

LAB_5_Sakshi

April 2, 2022

1 Problem 1: CNN classificaiton

Construct a CNN to classify the images in the MRI dataset.

```
[1]: import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
import matplotlib
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
import numpy as np
from tensorflow.keras.utils import to_categorical
from keras.utils import np_utils
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation, Dropout, Flatten,
    ↳MaxPooling2D
from tensorflow.keras.layers import Conv2D
import tensorflow as tf
from tensorflow import keras

[2]: file_dir = '/Users/sakshisuman12/Desktop/saint.math.1729/GitHub/
    ↳msam-northeastern/MATH7243/Labs/MRI_Images/'

labels = pd.read_csv(file_dir + 'labels.csv')
display(labels)
y = labels.CDR
```

| | Unnamed: 0 | Filename | ID | M/F | Hand | Age | Educ | \ |
|-----|------------|-----------------------|---------------|-----|------|-----|------|---|
| 0 | 0 | OAS1_0001_MR1_55.png | OAS1_0001_MR1 | F | R | 74 | 2 | |
| 1 | 1 | OAS1_0001_MR1_120.png | OAS1_0001_MR1 | F | R | 74 | 2 | |
| 2 | 2 | OAS1_0001_MR1_180.png | OAS1_0001_MR1 | F | R | 74 | 2 | |
| 3 | 3 | OAS1_0002_MR1_55.png | OAS1_0002_MR1 | F | R | 55 | 4 | |
| 4 | 4 | OAS1_0002_MR1_120.png | OAS1_0002_MR1 | F | R | 55 | 4 | |
| .. | ... | ... | ... | .. | ... | ... | ... | |
| 604 | 604 | OAS1_0449_MR1_120.png | OAS1_0449_MR1 | F | R | 71 | 3 | |
| 605 | 605 | OAS1_0449_MR1_180.png | OAS1_0449_MR1 | F | R | 71 | 3 | |
| 606 | 606 | OAS1_0456_MR1_55.png | OAS1_0456_MR1 | M | R | 61 | 5 | |

| | | | | | | | |
|-----|-----|-----------------------|---------------|---|---|----|---|
| 607 | 607 | OAS1_0456_MR1_120.png | OAS1_0456_MR1 | M | R | 61 | 5 |
| 608 | 608 | OAS1_0456_MR1_180.png | OAS1_0456_MR1 | M | R | 61 | 5 |

| | SES | MMSE | CDR | eTIV | nWBV | ASF | Delay | Slice |
|-----|-----|------|-----|------|-------|-------|-------|-------|
| 0 | 3.0 | 29 | 0.0 | 1344 | 0.743 | 1.306 | NaN | 55 |
| 1 | 3.0 | 29 | 0.0 | 1344 | 0.743 | 1.306 | NaN | 120 |
| 2 | 3.0 | 29 | 0.0 | 1344 | 0.743 | 1.306 | NaN | 180 |
| 3 | 1.0 | 29 | 0.0 | 1147 | 0.810 | 1.531 | NaN | 55 |
| 4 | 1.0 | 29 | 0.0 | 1147 | 0.810 | 1.531 | NaN | 120 |
| .. | ... | ... | ... | ... | ... | ... | ... | ... |
| 604 | 4.0 | 29 | 0.0 | 1264 | 0.818 | 1.388 | NaN | 120 |
| 605 | 4.0 | 29 | 0.0 | 1264 | 0.818 | 1.388 | NaN | 180 |
| 606 | 2.0 | 30 | 0.0 | 1637 | 0.780 | 1.072 | NaN | 55 |
| 607 | 2.0 | 30 | 0.0 | 1637 | 0.780 | 1.072 | NaN | 120 |
| 608 | 2.0 | 30 | 0.0 | 1637 | 0.780 | 1.072 | NaN | 180 |

[609 rows x 15 columns]

```
[3]: data = np.zeros([609, 30976])
      for n, file_name in enumerate(labels.FileName):
          data[n,:] = np.mean(matplotlib.image.imread(file_dir + file_name),axis=2).
          ↪reshape(-1)
```

```
[4]: from sklearn.model_selection import train_test_split

      x_train1, x_test1, y_train1, y_test1 = train_test_split(data, y, test_size=0.2,
      ↪random_state=0)
```

```
[5]: ## Normalize training data to be between 0 and 1, we have to typecast it as a
      ↪float to do so.
      X_train = x_train1.astype('float32')
      X_test = x_test1.astype('float32')
      X_train /= 255.0
      X_test /= 255.0

      NUM_LABELS = 4

      # one-hot encoding:
      Y_train = np_utils.to_categorical(y_train1, NUM_LABELS)
      Y_test = np_utils.to_categorical(y_test1, NUM_LABELS)

      print()
      print('MRI data loaded: train:',len(X_train),'test:',len(X_test))
      print('x_train:', x_train1.shape)
      print('X_train:', X_train.shape)
      print('y_train:', y_train1.shape)
      print('Y_train:', Y_train.shape)
```

```

MRI data loaded: train: 487 test: 122
x_train: (487, 30976)
X_train: (487, 30976)
y_train: (487,)
Y_train: (487, 4)

```

```

[6]: model = Sequential()

model.add(Conv2D(32, (7,7),
                padding='valid',
                input_shape=(176,176,1),
                activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Conv2D(32, (3,3),
                activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.25))


model.add(Flatten())
model.add(Dense(units=128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(4, activation='softmax'))

model.compile(loss='categorical_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])

print(model.summary())

```

```

Metal device set to: Apple M1 Max
Model: "sequential"

```

| Layer (type) | Output Shape | Param # |
|--------------------------------|----------------------|---------|
| conv2d (Conv2D) | (None, 170, 170, 32) | 1600 |
| max_pooling2d (MaxPooling2D) | (None, 85, 85, 32) | 0 |
| conv2d_1 (Conv2D) | (None, 83, 83, 32) | 9248 |
| max_pooling2d_1 (MaxPooling2D) | (None, 41, 41, 32) | 0 |

| | | |
|---------------------|--------------------|---------|
| dropout (Dropout) | (None, 41, 41, 32) | 0 |
| flatten (Flatten) | (None, 53792) | 0 |
| dense (Dense) | (None, 128) | 6885504 |
| dropout_1 (Dropout) | (None, 128) | 0 |
| dense_1 (Dense) | (None, 4) | 516 |

```
=====
Total params: 6,896,868
Trainable params: 6,896,868
Non-trainable params: 0
-----
None
```

```
2022-04-02 13:46:34.847266: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:305]
Could not identify NUMA node of platform GPU ID 0, defaulting to 0. Your kernel
may not have been built with NUMA support.
2022-04-02 13:46:34.847405: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:271]
Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 0
MB memory) -> physical PluggableDevice (device: 0, name: METAL, pci bus id:
<undefined>)
```

```
[7]: X_train = X_train.reshape(-1, 176, 176, 1)
      X_test = X_test.reshape(-1, 176, 176, 1)
```

```
[8]: tf.config.run_functions_eagerly(True)
      epochs = 5

      history = model.fit(X_train, Y_train,
                          epochs=epochs,
                          batch_size=128,
                          verbose=1,
                          validation_data=(X_test, Y_test))
```

Epoch 1/5

```
/Users/sakshisuman12/miniforge3/lib/python3.9/site-
packages/tensorflow/python/data/ops/structured_function.py:264: UserWarning:
Even though the `tf.config.experimental_run_functions_eagerly` option is set,
this option does not apply to tf.data functions. To force eager execution of
tf.data functions, please use `tf.data.experimental.enable_debug_mode()`.
```

```
warnings.warn(
2022-04-02 13:46:34.984775: W
tensorflow/core/platform/profile_utils/cpu_utils.cc:128] Failed to get CPU
```

frequency: 0 Hz

4/4 [=====] - 1s 282ms/step - loss: 0.8643 - accuracy: 0.6694 - val_loss: 0.5313 - val_accuracy: 0.8279

Epoch 2/5

4/4 [=====] - 1s 232ms/step - loss: 0.5132 - accuracy: 0.8768 - val_loss: 0.5444 - val_accuracy: 0.8279

Epoch 3/5

4/4 [=====] - 1s 233ms/step - loss: 0.4552 - accuracy: 0.8768 - val_loss: 0.5119 - val_accuracy: 0.8279

Epoch 4/5

4/4 [=====] - 1s 235ms/step - loss: 0.4386 - accuracy: 0.8768 - val_loss: 0.5085 - val_accuracy: 0.8279

Epoch 5/5

4/4 [=====] - 1s 233ms/step - loss: 0.4336 - accuracy: 0.8768 - val_loss: 0.5059 - val_accuracy: 0.8279

```
[9]: # saving the model
import os

SAVE_DIR = "."
MODEL_NAME = 'keras_mnist.h5'
model_path = os.path.join(SAVE_DIR, MODEL_NAME)

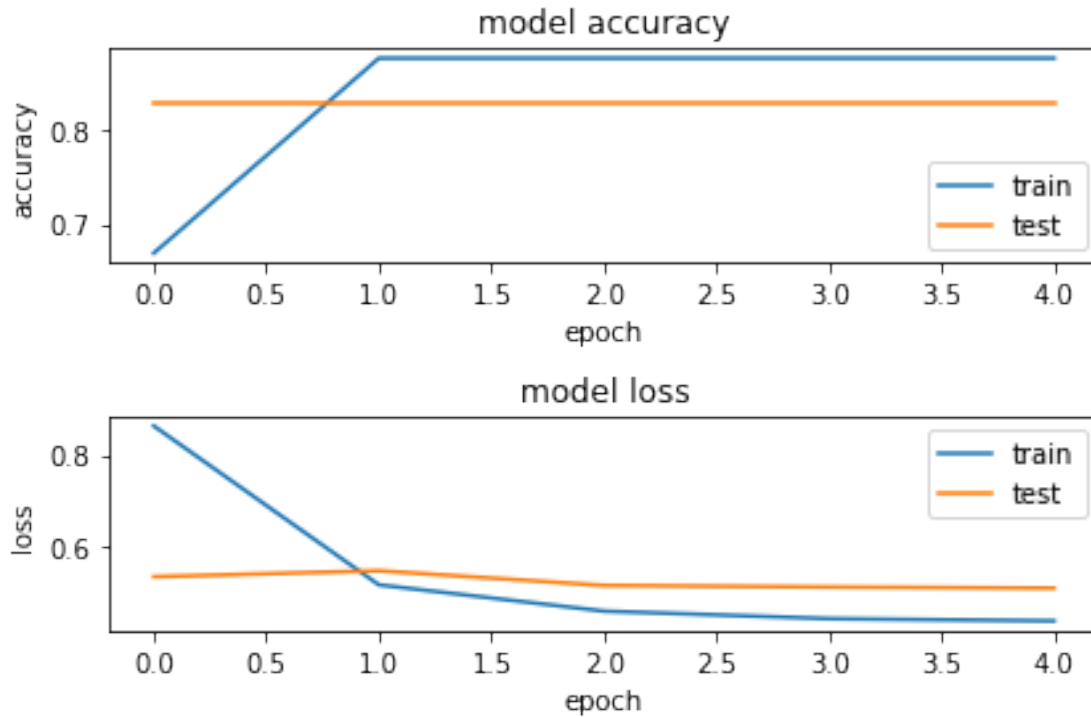
model.save(model_path)
print('Saved trained model at %s ' % model_path)
```

Saved trained model at ./keras_mnist.h5

```
[10]: fig = plt.figure()
plt.subplot(2,1,1)
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='lower right')

plt.subplot(2,1,2)
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='upper right')

plt.tight_layout()
```



2 Problem 2: Pretrained Networks

```
[11]: import numpy as np
import matplotlib.pyplot as plt
from keras.datasets import mnist, fashion_mnist
from keras.utils import np_utils
import keras
import sys
import sklearn
import tensorflow as tf
import os
import matplotlib
import matplotlib.pyplot as plt
import pandas as pd
from sklearn.model_selection import train_test_split
import random
from sklearn.preprocessing import StandardScaler
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation, Dropout, Flatten,
    MaxPooling2D
from tensorflow.keras.layers import Conv2D
import tensorflow as tf
from tensorflow import keras
```

```
print(tf.__version__)
```

2.8.0

```
[12]: def preprocess(image):
        resized_image = tf.image.resize(image, [224, 224])
        final_image = keras.applications.xception.preprocess_input(resized_image)
        return final_image
```

```
[13]: file_dir = '/Users/sakshisuman12/Desktop/saint.math.1729/GitHub/
        ↪msam-northeastern/MATH7243/Labs/MRI_Images/'
labels = pd.read_csv(file_dir + 'labels.csv', index_col=0)
display(labels)
y = labels.CDR

data = np.zeros([609, 224, 224, 3])
for n, file_name in enumerate(labels.FileName):
    data[n, :] = preprocess(matplotlib.image.imread(file_dir + file_name)[:,:,:0:
        ↪3]).reshape(1, 176, 176, 3))
```

| | Filename | ID | M/F | Hand | Age | Educ | SES | MMSE | CDR | \ |
|-----|-----------------------|---------------|-----|------|-----|------|-----|------|-----|---|
| 0 | OAS1_0001_MR1_55.png | OAS1_0001_MR1 | F | R | 74 | 2 | 3.0 | 29 | 0.0 | |
| 1 | OAS1_0001_MR1_120.png | OAS1_0001_MR1 | F | R | 74 | 2 | 3.0 | 29 | 0.0 | |
| 2 | OAS1_0001_MR1_180.png | OAS1_0001_MR1 | F | R | 74 | 2 | 3.0 | 29 | 0.0 | |
| 3 | OAS1_0002_MR1_55.png | OAS1_0002_MR1 | F | R | 55 | 4 | 1.0 | 29 | 0.0 | |
| 4 | OAS1_0002_MR1_120.png | OAS1_0002_MR1 | F | R | 55 | 4 | 1.0 | 29 | 0.0 | |
| .. | ... | ... | .. | ... | ... | ... | ... | | | |
| 604 | OAS1_0449_MR1_120.png | OAS1_0449_MR1 | F | R | 71 | 3 | 4.0 | 29 | 0.0 | |
| 605 | OAS1_0449_MR1_180.png | OAS1_0449_MR1 | F | R | 71 | 3 | 4.0 | 29 | 0.0 | |
| 606 | OAS1_0456_MR1_55.png | OAS1_0456_MR1 | M | R | 61 | 5 | 2.0 | 30 | 0.0 | |
| 607 | OAS1_0456_MR1_120.png | OAS1_0456_MR1 | M | R | 61 | 5 | 2.0 | 30 | 0.0 | |
| 608 | OAS1_0456_MR1_180.png | OAS1_0456_MR1 | M | R | 61 | 5 | 2.0 | 30 | 0.0 | |

| | eTIV | nWBV | ASF | Delay | Slice |
|-----|------|-------|-------|-------|-------|
| 0 | 1344 | 0.743 | 1.306 | NaN | 55 |
| 1 | 1344 | 0.743 | 1.306 | NaN | 120 |
| 2 | 1344 | 0.743 | 1.306 | NaN | 180 |
| 3 | 1147 | 0.810 | 1.531 | NaN | 55 |
| 4 | 1147 | 0.810 | 1.531 | NaN | 120 |
| .. | ... | ... | ... | ... | ... |
| 604 | 1264 | 0.818 | 1.388 | NaN | 120 |
| 605 | 1264 | 0.818 | 1.388 | NaN | 180 |
| 606 | 1637 | 0.780 | 1.072 | NaN | 55 |
| 607 | 1637 | 0.780 | 1.072 | NaN | 120 |
| 608 | 1637 | 0.780 | 1.072 | NaN | 180 |

[609 rows x 14 columns]

```
[14]: from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(data, y, test_size=0.2,
↳ random_state=0)
```

```
[15]: dicty = {0: 'type0', 0.5: 'type0.5', 1: 'type1', 2: 'type2'}
dicty2 = {'type0': 0, 'type0.5': 1, 'type1': 2, 'type2': 3}
y_train = y_train.replace(dicty)
y_train = y_train.replace(dicty2)
```

```
[16]: NUM_LABELS = 4
X_train = x_train.astype('float32')
X_test = x_test.astype('float32')
X_train /= 255.0
X_test /= 255.0

# one-hot encoding:
Y_train = np_utils.to_categorical(y_train, NUM_LABELS)
Y_test = np_utils.to_categorical(y_test, NUM_LABELS)

print()
print('MRI data loaded: train:', len(X_train), 'test:', len(X_test))
print('x_train:', x_train.shape)
print('X_train:', X_train.shape)
print('y_train:', y_train.shape)
print('Y_train:', Y_train.shape)
```

```
MRI data loaded: train: 487 test: 122
x_train: (487, 224, 224, 3)
X_train: (487, 224, 224, 3)
y_train: (487,)
Y_train: (487, 4)
```

```
[17]: n_classes=NUM_LABELS
base_model = tf.keras.applications.xception.Xception(weights="imagenet",
↳ include_top=False)
avg = tf.keras.layers.GlobalAveragePooling2D()(base_model.output)
output = tf.keras.layers.Dense(n_classes, activation="softmax")(avg)
model = tf.keras.Model(inputs=base_model.input, outputs=output)
model.summary()
for layer in base_model.layers:
    layer.trainable = False
model.summary()
```

```
Model: "model"
```

```
-----
-----
Layer (type)                Output Shape          Param #      Connected to
```



```

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

block1_conv1 (Conv2D)      (None, None, None, 864
['input_1[0][0]']
                          32)

block1_conv1_bn (BatchNormaliz (None, None, None, 128
['block1_conv1[0][0]']
ation)
                          32)

block1_conv1_act (Activation) (None, None, None, 0
['block1_conv1_bn[0][0]']
                          32)

block1_conv2 (Conv2D)      (None, None, None, 18432
['block1_conv1_act[0][0]']
                          64)

block1_conv2_bn (BatchNormaliz (None, None, None, 256
['block1_conv2[0][0]']
ation)
                          64)

block1_conv2_act (Activation) (None, None, None, 0
['block1_conv2_bn[0][0]']
                          64)

block2_sepconv1 (SeparableConv (None, None, None, 8768
['block1_conv2_act[0][0]']
2D)
                          128)

block2_sepconv1_bn (BatchNorma (None, None, None, 512
['block2_sepconv1[0][0]']
lization)
                          128)

block2_sepconv2_act (Activatio (None, None, None, 0
['block2_sepconv1_bn[0][0]']
n)
                          128)

block2_sepconv2 (SeparableConv (None, None, None, 17536
['block2_sepconv2_act[0][0]']
2D)
                          128)

block2_sepconv2_bn (BatchNorma (None, None, None, 512
['block2_sepconv2[0][0]']
lization)
                          128)

```

| | | | |
|--|-------------------------|-------|---------------|
| conv2d_2 (Conv2D) ['block1_conv2_act[0][0]'] | (None, None, None, 128) | 8192 | |
| block2_pool (MaxPooling2D) ['block2_sepconv2_bn[0][0]'] | (None, None, None, 128) | 0 | |
| batch_normalization (BatchNormal alization) | (None, None, None, 128) | 512 | |
| add (Add) ['block2_pool[0][0]', 'batch_normalization[0][0]'] | (None, None, None, 128) | 0 | |
| block3_sepconv1_act (Activatio n) | (None, None, None, 128) | 0 | ['add[0][0]'] |
| block3_sepconv1 (SeparableConv 2D) | (None, None, None, 256) | 33920 | |
| block3_sepconv1_bn (BatchNorma lization) | (None, None, None, 256) | 1024 | |
| block3_sepconv2_act (Activatio n) | (None, None, None, 256) | 0 | |
| block3_sepconv2 (SeparableConv 2D) | (None, None, None, 256) | 67840 | |
| block3_sepconv2_bn (BatchNorma lization) | (None, None, None, 256) | 1024 | |
| conv2d_3 (Conv2D) | (None, None, None, 256) | 32768 | ['add[0][0]'] |
| block3_pool (MaxPooling2D) ['block3_sepconv2_bn[0][0]'] | (None, None, None, 256) | 0 | |

| | | | |
|---|-------------------------|--------|-----------------|
| batch_normalization_1 (BatchNormal ization) | (None, None, None, 256) | 1024 | |
| add_1 (Add) | (None, None, None, 256) | 0 | |
| ['conv2d_3[0][0]', 'batch_normalization_1[0][0]'] | | | |
| block4_sepconv1_act (Activation) | (None, None, None, 256) | 0 | ['add_1[0][0]'] |
| block4_sepconv1 (SeparableConv 2D) | (None, None, None, 728) | 188672 | |
| block4_sepconv1_bn (BatchNormal ization) | (None, None, None, 728) | 2912 | |
| block4_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |
| block4_sepconv2 (SeparableConv 2D) | (None, None, None, 728) | 536536 | |
| block4_sepconv2_bn (BatchNormal ization) | (None, None, None, 728) | 2912 | |
| conv2d_4 (Conv2D) | (None, None, None, 728) | 186368 | ['add_1[0][0]'] |
| block4_pool (MaxPooling2D) | (None, None, None, 728) | 0 | |
| batch_normalization_2 (BatchNormal ization) | (None, None, None, 728) | 2912 | |
| add_2 (Add) | (None, None, None, 728) | 0 | |
| ['block4_pool[0][0]', 'batch_normalization_2[0][0]'] | | | |

| | | | |
|---|-------------------------|--------|-----------------|
| block5_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_2[0][0]'] |
| block5_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block5_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |
| block5_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block5_sepconv3_act (Activation) | (None, None, None, 728) | 0 | |
| block5_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv3_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| add_3 (Add) | (None, None, None, 728) | 0 | 'add_2[0][0]' |
| block6_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_3[0][0]'] |
| block6_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block6_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |

| | | |
|--|----------------------------|-----------------|
| lization) | 728) | |
| block6_sepconv2_act (Activatio ['block6_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv2 (SeparableConv ['block6_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv2_bn (BatchNorma ['block6_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block6_sepconv3_act (Activatio ['block6_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv3 (SeparableConv ['block6_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv3_bn (BatchNorma ['block6_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_4 (Add) ['block6_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 |
| | | 'add_3[0][0]'] |
| block7_sepconv1_act (Activatio n) | (None, None, None, 728) | 0 |
| | | ['add_4[0][0]'] |
| block7_sepconv1 (SeparableConv ['block7_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv1_bn (BatchNorma ['block7_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv2_act (Activatio ['block7_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv2 (SeparableConv ['block7_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |

| | | | |
|--------------------------------|--------------------|--------|-----------------|
| block7_sepconv2_bn (BatchNorma | (None, None, None, | 2912 | |
| ['block7_sepconv2[0][0]'] | | | |
| lization) | 728) | | |
| block7_sepconv3_act (Activatio | (None, None, None, | 0 | |
| ['block7_sepconv2_bn[0][0]'] | | | |
| n) | 728) | | |
| block7_sepconv3 (SeparableConv | (None, None, None, | 536536 | |
| ['block7_sepconv3_act[0][0]'] | | | |
| 2D) | 728) | | |
| block7_sepconv3_bn (BatchNorma | (None, None, None, | 2912 | |
| ['block7_sepconv3[0][0]'] | | | |
| lization) | 728) | | |
| add_5 (Add) | (None, None, None, | 0 | |
| ['block7_sepconv3_bn[0][0]', | | | |
| | 728) | | 'add_4[0][0]'] |
| block8_sepconv1_act (Activatio | (None, None, None, | 0 | |
| n) | 728) | | ['add_5[0][0]'] |
| block8_sepconv1 (SeparableConv | (None, None, None, | 536536 | |
| ['block8_sepconv1_act[0][0]'] | | | |
| 2D) | 728) | | |
| block8_sepconv1_bn (BatchNorma | (None, None, None, | 2912 | |
| ['block8_sepconv1[0][0]'] | | | |
| lization) | 728) | | |
| block8_sepconv2_act (Activatio | (None, None, None, | 0 | |
| ['block8_sepconv1_bn[0][0]'] | | | |
| n) | 728) | | |
| block8_sepconv2 (SeparableConv | (None, None, None, | 536536 | |
| ['block8_sepconv2_act[0][0]'] | | | |
| 2D) | 728) | | |
| block8_sepconv2_bn (BatchNorma | (None, None, None, | 2912 | |
| ['block8_sepconv2[0][0]'] | | | |
| lization) | 728) | | |
| block8_sepconv3_act (Activatio | (None, None, None, | 0 | |
| ['block8_sepconv2_bn[0][0]'] | | | |
| n) | 728) | | |

| | | | |
|--|----------------------------|--------|-----------------|
| block8_sepconv3 (SeparableConv ['block8_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block8_sepconv3_bn (BatchNorma ['block8_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| add_6 (Add) ['block8_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 | 'add_5[0][0]'] |
| block9_sepconv1_act (Activatio n) | (None, None, None, 728) | 0 | ['add_6[0][0]'] |
| block9_sepconv1 (SeparableConv ['block9_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block9_sepconv1_bn (BatchNorma ['block9_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block9_sepconv2_act (Activatio ['block9_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 | |
| block9_sepconv2 (SeparableConv ['block9_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block9_sepconv2_bn (BatchNorma ['block9_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block9_sepconv3_act (Activatio ['block9_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 | |
| block9_sepconv3 (SeparableConv ['block9_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block9_sepconv3_bn (BatchNorma ['block9_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| add_7 (Add) | (None, None, None, | 0 | |

| | | | |
|--|-------------------------|--------|-----------------|
| ['block9_sepconv3_bn[0][0]', | 728) | | 'add_6[0][0]' |
| block10_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_7[0][0]'] |
| block10_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block10_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block10_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |
| block10_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block10_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block10_sepconv3_act (Activation) | (None, None, None, 728) | 0 | |
| block10_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block10_sepconv3_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| add_8 (Add) | (None, None, None, 728) | 0 | 'add_7[0][0]' |
| block11_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_8[0][0]'] |
| block11_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |

| | | | |
|--|----------------------------|--------|-----------------|
| block11_sepconv1_bn (BatchNorm ['block11_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| block11_sepconv2_act (Activati ['block11_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 | |
| block11_sepconv2 (SeparableCon ['block11_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 | |
| block11_sepconv2_bn (BatchNorm ['block11_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| block11_sepconv3_act (Activati ['block11_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 | |
| block11_sepconv3 (SeparableCon ['block11_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 | |
| block11_sepconv3_bn (BatchNorm ['block11_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| add_9 (Add) ['block11_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 | 'add_8[0][0]'] |
| block12_sepconv1_act (Activati on) | (None, None, None, 728) | 0 | ['add_9[0][0]'] |
| block12_sepconv1 (SeparableCon ['block12_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv1_bn (BatchNorm ['block12_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| block12_sepconv2_act (Activati ['block12_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 | |

| | | | |
|---|-----------------------------|--------|---------------|
| block12_sepconv2 (SeparableCon ['block12_sepconv2_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv2_bn (BatchNorm ['block12_sepconv2[0][0]' alization) | (None, None, None, 728) | 2912 | |
| block12_sepconv3_act (Activati ['block12_sepconv2_bn[0][0]' on) | (None, None, None, 728) | 0 | |
| block12_sepconv3 (SeparableCon ['block12_sepconv3_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]' alization) | (None, None, None, 728) | 2912 | |
| add_10 (Add) ['block12_sepconv3_bn[0][0]' | (None, None, None, 728) | 0 | 'add_9[0][0]' |
| block13_sepconv1_act (Activati ['add_10[0][0]' on) | (None, None, None, 728) | 0 | |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]' alization) | (None, None, None, 728) | 2912 | |
| block13_sepconv2_act (Activati ['block13_sepconv1_bn[0][0]' on) | (None, None, None, 728) | 0 | |
| block13_sepconv2 (SeparableCon ['block13_sepconv2_act[0][0]' v2D) | (None, None, None, 1024) | 752024 | |
| block13_sepconv2_bn (BatchNorm ['block13_sepconv2[0][0]' alization) | (None, None, None, 1024) | 4096 | |

| | | |
|---|-----------------------------|---------|
| conv2d_5 (Conv2D) ['add_10[0][0]'] | (None, None, None, 1024) | 745472 |
| block13_pool (MaxPooling2D) ['block13_sepconv2_bn[0][0]'] | (None, None, None, 1024) | 0 |
| batch_normalization_3 (BatchNormal ization) ['conv2d_5[0][0]'] | (None, None, None, 1024) | 4096 |
| add_11 (Add) ['block13_pool[0][0]', 'batch_normalization_3[0][0]'] | (None, None, None, 1024) | 0 |
| block14_sepconv1 (SeparableCon v2D) ['add_11[0][0]'] | (None, None, None, 1536) | 1582080 |
| block14_sepconv1_bn (BatchNorm alization) ['block14_sepconv1[0][0]'] | (None, None, None, 1536) | 6144 |
| block14_sepconv1_act (Activati on) ['block14_sepconv1_bn[0][0]'] | (None, None, None, 1536) | 0 |
| block14_sepconv2 (SeparableCon v2D) ['block14_sepconv1_act[0][0]'] | (None, None, None, 2048) | 3159552 |
| block14_sepconv2_bn (BatchNorm alization) ['block14_sepconv2[0][0]'] | (None, None, None, 2048) | 8192 |
| block14_sepconv2_act (Activati on) ['block14_sepconv2_bn[0][0]'] | (None, None, None, 2048) | 0 |
| global_average_pooling2d (Glob alAveragePooling2D) ['block14_sepconv2_act[0][0]'] | (None, 2048) | 0 |
| dense_2 (Dense) ['global_average_pooling2d[0][0]'] | (None, 4) | 8196 |

]

```

=====
Total params: 20,869,676
Trainable params: 20,815,148
Non-trainable params: 54,528
-----

```

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-----
Model: "model"
-----

```

| Layer (type) | Output Shape | Param # | Connected to |
|--|-------------------------|---------|--------------|
| ===== | | | |
| input_1 (InputLayer) | [(None, None, None, 3)] | 0 | [] |
| block1_conv1 (Conv2D) ['input_1[0][0]'] | (None, None, None, 32) | 864 | |
| block1_conv1_bn (BatchNormaliz ['block1_conv1[0][0]'] ation) | (None, None, None, 32) | 128 | |
| block1_conv1_act (Activation) ['block1_conv1_bn[0][0]'] | (None, None, None, 32) | 0 | |
| block1_conv2 (Conv2D) ['block1_conv1_act[0][0]'] | (None, None, None, 64) | 18432 | |
| block1_conv2_bn (BatchNormaliz ['block1_conv2[0][0]'] ation) | (None, None, None, 64) | 256 | |
| block1_conv2_act (Activation) ['block1_conv2_bn[0][0]'] | (None, None, None, 64) | 0 | |
| block2_sepconv1 (SeparableConv ['block1_conv2_act[0][0]'] 2D) | (None, None, None, 128) | 8768 | |
| block2_sepconv1_bn (BatchNorma ['block2_sepconv1[0][0]'] lization) | (None, None, None, 128) | 512 | |

| | | | |
|--|-------------------------|-------|---------------|
| block2_sepconv2_act (Activation) | (None, None, None, 128) | 0 | |
| ['block2_sepconv1_bn[0][0]'] | | | |
| block2_sepconv2 (SeparableConv2D) | (None, None, None, 128) | 17536 | |
| ['block2_sepconv2_act[0][0]'] | | | |
| block2_sepconv2_bn (BatchNormalization) | (None, None, None, 128) | 512 | |
| ['block2_sepconv2[0][0]'] | | | |
| conv2d_2 (Conv2D) | (None, None, None, 128) | 8192 | |
| ['block1_conv2_act[0][0]'] | | | |
| block2_pool (MaxPooling2D) | (None, None, None, 128) | 0 | |
| ['block2_sepconv2_bn[0][0]'] | | | |
| batch_normalization (BatchNormalization) | (None, None, None, 128) | 512 | |
| ['conv2d_2[0][0]'] | | | |
| add (Add) | (None, None, None, 128) | 0 | |
| ['block2_pool[0][0]', | | | |
| 'batch_normalization[0][0]'] | | | |
| block3_sepconv1_act (Activation) | (None, None, None, 128) | 0 | ['add[0][0]'] |
| block3_sepconv1 (SeparableConv2D) | (None, None, None, 256) | 33920 | |
| ['block3_sepconv1_act[0][0]'] | | | |
| block3_sepconv1_bn (BatchNormalization) | (None, None, None, 256) | 1024 | |
| ['block3_sepconv1[0][0]'] | | | |
| block3_sepconv2_act (Activation) | (None, None, None, 256) | 0 | |
| ['block3_sepconv1_bn[0][0]'] | | | |
| block3_sepconv2 (SeparableConv2D) | (None, None, None, 256) | 67840 | |
| ['block3_sepconv2_act[0][0]'] | | | |

| | | | |
|---|-------------------------|--------|-----------------|
| block3_sepconv2_bn (BatchNormal ['block3_sepconv2[0][0]'] lization) | (None, None, None, 256) | 1024 | |
| conv2d_3 (Conv2D) | (None, None, None, 256) | 32768 | ['add[0][0]'] |
| block3_pool (MaxPooling2D) ['block3_sepconv2_bn[0][0]'] | (None, None, None, 256) | 0 | |
| batch_normalization_1 (BatchNo ['conv2d_3[0][0]'] rmalization) | (None, None, None, 256) | 1024 | |
| add_1 (Add) ['block3_pool[0][0]', 'batch_normalization_1[0][0]'] | (None, None, None, 256) | 0 | |
| block4_sepconv1_act (Activatio n) | (None, None, None, 256) | 0 | ['add_1[0][0]'] |
| block4_sepconv1 (SeparableConv ['block4_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 188672 | |
| block4_sepconv1_bn (BatchNorma ['block4_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block4_sepconv2_act (Activatio ['block4_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 | |
| block4_sepconv2 (SeparableConv ['block4_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block4_sepconv2_bn (BatchNorma ['block4_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| conv2d_4 (Conv2D) | (None, None, None, 728) | 186368 | ['add_1[0][0]'] |
| block4_pool (MaxPooling2D) | (None, None, None, 0) | 0 | |

| | | | |
|--|-------------------------|--------|-----------------|
| ['block4_sepconv2_bn[0][0]'] | 728) | | |
| batch_normalization_2 (BatchNormal ['conv2d_4[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| add_2 (Add) ['block4_pool[0][0]', | (None, None, None, 728) | 0 | |
| 'batch_normalization_2[0][0]'] | | | |
| block5_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_2[0][0]'] |
| block5_sepconv1 (SeparableConv ['block5_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv1_bn (BatchNormal ['block5_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| block5_sepconv2_act (Activation) ['block5_sepconv1_bn[0][0]'] | (None, None, None, 728) | 0 | |
| block5_sepconv2 (SeparableConv ['block5_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv2_bn (BatchNormal ['block5_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| block5_sepconv3_act (Activation) ['block5_sepconv2_bn[0][0]'] | (None, None, None, 728) | 0 | |
| block5_sepconv3 (SeparableConv ['block5_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block5_sepconv3_bn (BatchNormal ['block5_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 | |
| add_3 (Add) | (None, None, None, | 0 | |

| | | | |
|---|-------------------------|--------|-----------------|
| ['block5_sepconv3_bn[0][0]', | 728) | | 'add_2[0][0]'] |
| block6_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_3[0][0]'] |
| block6_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block6_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block6_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |
| block6_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block6_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| block6_sepconv3_act (Activation) | (None, None, None, 728) | 0 | |
| block6_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block6_sepconv3_bn (BatchNormalization) | (None, None, None, 728) | 2912 | |
| add_4 (Add) | (None, None, None, 728) | 0 | 'add_3[0][0]'] |
| block7_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_4[0][0]'] |
| block7_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |

| | | | |
|--|-------------------------|--------|-----------------|
| block7_sepconv1_bn (BatchNormaliza- tion) | (None, None, None, 728) | 2912 | |
| block7_sepconv1_act (Activation) | (None, None, None, 728) | 0 | |
| block7_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block7_sepconv2_bn (BatchNormaliza- tion) | (None, None, None, 728) | 2912 | |
| block7_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |
| block7_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block7_sepconv3_bn (BatchNormaliza- tion) | (None, None, None, 728) | 2912 | |
| block7_sepconv3_act (Activation) | (None, None, None, 728) | 0 | |
| block7_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| add_5 (Add) | (None, None, None, 728) | 0 | 'add_4[0][0]' |
| block8_sepconv1_act (Activation) | (None, None, None, 728) | 0 | ['add_5[0][0]'] |
| block8_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 | |
| block8_sepconv1_bn (BatchNormaliza- tion) | (None, None, None, 728) | 2912 | |
| block8_sepconv2_act (Activation) | (None, None, None, 728) | 0 | |

| | | | |
|--|----------------------------|--------|-----------------|
| block8_sepconv2 (SeparableConv ['block8_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block8_sepconv2_bn (BatchNorma ['block8_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block8_sepconv3_act (Activatio ['block8_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 | |
| block8_sepconv3 (SeparableConv ['block8_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block8_sepconv3_bn (BatchNorma ['block8_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| add_6 (Add) ['block8_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 | 'add_5[0][0]'] |
| block9_sepconv1_act (Activatio n) | (None, None, None, 728) | 0 | ['add_6[0][0]'] |
| block9_sepconv1 (SeparableConv ['block9_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block9_sepconv1_bn (BatchNorma ['block9_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block9_sepconv2_act (Activatio ['block9_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 | |
| block9_sepconv2 (SeparableConv ['block9_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 | |
| block9_sepconv2_bn (BatchNorma ['block9_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 | |
| block9_sepconv3_act (Activatio | (None, None, None, | 0 | |

| | | |
|--|-------------------------|-----------------|
| ['block9_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | |
| block9_sepconv3 (SeparableConv ['block9_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block9_sepconv3_bn (BatchNorma ['block9_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_7 (Add) ['block9_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 |
| | | 'add_6[0][0]'] |
| block10_sepconv1_act (Activati on) | (None, None, None, 728) | 0 |
| | | ['add_7[0][0]'] |
| block10_sepconv1 (SeparableCon ['block10_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv1_bn (BatchNorm ['block10_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv2_act (Activati ['block10_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv2 (SeparableCon ['block10_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv2_bn (BatchNorm ['block10_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv3_act (Activati ['block10_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv3 (SeparableCon ['block10_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv3_bn (BatchNorm ['block10_sepconv3[0][0]'] | (None, None, None, 728) | 2912 |

| | | |
|--------------------------------|--------------------|-----------------|
| alization) | 728) | |
| add_8 (Add) | (None, None, None, | 0 |
| ['block10_sepconv3_bn[0][0]', | 728) | 'add_7[0][0]' |
| block11_sepconv1_act (Activati | (None, None, None, | 0 |
| on) | 728) | ['add_8[0][0]'] |
| block11_sepconv1 (SeparableCon | (None, None, None, | 536536 |
| ['block11_sepconv1_act[0][0]'] | 728) | |
| v2D) | | |
| block11_sepconv1_bn (BatchNorm | (None, None, None, | 2912 |
| ['block11_sepconv1[0][0]'] | 728) | |
| alization) | | |
| block11_sepconv2_act (Activati | (None, None, None, | 0 |
| ['block11_sepconv1_bn[0][0]'] | 728) | |
| on) | | |
| block11_sepconv2 (SeparableCon | (None, None, None, | 536536 |
| ['block11_sepconv2_act[0][0]'] | 728) | |
| v2D) | | |
| block11_sepconv2_bn (BatchNorm | (None, None, None, | 2912 |
| ['block11_sepconv2[0][0]'] | 728) | |
| alization) | | |
| block11_sepconv3_act (Activati | (None, None, None, | 0 |
| ['block11_sepconv2_bn[0][0]'] | 728) | |
| on) | | |
| block11_sepconv3 (SeparableCon | (None, None, None, | 536536 |
| ['block11_sepconv3_act[0][0]'] | 728) | |
| v2D) | | |
| block11_sepconv3_bn (BatchNorm | (None, None, None, | 2912 |
| ['block11_sepconv3[0][0]'] | 728) | |
| alization) | | |
| add_9 (Add) | (None, None, None, | 0 |
| ['block11_sepconv3_bn[0][0]', | 728) | 'add_8[0][0]' |
| | | |
| block12_sepconv1_act (Activati | (None, None, None, | 0 |
| on) | 728) | ['add_9[0][0]'] |

| | | | |
|---|----------------------------|--------|---------------|
| block12_sepconv1 (SeparableCon ['block12_sepconv1_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv1_bn (BatchNorm ['block12_sepconv1[0][0]' alization) | (None, None, None, 728) | 2912 | |
| block12_sepconv2_act (Activati ['block12_sepconv1_bn[0][0]' on) | (None, None, None, 728) | 0 | |
| block12_sepconv2 (SeparableCon ['block12_sepconv2_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv2_bn (BatchNorm ['block12_sepconv2[0][0]' alization) | (None, None, None, 728) | 2912 | |
| block12_sepconv3_act (Activati ['block12_sepconv2_bn[0][0]' on) | (None, None, None, 728) | 0 | |
| block12_sepconv3 (SeparableCon ['block12_sepconv3_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]' alization) | (None, None, None, 728) | 2912 | |
| add_10 (Add) ['block12_sepconv3_bn[0][0]', | (None, None, None, 728) | 0 | 'add_9[0][0]' |
| block13_sepconv1_act (Activati ['add_10[0][0]' on) | (None, None, None, 728) | 0 | |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]' v2D) | (None, None, None, 728) | 536536 | |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]' alization) | (None, None, None, 728) | 2912 | |

| | | |
|--|--------------------------|---------|
| block13_sepconv2_act (Activation) | (None, None, None, 728) | 0 |
| ['block13_sepconv1_bn[0][0]'] | | |
| block13_sepconv2 (SeparableConv2D) | (None, None, None, 1024) | 752024 |
| ['block13_sepconv2_act[0][0]'] | | |
| block13_sepconv2_bn (BatchNormalization) | (None, None, None, 1024) | 4096 |
| ['block13_sepconv2[0][0]'] | | |
| conv2d_5 (Conv2D) | (None, None, None, 1024) | 745472 |
| ['add_10[0][0]'] | | |
| block13_pool (MaxPooling2D) | (None, None, None, 1024) | 0 |
| ['block13_sepconv2_bn[0][0]'] | | |
| batch_normalization_3 (BatchNormalization) | (None, None, None, 1024) | 4096 |
| ['conv2d_5[0][0]'] | | |
| add_11 (Add) | (None, None, None, 1024) | 0 |
| ['block13_pool[0][0]', | | |
| 'batch_normalization_3[0][0]'] | | |
| block14_sepconv1 (SeparableConv2D) | (None, None, None, 1536) | 1582080 |
| ['add_11[0][0]'] | | |
| block14_sepconv1_bn (BatchNormalization) | (None, None, None, 1536) | 6144 |
| ['block14_sepconv1[0][0]'] | | |
| block14_sepconv1_act (Activation) | (None, None, None, 1536) | 0 |
| ['block14_sepconv1_bn[0][0]'] | | |
| block14_sepconv2 (SeparableConv2D) | (None, None, None, 2048) | 3159552 |
| ['block14_sepconv1_act[0][0]'] | | |
| block14_sepconv2_bn (BatchNormalization) | (None, None, None, 2048) | 8192 |
| ['block14_sepconv2[0][0]'] | | |

```

block14_sepconv2_act (Activation) (None, None, None, 0
['block14_sepconv2_bn[0][0]']
on) 2048)

global_average_pooling2d (GlobalAveragePooling2D) (None, 2048) 0
['block14_sepconv2_act[0][0]']
alAveragePooling2D)

dense_2 (Dense) (None, 4) 8196
['global_average_pooling2d[0][0]']
]

```

```

=====
Total params: 20,869,676
Trainable params: 8,196
Non-trainable params: 20,861,480
-----

```

```

[18]: epochs = 20
optimizer = tf.keras.optimizers.SGD(learning_rate=0.2, momentum=0.9, decay=0.01)
model.compile(loss="sparse_categorical_crossentropy", optimizer=optimizer,
metrics=["accuracy"])
history = model.fit(X_train,
                    y_train,
                    epochs=epochs,
                    verbose=1,
                    batch_size=128,
                    validation_data=(X_test, y_test))

```

Epoch 1/20

```

/Users/sakshisuman12/miniforge3/lib/python3.9/site-
packages/tensorflow/python/data/ops/structured_function.py:264: UserWarning:
Even though the `tf.config.experimental_run_functions_eagerly` option is set,
this option does not apply to tf.data functions. To force eager execution of
tf.data functions, please use `tf.data.experimental.enable_debug_mode()`.
warnings.warn(

```

```

4/4 [=====] - 8s 2s/step - loss: 1.1502 - accuracy:
0.5791 - val_loss: 0.5406 - val_accuracy: 0.5410

```

Epoch 2/20

```

4/4 [=====] - 8s 2s/step - loss: 1.0453 - accuracy:
0.4867 - val_loss: 0.6380 - val_accuracy: 0.5410

```

Epoch 3/20

```

4/4 [=====] - 8s 2s/step - loss: 1.0087 - accuracy:
0.5791 - val_loss: 0.7834 - val_accuracy: 0.5410

```

Epoch 4/20
4/4 [=====] - 8s 2s/step - loss: 1.0211 - accuracy:
0.5791 - val_loss: 0.6414 - val_accuracy: 0.5410
Epoch 5/20
4/4 [=====] - 8s 2s/step - loss: 1.0264 - accuracy:
0.5791 - val_loss: 0.6327 - val_accuracy: 0.5410
Epoch 6/20
4/4 [=====] - 8s 2s/step - loss: 1.0040 - accuracy:
0.5791 - val_loss: 0.7459 - val_accuracy: 0.5410
Epoch 7/20
4/4 [=====] - 8s 2s/step - loss: 1.0047 - accuracy:
0.5791 - val_loss: 0.6602 - val_accuracy: 0.5410
Epoch 8/20
4/4 [=====] - 8s 2s/step - loss: 0.9924 - accuracy:
0.5791 - val_loss: 0.6284 - val_accuracy: 0.5410
Epoch 9/20
4/4 [=====] - 8s 2s/step - loss: 0.9876 - accuracy:
0.5791 - val_loss: 0.6651 - val_accuracy: 0.5410
Epoch 10/20
4/4 [=====] - 8s 2s/step - loss: 0.9856 - accuracy:
0.5791 - val_loss: 0.6529 - val_accuracy: 0.5410
Epoch 11/20
4/4 [=====] - 8s 2s/step - loss: 0.9787 - accuracy:
0.5791 - val_loss: 0.6632 - val_accuracy: 0.5410
Epoch 12/20
4/4 [=====] - 8s 2s/step - loss: 0.9891 - accuracy:
0.5791 - val_loss: 0.6458 - val_accuracy: 0.5410
Epoch 13/20
4/4 [=====] - 8s 2s/step - loss: 1.0067 - accuracy:
0.5791 - val_loss: 0.6498 - val_accuracy: 0.5410
Epoch 14/20
4/4 [=====] - 8s 2s/step - loss: 1.0014 - accuracy:
0.4620 - val_loss: 0.7277 - val_accuracy: 0.5410
Epoch 15/20
4/4 [=====] - 8s 2s/step - loss: 0.9917 - accuracy:
0.5791 - val_loss: 0.6132 - val_accuracy: 0.5410
Epoch 16/20
4/4 [=====] - 8s 2s/step - loss: 0.9723 - accuracy:
0.5791 - val_loss: 0.7633 - val_accuracy: 0.5410
Epoch 17/20
4/4 [=====] - 8s 2s/step - loss: 0.9805 - accuracy:
0.5791 - val_loss: 0.6223 - val_accuracy: 0.5410
Epoch 18/20
4/4 [=====] - 9s 2s/step - loss: 0.9801 - accuracy:
0.5791 - val_loss: 0.7021 - val_accuracy: 0.5410
Epoch 19/20
4/4 [=====] - 9s 2s/step - loss: 0.9744 - accuracy:
0.5791 - val_loss: 0.6682 - val_accuracy: 0.5410

Epoch 20/20
 4/4 [=====] - 9s 2s/step - loss: 0.9730 - accuracy:
 0.5791 - val_loss: 0.6532 - val_accuracy: 0.5410

```
[19]: X_train = x_train.astype('float32')
X_test = x_test.astype('float32')
X_train /= 255.0
X_test /= 255.0

# one-hot encoding:
Y_train = np_utils.to_categorical(y_train, NUM_LABELS)
Y_test = np_utils.to_categorical(y_test, NUM_LABELS)

print()
print('MRI data loaded: train:', len(X_train), 'test:', len(X_test))
print('x_train:', x_train.shape)
print('X_train:', X_train.shape)
print('y_train:', y_train.shape)
print('Y_train:', Y_train.shape)
```

MRI data loaded: train: 487 test: 122
 x_train: (487, 224, 224, 3)
 X_train: (487, 224, 224, 3)
 y_train: (487,)
 Y_train: (487, 4)

```
[20]: n_classes=NUM_LABELS
base_model = tf.keras.applications.xception.Xception(weights="imagenet",
include_top=False)
avg = tf.keras.layers.GlobalAveragePooling2D()(base_model.output)
output = tf.keras.layers.Dense(n_classes, activation="softmax")(avg)
model = tf.keras.Model(inputs=base_model.input, outputs=output)
model.summary()
for layer in base_model.layers:
    layer.trainable = False
model.summary()
```

Model: "model_1"

```
-----
Layer (type)                Output Shape          Param #   Connected to
=====
input_2 (InputLayer)        [(None, None, None,  0
                        3)]
block1_conv1 (Conv2D)        (None, None, None,   864
['input_2[0][0]'])
```

```

32)

block1_conv1_bn (BatchNormaliz (None, None, None, 128
['block1_conv1[0][0] '
ation)
32)

block1_conv1_act (Activation) (None, None, None, 0
['block1_conv1_bn[0][0] '
32)

block1_conv2 (Conv2D) (None, None, None, 18432
['block1_conv1_act[0][0] '
64)

block1_conv2_bn (BatchNormaliz (None, None, None, 256
['block1_conv2[0][0] '
ation)
64)

block1_conv2_act (Activation) (None, None, None, 0
['block1_conv2_bn[0][0] '
64)

block2_sepconv1 (SeparableConv (None, None, None, 8768
['block1_conv2_act[0][0] '
2D)
128)

block2_sepconv1_bn (BatchNorma (None, None, None, 512
['block2_sepconv1[0][0] '
lization)
128)

block2_sepconv2_act (Activatio (None, None, None, 0
['block2_sepconv1_bn[0][0] '
n)
128)

block2_sepconv2 (SeparableConv (None, None, None, 17536
['block2_sepconv2_act[0][0] '
2D)
128)

block2_sepconv2_bn (BatchNorma (None, None, None, 512
['block2_sepconv2[0][0] '
lization)
128)

conv2d_6 (Conv2D) (None, None, None, 8192
['block1_conv2_act[0][0] '
128)

block2_pool (MaxPooling2D) (None, None, None, 0
['block2_sepconv2_bn[0][0] '

```

```

128)

batch_normalization_4 (BatchNormalizatio (None, None, None, 512
['conv2d_6[0][0]'])
rmalization) 128)

add_12 (Add) (None, None, None, 0
['block2_pool[0][0]',
128)
'batch_normalization_4[0][0]'])

block3_sepconv1_act (Activation) (None, None, None, 0
['add_12[0][0]'])
n) 128)

block3_sepconv1 (SeparableConv2D) (None, None, None, 33920
['block3_sepconv1_act[0][0]'])
2D) 256)

block3_sepconv1_bn (BatchNormalization) (None, None, None, 1024
['block3_sepconv1[0][0]'])
lization) 256)

block3_sepconv2_act (Activation) (None, None, None, 0
['block3_sepconv1_bn[0][0]'])
n) 256)

block3_sepconv2 (SeparableConv2D) (None, None, None, 67840
['block3_sepconv2_act[0][0]'])
2D) 256)

block3_sepconv2_bn (BatchNormalization) (None, None, None, 1024
['block3_sepconv2[0][0]'])
lization) 256)

conv2d_7 (Conv2D) (None, None, None, 32768
['add_12[0][0]'])
256)

block3_pool (MaxPooling2D) (None, None, None, 0
['block3_sepconv2_bn[0][0]'])
256)

batch_normalization_5 (BatchNormalization) (None, None, None, 1024
['conv2d_7[0][0]'])
rmalization) 256)

add_13 (Add) (None, None, None, 0

```

```

['block3_pool[0][0]',
                                256)
'batch_normalization_5[0][0]']

block4_sepconv1_act (Activation) (None, None, None, 0
['add_13[0][0]']
n)                                256)

block4_sepconv1 (SeparableConv) (None, None, None, 188672
['block4_sepconv1_act[0][0]']
2D)                                728)

block4_sepconv1_bn (BatchNormaliza (None, None, None, 2912
['block4_sepconv1[0][0]']
lization)                                728)

block4_sepconv2_act (Activation) (None, None, None, 0
['block4_sepconv1_bn[0][0]']
n)                                728)

block4_sepconv2 (SeparableConv) (None, None, None, 536536
['block4_sepconv2_act[0][0]']
2D)                                728)

block4_sepconv2_bn (BatchNormaliza (None, None, None, 2912
['block4_sepconv2[0][0]']
lization)                                728)

conv2d_8 (Conv2D) (None, None, None, 186368
['add_13[0][0]']
                                728)

block4_pool (MaxPooling2D) (None, None, None, 0
['block4_sepconv2_bn[0][0]']
                                728)

batch_normalization_6 (BatchNormaliza (None, None, None, 2912
['conv2d_8[0][0]']
tion)                                728)

add_14 (Add) (None, None, None, 0
['block4_pool[0][0]',
                                728)
'batch_normalization_6[0][0]']

block5_sepconv1_act (Activation) (None, None, None, 0
['add_14[0][0]']
n)                                728)

```

| | | |
|--|----------------------------|--------|
| block5_sepconv1 (SeparableConv ['block5_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv1_bn (BatchNorma ['block5_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block5_sepconv2_act (Activatio ['block5_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block5_sepconv2 (SeparableConv ['block5_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv2_bn (BatchNorma ['block5_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block5_sepconv3_act (Activatio ['block5_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block5_sepconv3 (SeparableConv ['block5_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv3_bn (BatchNorma ['block5_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_15 (Add) ['block5_sepconv3_bn[0][0]', 'add_14[0][0]'] | (None, None, None, 728) | 0 |
| block6_sepconv1_act (Activatio ['add_15[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv1 (SeparableConv ['block6_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv1_bn (BatchNorma ['block6_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |

| | | |
|--|----------------------------|--------|
| lization) | 728) | |
| block6_sepconv2_act (Activatio ['block6_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv2 (SeparableConv ['block6_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv2_bn (BatchNorma ['block6_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block6_sepconv3_act (Activatio ['block6_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv3 (SeparableConv ['block6_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv3_bn (BatchNorma ['block6_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_16 (Add) ['block6_sepconv3_bn[0][0]', 'add_15[0][0]'] | (None, None, None, 728) | 0 |
| block7_sepconv1_act (Activatio ['add_16[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv1 (SeparableConv ['block7_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv1_bn (BatchNorma ['block7_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv2_act (Activatio ['block7_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv2 (SeparableConv | (None, None, None, | 536536 |

| | | |
|--|-------------------------|--------|
| ['block7_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 2912 |
| block7_sepconv2_bn (BatchNorma ['block7_sepconv2[0][0]'] lization) | (None, None, None, 728) | 0 |
| block7_sepconv3_act (Activatio ['block7_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 536536 |
| block7_sepconv3 (SeparableConv ['block7_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 2912 |
| block7_sepconv3_bn (BatchNorma ['block7_sepconv3[0][0]'] lization) | (None, None, None, 728) | 0 |
| add_17 (Add) ['block7_sepconv3_bn[0][0]', 'add_16[0][0]'] | (None, None, None, 728) | 0 |
| block8_sepconv1_act (Activatio ['add_17[0][0]'] n) | (None, None, None, 728) | 536536 |
| block8_sepconv1 (SeparableConv ['block8_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 2912 |
| block8_sepconv1_bn (BatchNorma ['block8_sepconv1[0][0]'] lization) | (None, None, None, 728) | 0 |
| block8_sepconv2_act (Activatio ['block8_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 536536 |
| block8_sepconv2 (SeparableConv ['block8_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 2912 |
| block8_sepconv2_bn (BatchNorma ['block8_sepconv2[0][0]'] lization) | (None, None, None, 728) | |

| | | |
|---|-------------------------|--------|
| block8_sepconv3_act (Activation) | (None, None, None, 0) | 0 |
| ['block8_sepconv2_bn[0][0]'] | 728) | |
| block8_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block8_sepconv3_act[0][0]'] | | |
| block8_sepconv3_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block8_sepconv3[0][0]'] | | |
| add_18 (Add) | (None, None, None, 0) | 0 |
| ['block8_sepconv3_bn[0][0]', | 728) | |
| 'add_17[0][0]'] | | |
| block9_sepconv1_act (Activation) | (None, None, None, 0) | 0 |
| ['add_18[0][0]'] | 728) | |
| block9_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv1_act[0][0]'] | | |
| block9_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block9_sepconv1[0][0]'] | | |
| block9_sepconv2_act (Activation) | (None, None, None, 0) | 0 |
| ['block9_sepconv1_bn[0][0]'] | 728) | |
| block9_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv2_act[0][0]'] | | |
| block9_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block9_sepconv2[0][0]'] | | |
| block9_sepconv3_act (Activation) | (None, None, None, 0) | 0 |
| ['block9_sepconv2_bn[0][0]'] | 728) | |
| block9_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv3_act[0][0]'] | | |


```

block9_sepconv3_bn (BatchNorm (None, None, None, 2912
['block9_sepconv3[0][0] ']
lization) 728)

add_19 (Add) (None, None, None, 0
['block9_sepconv3_bn[0][0] ',
728)
'add_18[0][0] ']

block10_sepconv1_act (Activati (None, None, None, 0
['add_19[0][0] ']
on) 728)

block10_sepconv1 (SeparableCon (None, None, None, 536536
['block10_sepconv1_act[0][0] ']
v2D) 728)

block10_sepconv1_bn (BatchNorm (None, None, None, 2912
['block10_sepconv1[0][0] ']
alization) 728)

block10_sepconv2_act (Activati (None, None, None, 0
['block10_sepconv1_bn[0][0] ']
on) 728)

block10_sepconv2 (SeparableCon (None, None, None, 536536
['block10_sepconv2_act[0][0] ']
v2D) 728)

block10_sepconv2_bn (BatchNorm (None, None, None, 2912
['block10_sepconv2[0][0] ']
alization) 728)

block10_sepconv3_act (Activati (None, None, None, 0
['block10_sepconv2_bn[0][0] ']
on) 728)

block10_sepconv3 (SeparableCon (None, None, None, 536536
['block10_sepconv3_act[0][0] ']
v2D) 728)

block10_sepconv3_bn (BatchNorm (None, None, None, 2912
['block10_sepconv3[0][0] ']
alization) 728)

add_20 (Add) (None, None, None, 0
['block10_sepconv3_bn[0][0] ',

```

```

728)
'add_19[0][0]']

block11_sepconv1_act (Activati (None, None, None, 0
['add_20[0][0]']
on) 728)

block11_sepconv1 (SeparableCon (None, None, None, 536536
['block11_sepconv1_act[0][0]']
v2D) 728)

block11_sepconv1_bn (BatchNorm (None, None, None, 2912
['block11_sepconv1[0][0]']
alization) 728)

block11_sepconv2_act (Activati (None, None, None, 0
['block11_sepconv1_bn[0][0]']
on) 728)

block11_sepconv2 (SeparableCon (None, None, None, 536536
['block11_sepconv2_act[0][0]']
v2D) 728)

block11_sepconv2_bn (BatchNorm (None, None, None, 2912
['block11_sepconv2[0][0]']
alization) 728)

block11_sepconv3_act (Activati (None, None, None, 0
['block11_sepconv2_bn[0][0]']
on) 728)

block11_sepconv3 (SeparableCon (None, None, None, 536536
['block11_sepconv3_act[0][0]']
v2D) 728)

block11_sepconv3_bn (BatchNorm (None, None, None, 2912
['block11_sepconv3[0][0]']
alization) 728)

add_21 (Add) (None, None, None, 0
['block11_sepconv3_bn[0][0]'],
728)
'add_20[0][0]']

block12_sepconv1_act (Activati (None, None, None, 0
['add_21[0][0]']
on) 728)

```

| | | |
|---|----------------------------|--------|
| block12_sepconv1 (SeparableCon ['block12_sepconv1_act[0][0]' v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv1_bn (BatchNorm ['block12_sepconv1[0][0]' alization) | (None, None, None, 728) | 2912 |
| block12_sepconv2_act (Activati ['block12_sepconv1_bn[0][0]' on) | (None, None, None, 728) | 0 |
| block12_sepconv2 (SeparableCon ['block12_sepconv2_act[0][0]' v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv2_bn (BatchNorm ['block12_sepconv2[0][0]' alization) | (None, None, None, 728) | 2912 |
| block12_sepconv3_act (Activati ['block12_sepconv2_bn[0][0]' on) | (None, None, None, 728) | 0 |
| block12_sepconv3 (SeparableCon ['block12_sepconv3_act[0][0]' v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]' alization) | (None, None, None, 728) | 2912 |
| add_22 (Add) ['block12_sepconv3_bn[0][0]' 'add_21[0][0]'] | (None, None, None, 728) | 0 |
| block13_sepconv1_act (Activati ['add_22[0][0]' on) | (None, None, None, 728) | 0 |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]' v2D) | (None, None, None, 728) | 536536 |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]' alization) | (None, None, None, 728) | 2912 |

| | | |
|--|--------------------------|---------|
| block13_sepconv2_act (Activation) | (None, None, None, 728) | 0 |
| ['block13_sepconv1_bn[0][0]'] | | |
| block13_sepconv2 (SeparableConv2D) | (None, None, None, 1024) | 752024 |
| ['block13_sepconv2_act[0][0]'] | | |
| block13_sepconv2_bn (BatchNormalization) | (None, None, None, 1024) | 4096 |
| ['block13_sepconv2[0][0]'] | | |
| conv2d_9 (Conv2D) | (None, None, None, 1024) | 745472 |
| ['add_22[0][0]'] | | |
| block13_pool (MaxPooling2D) | (None, None, None, 1024) | 0 |
| ['block13_sepconv2_bn[0][0]'] | | |
| batch_normalization_7 (BatchNormalization) | (None, None, None, 1024) | 4096 |
| ['conv2d_9[0][0]'] | | |
| add_23 (Add) | (None, None, None, 1024) | 0 |
| ['block13_pool[0][0]', | | |
| 'batch_normalization_7[0][0]'] | | |
| block14_sepconv1 (SeparableConv2D) | (None, None, None, 1536) | 1582080 |
| ['add_23[0][0]'] | | |
| block14_sepconv1_bn (BatchNormalization) | (None, None, None, 1536) | 6144 |
| ['block14_sepconv1[0][0]'] | | |
| block14_sepconv1_act (Activation) | (None, None, None, 1536) | 0 |
| ['block14_sepconv1_bn[0][0]'] | | |
| block14_sepconv2 (SeparableConv2D) | (None, None, None, 2048) | 3159552 |
| ['block14_sepconv1_act[0][0]'] | | |
| block14_sepconv2_bn (BatchNormalization) | (None, None, None, 8192) | |
| ['block14_sepconv2[0][0]'] | | |

```

alization)                                2048)

block14_sepconv2_act (Activation) (None, None, None, 0
['block14_sepconv2_bn[0][0]']
on)                                2048)

global_average_pooling2d_1 (GlobalAveragePooling2D) (None, 2048) 0
['block14_sepconv2_act[0][0]']
obalAveragePooling2D)

dense_3 (Dense) (None, 4) 8196
['global_average_pooling2d_1[0][0]']
]']

```

```

=====
Total params: 20,869,676
Trainable params: 20,815,148
Non-trainable params: 54,528
-----

```

```

-----
Model: "model_1"
-----

```

| Layer (type) | Output Shape | Param # | Connected to |
|--|-------------------------|---------|--------------|
| input_2 (InputLayer) | [(None, None, None, 3)] | 0 | [] |
| block1_conv1 (Conv2D) ['input_2[0][0]'] | (None, None, None, 32) | 864 | |
| block1_conv1_bn (BatchNormalization) ['block1_conv1[0][0]'] | (None, None, None, 32) | 128 | |
| block1_conv1_act (Activation) ['block1_conv1_bn[0][0]'] | (None, None, None, 32) | 0 | |
| block1_conv2 (Conv2D) ['block1_conv1_act[0][0]'] | (None, None, None, 64) | 18432 | |
| block1_conv2_bn (BatchNormalization) ['block1_conv2[0][0]'] | (None, None, None, 64) | 256 | |

| | | |
|--------------------------------|---------------------------|-------|
| ation) | (None, None, None, 64) | |
| block1_conv2_act (Activation) | (None, None, None, 64) | 0 |
| ['block1_conv2_bn[0][0]'] | | |
| block2_sepconv1 (SeparableConv | (None, None, None, 128) | 8768 |
| ['block1_conv2_act[0][0]'] | | |
| 2D) | | |
| block2_sepconv1_bn (BatchNorma | (None, None, None, 128) | 512 |
| ['block2_sepconv1[0][0]'] | | |
| lization) | | |
| block2_sepconv2_act (Activatio | (None, None, None, 128) | 0 |
| ['block2_sepconv1_bn[0][0]'] | | |
| n) | | |
| block2_sepconv2 (SeparableConv | (None, None, None, 128) | 17536 |
| ['block2_sepconv2_act[0][0]'] | | |
| 2D) | | |
| block2_sepconv2_bn (BatchNorma | (None, None, None, 128) | 512 |
| ['block2_sepconv2[0][0]'] | | |
| lization) | | |
| conv2d_6 (Conv2D) | (None, None, None, 128) | 8192 |
| ['block1_conv2_act[0][0]'] | | |
| block2_pool (MaxPooling2D) | (None, None, None, 128) | 0 |
| ['block2_sepconv2_bn[0][0]'] | | |
| batch_normalization_4 (BatchNo | (None, None, None, 128) | 512 |
| ['conv2d_6[0][0]'] | | |
| rmalization) | | |
| add_12 (Add) | (None, None, None, 128) | 0 |
| ['block2_pool[0][0]', | | |
| 'batch_normalization_4[0][0]'] | | |
| block3_sepconv1_act (Activatio | (None, None, None, 128) | 0 |
| ['add_12[0][0]'] | | |
| n) | | |
| block3_sepconv1 (SeparableConv | (None, None, None, 33920) | |

| | | |
|--|-------------------------|--------|
| ['block3_sepconv1_act[0][0]'] 2D) | (None, None, None, 256) | 1024 |
| block3_sepconv1_bn (BatchNorma ['block3_sepconv1[0][0]'] lization) | (None, None, None, 256) | 1024 |
| block3_sepconv2_act (Activatio ['block3_sepconv1_bn[0][0]'] n) | (None, None, None, 256) | 0 |
| block3_sepconv2 (SeparableConv ['block3_sepconv2_act[0][0]'] 2D) | (None, None, None, 256) | 67840 |
| block3_sepconv2_bn (BatchNorma ['block3_sepconv2[0][0]'] lization) | (None, None, None, 256) | 1024 |
| conv2d_7 (Conv2D) ['add_12[0][0]'] | (None, None, None, 256) | 32768 |
| block3_pool (MaxPooling2D) ['block3_sepconv2_bn[0][0]'] | (None, None, None, 256) | 0 |
| batch_normalization_5 (BatchNo ['conv2d_7[0][0]'] rmalization) | (None, None, None, 256) | 1024 |
| add_13 (Add) ['block3_pool[0][0]', 'batch_normalization_5[0][0]'] | (None, None, None, 256) | 0 |
| block4_sepconv1_act (Activatio ['add_13[0][0]'] n) | (None, None, None, 256) | 0 |
| block4_sepconv1 (SeparableConv ['block4_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 188672 |
| block4_sepconv1_bn (BatchNorma ['block4_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |

| | | |
|--|-------------------------|--------|
| block4_sepconv2_act (Activation) | (None, None, None, 728) | 0 |
| ['block4_sepconv1_bn[0][0]'] | | |
| block4_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block4_sepconv2_act[0][0]'] | | |
| block4_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block4_sepconv2[0][0]'] | | |
| conv2d_8 (Conv2D) | (None, None, None, 728) | 186368 |
| ['add_13[0][0]'] | | |
| block4_pool (MaxPooling2D) | (None, None, None, 728) | 0 |
| ['block4_sepconv2_bn[0][0]'] | | |
| batch_normalization_6 (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['conv2d_8[0][0]'] | | |
| add_14 (Add) | (None, None, None, 728) | 0 |
| ['block4_pool[0][0]', | | |
| 'batch_normalization_6[0][0]'] | | |
| block5_sepconv1_act (Activation) | (None, None, None, 728) | 0 |
| ['add_14[0][0]'] | | |
| block5_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block5_sepconv1_act[0][0]'] | | |
| block5_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block5_sepconv1[0][0]'] | | |
| block5_sepconv2_act (Activation) | (None, None, None, 728) | 0 |
| ['block5_sepconv1_bn[0][0]'] | | |
| block5_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block5_sepconv2_act[0][0]'] | | |

| | | |
|--|----------------------------|--------|
| block5_sepconv2_bn (BatchNorma ['block5_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block5_sepconv3_act (Activatio ['block5_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block5_sepconv3 (SeparableConv ['block5_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv3_bn (BatchNorma ['block5_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_15 (Add) ['block5_sepconv3_bn[0][0]', 'add_14[0][0]'] | (None, None, None, 728) | 0 |
| block6_sepconv1_act (Activatio ['add_15[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv1 (SeparableConv ['block6_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv1_bn (BatchNorma ['block6_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block6_sepconv2_act (Activatio ['block6_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv2 (SeparableConv ['block6_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv2_bn (BatchNorma ['block6_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block6_sepconv3_act (Activatio ['block6_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |

| | | |
|--|----------------------------|--------|
| n) | 728) | |
| block6_sepconv3 (SeparableConv ['block6_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv3_bn (BatchNorma ['block6_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_16 (Add) ['block6_sepconv3_bn[0][0]', 'add_15[0][0]'] | (None, None, None, 728) | 0 |
| block7_sepconv1_act (Activatio ['add_16[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv1 (SeparableConv ['block7_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv1_bn (BatchNorma ['block7_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv2_act (Activatio ['block7_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv2 (SeparableConv ['block7_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv2_bn (BatchNorma ['block7_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv3_act (Activatio ['block7_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv3 (SeparableConv ['block7_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv3_bn (BatchNorma | (None, None, None, | 2912 |

```

['block7_sepconv3[0][0]']
lization)                                728)

add_17 (Add)                             (None, None, None, 0
['block7_sepconv3_bn[0][0]',
728)
'add_16[0][0]']

block8_sepconv1_act (Activatio (None, None, None, 0
['add_17[0][0]']
n)                                728)

block8_sepconv1 (SeparableConv (None, None, None, 536536
['block8_sepconv1_act[0][0]']
2D)                                728)

block8_sepconv1_bn (BatchNorma (None, None, None, 2912
['block8_sepconv1[0][0]']
lization)                            728)

block8_sepconv2_act (Activatio (None, None, None, 0
['block8_sepconv1_bn[0][0]']
n)                                728)

block8_sepconv2 (SeparableConv (None, None, None, 536536
['block8_sepconv2_act[0][0]']
2D)                                728)

block8_sepconv2_bn (BatchNorma (None, None, None, 2912
['block8_sepconv2[0][0]']
lization)                            728)

block8_sepconv3_act (Activatio (None, None, None, 0
['block8_sepconv2_bn[0][0]']
n)                                728)

block8_sepconv3 (SeparableConv (None, None, None, 536536
['block8_sepconv3_act[0][0]']
2D)                                728)

block8_sepconv3_bn (BatchNorma (None, None, None, 2912
['block8_sepconv3[0][0]']
lization)                            728)

add_18 (Add)                             (None, None, None, 0
['block8_sepconv3_bn[0][0]',
728)
'add_17[0][0]']

```

| | | |
|---|-------------------------|--------|
| block9_sepconv1_act (Activation) | (None, None, None, 0) | 0 |
| ['add_18[0][0]'] | | |
| n) | 728) | |
| block9_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv1_act[0][0]'] | | |
| block9_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block9_sepconv1[0][0]'] | | |
| block9_sepconv2_act (Activation) | (None, None, None, 0) | 0 |
| ['block9_sepconv1_bn[0][0]'] | | |
| n) | 728) | |
| block9_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv2_act[0][0]'] | | |
| block9_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block9_sepconv2[0][0]'] | | |
| block9_sepconv3_act (Activation) | (None, None, None, 0) | 0 |
| ['block9_sepconv2_bn[0][0]'] | | |
| n) | 728) | |
| block9_sepconv3 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block9_sepconv3_act[0][0]'] | | |
| block9_sepconv3_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| ['block9_sepconv3[0][0]'] | | |
| add_19 (Add) | (None, None, None, 0) | 0 |
| ['block9_sepconv3_bn[0][0]', | | |
| 'add_18[0][0]'] | 728) | |
| block10_sepconv1_act (Activation) | (None, None, None, 0) | 0 |
| ['add_19[0][0]'] | | |
| on) | 728) | |
| block10_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| ['block10_sepconv1_act[0][0]'] | | |

| | | |
|--|----------------------------|--------|
| v2D) | 728) | |
| block10_sepconv1_bn (BatchNorm ['block10_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv2_act (Activati ['block10_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv2 (SeparableCon ['block10_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv2_bn (BatchNorm ['block10_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv3_act (Activati ['block10_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv3 (SeparableCon ['block10_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv3_bn (BatchNorm ['block10_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_20 (Add) ['block10_sepconv3_bn[0][0]'] 'add_19[0][0]'] | (None, None, None, 728) | 0 |
| block11_sepconv1_act (Activati ['add_20[0][0]'] on) | (None, None, None, 728) | 0 |
| block11_sepconv1 (SeparableCon ['block11_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block11_sepconv1_bn (BatchNorm ['block11_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block11_sepconv2_act (Activati | (None, None, None, | 0 |

```

['block11_sepconv1_bn[0][0]']
on)                                728)

block11_sepconv2 (SeparableCon (None, None, None, 536536
['block11_sepconv2_act[0][0]']
v2D)                                728)

block11_sepconv2_bn (BatchNorm (None, None, None, 2912
['block11_sepconv2[0][0]']
alization)                            728)

block11_sepconv3_act (Activati (None, None, None, 0
['block11_sepconv2_bn[0][0]']
on)                                728)

block11_sepconv3 (SeparableCon (None, None, None, 536536
['block11_sepconv3_act[0][0]']
v2D)                                728)

block11_sepconv3_bn (BatchNorm (None, None, None, 2912
['block11_sepconv3[0][0]']
alization)                            728)

add_21 (Add)                        (None, None, None, 0
['block11_sepconv3_bn[0][0]',
728)
'add_20[0][0]']

block12_sepconv1_act (Activati (None, None, None, 0
['add_21[0][0]']
on)                                728)

block12_sepconv1 (SeparableCon (None, None, None, 536536
['block12_sepconv1_act[0][0]']
v2D)                                728)

block12_sepconv1_bn (BatchNorm (None, None, None, 2912
['block12_sepconv1[0][0]']
alization)                            728)

block12_sepconv2_act (Activati (None, None, None, 0
['block12_sepconv1_bn[0][0]']
on)                                728)

block12_sepconv2 (SeparableCon (None, None, None, 536536
['block12_sepconv2_act[0][0]']
v2D)                                728)

```

| | | |
|--|-----------------------------|--------|
| block12_sepconv2_bn (BatchNorm ['block12_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block12_sepconv3_act (Activati ['block12_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block12_sepconv3 (SeparableCon ['block12_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_22 (Add) ['block12_sepconv3_bn[0][0]', 'add_21[0][0]'] | (None, None, None, 728) | 0 |
| block13_sepconv1_act (Activati ['add_22[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block13_sepconv2_act (Activati ['block13_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv2 (SeparableCon ['block13_sepconv2_act[0][0]'] v2D) | (None, None, None, 1024) | 752024 |
| block13_sepconv2_bn (BatchNorm ['block13_sepconv2[0][0]'] alization) | (None, None, None, 1024) | 4096 |
| conv2d_9 (Conv2D) ['add_22[0][0]'] | (None, None, None, 1024) | 745472 |

```

block13_pool (MaxPooling2D)      (None, None, None, 0
['block13_sepconv2_bn[0][0]']
1024)

batch_normalization_7 (BatchNorm (None, None, None, 4096
['conv2d_9[0][0]']
alization)
1024)

add_23 (Add)                     (None, None, None, 0
['block13_pool[0][0]',
1024)
'batch_normalization_7[0][0]']

block14_sepconv1 (SeparableConv (None, None, None, 1582080
['add_23[0][0]']
v2D)
1536)

block14_sepconv1_bn (BatchNorm (None, None, None, 6144
['block14_sepconv1[0][0]']
alization)
1536)

block14_sepconv1_act (Activation (None, None, None, 0
['block14_sepconv1_bn[0][0]']
on)
1536)

block14_sepconv2 (SeparableConv (None, None, None, 3159552
['block14_sepconv1_act[0][0]']
v2D)
2048)

block14_sepconv2_bn (BatchNorm (None, None, None, 8192
['block14_sepconv2[0][0]']
alization)
2048)

block14_sepconv2_act (Activation (None, None, None, 0
['block14_sepconv2_bn[0][0]']
on)
2048)

global_average_pooling2d_1 (GlobalAveragePooling2D) (None, 2048) 0
['block14_sepconv2_act[0][0]']

dense_3 (Dense)                  (None, 4)      8196
['global_average_pooling2d_1[0][0]']

]']

```

```

=====
=====

```


Total params: 20,869,676
Trainable params: 8,196
Non-trainable params: 20,861,480

```
[21]: ids = list(set(labels.ID))

random.shuffle(ids)
ids_train = ids[:123]
ids_test = ids[123:]
tr_len = len(ids_train)
ts_len = len(ids_test)
print('Train Length:',tr_len)
print('Test Length:',ts_len)

X_train = np.zeros([369,224,224,3])
y_train = []
for n, ID in enumerate(ids_train):
    y_train = y_train + list(y[labels.ID == ID])

    for i, s in enumerate(["_55", "_120", "_180"]):
        file_name = file_dir + ID + s + '.png'
        tmp=matplotlib.image.imread(file_name)[:,:,:0:3].reshape(1,176,176,3)
        X_train[3*n+i,:,:,:] = preprocess(tmp)
y_train=np.array(y_train)

print(len(y_train))

X_test = np.zeros([240,224,224,3])
y_test = []
for n, ID in enumerate(ids_test):
    y_test = y_test + list(y[labels.ID == ID])

    for i, s in enumerate(["_55", "_120", "_180"]):
        file_name = file_dir + ID + s + '.png'
        tmp=matplotlib.image.imread(file_name)[:,:,:0:3].reshape(1,176,176,3)
        X_test[3*n+i,:,:,:] = preprocess(tmp)
y_test=np.array(y_test)
print(len(y_test))

NUM_LABELS=4
Y_train = np_utils.to_categorical(y_train, NUM_LABELS)
Y_test = np_utils.to_categorical(y_test, NUM_LABELS)
```

Train Length: 123
Test Length: 80

369
240

```
[22]: print('MRI data loaded: train:',len(X_train),'test:',len(X_test))
      print('x_train:', x_train.shape)
      print('X_train:', X_train.shape)
      print('y_train:', y_train.shape)
      print('Y_train:', Y_train.shape)
```

MRI data loaded: train: 369 test: 240
x_train: (487, 224, 224, 3)
X_train: (369, 224, 224, 3)
y_train: (369,)
Y_train: (369, 4)

```
[23]: n_classes=NUM_LABELS
      base_model = tf.keras.applications.xception.Xception(weights="imagenet",
      ↪include_top=False)
      avg = tf.keras.layers.GlobalAveragePooling2D()(base_model.output)
      output = tf.keras.layers.Dense(n_classes, activation="softmax")(avg)
      model = tf.keras.Model(inputs=base_model.input, outputs=output)
      model.summary()
      for layer in base_model.layers:
          layer.trainable = False
      model.summary()
```

Model: "model_2"

| ----- | | | |
|--|-------------------------------|---------|----------------------------|
| Layer (type) | Output Shape | Param # | Connected to |
| ===== | | | |
| input_3 (InputLayer) | [(None, None, None, 0 3)] | 0 | [] |
| block1_conv1 (Conv2D) | (None, None, None, 864 32) | 864 | ['input_3[0][0]'] |
| block1_conv1_bn (BatchNormaliz ation) | (None, None, None, 32) | 128 | ['block1_conv1[0][0]'] |
| block1_conv1_act (Activation) | (None, None, None, 32) | 0 | ['block1_conv1_bn[0][0]'] |
| block1_conv2 (Conv2D) | (None, None, None, 18432) | 18432 | ['block1_conv1_act[0][0]'] |

| | | |
|--------------------------------|--------------------|-------|
| | 64) | |
| block1_conv2_bn (BatchNormaliz | (None, None, None, | 256 |
| ['block1_conv2[0][0]'] | | |
| ation) | 64) | |
| block1_conv2_act (Activation) | (None, None, None, | 0 |
| ['block1_conv2_bn[0][0]'] | | |
| | 64) | |
| block2_sepconv1 (SeparableConv | (None, None, None, | 8768 |
| ['block1_conv2_act[0][0]'] | | |
| 2D) | 128) | |
| block2_sepconv1_bn (BatchNorma | (None, None, None, | 512 |
| ['block2_sepconv1[0][0]'] | | |
| lization) | 128) | |
| block2_sepconv2_act (Activatio | (None, None, None, | 0 |
| ['block2_sepconv1_bn[0][0]'] | | |
| n) | 128) | |
| block2_sepconv2 (SeparableConv | (None, None, None, | 17536 |
| ['block2_sepconv2_act[0][0]'] | | |
| 2D) | 128) | |
| block2_sepconv2_bn (BatchNorma | (None, None, None, | 512 |
| ['block2_sepconv2[0][0]'] | | |
| lization) | 128) | |
| conv2d_10 (Conv2D) | (None, None, None, | 8192 |
| ['block1_conv2_act[0][0]'] | | |
| | 128) | |
| block2_pool (MaxPooling2D) | (None, None, None, | 0 |
| ['block2_sepconv2_bn[0][0]'] | | |
| | 128) | |
| batch_normalization_8 (BatchNo | (None, None, None, | 512 |
| ['conv2d_10[0][0]'] | | |
| rmalization) | 128) | |
| add_24 (Add) | (None, None, None, | 0 |
| ['block2_pool[0][0]', | | |
| | 128) | |
| 'batch_normalization_8[0][0]'] | | |
| block3_sepconv1_act (Activatio | (None, None, None, | 0 |

| | | |
|--|-------------------------|--------|
| ['add_24[0][0]'] n) | (None, None, None, 256) | 128) |
| block3_sepconv1 (SeparableConv ['block3_sepconv1_act[0][0]'] 2D) | (None, None, None, 256) | 33920 |
| block3_sepconv1_bn (BatchNorma ['block3_sepconv1[0][0]'] lization) | (None, None, None, 256) | 1024 |
| block3_sepconv2_act (Activatio ['block3_sepconv1_bn[0][0]'] n) | (None, None, None, 256) | 0 |
| block3_sepconv2 (SeparableConv ['block3_sepconv2_act[0][0]'] 2D) | (None, None, None, 256) | 67840 |
| block3_sepconv2_bn (BatchNorma ['block3_sepconv2[0][0]'] lization) | (None, None, None, 256) | 1024 |
| conv2d_11 (Conv2D) ['add_24[0][0]'] | (None, None, None, 256) | 32768 |
| block3_pool (MaxPooling2D) ['block3_sepconv2_bn[0][0]'] | (None, None, None, 256) | 0 |
| batch_normalization_9 (BatchNo ['conv2d_11[0][0]'] rmalization) | (None, None, None, 256) | 1024 |
| add_25 (Add) ['block3_pool[0][0]', 'batch_normalization_9[0][0]'] | (None, None, None, 256) | 0 |
| block4_sepconv1_act (Activatio ['add_25[0][0]'] n) | (None, None, None, 256) | 0 |
| block4_sepconv1 (SeparableConv ['block4_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 188672 |

| | | |
|---|-------------------------|--------|
| block4_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| block4_sepconv2_act (Activation) | (None, None, None, 728) | 0 |
| block4_sepconv2 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| block4_sepconv2_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| conv2d_12 (Conv2D) | (None, None, None, 728) | 186368 |
| block4_pool (MaxPooling2D) | (None, None, None, 728) | 0 |
| batch_normalization_10 (BatchNormalization) | (None, None, None, 728) | 2912 |
| add_26 (Add) | (None, None, None, 728) | 0 |
| block5_sepconv1_act (Activation) | (None, None, None, 728) | 0 |
| block5_sepconv1 (SeparableConv2D) | (None, None, None, 728) | 536536 |
| block5_sepconv1_bn (BatchNormalization) | (None, None, None, 728) | 2912 |
| block5_sepconv2_act (Activation) | (None, None, None, 728) | 0 |

| | | |
|--|----------------------------|--------|
| block5_sepconv2 (SeparableConv ['block5_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv2_bn (BatchNorma ['block5_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block5_sepconv3_act (Activatio ['block5_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block5_sepconv3 (SeparableConv ['block5_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block5_sepconv3_bn (BatchNorma ['block5_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_27 (Add) ['block5_sepconv3_bn[0][0]', 'add_26[0][0]'] | (None, None, None, 728) | 0 |
| block6_sepconv1_act (Activatio ['add_27[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv1 (SeparableConv ['block6_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv1_bn (BatchNorma ['block6_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block6_sepconv2_act (Activatio ['block6_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv2 (SeparableConv ['block6_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv2_bn (BatchNorma ['block6_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |

| | | |
|--|----------------------------|--------|
| lization) | 728) | |
| block6_sepconv3_act (Activatio ['block6_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block6_sepconv3 (SeparableConv ['block6_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block6_sepconv3_bn (BatchNorma ['block6_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_28 (Add) ['block6_sepconv3_bn[0][0]', 'add_27[0][0]'] | (None, None, None, 728) | 0 |
| block7_sepconv1_act (Activatio ['add_28[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv1 (SeparableConv ['block7_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv1_bn (BatchNorma ['block7_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv2_act (Activatio ['block7_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv2 (SeparableConv ['block7_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block7_sepconv2_bn (BatchNorma ['block7_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block7_sepconv3_act (Activatio ['block7_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block7_sepconv3 (SeparableConv | (None, None, None, | 536536 |

```

['block7_sepconv3_act[0][0]']
2D)                                728)

block7_sepconv3_bn (BatchNorma (None, None, None, 2912
['block7_sepconv3[0][0]']
lization)                                728)

add_29 (Add)                        (None, None, None, 0
['block7_sepconv3_bn[0][0]',
728)
'add_28[0][0]']

block8_sepconv1_act (Activatio (None, None, None, 0
['add_29[0][0]']
n)                                728)

block8_sepconv1 (SeparableConv (None, None, None, 536536
['block8_sepconv1_act[0][0]']
2D)                                728)

block8_sepconv1_bn (BatchNorma (None, None, None, 2912
['block8_sepconv1[0][0]']
lization)                                728)

block8_sepconv2_act (Activatio (None, None, None, 0
['block8_sepconv1_bn[0][0]']
n)                                728)

block8_sepconv2 (SeparableConv (None, None, None, 536536
['block8_sepconv2_act[0][0]']
2D)                                728)

block8_sepconv2_bn (BatchNorma (None, None, None, 2912
['block8_sepconv2[0][0]']
lization)                                728)

block8_sepconv3_act (Activatio (None, None, None, 0
['block8_sepconv2_bn[0][0]']
n)                                728)

block8_sepconv3 (SeparableConv (None, None, None, 536536
['block8_sepconv3_act[0][0]']
2D)                                728)

block8_sepconv3_bn (BatchNorma (None, None, None, 2912
['block8_sepconv3[0][0]']
lization)                                728)

```



```

add_30 (Add) (None, None, None, 0
['block8_sepconv3_bn[0][0]',
728)
'add_29[0][0]']

block9_sepconv1_act (Activation) (None, None, None, 0
['add_30[0][0]']
n) 728)

block9_sepconv1 (SeparableConv) (None, None, None, 536536
['block9_sepconv1_act[0][0]']
2D) 728)

block9_sepconv1_bn (BatchNormaliza (None, None, None, 2912
['block9_sepconv1[0][0]']
lization) 728)

block9_sepconv2_act (Activation) (None, None, None, 0
['block9_sepconv1_bn[0][0]']
n) 728)

block9_sepconv2 (SeparableConv) (None, None, None, 536536
['block9_sepconv2_act[0][0]']
2D) 728)

block9_sepconv2_bn (BatchNormaliza (None, None, None, 2912
['block9_sepconv2[0][0]']
lization) 728)

block9_sepconv3_act (Activation) (None, None, None, 0
['block9_sepconv2_bn[0][0]']
n) 728)

block9_sepconv3 (SeparableConv) (None, None, None, 536536
['block9_sepconv3_act[0][0]']
2D) 728)

block9_sepconv3_bn (BatchNormaliza (None, None, None, 2912
['block9_sepconv3[0][0]']
lization) 728)

add_31 (Add) (None, None, None, 0
['block9_sepconv3_bn[0][0]',
728)
'add_30[0][0]']

block10_sepconv1_act (Activation) (None, None, None, 0
['add_31[0][0]']

```

| | | |
|--|----------------------------|--------|
| on) | 728) | |
| block10_sepconv1 (SeparableCon ['block10_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv1_bn (BatchNorm ['block10_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv2_act (Activati ['block10_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv2 (SeparableCon ['block10_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv2_bn (BatchNorm ['block10_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv3_act (Activati ['block10_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv3 (SeparableCon ['block10_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv3_bn (BatchNorm ['block10_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_32 (Add) ['block10_sepconv3_bn[0][0]', 'add_31[0][0]'] | (None, None, None, 728) | 0 |
| block11_sepconv1_act (Activati ['add_32[0][0]'] on) | (None, None, None, 728) | 0 |
| block11_sepconv1 (SeparableCon ['block11_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block11_sepconv1_bn (BatchNorm | (None, None, None, | 2912 |

```

['block11_sepconv1[0][0]']
alization)                                728)

block11_sepconv2_act (Activati (None, None, None, 0
['block11_sepconv1_bn[0][0]']
on)                                728)

block11_sepconv2 (SeparableCon (None, None, None, 536536
['block11_sepconv2_act[0][0]']
v2D)                                728)

block11_sepconv2_bn (BatchNorm (None, None, None, 2912
['block11_sepconv2[0][0]']
alization)                                728)

block11_sepconv3_act (Activati (None, None, None, 0
['block11_sepconv2_bn[0][0]']
on)                                728)

block11_sepconv3 (SeparableCon (None, None, None, 536536
['block11_sepconv3_act[0][0]']
v2D)                                728)

block11_sepconv3_bn (BatchNorm (None, None, None, 2912
['block11_sepconv3[0][0]']
alization)                                728)

add_33 (Add)                            (None, None, None, 0
['block11_sepconv3_bn[0][0]',
728)
'add_32[0][0]']

block12_sepconv1_act (Activati (None, None, None, 0
['add_33[0][0]']
on)                                728)

block12_sepconv1 (SeparableCon (None, None, None, 536536
['block12_sepconv1_act[0][0]']
v2D)                                728)

block12_sepconv1_bn (BatchNorm (None, None, None, 2912
['block12_sepconv1[0][0]']
alization)                                728)

block12_sepconv2_act (Activati (None, None, None, 0
['block12_sepconv1_bn[0][0]']
on)                                728)

```

| | | |
|--|-----------------------------|--------|
| block12_sepconv2 (SeparableCon ['block12_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv2_bn (BatchNorm ['block12_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block12_sepconv3_act (Activati ['block12_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block12_sepconv3 (SeparableCon ['block12_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_34 (Add) ['block12_sepconv3_bn[0][0]', 'add_33[0][0]'] | (None, None, None, 728) | 0 |
| block13_sepconv1_act (Activati ['add_34[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block13_sepconv2_act (Activati ['block13_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv2 (SeparableCon ['block13_sepconv2_act[0][0]'] v2D) | (None, None, None, 1024) | 752024 |
| block13_sepconv2_bn (BatchNorm ['block13_sepconv2[0][0]'] alization) | (None, None, None, 1024) | 4096 |

| | | |
|---|-----------------------------|---------|
| conv2d_13 (Conv2D) ['add_34[0][0]'] | (None, None, None, 1024) | 745472 |
| block13_pool (MaxPooling2D) ['block13_sepconv2_bn[0][0]'] | (None, None, None, 1024) | 0 |
| batch_normalization_11 (BatchN ormalization) | (None, None, None, 1024) | 4096 |
| add_35 (Add) ['block13_pool[0][0]', 'batch_normalization_11[0][0]'] | (None, None, None, 1024) | 0 |
| block14_sepconv1 (SeparableCon v2D) | (None, None, None, 1536) | 1582080 |
| block14_sepconv1_bn (BatchNorm alization) | (None, None, None, 1536) | 6144 |
| block14_sepconv1_act (Activati on) | (None, None, None, 1536) | 0 |
| block14_sepconv2 (SeparableCon v2D) | (None, None, None, 2048) | 3159552 |
| block14_sepconv2_bn (BatchNorm alization) | (None, None, None, 2048) | 8192 |
| block14_sepconv2_act (Activati on) | (None, None, None, 2048) | 0 |
| global_average_pooling2d_2 (Gl obalAveragePooling2D) | (None, 2048) | 0 |
| dense_4 (Dense) ['global_average_pooling2d_2[0][0] | (None, 4) | 8196 |

']']

```
=====
=====
Total params: 20,869,676
Trainable params: 20,815,148
Non-trainable params: 54,528
-----
-----
Model: "model_2"
-----
-----
Layer (type)                Output Shape                Param #   Connected to
=====
input_3 (InputLayer)        [(None, None, None, 0     []
                               3)]

block1_conv1 (Conv2D)        (None, None, None, 864
['input_3[0][0]']
                               32)

block1_conv1_bn (BatchNormaliz (None, None, None, 128
['block1_conv1[0][0]']
                               32)
          ation)

block1_conv1_act (Activation) (None, None, None, 0
['block1_conv1_bn[0][0]']
                               32)

block1_conv2 (Conv2D)        (None, None, None, 18432
['block1_conv1_act[0][0]']
                               64)

block1_conv2_bn (BatchNormaliz (None, None, None, 256
['block1_conv2[0][0]']
                               64)
          ation)

block1_conv2_act (Activation) (None, None, None, 0
['block1_conv2_bn[0][0]']
                               64)

block2_sepconv1 (SeparableConv (None, None, None, 8768
['block1_conv2_act[0][0]']
          2D)                128)

block2_sepconv1_bn (BatchNorma (None, None, None, 512
['block2_sepconv1[0][0]']
          ation)


```

| | | |
|--|----------------------------|-------|
| lization) | 128) | |
| block2_sepconv2_act (Activatio ['block2_sepconv1_bn[0][0]'] n) | (None, None, None, 128) | 0 |
| block2_sepconv2 (SeparableConv ['block2_sepconv2_act[0][0]'] 2D) | (None, None, None, 128) | 17536 |
| block2_sepconv2_bn (BatchNorma ['block2_sepconv2[0][0]'] lization) | (None, None, None, 128) | 512 |
| conv2d_10 (Conv2D) ['block1_conv2_act[0][0]'] | (None, None, None, 128) | 8192 |
| block2_pool (MaxPooling2D) ['block2_sepconv2_bn[0][0]'] | (None, None, None, 128) | 0 |
| batch_normalization_8 (BatchNo ['conv2d_10[0][0]'] rmalization) | (None, None, None, 128) | 512 |
| add_24 (Add) ['block2_pool[0][0]', 'batch_normalization_8[0][0]'] | (None, None, None, 128) | 0 |
| block3_sepconv1_act (Activatio ['add_24[0][0]'] n) | (None, None, None, 128) | 0 |
| block3_sepconv1 (SeparableConv ['block3_sepconv1_act[0][0]'] 2D) | (None, None, None, 256) | 33920 |
| block3_sepconv1_bn (BatchNorma ['block3_sepconv1[0][0]'] lization) | (None, None, None, 256) | 1024 |
| block3_sepconv2_act (Activatio ['block3_sepconv1_bn[0][0]'] n) | (None, None, None, 256) | 0 |
| block3_sepconv2 (SeparableConv | (None, None, None, | 67840 |

| | | |
|--|-------------------------|--------|
| ['block3_sepconv2_act[0][0]'] 2D) | (None, None, None, 256) | |
| block3_sepconv2_bn (BatchNorma ['block3_sepconv2[0][0]'] lization) | (None, None, None, 256) | 1024 |
| conv2d_11 (Conv2D) ['add_24[0][0]'] | (None, None, None, 256) | 32768 |
| block3_pool (MaxPooling2D) ['block3_sepconv2_bn[0][0]'] | (None, None, None, 256) | 0 |
| batch_normalization_9 (BatchNo ['conv2d_11[0][0]'] rmalization) | (None, None, None, 256) | 1024 |
| add_25 (Add) ['block3_pool[0][0]', 'batch_normalization_9[0][0]'] | (None, None, None, 256) | 0 |
| block4_sepconv1_act (Activatio ['add_25[0][0]'] n) | (None, None, None, 256) | 0 |
| block4_sepconv1 (SeparableConv ['block4_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 188672 |
| block4_sepconv1_bn (BatchNorma ['block4_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block4_sepconv2_act (Activatio ['block4_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block4_sepconv2 (SeparableConv ['block4_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block4_sepconv2_bn (BatchNorma ['block4_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |

| | | |
|---------------------------------|--------------------|--------|
| conv2d_12 (Conv2D) | (None, None, None, | 186368 |
| ['add_25[0][0]'] | 728) | |
| block4_pool (MaxPooling2D) | (None, None, None, | 0 |
| ['block4_sepconv2_bn[0][0]'] | 728) | |
| batch_normalization_10 (BatchN | (None, None, None, | 2912 |
| ormalization) | 728) | |
| add_26 (Add) | (None, None, None, | 0 |
| ['block4_pool[0][0]', | 728) | |
| 'batch_normalization_10[0][0]'] | | |
| block5_sepconv1_act (Activatio | (None, None, None, | 0 |
| ['add_26[0][0]'] | 728) | |
| n) | | |
| block5_sepconv1 (SeparableConv | (None, None, None, | 536536 |
| ['block5_sepconv1_act[0][0]'] | 728) | |
| 2D) | | |
| block5_sepconv1_bn (BatchNorma | (None, None, None, | 2912 |
| ['block5_sepconv1[0][0]'] | 728) | |
| lization) | | |
| block5_sepconv2_act (Activatio | (None, None, None, | 0 |
| ['block5_sepconv1_bn[0][0]'] | 728) | |
| n) | | |
| block5_sepconv2 (SeparableConv | (None, None, None, | 536536 |
| ['block5_sepconv2_act[0][0]'] | 728) | |
| 2D) | | |
| block5_sepconv2_bn (BatchNorma | (None, None, None, | 2912 |
| ['block5_sepconv2[0][0]'] | 728) | |
| lization) | | |
| block5_sepconv3_act (Activatio | (None, None, None, | 0 |
| ['block5_sepconv2_bn[0][0]'] | 728) | |
| n) | | |
| block5_sepconv3 (SeparableConv | (None, None, None, | 536536 |
| ['block5_sepconv3_act[0][0]'] | 728) | |
| 2D) | | |

```

block5_sepconv3_bn (BatchNorma (None, None, None, 2912
['block5_sepconv3[0][0]']
lization) 728)

add_27 (Add) (None, None, None, 0
['block5_sepconv3_bn[0][0]',
728)
'add_26[0][0]']

block6_sepconv1_act (Activatio (None, None, None, 0
['add_27[0][0]']
n) 728)

block6_sepconv1 (SeparableConv (None, None, None, 536536
['block6_sepconv1_act[0][0]']
2D) 728)

block6_sepconv1_bn (BatchNorma (None, None, None, 2912
['block6_sepconv1[0][0]']
lization) 728)

block6_sepconv2_act (Activatio (None, None, None, 0
['block6_sepconv1_bn[0][0]']
n) 728)

block6_sepconv2 (SeparableConv (None, None, None, 536536
['block6_sepconv2_act[0][0]']
2D) 728)

block6_sepconv2_bn (BatchNorma (None, None, None, 2912
['block6_sepconv2[0][0]']
lization) 728)

block6_sepconv3_act (Activatio (None, None, None, 0
['block6_sepconv2_bn[0][0]']
n) 728)

block6_sepconv3 (SeparableConv (None, None, None, 536536
['block6_sepconv3_act[0][0]']
2D) 728)

block6_sepconv3_bn (BatchNorma (None, None, None, 2912
['block6_sepconv3[0][0]']
lization) 728)

add_28 (Add) (None, None, None, 0
['block6_sepconv3_bn[0][0]',

```

```

728)
'add_27[0][0]']

block7_sepconv1_act (Activation) (None, None, None, 0
['add_28[0][0]']
n) 728)

block7_sepconv1 (SeparableConv) (None, None, None, 536536
['block7_sepconv1_act[0][0]']
2D) 728)

block7_sepconv1_bn (BatchNormalization) (None, None, None, 2912
['block7_sepconv1[0][0]']
lization) 728)

block7_sepconv2_act (Activation) (None, None, None, 0
['block7_sepconv1_bn[0][0]']
n) 728)

block7_sepconv2 (SeparableConv) (None, None, None, 536536
['block7_sepconv2_act[0][0]']
2D) 728)

block7_sepconv2_bn (BatchNormalization) (None, None, None, 2912
['block7_sepconv2[0][0]']
lization) 728)

block7_sepconv3_act (Activation) (None, None, None, 0
['block7_sepconv2_bn[0][0]']
n) 728)

block7_sepconv3 (SeparableConv) (None, None, None, 536536
['block7_sepconv3_act[0][0]']
2D) 728)

block7_sepconv3_bn (BatchNormalization) (None, None, None, 2912
['block7_sepconv3[0][0]']
lization) 728)

add_29 (Add) (None, None, None, 0
['block7_sepconv3_bn[0][0]',
728)
'add_28[0][0]']

block8_sepconv1_act (Activation) (None, None, None, 0
['add_29[0][0]']
n) 728)

```

| | | |
|--|----------------------------|--------|
| block8_sepconv1 (SeparableConv ['block8_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block8_sepconv1_bn (BatchNorma ['block8_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block8_sepconv2_act (Activatio ['block8_sepconv1_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block8_sepconv2 (SeparableConv ['block8_sepconv2_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block8_sepconv2_bn (BatchNorma ['block8_sepconv2[0][0]'] lization) | (None, None, None, 728) | 2912 |
| block8_sepconv3_act (Activatio ['block8_sepconv2_bn[0][0]'] n) | (None, None, None, 728) | 0 |
| block8_sepconv3 (SeparableConv ['block8_sepconv3_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block8_sepconv3_bn (BatchNorma ['block8_sepconv3[0][0]'] lization) | (None, None, None, 728) | 2912 |
| add_30 (Add) ['block8_sepconv3_bn[0][0]', 'add_29[0][0]'] | (None, None, None, 728) | 0 |
| block9_sepconv1_act (Activatio ['add_30[0][0]'] n) | (None, None, None, 728) | 0 |
| block9_sepconv1 (SeparableConv ['block9_sepconv1_act[0][0]'] 2D) | (None, None, None, 728) | 536536 |
| block9_sepconv1_bn (BatchNorma ['block9_sepconv1[0][0]'] lization) | (None, None, None, 728) | 2912 |

| | |
|--|----------------------------|
| block9_sepconv2_act (Activation) | (None, None, None, 0) |
| ['block9_sepconv1_bn[0][0]'] | |
| n) | 728) |
| block9_sepconv2 (SeparableConv2D) | (None, None, None, 536536) |
| ['block9_sepconv2_act[0][0]'] | |
| 2D) | 728) |
| block9_sepconv2_bn (BatchNormalization) | (None, None, None, 2912) |
| ['block9_sepconv2[0][0]'] | |
| lization) | 728) |
| block9_sepconv3_act (Activation) | (None, None, None, 0) |
| ['block9_sepconv2_bn[0][0]'] | |
| n) | 728) |
| block9_sepconv3 (SeparableConv2D) | (None, None, None, 536536) |
| ['block9_sepconv3_act[0][0]'] | |
| 2D) | 728) |
| block9_sepconv3_bn (BatchNormalization) | (None, None, None, 2912) |
| ['block9_sepconv3[0][0]'] | |
| lization) | 728) |
| add_31 (Add) | (None, None, None, 0) |
| ['block9_sepconv3_bn[0][0]', | |
| 'add_30[0][0]'] | 728) |
| block10_sepconv1_act (Activation) | (None, None, None, 0) |
| ['add_31[0][0]'] | |
| on) | 728) |
| block10_sepconv1 (SeparableConv2D) | (None, None, None, 536536) |
| ['block10_sepconv1_act[0][0]'] | |
| v2D) | 728) |
| block10_sepconv1_bn (BatchNormalization) | (None, None, None, 2912) |
| ['block10_sepconv1[0][0]'] | |
| alization) | 728) |
| block10_sepconv2_act (Activation) | (None, None, None, 0) |
| ['block10_sepconv1_bn[0][0]'] | |
| on) | 728) |
| block10_sepconv2 (SeparableConv2D) | (None, None, None, 536536) |
| ['block10_sepconv2_act[0][0]'] | |

| | | |
|--|----------------------------|--------|
| v2D) | 728) | |
| block10_sepconv2_bn (BatchNorm ['block10_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block10_sepconv3_act (Activati ['block10_sepconv2_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block10_sepconv3 (SeparableCon ['block10_sepconv3_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block10_sepconv3_bn (BatchNorm ['block10_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_32 (Add) ['block10_sepconv3_bn[0][0]', 'add_31[0][0]'] | (None, None, None, 728) | 0 |
| block11_sepconv1_act (Activati ['add_32[0][0]'] on) | (None, None, None, 728) | 0 |
| block11_sepconv1 (SeparableCon ['block11_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block11_sepconv1_bn (BatchNorm ['block11_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block11_sepconv2_act (Activati ['block11_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block11_sepconv2 (SeparableCon ['block11_sepconv2_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block11_sepconv2_bn (BatchNorm ['block11_sepconv2[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block11_sepconv3_act (Activati | (None, None, None, | 0 |

```

['block11_sepconv2_bn[0][0]']
on)                                728)

block11_sepconv3 (SeparableCon (None, None, None, 536536
['block11_sepconv3_act[0][0]']
v2D)                                728)

block11_sepconv3_bn (BatchNorm (None, None, None, 2912
['block11_sepconv3[0][0]']
alization)                        728)

add_33 (Add)                        (None, None, None, 0
['block11_sepconv3_bn[0][0]',
728)
'add_32[0][0]']

block12_sepconv1_act (Activati (None, None, None, 0
['add_33[0][0]']
on)                                728)

block12_sepconv1 (SeparableCon (None, None, None, 536536
['block12_sepconv1_act[0][0]']
v2D)                                728)

block12_sepconv1_bn (BatchNorm (None, None, None, 2912
['block12_sepconv1[0][0]']
alization)                        728)

block12_sepconv2_act (Activati (None, None, None, 0
['block12_sepconv1_bn[0][0]']
on)                                728)

block12_sepconv2 (SeparableCon (None, None, None, 536536
['block12_sepconv2_act[0][0]']
v2D)                                728)

block12_sepconv2_bn (BatchNorm (None, None, None, 2912
['block12_sepconv2[0][0]']
alization)                        728)

block12_sepconv3_act (Activati (None, None, None, 0
['block12_sepconv2_bn[0][0]']
on)                                728)

block12_sepconv3 (SeparableCon (None, None, None, 536536
['block12_sepconv3_act[0][0]']
v2D)                                728)

```

| | | |
|--|-----------------------------|--------|
| block12_sepconv3_bn (BatchNorm ['block12_sepconv3[0][0]'] alization) | (None, None, None, 728) | 2912 |
| add_34 (Add) ['block12_sepconv3_bn[0][0]', 'add_33[0][0]'] | (None, None, None, 728) | 0 |
| block13_sepconv1_act (Activati ['add_34[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv1 (SeparableCon ['block13_sepconv1_act[0][0]'] v2D) | (None, None, None, 728) | 536536 |
| block13_sepconv1_bn (BatchNorm ['block13_sepconv1[0][0]'] alization) | (None, None, None, 728) | 2912 |
| block13_sepconv2_act (Activati ['block13_sepconv1_bn[0][0]'] on) | (None, None, None, 728) | 0 |
| block13_sepconv2 (SeparableCon ['block13_sepconv2_act[0][0]'] v2D) | (None, None, None, 1024) | 752024 |
| block13_sepconv2_bn (BatchNorm ['block13_sepconv2[0][0]'] alization) | (None, None, None, 1024) | 4096 |
| conv2d_13 (Conv2D) ['add_34[0][0]'] | (None, None, None, 1024) | 745472 |
| block13_pool (MaxPooling2D) ['block13_sepconv2_bn[0][0]'] | (None, None, None, 1024) | 0 |
| batch_normalization_11 (BatchN ['conv2d_13[0][0]'] ormalization) | (None, None, None, 1024) | 4096 |
| add_35 (Add) ['block13_pool[0][0]', 1024) | (None, None, None, 1024) | 0 |


```

'batch_normalization_11[0][0]']

block14_sepconv1 (SeparableConv2D) (None, None, None, 1582080
['add_35[0][0]']
v2D) 1536)

block14_sepconv1_bn (BatchNormaliza (None, None, None, 6144
['block14_sepconv1[0][0]']
alization) 1536)

block14_sepconv1_act (Activation) (None, None, None, 0
['block14_sepconv1_bn[0][0]']
on) 1536)

block14_sepconv2 (SeparableConv2D) (None, None, None, 3159552
['block14_sepconv1_act[0][0]']
v2D) 2048)

block14_sepconv2_bn (BatchNormaliza (None, None, None, 8192
['block14_sepconv2[0][0]']
alization) 2048)

block14_sepconv2_act (Activation) (None, None, None, 0
['block14_sepconv2_bn[0][0]']
on) 2048)

global_average_pooling2d_2 (GlobalAveragePooling2D) (None, 2048) 0
['block14_sepconv2_act[0][0]']
obalAveragePooling2D)

dense_4 (Dense) (None, 4) 8196
['global_average_pooling2d_2[0][0]']

]']

```

```

=====
=====
Total params: 20,869,676
Trainable params: 8,196
Non-trainable params: 20,861,480
-----
-----

```

```

[24]: from tensorflow.keras.applications import VGG16

# include_top should be False to remove the softmax layer
pretrained_model = VGG16(include_top=False, weights='imagenet')
pretrained_model.summary()

```

Model: "vgg16"

| Layer (type) | Output Shape | Param # |
|------------------------------|-------------------------|---------|
| input_4 (InputLayer) | [(None, None, None, 3)] | 0 |
| block1_conv1 (Conv2D) | (None, None, None, 64) | 1792 |
| block1_conv2 (Conv2D) | (None, None, None, 64) | 36928 |
| block1_pool (MaxPooling2D) | (None, None, None, 64) | 0 |
| block2_conv1 (Conv2D) | (None, None, None, 128) | 73856 |
| block2_conv2 (Conv2D) | (None, None, None, 128) | 147584 |
| block2_pool (MaxPooling2D) | (None, None, None, 128) | 0 |
| block3_conv1 (Conv2D) | (None, None, None, 256) | 295168 |
| block3_conv2 (Conv2D) | (None, None, None, 256) | 590080 |
| block3_conv3 (Conv2D) | (None, None, None, 256) | 590080 |
| block3_pool (MaxPooling2D) | (None, None, None, 256) | 0 |
| block4_conv1 (Conv2D) | (None, None, None, 512) | 1180160 |
| block4_conv2 (Conv2D) | (None, None, None, 512) | 2359808 |
| block4_conv3 (Conv2D) | (None, None, None, 512) | 2359808 |
| block4_pool (MaxPooling2D) | (None, None, None, 512) | 0 |
| block5_conv1 (Conv2D) | (None, None, None, 512) | 2359808 |
| block5_conv2 (Conv2D) | (None, None, None, 512) | 2359808 |
| block5_conv3 (Conv2D) | (None, None, None, 512) | 2359808 |
| block5_pool (MaxPooling2D) | (None, None, None, 512) | 0 |
| ===== | | |
| Total params: 14,714,688 | | |
| Trainable params: 14,714,688 | | |
| Non-trainable params: 0 | | |
| ----- | | |

```
[25]: from tensorflow.keras.utils import to_categorical
# extract train and val features
vgg_features_train = pretrained_model.predict(X_train)
vgg_features_val = pretrained_model.predict(X_test)
```

```
[26]: # OHE target column
train_target = Y_train
val_target = Y_test
```

```
[27]: model2 = Sequential()
model2.add(Flatten(input_shape=(7,7,512)))
model2.add(Dense(100, activation='relu'))
model2.add(Dropout(0.5))
model2.add(tf.keras.layers.BatchNormalization())
model2.add(Dense(4, activation='softmax'))

# compile the model
model2.compile(optimizer='adam', metrics=['accuracy'],
               loss='categorical_crossentropy')

model2.summary()

# train model using features generated from VGG16 model
model2.fit(vgg_features_train, train_target, epochs=50, batch_size=128,
          validation_data=(vgg_features_val, val_target))
```

Model: "sequential_1"

| Layer (type) | Output Shape | Param # |
|--|---------------|---------|
| flatten_1 (Flatten) | (None, 25088) | 0 |
| dense_5 (Dense) | (None, 100) | 2508900 |
| dropout_2 (Dropout) | (None, 100) | 0 |
| batch_normalization_12 (Batch Normalization) | (None, 100) | 400 |
| dense_6 (Dense) | (None, 4) | 404 |

```
=====
Total params: 2,509,704
Trainable params: 2,509,504
Non-trainable params: 200
```

```
-----
Epoch 1/50
3/3 [=====] - 0s 90ms/step - loss: 1.4923 - accuracy:
```

0.3279 - val_loss: 1.6871 - val_accuracy: 0.0000e+00
Epoch 2/50
3/3 [=====] - 0s 52ms/step - loss: 1.3774 - accuracy: 0.4417 - val_loss: 1.5979 - val_accuracy: 0.0000e+00
Epoch 3/50
3/3 [=====] - 0s 56ms/step - loss: 1.3222 - accuracy: 0.5339 - val_loss: 1.3913 - val_accuracy: 0.0000e+00
Epoch 4/50
3/3 [=====] - 0s 56ms/step - loss: 1.2915 - accuracy: 0.5637 - val_loss: 1.2429 - val_accuracy: 0.0000e+00
Epoch 5/50
3/3 [=====] - 0s 61ms/step - loss: 1.2527 - accuracy: 0.8157 - val_loss: 1.2069 - val_accuracy: 0.0000e+00
Epoch 6/50
3/3 [=====] - 0s 101ms/step - loss: 1.2244 - accuracy: 0.8780 - val_loss: 1.1723 - val_accuracy: 0.8500
Epoch 7/50
3/3 [=====] - 0s 53ms/step - loss: 1.1838 - accuracy: 0.8780 - val_loss: 1.1378 - val_accuracy: 0.8500
Epoch 8/50
3/3 [=====] - 0s 55ms/step - loss: 1.1519 - accuracy: 0.8780 - val_loss: 1.1014 - val_accuracy: 0.8500
Epoch 9/50
3/3 [=====] - 0s 56ms/step - loss: 1.1070 - accuracy: 0.8780 - val_loss: 1.0642 - val_accuracy: 0.8500
Epoch 10/50
3/3 [=====] - 0s 54ms/step - loss: 1.0692 - accuracy: 0.8780 - val_loss: 1.0271 - val_accuracy: 0.8500
Epoch 11/50
3/3 [=====] - 0s 52ms/step - loss: 1.0333 - accuracy: 0.8780 - val_loss: 0.9905 - val_accuracy: 0.8500
Epoch 12/50
3/3 [=====] - 0s 54ms/step - loss: 0.9879 - accuracy: 0.8780 - val_loss: 0.9540 - val_accuracy: 0.8500
Epoch 13/50
3/3 [=====] - 0s 58ms/step - loss: 0.9453 - accuracy: 0.8780 - val_loss: 0.9184 - val_accuracy: 0.8500
Epoch 14/50
3/3 [=====] - 0s 54ms/step - loss: 0.9086 - accuracy: 0.8780 - val_loss: 0.8836 - val_accuracy: 0.8500
Epoch 15/50
3/3 [=====] - 0s 57ms/step - loss: 0.8663 - accuracy: 0.8780 - val_loss: 0.8496 - val_accuracy: 0.8500
Epoch 16/50
3/3 [=====] - 0s 52ms/step - loss: 0.8223 - accuracy: 0.8780 - val_loss: 0.8162 - val_accuracy: 0.8500
Epoch 17/50
3/3 [=====] - 0s 54ms/step - loss: 0.7928 - accuracy:

0.8780 - val_loss: 0.7849 - val_accuracy: 0.8500
Epoch 18/50
3/3 [=====] - 0s 51ms/step - loss: 0.7468 - accuracy:
0.8780 - val_loss: 0.7555 - val_accuracy: 0.8500
Epoch 19/50
3/3 [=====] - 0s 53ms/step - loss: 0.7152 - accuracy:
0.8780 - val_loss: 0.7282 - val_accuracy: 0.8500
Epoch 20/50
3/3 [=====] - 0s 60ms/step - loss: 0.6812 - accuracy:
0.8780 - val_loss: 0.7028 - val_accuracy: 0.8500
Epoch 21/50
3/3 [=====] - 0s 53ms/step - loss: 0.6594 - accuracy:
0.8780 - val_loss: 0.6796 - val_accuracy: 0.8500
Epoch 22/50
3/3 [=====] - 0s 51ms/step - loss: 0.6277 - accuracy:
0.8780 - val_loss: 0.6589 - val_accuracy: 0.8500
Epoch 23/50
3/3 [=====] - 0s 54ms/step - loss: 0.6026 - accuracy:
0.8780 - val_loss: 0.6406 - val_accuracy: 0.8500
Epoch 24/50
3/3 [=====] - 0s 55ms/step - loss: 0.5855 - accuracy:
0.8780 - val_loss: 0.6244 - val_accuracy: 0.8500
Epoch 25/50
3/3 [=====] - 0s 54ms/step - loss: 0.5671 - accuracy:
0.8780 - val_loss: 0.6105 - val_accuracy: 0.8500
Epoch 26/50
3/3 [=====] - 0s 55ms/step - loss: 0.5520 - accuracy:
0.8780 - val_loss: 0.5984 - val_accuracy: 0.8500
Epoch 27/50
3/3 [=====] - 0s 55ms/step - loss: 0.5378 - accuracy:
0.8780 - val_loss: 0.5881 - val_accuracy: 0.8500
Epoch 28/50
3/3 [=====] - 0s 57ms/step - loss: 0.5229 - accuracy:
0.8780 - val_loss: 0.5793 - val_accuracy: 0.8500
Epoch 29/50
3/3 [=====] - 0s 52ms/step - loss: 0.5148 - accuracy:
0.8780 - val_loss: 0.5715 - val_accuracy: 0.8500
Epoch 30/50
3/3 [=====] - 0s 50ms/step - loss: 0.5046 - accuracy:
0.8780 - val_loss: 0.5648 - val_accuracy: 0.8500
Epoch 31/50
3/3 [=====] - 0s 52ms/step - loss: 0.4951 - accuracy:
0.8780 - val_loss: 0.5588 - val_accuracy: 0.8500
Epoch 32/50
3/3 [=====] - 0s 53ms/step - loss: 0.4897 - accuracy:
0.8780 - val_loss: 0.5535 - val_accuracy: 0.8500
Epoch 33/50
3/3 [=====] - 0s 56ms/step - loss: 0.4882 - accuracy:

0.8780 - val_loss: 0.5487 - val_accuracy: 0.8500
Epoch 34/50
3/3 [=====] - 0s 55ms/step - loss: 0.4822 - accuracy:
0.8780 - val_loss: 0.5443 - val_accuracy: 0.8500
Epoch 35/50
3/3 [=====] - 0s 53ms/step - loss: 0.4746 - accuracy:
0.8780 - val_loss: 0.5402 - val_accuracy: 0.8500
Epoch 36/50
3/3 [=====] - 0s 53ms/step - loss: 0.4729 - accuracy:
0.8780 - val_loss: 0.5365 - val_accuracy: 0.8500
Epoch 37/50
3/3 [=====] - 0s 54ms/step - loss: 0.4706 - accuracy:
0.8780 - val_loss: 0.5328 - val_accuracy: 0.8500
Epoch 38/50
3/3 [=====] - 0s 53ms/step - loss: 0.4665 - accuracy:
0.8780 - val_loss: 0.5294 - val_accuracy: 0.8500
Epoch 39/50
3/3 [=====] - 0s 63ms/step - loss: 0.4644 - accuracy:
0.8780 - val_loss: 0.5261 - val_accuracy: 0.8500
Epoch 40/50
3/3 [=====] - 0s 49ms/step - loss: 0.4610 - accuracy:
0.8780 - val_loss: 0.5228 - val_accuracy: 0.8500
Epoch 41/50
3/3 [=====] - 0s 52ms/step - loss: 0.4596 - accuracy:
0.8780 - val_loss: 0.5195 - val_accuracy: 0.8500
Epoch 42/50
3/3 [=====] - 0s 52ms/step - loss: 0.4579 - accuracy:
0.8780 - val_loss: 0.5165 - val_accuracy: 0.8500
Epoch 43/50
3/3 [=====] - 0s 54ms/step - loss: 0.4546 - accuracy:
0.8780 - val_loss: 0.5134 - val_accuracy: 0.8500
Epoch 44/50
3/3 [=====] - 0s 56ms/step - loss: 0.4562 - accuracy:
0.8780 - val_loss: 0.5104 - val_accuracy: 0.8500
Epoch 45/50
3/3 [=====] - 0s 57ms/step - loss: 0.4491 - accuracy:
0.8780 - val_loss: 0.5073 - val_accuracy: 0.8500
Epoch 46/50
3/3 [=====] - 0s 55ms/step - loss: 0.4497 - accuracy:
0.8780 - val_loss: 0.5044 - val_accuracy: 0.8500
Epoch 47/50
3/3 [=====] - 0s 55ms/step - loss: 0.4497 - accuracy:
0.8780 - val_loss: 0.5013 - val_accuracy: 0.8500
Epoch 48/50
3/3 [=====] - 0s 52ms/step - loss: 0.4487 - accuracy:
0.8780 - val_loss: 0.4981 - val_accuracy: 0.8500
Epoch 49/50
3/3 [=====] - 0s 57ms/step - loss: 0.4430 - accuracy:

```
0.8780 - val_loss: 0.4958 - val_accuracy: 0.8500
Epoch 50/50
3/3 [=====] - 0s 53ms/step - loss: 0.4472 - accuracy:
0.8780 - val_loss: 0.4935 - val_accuracy: 0.8500
```

[27]: <keras.callbacks.History at 0x2ca9960a0>

[28]: `model2.evaluate(vgg_features_val, val_target)`

```
8/8 [=====] - 0s 18ms/step - loss: 0.4935 - accuracy:
0.8500
```

[28]: [0.4935258626937866, 0.8500000238418579]

3 The accuracy of our model has increased to 85%

[]: