EN2550 - Fundementals of Image Processing and Machine Vision

Name : R.G.S.M. RANATUNGA

Index No. : 190504H

In [ ]:
```
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import datasets, layers, models
```

Part 1

In [ ]:
```
mnist = keras.datasets.mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()

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.r
```

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

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

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 6)         156

 average_pooling2d (AverageP  (None, 14, 14, 6)        0
 ooling2D)

 conv2d_1 (Conv2D)           (None, 10, 10, 16)        2416

 average_pooling2d_1 (Averag  (None, 5, 5, 16)         0
 ePooling2D)

 flatten (Flatten)           (None, 400)               0

 dense (Dense)               (None, 120)               48120

 dense_1 (Dense)             (None, 84)                10164

 dense_2 (Dense)             (None, 10)                850

=================================================================
Total params: 61,706
Trainable params: 61,706
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/5
1875/1875 [==============================] - 15s 7ms/step - loss: 0.1941 - accuracy:
0.9411
Epoch 2/5
1875/1875 [==============================] - 12s 6ms/step - loss: 0.0648 - accuracy:
0.9799
Epoch 3/5
1875/1875 [==============================] - 12s 6ms/step - loss: 0.0477 - accuracy:
0.9847
Epoch 4/5
1875/1875 [==============================] - 12s 6ms/step - loss: 0.0369 - accuracy:
0.9882
Epoch 5/5
1875/1875 [==============================] - 12s 6ms/step - loss: 0.0303 - accuracy:
0.9905
313/313 - 1s - loss: 0.0335 - accuracy: 0.9890 - 1s/epoch - 3ms/step
```

Part 2

In [ ]:
```
(train_images, train_labels), (test_images, test_labels) = datasets.cifar10.load_data(

train_images, test_images = train_images / 255.0, test_images / 255.0
class_names = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse'
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)
```

```
train_images.shape:  (50000, 32, 32, 3)
train_labels.shape:  (50000, 1)
test_images.shape: (10000, 32, 32, 3)
test_labels.shape: (10000, 1)
```

In [ ]:
```
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))
```

In [ ]:
```
model.compile(optimizer = keras.optimizers.Adam(learning_rate=0.001),loss = tf.keras.l
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 0x000001
8C4F3A33A0>>
Epoch 1/5
1563/1563 [==============================] - 24s 15ms/step - loss: 1.5247 - accuracy:
0.4450
Epoch 2/5
1563/1563 [==============================] - 24s 15ms/step - loss: 1.1671 - accuracy:
0.5863
Epoch 3/5
1563/1563 [==============================] - 24s 15ms/step - loss: 1.0065 - accuracy:
0.6472
Epoch 4/5
1563/1563 [==============================] - 24s 15ms/step - loss: 0.8983 - accuracy:
0.6870
Epoch 5/5
1563/1563 [==============================] - 24s 16ms/step - loss: 0.8099 - accuracy:
0.7173
313/313 - 2s - loss: 0.9504 - accuracy: 0.6798 - 2s/epoch - 6ms/step
0.6797999739646912
```

Part 3

In [ ]:
```
mnist = keras.datasets.mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()

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.r

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.SparseCa
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,)
Model: "sequential_2"
```

Layer (type)	Output Shape	Param #
conv2d_5 (Conv2D)	(None, 30, 30, 32)	320
max_pooling2d_3 (MaxPooling 2D)	(None, 15, 15, 32)	0
conv2d_6 (Conv2D)	(None, 13, 13, 64)	18496
max_pooling2d_4 (MaxPooling 2D)	(None, 6, 6, 64)	0
conv2d_7 (Conv2D)	(None, 4, 4, 64)	36928
flatten_2 (Flatten)	(None, 1024)	0
dense_5 (Dense)	(None, 64)	65600
dense_6 (Dense)	(None, 10)	650

```
Total params: 121,994
Trainable params: 121,994
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/2
1875/1875 [==============================] - 28s 15ms/step - loss: 0.1399 - accuracy:
0.9567
Epoch 2/2
1875/1875 [==============================] - 26s 14ms/step - loss: 0.0428 - accuracy:
0.9870
313/313 - 2s - loss: 0.0370 - accuracy: 0.9894 - 2s/epoch - 5ms/step
```

Part 4

In [ ]:

```
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.SparseCate

print(model_lw.summary())

model_lw.load_weights('saved_weights/')
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/')
```

```
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
Epoch 1/2
1875/1875 [==============================] - 29s 15ms/step - loss: 0.0306 - accuracy:
0.9905
Epoch 2/2
1875/1875 [==============================] - 26s 14ms/step - loss: 0.0230 - accuracy:
0.9927
313/313 - 2s - loss: 0.0289 - accuracy: 0.9914 - 2s/epoch - 5ms/step
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_comp
iled_convolution_op, _jit_compiled_convolution_op while saving (showing 3 of 3). Thes
e functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: saved_model/assets
INFO:tensorflow:Assets written to: saved_model/assets
```

Part 5 (Load the Model)

In [ ]:
```
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 - 2s - loss: 0.0289 - accuracy: 0.9914 - 2s/epoch - 5ms/step
```

Out[ ]:
```
[0.028874719515442848, 0.9914000034332275]
```

Part 6 (Fine tune the model)

In [ ]:
```
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.SparseCa
print(new_model.summary())

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

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8_input (InputLayer)  [(None, 32, 32, 1)]      0

 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_9 (Dense)             (None, 10)                650

=================================================================
Total params: 121,994
Trainable params: 121,994
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/3
1875/1875 [==============================] - 28s 15ms/step - loss: 0.0581 - accuracy:
0.9840
Epoch 2/3
1875/1875 [==============================] - 27s 15ms/step - loss: 0.0190 - accuracy:
0.9938
Epoch 3/3
1875/1875 [==============================] - 26s 14ms/step - loss: 0.0141 - accuracy:
0.9954
313/313 - 2s - loss: 0.0379 - accuracy: 0.9895 - 2s/epoch - 5ms/step
```

Part 7

In [ ]:

```
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.SparseCa
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 - 9s - loss: 0.2303 - accuracy: 0.9510 - 9s/epoch - 5ms/step
Epoch 2/3
1875/1875 - 9s - loss: 0.0151 - accuracy: 0.9959 - 9s/epoch - 5ms/step
Epoch 3/3
1875/1875 - 9s - loss: 0.0112 - accuracy: 0.9967 - 9s/epoch - 5ms/step
313/313 - 2s - loss: 0.0227 - accuracy: 0.9929 - 2s/epoch - 5ms/step
```

Out[ ]: [0.02272079698741436, 0.992900013923645]

Part 8

In [ ]:
```
resnet = keras.applications.resnet_v2.ResNet50V2(include_top= True)
resnet.trainable = False

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

base_inputs = resnet.layers[0].input
base_outputs = resnet.layers[-2].output

output = layers.Dense(5)(base_outputs)

rand_list = list(np.random.randint(0,4,5))
train_images = tf.random.normal(shape=(5,224,224,3))
train_labels = tf.constant(rand_list)

new_model = keras.Model(inputs = base_inputs, outputs = output)
new_model.compile(optimizer = keras.optimizers.Adam(), loss = tf.keras.losses.SparseCa
print(new_model.summary())


new_model.fit(train_images, train_labels, epochs=8,verbose = 2)
```

```
Model: "model_4"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_3 (InputLayer)           [(None, 224, 224, 3  0           []
                                )]

 conv1_pad (ZeroPadding2D)      (None, 230, 230, 3)  0           ['input_3[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_preac
t_bn[0][0]']
 vation)

 conv2_block1_1_conv (Conv2D)   (None, 56, 56, 64)   4096        ['conv2_block1_preac
t_relu[0][0]'
                                                                 ]

 conv2_block1_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block1_1_con
v[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_rel
u[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_con
v[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_preac
t_relu[0][0]'
                                                                 ]

 conv2_block1_3_conv (Conv2D)   (None, 56, 56, 256)  16640       ['conv2_block1_2_rel
u[0][0]']
```

```
 conv2_block1_out (Add)         (None, 56, 56, 256)  0           ['conv2_block1_0_con
v[0][0]',
                                                                  'conv2_block1_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv2_block2_1_conv (Conv2D)   (None, 56, 56, 64)   16384       ['conv2_block2_preac
t_relu[0][0]'
                                                                 ]

 conv2_block2_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block2_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']

 conv2_block2_out (Add)         (None, 56, 56, 256)  0           ['conv2_block1_out
[0][0]',
                                                                  'conv2_block2_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv2_block3_1_conv (Conv2D)   (None, 56, 56, 64)   16384       ['conv2_block3_preac
t_relu[0][0]'
                                                                 ]
```

```
 conv2_block3_1_bn (BatchNormal  (None, 56, 56, 64)  256         ['conv2_block3_1_con
v[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_rel
u[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_con
v[0][0]']
 ization)

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

 max_pooling2d_13 (MaxPooling2D  (None, 28, 28, 256)  0          ['conv2_block2_out
[0][0]']
 )

 conv2_block3_3_conv (Conv2D)   (None, 28, 28, 256)  16640       ['conv2_block3_2_rel
u[0][0]']

 conv2_block3_out (Add)         (None, 28, 28, 256)  0           ['max_pooling2d_13
[0][0]',
                                                                  'conv2_block3_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv3_block1_1_conv (Conv2D)   (None, 28, 28, 128)  32768       ['conv3_block1_preac
t_relu[0][0]'
                                                                 ]

 conv3_block1_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block1_1_con
v[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_rel
u[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_con
v[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_preac
t_relu[0][0]'
                                                                 ]

 conv3_block1_3_conv (Conv2D)   (None, 28, 28, 512)  66048      ['conv3_block1_2_rel
u[0][0]']

 conv3_block1_out (Add)         (None, 28, 28, 512)  0          ['conv3_block1_0_con
v[0][0]',
                                                                  'conv3_block1_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv3_block2_1_conv (Conv2D)   (None, 28, 28, 128)  65536      ['conv3_block2_preac
t_relu[0][0]'
                                                                 ]

 conv3_block2_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block2_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']
```

```
 conv3_block2_out (Add)         (None, 28, 28, 512)  0           ['conv3_block1_out
[0][0]',
                                                                  'conv3_block2_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv3_block3_1_conv (Conv2D)   (None, 28, 28, 128)  65536       ['conv3_block3_preac
t_relu[0][0]'
                                                                  ]

 conv3_block3_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block3_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']

 conv3_block3_out (Add)         (None, 28, 28, 512)  0           ['conv3_block2_out
[0][0]',
                                                                  'conv3_block3_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv3_block4_1_conv (Conv2D)   (None, 28, 28, 128)  65536       ['conv3_block4_preac
t_relu[0][0]'
                                                                  ]
```

```
 conv3_block4_1_bn (BatchNormal  (None, 28, 28, 128)  512        ['conv3_block4_1_con
v[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_rel
u[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_con
v[0][0]']
 ization)

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

 max_pooling2d_14 (MaxPooling2D  (None, 14, 14, 512)  0          ['conv3_block3_out
[0][0]']
 )

 conv3_block4_3_conv (Conv2D)   (None, 14, 14, 512)  66048       ['conv3_block4_2_rel
u[0][0]']

 conv3_block4_out (Add)         (None, 14, 14, 512)  0           ['max_pooling2d_14
[0][0]',
                                                                  'conv3_block4_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv4_block1_1_conv (Conv2D)   (None, 14, 14, 256)  131072      ['conv4_block1_preac
t_relu[0][0]'
                                                                 ]

 conv4_block1_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block1_1_con
v[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_rel
u[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_con
v[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_preac
t_relu[0][0]'
                                )                                 ]

 conv4_block1_3_conv (Conv2D)   (None, 14, 14, 1024  263168      ['conv4_block1_2_rel
u[0][0']
                                )

 conv4_block1_out (Add)         (None, 14, 14, 1024  0           ['conv4_block1_0_con
v[0][0]',
                                )                                 'conv4_block1_3_con
v[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_preac
t_bn[0][0']
 vation)                        )

 conv4_block2_1_conv (Conv2D)   (None, 14, 14, 256)  262144      ['conv4_block2_preac
t_relu[0][0]'
                                                                  ]

 conv4_block2_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block2_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0']
```

```
                                )

 conv4_block2_out (Add)         (None, 14, 14, 1024  0           ['conv4_block1_out
[0][0]',
                                )                                 'conv4_block2_3_con
v[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_preac
t_bn[0][0]']
 vation)                        )

 conv4_block3_1_conv (Conv2D)   (None, 14, 14, 256)  262144      ['conv4_block3_preac
t_relu[0][0]'
                                                                 ]

 conv4_block3_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block3_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']
                                )

 conv4_block3_out (Add)         (None, 14, 14, 1024  0           ['conv4_block2_out
[0][0]',
                                )                                 'conv4_block3_3_con
v[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_preac
t_bn[0][0]']
 vation)                        )

 conv4_block4_1_conv (Conv2D)   (None, 14, 14, 256)  262144      ['conv4_block4_preac
```

```
t_relu[0][0]'
                                                                  ]

 conv4_block4_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block4_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']
                                )

 conv4_block4_out (Add)         (None, 14, 14, 1024  0           ['conv4_block3_out
[0][0]',
                                )                                 'conv4_block4_3_con
v[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_preac
t_bn[0][0]']
 vation)                        )

 conv4_block5_1_conv (Conv2D)   (None, 14, 14, 256)  262144      ['conv4_block5_preac
t_relu[0][0]'
                                                                  ]

 conv4_block5_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block5_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0']
                                )

 conv4_block5_out (Add)         (None, 14, 14, 1024  0           ['conv4_block4_out
[0][0',
                                )                                 'conv4_block5_3_con
v[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_preac
t_bn[0][0']
 vation)                        )

 conv4_block6_1_conv (Conv2D)   (None, 14, 14, 256)  262144      ['conv4_block6_preac
t_relu[0][0]'
                                                                 ]

 conv4_block6_1_bn (BatchNormal  (None, 14, 14, 256)  1024       ['conv4_block6_1_con
v[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_rel
u[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_con
v[0][0']
 ization)

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

 max_pooling2d_15 (MaxPooling2D  (None, 7, 7, 1024)  0           ['conv4_block5_out
[0][0']
 )

 conv4_block6_3_conv (Conv2D)   (None, 7, 7, 1024)   263168      ['conv4_block6_2_rel
u[0][0']
```

```
 conv4_block6_out (Add)         (None, 7, 7, 1024)   0           ['max_pooling2d_15
[0][0]',
                                                                  'conv4_block6_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv5_block1_1_conv (Conv2D)   (None, 7, 7, 512)    524288      ['conv5_block1_preac
t_relu[0][0]'
                                                                 ]

 conv5_block1_1_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block1_1_con
v[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_rel
u[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_con
v[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_preac
t_relu[0][0]'
                                                                 ]

 conv5_block1_3_conv (Conv2D)   (None, 7, 7, 2048)   1050624     ['conv5_block1_2_rel
u[0][0]']

 conv5_block1_out (Add)         (None, 7, 7, 2048)   0           ['conv5_block1_0_con
v[0][0]',
                                                                  'conv5_block1_3_con
v[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_preac
t_bn[0][0]']
 vation)
```

```
 conv5_block2_1_conv (Conv2D)   (None, 7, 7, 512)    1048576     ['conv5_block2_preac
t_relu[0][0]'
                                                                 ]

 conv5_block2_1_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block2_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']

 conv5_block2_out (Add)         (None, 7, 7, 2048)   0           ['conv5_block1_out
[0][0]',
                                                                  'conv5_block2_3_con
v[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_preac
t_bn[0][0]']
 vation)

 conv5_block3_1_conv (Conv2D)   (None, 7, 7, 512)    1048576     ['conv5_block3_preac
t_relu[0][0]'
                                                                 ]

 conv5_block3_1_bn (BatchNormal  (None, 7, 7, 512)   2048        ['conv5_block3_1_con
v[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_rel
u[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_con
v[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_rel
u[0][0]']

 conv5_block3_out (Add)         (None, 7, 7, 2048)   0           ['conv5_block2_out
[0][0]',
                                                                  'conv5_block3_3_con
v[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_13 (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 1/8
1/1 - 3s - loss: 1.5140 - accuracy: 0.4000 - 3s/epoch - 3s/step
Epoch 2/8
1/1 - 0s - loss: 1.3646 - accuracy: 0.4000 - 231ms/epoch - 231ms/step
Epoch 3/8
1/1 - 0s - loss: 1.2566 - accuracy: 0.4000 - 233ms/epoch - 233ms/step
Epoch 4/8
1/1 - 0s - loss: 1.1822 - accuracy: 0.6000 - 238ms/epoch - 238ms/step
Epoch 5/8
1/1 - 0s - loss: 1.1350 - accuracy: 0.2000 - 241ms/epoch - 241ms/step
Epoch 6/8
1/1 - 0s - loss: 1.1063 - accuracy: 0.4000 - 228ms/epoch - 228ms/step
Epoch 7/8
1/1 - 0s - loss: 1.0856 - accuracy: 0.4000 - 236ms/epoch - 236ms/step
Epoch 8/8
1/1 - 0s - loss: 1.0640 - accuracy: 0.4000 - 248ms/epoch - 248ms/step
```

Out[ ]:
```
<keras.callbacks.History at 0x18c5b142ef0>
```