190108X_Exercise_11

June 1, 2022

Exercise 11

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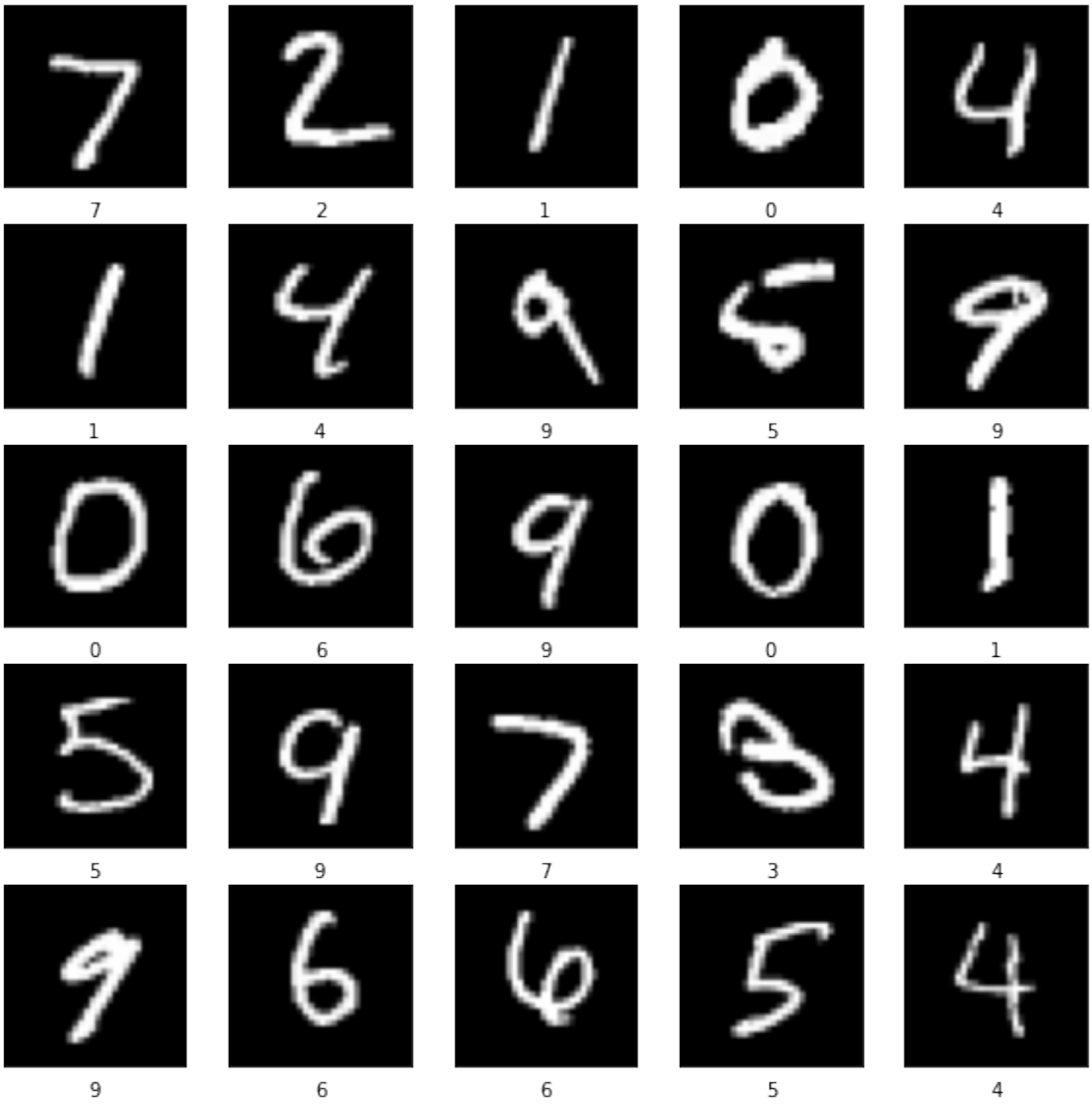
Question 1

[4]:
```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import datasets, layers, models
import numpy as np
import matplotlib.pyplot as plt

mnist = keras.datasets.mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()

# Padding
paddings = tf.constant([[0, 0], [2, 2], [2, 2]])
train_images = tf.pad(train_images, paddings, constant_values=0)
test_images = tf.pad(test_images, paddings, constant_values=0)

print('train_images.shape: ', train_images.shape)
print('train_labels.shape: ', train_labels.shape)
print('test_images.shape:', test_images.shape)
print('test_labels.shape:', test_labels.shape)
class_names = ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']

train_images = tf.dtypes.cast(train_images, tf.float32)
test_images = tf.dtypes.cast(test_images, tf.float32)
train_images, test_images = train_images[..., np.newaxis]/255.0, test_images[...
 ↪, np.newaxis]/255.0
```

```
train_images.shape:  (60000, 32, 32)
train_labels.shape:  (60000,)
test_images.shape: (10000, 32, 32)
test_labels.shape: (10000,)
```

[5]:
```
plt.figure(figsize=(10,10))
for i in range(25):
```

```
    plt.subplot(5,5,i+1)
    plt.xticks([])
    plt.yticks([])
    plt.grid(False)
    plt.imshow(tf.reshape(test_images[i],[32,32]),cmap=plt.cm.gray)
    plt.xlabel(class_names[test_labels[i]])

plt.show()
```



[2]:
```
model = models.Sequential()
model.add(layers.Conv2D(6,(5,5),activation = 'relu',input_shape = (32,32,1)))
model.add(layers.AveragePooling2D((2,2)))
```

```
model.add(layers.Conv2D(16,(5,5),activation = 'relu'))
model.add(layers.AveragePooling2D((2,2)))

model.add(layers.Flatten())
model.add(layers.Dense(120,activation = 'relu'))
model.add(layers.Dense(84,activation = 'relu'))
model.add(layers.Dense(10))

model.compile(optimizer = 'adam',loss = tf.keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True),metrics = ['accuracy'])
print(model.summary)
model.fit(train_images,train_labels,epochs = 5)
test_loss, test_accuracy = model.evaluate(test_images,test_labels,verbose = 2)
```

```
<bound method Model.summary of <keras.engine.sequential.Sequential object at
0x00000282503101F0>>
Epoch 1/5
1875/1875 [==============================] - 50s 26ms/step - loss: 0.2157 -
accuracy: 0.9344
Epoch 2/5
1875/1875 [==============================] - 46s 25ms/step - loss: 0.0711 -
accuracy: 0.9785
Epoch 3/5
1875/1875 [==============================] - 48s 26ms/step - loss: 0.0506 -
accuracy: 0.9843
Epoch 4/5
1875/1875 [==============================] - 47s 25ms/step - loss: 0.0392 -
accuracy: 0.9872
Epoch 5/5
1875/1875 [==============================] - 47s 25ms/step - loss: 0.0317 -
accuracy: 0.9898
313/313 - 3s - loss: 0.0316 - accuracy: 0.9893 - 3s/epoch - 10ms/step
```

Question 2

[3]:
```
# for CIFAR10
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import cifar10, mnist
import tensorflow as tf
import matplotlib.pyplot as plt
(train_images, train_labels), (test_images, test_labels) = datasets.cifar10.
 ↪load_data()

# Normalize pixel values to be between 0 and 1
train_images, test_images = train_images / 255.0, test_images / 255.0
```

```
class_names = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog',␣
↪'horse', 'ship', 'truck']
```

[4]:
```
model = models.Sequential()
model.add(layers.Conv2D(32,(5,5),activation = 'relu',input_shape = (32,32,3)))
model.add(layers.MaxPool2D((2,2)))
model.add(layers.Conv2D(64,(3,3),activation = 'relu'))
model.add(layers.MaxPool2D((2,2)))
model.add(layers.Conv2D(128,(3,3),activation = 'relu'))
model.add(layers.MaxPool2D((2,2)))
model.add(layers.Flatten())
model.add(layers.Dense(64,activation = 'relu'))
model.add(layers.Dense(10))

model.compile(optimizer=keras.optimizers.Adam(learning_rate = 0.001),loss = tf.
↪keras.losses.SparseCategoricalCrossentropy(from_logits=True),metrics =␣
↪['accuracy'])
print(model.summary)

model.fit(train_images,train_labels,epochs = 5)
test_loss, test_accuracy = model.evaluate(test_images,test_labels,verbose = 2)
print(test_accuracy)
```

```
<bound method Model.summary of <keras.engine.sequential.Sequential object at
0x0000028268D26670>>
Epoch 1/5
1563/1563 [==============================] - 125s 79ms/step - loss: 1.5619 -
accuracy: 0.4308
Epoch 2/5
1563/1563 [==============================] - 117s 75ms/step - loss: 1.2059 -
accuracy: 0.5719
Epoch 3/5
1563/1563 [==============================] - 116s 74ms/step - loss: 1.0487 -
accuracy: 0.6320
Epoch 4/5
1563/1563 [==============================] - 110s 70ms/step - loss: 0.9426 -
accuracy: 0.6691
Epoch 5/5
1563/1563 [==============================] - 113s 72ms/step - loss: 0.8551 -
accuracy: 0.7014
313/313 - 6s - loss: 0.9239 - accuracy: 0.6785 - 6s/epoch - 19ms/step
0.6784999966621399
```

Question 3

[5]:
```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import datasets, layers, models
```

```
import numpy as np
import matplotlib.pyplot as plt

mnist = keras.datasets.mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()

# Padding
paddings = tf.constant([[0, 0], [2, 2], [2, 2]])
train_images = tf.pad(train_images, paddings, constant_values=0)
test_images = tf.pad(test_images, paddings, constant_values=0)

print('train_images.shape: ', train_images.shape)
print('train_labels.shape: ', train_labels.shape)
print('test_images.shape:', test_images.shape)
print('test_labels.shape:', test_labels.shape)
class_names = ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']

train_images = tf.dtypes.cast(train_images, tf.float32)
test_images = tf.dtypes.cast(test_images, tf.float32)
train_images, test_images = train_images[..., np.newaxis]/255.0, test_images[...
 ↪, np.newaxis]/255.0

model_base = models.Sequential()
model_base.add(layers.Conv2D(32,(3,3),activation = 'relu',input_shape =␣
 ↪(32,32,1)))
model_base.add(layers.MaxPool2D((2,2)))
model_base.add(layers.Conv2D(64,(3,3),activation = 'relu'))
model_base.add(layers.MaxPool2D((2,2)))
model_base.add(layers.Conv2D(64,(3,3),activation = 'relu'))

model_base.add(layers.Flatten())
model_base.add(layers.Dense(64,activation = 'relu'))
model_base.add(layers.Dense(10))

model_base.compile(optimizer =keras.optimizers.Adam(),loss = tf.keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True),metrics = ['accuracy'])
print(model_base.summary)

model_base.fit(train_images,train_labels,epochs = 2)
test_loss, test_accuracy = model_base.evaluate(test_images,test_labels,verbose␣
 ↪= 2)
model_base.save_weights('saved_weights/')
```

```
train_images.shape:  (60000, 32, 32)
train_labels.shape:  (60000,)
test_images.shape: (10000, 32, 32)
test_labels.shape: (10000,)
```

```
<bound method Model.summary of <keras.engine.sequential.Sequential object at
0x0000028268CF4A90>>
Epoch 1/2
1875/1875 [==============================] - 112s 59ms/step - loss: 0.1273 -
accuracy: 0.9613
Epoch 2/2
1875/1875 [==============================] - 107s 57ms/step - loss: 0.0408 -
accuracy: 0.9872
313/313 - 6s - loss: 0.0569 - accuracy: 0.9818 - 6s/epoch - 18ms/step
```

Question 4

[6]:
```
model_lw = models.Sequential()
model_lw.add(layers.Conv2D(32,(3,3),activation = 'relu',input_shape =␣
 ↪(32,32,1)))
model_lw.add(layers.MaxPool2D((2,2)))
model_lw.add(layers.Conv2D(64,(3,3),activation = 'relu'))
model_lw.add(layers.MaxPool2D((2,2)))
model_lw.add(layers.Conv2D(64,(3,3),activation = 'relu'))

model_lw.add(layers.Flatten())
model_lw.add(layers.Dense(64,activation = 'relu'))
model_lw.add(layers.Dense(10))

model_lw.compile(optimizer =keras.optimizers.Adam(),loss = tf.keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True),metrics = ['accuracy'])
print(model_lw.summary)

model_lw.fit(train_images,train_labels,epochs = 2)
test_loss, test_accuracy = model_lw.evaluate(test_images,test_labels,verbose =␣
 ↪2)
model_lw.save('saved_model/')
```

```
<bound method Model.summary of <keras.engine.sequential.Sequential object at
0x00000282503102B0>>
Epoch 1/2
1875/1875 [==============================] - 131s 69ms/step - loss: 0.1366 -
accuracy: 0.9578
Epoch 2/2
1875/1875 [==============================] - 121s 64ms/step - loss: 0.0437 -
accuracy: 0.9865
313/313 - 6s - loss: 0.0374 - accuracy: 0.9886 - 6s/epoch - 19ms/step

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op,
_jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing
3 of 3). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: saved_model/assets

INFO:tensorflow:Assets written to: saved_model/assets
```

Question 5

[7]:
```
# loading the model
model_ld = keras.models.load_model('saved_model/')
print(model_ld.summary())
model_ld.evaluate(test_images,test_labels, verbose=2)
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8 (Conv2D)           (None, 30, 30, 32)        320

 max_pooling2d_5 (MaxPooling  (None, 15, 15, 32)       0
 2D)

 conv2d_9 (Conv2D)           (None, 13, 13, 64)        18496

 max_pooling2d_6 (MaxPooling  (None, 6, 6, 64)         0
 2D)

 conv2d_10 (Conv2D)          (None, 4, 4, 64)          36928

 flatten_3 (Flatten)         (None, 1024)              0

 dense_7 (Dense)             (None, 64)                65600

 dense_8 (Dense)             (None, 10)                650

=================================================================
Total params: 121,994
Trainable params: 121,994
Non-trainable params: 0
_________________________________________________________________
None
313/313 - 7s - loss: 0.0374 - accuracy: 0.9886 - 7s/epoch - 21ms/step
```

[7]:
```
[0.037437766790390015, 0.9886000156402588]
```

Question 6

[8]:
```
base_inputs = model_ld.layers[0].input
base_outputs = model_ld.layers[-2].output
output = layers.Dense(10)(base_outputs)

new_model = keras.Model(inputs=base_inputs, outputs = output)
new_model.compile(optimizer =keras.optimizers.Adam(),loss = tf.keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True),metrics = ['accuracy'])
```

```
print(new_model.summary)

new_model.fit(train_images,train_labels,epochs = 3,verbose = 2)
new_model.evaluate(test_images, test_labels, verbose=2)
```

```
<bound method Model.summary of <keras.engine.functional.Functional object at
0x000002826A407250>>
Epoch 1/3
1875/1875 - 102s - loss: 0.0821 - accuracy: 0.9775 - 102s/epoch - 54ms/step
Epoch 2/3
1875/1875 - 101s - loss: 0.0272 - accuracy: 0.9918 - 101s/epoch - 54ms/step
Epoch 3/3
1875/1875 - 99s - loss: 0.0204 - accuracy: 0.9937 - 99s/epoch - 53ms/step
313/313 - 6s - loss: 0.0288 - accuracy: 0.9915 - 6s/epoch - 20ms/step
```

[8]: `[0.028831729665398598, 0.9915000200271606]`

Question 7

[9]:
```
#transfer learning
model_for_tl =keras.models.load_model('saved_model/')
model_for_tl.trainable = False
for layer in model_for_tl.layers:
    assert layer.trainable == False

base_inputs = model_for_tl.layers[0].input
base_outputs = model_for_tl.layers[-2].output
output = layers.Dense(10)(base_outputs)

new_model = keras.Model(inputs=base_inputs, outputs = output)
new_model.compile(optimizer =keras.optimizers.Adam(),loss = tf.keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True),metrics = ['accuracy'])

new_model.fit(train_images,train_labels,epochs = 3,verbose = 2)
new_model.evaluate(test_images, test_labels, verbose=2)
```

```
Epoch 1/3
1875/1875 - 34s - loss: 0.2863 - accuracy: 0.9366 - 34s/epoch - 18ms/step
Epoch 2/3
1875/1875 - 41s - loss: 0.0276 - accuracy: 0.9921 - 41s/epoch - 22ms/step
Epoch 3/3
1875/1875 - 35s - loss: 0.0222 - accuracy: 0.9933 - 35s/epoch - 19ms/step
313/313 - 6s - loss: 0.0282 - accuracy: 0.9912 - 6s/epoch - 18ms/step
```

[9]: `[0.028241192921996117, 0.9911999702453613]`

Question 8

[3]:
```
resnet_model=keras.applications.resnet_v2.ResNet50V2()

resnet_model.trainable=False
for layer in resnet_model.layers:
    assert layer.trainable==False

base_innputs=resnet_model.layers[0].input
base_ouputs=resnet_model.layers[-2].output
output=layers.Dense(5)(base_ouputs)

resnet_model=keras.Model(inputs=base_innputs,outputs=output)
resnet_model.compile(optimizer=keras.optimizers.Adam(), loss=keras.losses.
 ↪SparseCategoricalCrossentropy(from_logits=True), metrics=['accuracy'])
print(resnet_model.summary())

train_images=np.random.randint(0,256,(1000,224, 224, 3))
train_labels=np.random.randint(0,5,1000)

resnet_model.fit(train_images,train_labels,epochs=3,verbose=2)
```

```
Model: "model_1"
__________________________________________________________________________________
__________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================
==================
 input_2 (InputLayer)           [(None, 224, 224, 3  0           []
                                )]

 conv1_pad (ZeroPadding2D)      (None, 230, 230, 3)  0
['input_2[0][0]']

 conv1_conv (Conv2D)            (None, 112, 112, 64  9472
['conv1_pad[0][0]']
                                )

 pool1_pad (ZeroPadding2D)      (None, 114, 114, 64  0
['conv1_conv[0][0]']
                                )

 pool1_pool (MaxPooling2D)      (None, 56, 56, 64)   0
['pool1_pad[0][0]']

 conv2_block1_preact_bn (BatchN  (None, 56, 56, 64)  256
['pool1_pool[0][0]']
 ormalization)

 conv2_block1_preact_relu (Acti  (None, 56, 56, 64)  0
```

```
['conv2_block1_preact_bn[0][0]']
 vation)

 conv2_block1_1_conv (Conv2D)   (None, 56, 56, 64)   4096
['conv2_block1_preact_relu[0][0]'
                                                                ]

 conv2_block1_1_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block1_1_conv[0][0]']
 ization)

 conv2_block1_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block1_1_bn[0][0]']
 n)

 conv2_block1_2_pad (ZeroPaddin  (None, 58, 58, 64)  0
['conv2_block1_1_relu[0][0]']
 g2D)

 conv2_block1_2_conv (Conv2D)   (None, 56, 56, 64)   36864
['conv2_block1_2_pad[0][0]']

 conv2_block1_2_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block1_2_conv[0][0]']
 ization)

 conv2_block1_2_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block1_2_bn[0][0]']
 n)

 conv2_block1_0_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block1_preact_relu[0][0]'
                                                                ]

 conv2_block1_3_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block1_2_relu[0][0]']

 conv2_block1_out (Add)         (None, 56, 56, 256)  0
['conv2_block1_0_conv[0][0]',
'conv2_block1_3_conv[0][0]']

 conv2_block2_preact_bn (BatchN  (None, 56, 56, 256)  1024
['conv2_block1_out[0][0]']
 ormalization)

 conv2_block2_preact_relu (Acti  (None, 56, 56, 256)  0
['conv2_block2_preact_bn[0][0]']
 vation)
```

```
 conv2_block2_1_conv (Conv2D)   (None, 56, 56, 64)   16384
['conv2_block2_preact_relu[0][0]'
                                                                ]

 conv2_block2_1_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block2_1_conv[0][0]']
 ization)

 conv2_block2_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block2_1_bn[0][0]']
 n)

 conv2_block2_2_pad (ZeroPaddin  (None, 58, 58, 64)  0
['conv2_block2_1_relu[0][0]']
 g2D)

 conv2_block2_2_conv (Conv2D)   (None, 56, 56, 64)   36864
['conv2_block2_2_pad[0][0]']

 conv2_block2_2_bn (BatchNormal  (None, 56, 56, 64)  256
['conv2_block2_2_conv[0][0]']
 ization)

 conv2_block2_2_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block2_2_bn[0][0]']
 n)

 conv2_block2_3_conv (Conv2D)   (None, 56, 56, 256)  16640
['conv2_block2_2_relu[0][0]']

 conv2_block2_out (Add)         (None, 56, 56, 256)  0
['conv2_block1_out[0][0]',
'conv2_block2_3_conv[0][0]']

 conv2_block3_preact_bn (BatchN  (None, 56, 56, 256)  1024
['conv2_block2_out[0][0]']
 ormalization)

 conv2_block3_preact_relu (Acti  (None, 56, 56, 256)  0
['conv2_block3_preact_bn[0][0]']
 vation)

 conv2_block3_1_conv (Conv2D)   (None, 56, 56, 64)   16384
['conv2_block3_preact_relu[0][0]'
                                                                ]

 conv2_block3_1_bn (BatchNormal  (None, 56, 56, 64)  256
```

```
['conv2_block3_1_conv[0][0]']
 ization)

 conv2_block3_1_relu (Activatio  (None, 56, 56, 64)  0
['conv2_block3_1_bn[0][0]']
 n)

 conv2_block3_2_pad (ZeroPaddin  (None, 58, 58, 64)  0
['conv2_block3_1_relu[0][0]']
 g2D)

 conv2_block3_2_conv (Conv2D)   (None, 28, 28, 64)   36864
['conv2_block3_2_pad[0][0]']

 conv2_block3_2_bn (BatchNormal  (None, 28, 28, 64)  256
['conv2_block3_2_conv[0][0]']
 ization)

 conv2_block3_2_relu (Activatio  (None, 28, 28, 64)  0
['conv2_block3_2_bn[0][0]']
 n)

 max_pooling2d_3 (MaxPooling2D)  (None, 28, 28, 256)  0
['conv2_block2_out[0][0]']

 conv2_block3_3_conv (Conv2D)   (None, 28, 28, 256)  16640
['conv2_block3_2_relu[0][0]']

 conv2_block3_out (Add)         (None, 28, 28, 256)  0
['max_pooling2d_3[0][0]',
'conv2_block3_3_conv[0][0]']

 conv3_block1_preact_bn (BatchN  (None, 28, 28, 256)  1024
['conv2_block3_out[0][0]']
 ormalization)

 conv3_block1_preact_relu (Acti  (None, 28, 28, 256)  0
['conv3_block1_preact_bn[0][0]']
 vation)

 conv3_block1_1_conv (Conv2D)   (None, 28, 28, 128)  32768
['conv3_block1_preact_relu[0][0]'
                                                                ]

 conv3_block1_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block1_1_conv[0][0]']
 ization)
```

```
 conv3_block1_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block1_1_bn[0][0]']
 n)

 conv3_block1_2_pad (ZeroPaddin  (None, 30, 30, 128)  0
['conv3_block1_1_relu[0][0]']
 g2D)

 conv3_block1_2_conv (Conv2D)   (None, 28, 28, 128)  147456
['conv3_block1_2_pad[0][0]']

 conv3_block1_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block1_2_conv[0][0]']
 ization)

 conv3_block1_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block1_2_bn[0][0]']
 n)

 conv3_block1_0_conv (Conv2D)   (None, 28, 28, 512)  131584
['conv3_block1_preact_relu[0][0]'
                                                                 ]

 conv3_block1_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block1_2_relu[0][0]']

 conv3_block1_out (Add)         (None, 28, 28, 512)  0
['conv3_block1_0_conv[0][0]',
'conv3_block1_3_conv[0][0]']

 conv3_block2_preact_bn (BatchN  (None, 28, 28, 512)  2048
['conv3_block1_out[0][0]']
 ormalization)

 conv3_block2_preact_relu (Acti  (None, 28, 28, 512)  0
['conv3_block2_preact_bn[0][0]']
 vation)

 conv3_block2_1_conv (Conv2D)   (None, 28, 28, 128)  65536
['conv3_block2_preact_relu[0][0]'
                                                                 ]

 conv3_block2_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block2_1_conv[0][0]']
 ization)

 conv3_block2_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block2_1_bn[0][0]']
```

```
 n)

 conv3_block2_2_pad (ZeroPaddin  (None, 30, 30, 128)  0
['conv3_block2_1_relu[0][0]']
 g2D)

 conv3_block2_2_conv (Conv2D)   (None, 28, 28, 128)  147456
['conv3_block2_2_pad[0][0]']

 conv3_block2_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block2_2_conv[0][0]']
 ization)

 conv3_block2_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block2_2_bn[0][0]']
 n)

 conv3_block2_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block2_2_relu[0][0]']

 conv3_block2_out (Add)         (None, 28, 28, 512)  0
['conv3_block1_out[0][0]',
'conv3_block2_3_conv[0][0]']

 conv3_block3_preact_bn (BatchN  (None, 28, 28, 512)  2048
['conv3_block2_out[0][0]']
 ormalization)

 conv3_block3_preact_relu (Acti  (None, 28, 28, 512)  0
['conv3_block3_preact_bn[0][0]']
 vation)

 conv3_block3_1_conv (Conv2D)   (None, 28, 28, 128)  65536
['conv3_block3_preact_relu[0][0]'
                                                                  ]

 conv3_block3_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block3_1_conv[0][0]']
 ization)

 conv3_block3_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block3_1_bn[0][0]']
 n)

 conv3_block3_2_pad (ZeroPaddin  (None, 30, 30, 128)  0
['conv3_block3_1_relu[0][0]']
 g2D)
```

```
 conv3_block3_2_conv (Conv2D)   (None, 28, 28, 128)  147456
['conv3_block3_2_pad[0][0]']

 conv3_block3_2_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block3_2_conv[0][0]']
 ization)

 conv3_block3_2_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block3_2_bn[0][0]']
 n)

 conv3_block3_3_conv (Conv2D)   (None, 28, 28, 512)  66048
['conv3_block3_2_relu[0][0]']

 conv3_block3_out (Add)         (None, 28, 28, 512)  0
['conv3_block2_out[0][0]',
'conv3_block3_3_conv[0][0]']

 conv3_block4_preact_bn (BatchN  (None, 28, 28, 512)  2048
['conv3_block3_out[0][0]']
 ormalization)

 conv3_block4_preact_relu (Acti  (None, 28, 28, 512)  0
['conv3_block4_preact_bn[0][0]']
 vation)

 conv3_block4_1_conv (Conv2D)   (None, 28, 28, 128)  65536
['conv3_block4_preact_relu[0][0]'
                                                                 ]

 conv3_block4_1_bn (BatchNormal  (None, 28, 28, 128)  512
['conv3_block4_1_conv[0][0]']
 ization)

 conv3_block4_1_relu (Activatio  (None, 28, 28, 128)  0
['conv3_block4_1_bn[0][0]']
 n)

 conv3_block4_2_pad (ZeroPaddin  (None, 30, 30, 128)  0
['conv3_block4_1_relu[0][0]']
 g2D)

 conv3_block4_2_conv (Conv2D)   (None, 14, 14, 128)  147456
['conv3_block4_2_pad[0][0]']

 conv3_block4_2_bn (BatchNormal  (None, 14, 14, 128)  512
['conv3_block4_2_conv[0][0]']
 ization)
```

```
 conv3_block4_2_relu (Activatio  (None, 14, 14, 128)  0
['conv3_block4_2_bn[0][0]']
 n)

 max_pooling2d_4 (MaxPooling2D)  (None, 14, 14, 512)  0
['conv3_block3_out[0][0]']

 conv3_block4_3_conv (Conv2D)   (None, 14, 14, 512)  66048
['conv3_block4_2_relu[0][0]']

 conv3_block4_out (Add)         (None, 14, 14, 512)  0
['max_pooling2d_4[0][0]',
'conv3_block4_3_conv[0][0]']

 conv4_block1_preact_bn (BatchN  (None, 14, 14, 512)  2048
['conv3_block4_out[0][0]']
 ormalization)

 conv4_block1_preact_relu (Acti  (None, 14, 14, 512)  0
['conv4_block1_preact_bn[0][0]']
 vation)

 conv4_block1_1_conv (Conv2D)   (None, 14, 14, 256)  131072
['conv4_block1_preact_relu[0][0]'
                                                                 ]

 conv4_block1_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block1_1_conv[0][0]']
 ization)

 conv4_block1_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block1_1_bn[0][0]']
 n)

 conv4_block1_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block1_1_relu[0][0]']
 g2D)

 conv4_block1_2_conv (Conv2D)   (None, 14, 14, 256)  589824
['conv4_block1_2_pad[0][0]']

 conv4_block1_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block1_2_conv[0][0]']
 ization)

 conv4_block1_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block1_2_bn[0][0]']
```

```
 n)

 conv4_block1_0_conv (Conv2D)   (None, 14, 14, 1024  525312
['conv4_block1_preact_relu[0][0]'
                                )                                 ]

 conv4_block1_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block1_2_relu[0][0]']
                                )

 conv4_block1_out (Add)         (None, 14, 14, 1024  0
['conv4_block1_0_conv[0][0]',
                                )
'conv4_block1_3_conv[0][0]']

 conv4_block2_preact_bn (BatchN  (None, 14, 14, 1024  4096
['conv4_block1_out[0][0]']
 ormalization)                  )

 conv4_block2_preact_relu (Acti  (None, 14, 14, 1024  0
['conv4_block2_preact_bn[0][0]']
 vation)                        )

 conv4_block2_1_conv (Conv2D)   (None, 14, 14, 256)  262144
['conv4_block2_preact_relu[0][0]'
                                                                  ]

 conv4_block2_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block2_1_conv[0][0]']
 ization)

 conv4_block2_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block2_1_bn[0][0]']
 n)

 conv4_block2_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block2_1_relu[0][0]']
 g2D)

 conv4_block2_2_conv (Conv2D)   (None, 14, 14, 256)  589824
['conv4_block2_2_pad[0][0]']

 conv4_block2_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block2_2_conv[0][0]']
 ization)

 conv4_block2_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block2_2_bn[0][0]']
```

```
 n)

 conv4_block2_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block2_2_relu[0][0]']
                                )

 conv4_block2_out (Add)         (None, 14, 14, 1024  0
['conv4_block1_out[0][0]',
                                )
'conv4_block2_3_conv[0][0]']

 conv4_block3_preact_bn (BatchN  (None, 14, 14, 1024  4096
['conv4_block2_out[0][0]']
 ormalization)                  )

 conv4_block3_preact_relu (Acti  (None, 14, 14, 1024  0
['conv4_block3_preact_bn[0][0]']
 vation)                        )

 conv4_block3_1_conv (Conv2D)   (None, 14, 14, 256)  262144
['conv4_block3_preact_relu[0][0]'
                                                                  ]

 conv4_block3_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block3_1_conv[0][0]']
 ization)

 conv4_block3_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block3_1_bn[0][0]']
 n)

 conv4_block3_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block3_1_relu[0][0]']
 g2D)

 conv4_block3_2_conv (Conv2D)   (None, 14, 14, 256)  589824
['conv4_block3_2_pad[0][0]']

 conv4_block3_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block3_2_conv[0][0]']
 ization)

 conv4_block3_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block3_2_bn[0][0]']
 n)

 conv4_block3_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block3_2_relu[0][0]']
```

```
                                )

 conv4_block3_out (Add)         (None, 14, 14, 1024  0
['conv4_block2_out[0][0]',
                                )
'conv4_block3_3_conv[0][0]']

 conv4_block4_preact_bn (BatchN  (None, 14, 14, 1024  4096
['conv4_block3_out[0][0]']
 ormalization)                  )

 conv4_block4_preact_relu (Acti  (None, 14, 14, 1024  0
['conv4_block4_preact_bn[0][0]']
 vation)                        )

 conv4_block4_1_conv (Conv2D)   (None, 14, 14, 256)  262144
['conv4_block4_preact_relu[0][0]'
                                                                  ]

 conv4_block4_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block4_1_conv[0][0]']
 ization)

 conv4_block4_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block4_1_bn[0][0]']
 n)

 conv4_block4_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block4_1_relu[0][0]']
 g2D)

 conv4_block4_2_conv (Conv2D)   (None, 14, 14, 256)  589824
['conv4_block4_2_pad[0][0]']

 conv4_block4_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block4_2_conv[0][0]']
 ization)

 conv4_block4_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block4_2_bn[0][0]']
 n)

 conv4_block4_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block4_2_relu[0][0]']
                                )

 conv4_block4_out (Add)         (None, 14, 14, 1024  0
['conv4_block3_out[0][0]',
```

```
                                )
'conv4_block4_3_conv[0][0]']

 conv4_block5_preact_bn (BatchN  (None, 14, 14, 1024  4096
['conv4_block4_out[0][0]']
 ormalization)                  )

 conv4_block5_preact_relu (Acti  (None, 14, 14, 1024  0
['conv4_block5_preact_bn[0][0]']
 vation)                        )

 conv4_block5_1_conv (Conv2D)   (None, 14, 14, 256)  262144
['conv4_block5_preact_relu[0][0]'
                                                                 ]

 conv4_block5_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block5_1_conv[0][0]']
 ization)

 conv4_block5_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block5_1_bn[0][0]']
 n)

 conv4_block5_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block5_1_relu[0][0]']
 g2D)

 conv4_block5_2_conv (Conv2D)   (None, 14, 14, 256)  589824
['conv4_block5_2_pad[0][0]']

 conv4_block5_2_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block5_2_conv[0][0]']
 ization)

 conv4_block5_2_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block5_2_bn[0][0]']
 n)

 conv4_block5_3_conv (Conv2D)   (None, 14, 14, 1024  263168
['conv4_block5_2_relu[0][0]']
                                )

 conv4_block5_out (Add)         (None, 14, 14, 1024  0
['conv4_block4_out[0][0]',
                                )
'conv4_block5_3_conv[0][0]']

 conv4_block6_preact_bn (BatchN  (None, 14, 14, 1024  4096
```

```
['conv4_block5_out[0][0]']
 ormalization)                  )

 conv4_block6_preact_relu (Acti  (None, 14, 14, 1024  0
['conv4_block6_preact_bn[0][0]']
 vation)                        )

 conv4_block6_1_conv (Conv2D)   (None, 14, 14, 256)  262144
['conv4_block6_preact_relu[0][0]'
                                                                ]

 conv4_block6_1_bn (BatchNormal  (None, 14, 14, 256)  1024
['conv4_block6_1_conv[0][0]']
 ization)

 conv4_block6_1_relu (Activatio  (None, 14, 14, 256)  0
['conv4_block6_1_bn[0][0]']
 n)

 conv4_block6_2_pad (ZeroPaddin  (None, 16, 16, 256)  0
['conv4_block6_1_relu[0][0]']
 g2D)

 conv4_block6_2_conv (Conv2D)   (None, 7, 7, 256)    589824
['conv4_block6_2_pad[0][0]']

 conv4_block6_2_bn (BatchNormal  (None, 7, 7, 256)   1024
['conv4_block6_2_conv[0][0]']
 ization)

 conv4_block6_2_relu (Activatio  (None, 7, 7, 256)   0
['conv4_block6_2_bn[0][0]']
 n)

 max_pooling2d_5 (MaxPooling2D)  (None, 7, 7, 1024)  0
['conv4_block5_out[0][0]']

 conv4_block6_3_conv (Conv2D)   (None, 7, 7, 1024)   263168
['conv4_block6_2_relu[0][0]']

 conv4_block6_out (Add)         (None, 7, 7, 1024)   0
['max_pooling2d_5[0][0]',
'conv4_block6_3_conv[0][0]']

 conv5_block1_preact_bn (BatchN  (None, 7, 7, 1024)  4096
['conv4_block6_out[0][0]']
 ormalization)
```

```
 conv5_block1_preact_relu (Acti  (None, 7, 7, 1024)  0
['conv5_block1_preact_bn[0][0]']
 vation)

 conv5_block1_1_conv (Conv2D)   (None, 7, 7, 512)    524288
['conv5_block1_preact_relu[0][0]'
                                                                 ]

 conv5_block1_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block1_1_conv[0][0]']
 ization)

 conv5_block1_1_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block1_1_bn[0][0]']
 n)

 conv5_block1_2_pad (ZeroPaddin  (None, 9, 9, 512)   0
['conv5_block1_1_relu[0][0]']
 g2D)

 conv5_block1_2_conv (Conv2D)   (None, 7, 7, 512)    2359296
['conv5_block1_2_pad[0][0]']

 conv5_block1_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block1_2_conv[0][0]']
 ization)

 conv5_block1_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block1_2_bn[0][0]']
 n)

 conv5_block1_0_conv (Conv2D)   (None, 7, 7, 2048)   2099200
['conv5_block1_preact_relu[0][0]'
                                                                 ]

 conv5_block1_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block1_2_relu[0][0]']

 conv5_block1_out (Add)         (None, 7, 7, 2048)   0
['conv5_block1_0_conv[0][0]',
'conv5_block1_3_conv[0][0]']

 conv5_block2_preact_bn (BatchN  (None, 7, 7, 2048)  8192
['conv5_block1_out[0][0]']
 ormalization)

 conv5_block2_preact_relu (Acti  (None, 7, 7, 2048)  0
['conv5_block2_preact_bn[0][0]']
```

```
 vation)

 conv5_block2_1_conv (Conv2D)   (None, 7, 7, 512)    1048576
['conv5_block2_preact_relu[0][0]'
                                                                 ]

 conv5_block2_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block2_1_conv[0][0]']
 ization)

 conv5_block2_1_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block2_1_bn[0][0]']
 n)

 conv5_block2_2_pad (ZeroPaddin  (None, 9, 9, 512)   0
['conv5_block2_1_relu[0][0]']
 g2D)

 conv5_block2_2_conv (Conv2D)   (None, 7, 7, 512)    2359296
['conv5_block2_2_pad[0][0]']

 conv5_block2_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block2_2_conv[0][0]']
 ization)

 conv5_block2_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block2_2_bn[0][0]']
 n)

 conv5_block2_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block2_2_relu[0][0]']

 conv5_block2_out (Add)         (None, 7, 7, 2048)   0
['conv5_block1_out[0][0]',
'conv5_block2_3_conv[0][0]']

 conv5_block3_preact_bn (BatchN  (None, 7, 7, 2048)  8192
['conv5_block2_out[0][0]']
 ormalization)

 conv5_block3_preact_relu (Acti  (None, 7, 7, 2048)  0
['conv5_block3_preact_bn[0][0]']
 vation)

 conv5_block3_1_conv (Conv2D)   (None, 7, 7, 512)    1048576
['conv5_block3_preact_relu[0][0]'
                                                                 ]
```

```
 conv5_block3_1_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block3_1_conv[0][0]']
 ization)

 conv5_block3_1_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block3_1_bn[0][0]']
 n)

 conv5_block3_2_pad (ZeroPaddin  (None, 9, 9, 512)   0
['conv5_block3_1_relu[0][0]']
 g2D)

 conv5_block3_2_conv (Conv2D)   (None, 7, 7, 512)    2359296
['conv5_block3_2_pad[0][0]']

 conv5_block3_2_bn (BatchNormal  (None, 7, 7, 512)   2048
['conv5_block3_2_conv[0][0]']
 ization)

 conv5_block3_2_relu (Activatio  (None, 7, 7, 512)   0
['conv5_block3_2_bn[0][0]']
 n)

 conv5_block3_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624
['conv5_block3_2_relu[0][0]']

 conv5_block3_out (Add)         (None, 7, 7, 2048)   0
['conv5_block2_out[0][0]',
'conv5_block3_3_conv[0][0]']

 post_bn (BatchNormalization)   (None, 7, 7, 2048)   8192
['conv5_block3_out[0][0]']

 post_relu (Activation)         (None, 7, 7, 2048)   0
['post_bn[0][0]']

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

 dense_1 (Dense)                (None, 5)            10245
['avg_pool[0][0]']

==================================================================================
==================
Total params: 23,575,045
Trainable params: 10,245
Non-trainable params: 23,564,800
```

```
_________________________________________________________________
_________________
None
Epoch 1/3
32/32 - 192s - loss: 31.1466 - accuracy: 0.2110 - 192s/epoch - 6s/step
Epoch 2/3
32/32 - 171s - loss: 8.5644 - accuracy: 0.1990 - 171s/epoch - 5s/step
Epoch 3/3
32/32 - 172s - loss: 7.4302 - accuracy: 0.2080 - 172s/epoch - 5s/step
```

[3]: <keras.callbacks.History at 0x247a9cb0b80>