to established classification architectures

G - Explainable AI with Class Activation Heatmap

In [116]:
```
import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import Model,layers
# Display
from IPython.display import Image, display
import matplotlib.pyplot as plt
import matplotlib.cm as cm
```

In [117]:
```
model_builder = keras.applications.mobilenet_v2.MobileNetV2
img_size = (224, 224)
preprocess_input = keras.applications.mobilenet_v2.preprocess_input
decode_predictions = keras.applications.mobilenet_v2.decode_predictions

last_conv_layer_name = "out_relu"

#img_path = '../content/Positive/19425.jpg'
#img_path = '../content/Negative/15452.jpg'

img_path_neg = '../content/Negative/08975.jpg'
img_path_pos = '../content/Positive/01223.jpg'

#display(Image(img_path))
```

In [118]:
```
def get_img_array(img_path, size):
    # `img` is a PIL image of size 299x299
    img = keras.preprocessing.image.load_img(img_path, target_size=size)
    # `array` is a float32 Numpy array of shape (299, 299, 3)
    array = keras.preprocessing.image.img_to_array(img)
    # Add dimension to transform our array into a "batch"
    # of size (1, 299, 299, 3)
    array = np.expand_dims(array, axis=0)
    return array


def make_gradcam_heatmap(img_array, model, last_conv_layer_name, pred_index=No
ne):
    # create model that maps the input image to the activations
    # of the last conv layer and output predictions
    grad_model = tf.keras.models.Model(
        [model.inputs], [model.get_layer(last_conv_layer_name).output, model.o
utput]
    )

    # compute the gradient of the top predicted class for our input image
    # with respect to the activations of the last conv layer
    with tf.GradientTape() as tape:
        last_conv_layer_output, preds = grad_model(img_array)
        if pred_index is None:
            pred_index = tf.argmax(preds[0])
        class_channel = preds[:, pred_index]

    # gradient of the output neuron with regard to the output feature map of t
he last conv layer
    grads = tape.gradient(class_channel, last_conv_layer_output)

    # vector where each entry is the mean intensity of the gradient over a spe
cific feature map channel
    pooled_grads = tf.reduce_mean(grads, axis=(0, 1, 2))

    # multiply each channel in the feature map array by how important this cha
nnel is with regard to the top predicted class, then sum the channels to obtai
n the heatmap class activation
    last_conv_layer_output = last_conv_layer_output[0]
    heatmap = last_conv_layer_output @ pooled_grads[..., tf.newaxis]
    heatmap = tf.squeeze(heatmap)

    # normalize the heatmap between 0 & 1
    heatmap = tf.maximum(heatmap, 0) / tf.math.reduce_max(heatmap)
    return heatmap.numpy()
```

In [119]:
```
# Prepare image
img_array = preprocess_input(get_img_array(img_path_neg, size=img_size))

# Make model
model = model_builder(weights="imagenet")

last_layer = model.get_layer('predictions')
last_output = last_layer.output

# Flatten the output layer to 1 dimension
x = layers.Flatten()(last_output)
# Add a fully connected layer with 512 hidden units and ReLU activation
x = layers.Dense(512, activation='relu')(x)
# Add a dropout layer to prevent overfitting
x = layers.Dropout(0.5)(x)
# Add a final softmax layer for classification
x = layers.Dense  (2, activation='softmax')(x)
model = Model(model.input, x)

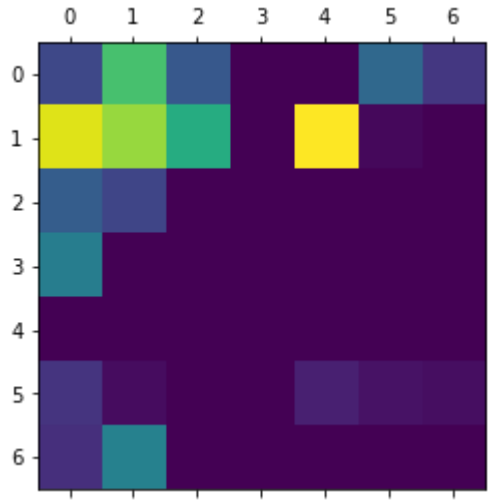
# Remove last layer's softmax
model.layers[-1].activation = None

# Print what the top predicted class is
preds = model.predict(img_array)
print(preds[0])
#print("Predicted:", decode_predictions(preds, top=1)[0])
if(preds[0][1]>preds[0][0]):
    print("Crack Detected")#plt.title("Crack Detected")
else:
    print("No Crack Detected")#plt.title("No Crack Detected")

# Generate class activation heatmap
heatmap_neg = make_gradcam_heatmap(img_array, model, last_conv_layer_name)

# Display heatmap
plt.matshow(heatmap_neg)
plt.show()
```

```
1/1 [==============================] - 1s 933ms/step
[-0.00266686 -0.00340406]
No Crack Detected
```



In [120]:
```
# Prepare image
img_array = preprocess_input(get_img_array(img_path_pos, size=img_size))

# Make model
model = model_builder(weights="imagenet")

last_layer = model.get_layer('predictions')
last_output = last_layer.output

# Flatten the output layer to 1 dimension
x = layers.Flatten()(last_output)
# Add a fully connected layer with 512 hidden units and ReLU activation
x = layers.Dense(512, activation='relu')(x)
# Add a dropout layer to prevent overfitting
x = layers.Dropout(0.5)(x)
# Add a final softmax layer for classification
x = layers.Dense  (2, activation='softmax')(x)
model = Model(model.input, x)

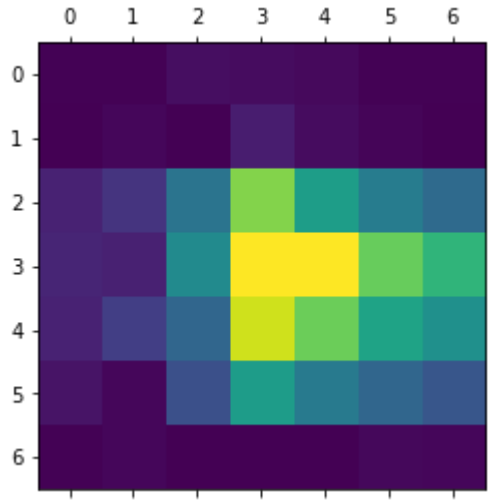
# Remove last layer's softmax
model.layers[-1].activation = None

# Print what the top predicted class is
preds = model.predict(img_array)
print(preds[0])
#print("Predicted:", decode_predictions(preds, top=1)[0])
if(preds[0][1]>preds[0][0]):
    print("Crack Detected")#plt.title("Crack Detected")
else:
    print("No Crack Detected")#plt.title("No Crack Detected")

# Generate class activation heatmap
heatmap_pos = make_gradcam_heatmap(img_array, model, last_conv_layer_name)

# Display heatmap
plt.matshow(heatmap_pos)
plt.show()
```

```
1/1 [==============================] - 1s 920ms/step
[-0.00604577  0.00768467]
Crack Detected
```



In [121]:
```
def save_and_display_gradcam(img_path, heatmap, cam_path="cam.jpg", alpha=0.
4):
    # Load the original image
    img = keras.preprocessing.image.load_img(img_path)
    img = keras.preprocessing.image.img_to_array(img)

    # Rescale heatmap to a range 0-255
    heatmap = np.uint8(255 * heatmap)

    # Use jet colormap to colorize heatmap
    jet = cm.get_cmap("jet")

    # Use RGB values of the colormap
    jet_colors = jet(np.arange(256))[:, :3]
    jet_heatmap = jet_colors[heatmap]

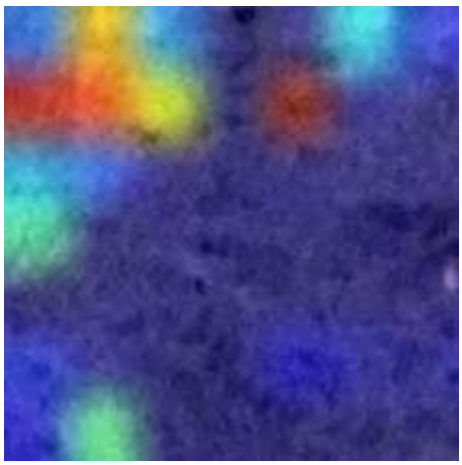
    # Create an image with RGB colorized heatmap
    jet_heatmap = keras.preprocessing.image.array_to_img(jet_heatmap)
    jet_heatmap = jet_heatmap.resize((img.shape[1], img.shape[0]))
    jet_heatmap = keras.preprocessing.image.img_to_array(jet_heatmap)

    # Superimpose the heatmap on original image
    superimposed_img = jet_heatmap * alpha + img
    superimposed_img = keras.preprocessing.image.array_to_img(superimposed_im
g)

    # Save the superimposed image
    superimposed_img.save(cam_path)

    # Display Grad CAM
    display(Image(cam_path))


save_and_display_gradcam(img_path_pos, heatmap_pos)
save_and_display_gradcam(img_path_neg, heatmap_neg)
```



In [121]: