

✓ Fine Tuning using ResNet101V2

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```
from google.colab import drive
drive.mount('/content/gdrive')
```

↗ Mounted at /content/gdrive

```
import tensorflow as tf
print(tf.__version__)
```

```
from tensorflow import keras
tf.random.set_seed(42)
```

```
import numpy as np
np.random.seed(42)
```

```
import matplotlib.pyplot as plt
%matplotlib inline
```

↗ 2.17.1

✓ Load the preprocessed dataset and model from drive

```
# load numpy array from npy file
from numpy import load
```

```
X_train_std = load('/content/gdrive/MyDrive/DL/X_train_std_model2.npy')
X_test_std = load('/content/gdrive/MyDrive/DL/X_test_std_model2.npy')
```

```
y_train = load('/content/gdrive/MyDrive/DL/y_train_model2.npy')
y_test = load('/content/gdrive/MyDrive/DL/y_test_model2.npy')
```

```
print("X_train_std_shape: {}".format(X_train_std.shape))
print("X_test_std_shape: {}".format(X_test_std.shape))
```

```
⇒ X_train_std_shape: (1245, 224, 224, 3)
   X_test_std_shape: (416, 224, 224, 3)
```

```
model2_FT = keras.models.load_model('/content/gdrive/MyDrive/DL/ResNet101V2_Best_Model2_FT.h5')
model2_FT.summary()
```

```
⇒ WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be trained.
Model: "functional"
```

Layer (type)	Output Shape	Param #	Connected to
input_layer_1 (InputLayer)	(None, 224, 224, 3)	0	—
conv1_pad (ZeroPadding2D)	(None, 230, 230, 3)	0	input_layer_1
conv1_conv (Conv2D)	(None, 112, 112, 64)	9,472	conv1_pad
pool1_pad (ZeroPadding2D)	(None, 114, 114, 64)	0	conv1_conv
pool1_pool (MaxPooling2D)	(None, 56, 56, 64)	0	pool1_pad
conv2_block1_preact_bn (BatchNormalization)	(None, 56, 56, 64)	256	pool1_pool
conv2_block1_preact_relu (Activation)	(None, 56, 56, 64)	0	conv2_block1_preact_bn
conv2_block1_1_conv (Conv2D)	(None, 56, 56, 64)	4,096	conv2_block1_preact_relu
conv2_block1_1_bn (BatchNormalization)	(None, 56, 56, 64)	256	conv2_block1_1_conv
conv2_block1_1_relu	(None, 56, 56, 64)	0	conv2_block1_1_bn

(Activation)			
conv2_block1_2_pad (ZeroPadding2D)	(None, 58, 58, 64)	0	conv2_
conv2_block1_2_conv (Conv2D)	(None, 56, 56, 64)	36,864	conv2_
conv2_block1_2_bn (BatchNormalization)	(None, 56, 56, 64)	256	conv2_
conv2_block1_2_relu (Activation)	(None, 56, 56, 64)	0	conv2_
conv2_block1_0_conv (Conv2D)	(None, 56, 56, 256)	16,640	conv2_
conv2_block1_3_conv (Conv2D)	(None, 56, 56, 256)	16,640	conv2_
conv2_block1_out (Add)	(None, 56, 56, 256)	0	conv2_ conv2_
conv2_block2_preact_bn (BatchNormalization)	(None, 56, 56, 256)	1,024	conv2_
conv2_block2_preact_relu (Activation)	(None, 56, 56, 256)	0	conv2_
conv2_block2_1_conv (Conv2D)	(None, 56, 56, 64)	16,384	conv2_
conv2_block2_1_bn (BatchNormalization)	(None, 56, 56, 64)	256	conv2_
conv2_block2_1_relu (Activation)	(None, 56, 56, 64)	0	conv2_
conv2_block2_2_pad (ZeroPadding2D)	(None, 58, 58, 64)	0	conv2_
conv2_block2_2_conv (Conv2D)	(None, 56, 56, 64)	36,864	conv2_
conv2_block2_2_bn (BatchNormalization)	(None, 56, 56, 64)	256	conv2_
conv2_block2_2_relu (Activation)	(None, 56, 56, 64)	0	conv2_
conv2_block2_3_conv (Conv2D)	(None, 56, 56, 256)	16,640	conv2_
conv2_block2_out (Add)	(None, 56, 56, 256)	0	conv2_

conv2_block2_out (Add)	(None, 56, 56, 256)	0	conv2_block2_out (Add)
conv2_block3_preact_bn (BatchNormalization)	(None, 56, 56, 256)	1,024	conv2_block3_preact_bn (BatchNormalization)
conv2_block3_preact_relu (Activation)	(None, 56, 56, 256)	0	conv2_block3_preact_relu (Activation)
conv2_block3_1_conv (Conv2D)	(None, 56, 56, 64)	16,384	conv2_block3_1_conv (Conv2D)
conv2_block3_1_bn (BatchNormalization)	(None, 56, 56, 64)	256	conv2_block3_1_bn (BatchNormalization)
conv2_block3_1_relu (Activation)	(None, 56, 56, 64)	0	conv2_block3_1_relu (Activation)
conv2_block3_2_pad (ZeroPadding2D)	(None, 58, 58, 64)	0	conv2_block3_2_pad (ZeroPadding2D)
conv2_block3_2_conv (Conv2D)	(None, 28, 28, 64)	36,864	conv2_block3_2_conv (Conv2D)
conv2_block3_2_bn (BatchNormalization)	(None, 28, 28, 64)	256	conv2_block3_2_bn (BatchNormalization)
conv2_block3_2_relu (Activation)	(None, 28, 28, 64)	0	conv2_block3_2_relu (Activation)
max_pooling2d_3 (MaxPooling2D)	(None, 28, 28, 256)	0	max_pooling2d_3 (MaxPooling2D)
conv2_block3_3_conv (Conv2D)	(None, 28, 28, 256)	16,640	conv2_block3_3_conv (Conv2D)
conv2_block3_out (Add)	(None, 28, 28, 256)	0	conv2_block3_out (Add)
conv3_block1_preact_bn (BatchNormalization)	(None, 28, 28, 256)	1,024	conv3_block1_preact_bn (BatchNormalization)
conv3_block1_preact_relu (Activation)	(None, 28, 28, 256)	0	conv3_block1_preact_relu (Activation)
conv3_block1_1_conv (Conv2D)	(None, 28, 28, 128)	32,768	conv3_block1_1_conv (Conv2D)
conv3_block1_1_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_block1_1_bn (BatchNormalization)
conv3_block1_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_block1_1_relu (Activation)

conv3_block1_2_pad (ZeroPadding2D)	(None, 30, 30, 128)	0	conv3_
conv3_block1_2_conv (Conv2D)	(None, 28, 28, 128)	147,456	conv3_
conv3_block1_2_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block1_2_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block1_0_conv (Conv2D)	(None, 28, 28, 512)	131,584	conv3_
conv3_block1_3_conv (Conv2D)	(None, 28, 28, 512)	66,048	conv3_
conv3_block1_out (Add)	(None, 28, 28, 512)	0	conv3_ conv3_
conv3_block2_preact_bn (BatchNormalization)	(None, 28, 28, 512)	2,048	conv3_
conv3_block2_preact_relu (Activation)	(None, 28, 28, 512)	0	conv3_
conv3_block2_1_conv (Conv2D)	(None, 28, 28, 128)	65,536	conv3_
conv3_block2_1_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block2_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block2_2_pad (ZeroPadding2D)	(None, 30, 30, 128)	0	conv3_
conv3_block2_2_conv (Conv2D)	(None, 28, 28, 128)	147,456	conv3_
conv3_block2_2_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block2_2_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block2_3_conv (Conv2D)	(None, 28, 28, 512)	66,048	conv3_
conv3_block2_out (Add)	(None, 28, 28, 512)	0	conv3_ conv3_

conv3_block3_preact_bn (BatchNormalization)	(None, 28, 28, 512)	2,048	conv3_
conv3_block3_preact_relu (Activation)	(None, 28, 28, 512)	0	conv3_
conv3_block3_1_conv (Conv2D)	(None, 28, 28, 128)	65,536	conv3_
conv3_block3_1_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block3_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block3_2_pad (ZeroPadding2D)	(None, 30, 30, 128)	0	conv3_
conv3_block3_2_conv (Conv2D)	(None, 28, 28, 128)	147,456	conv3_
conv3_block3_2_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block3_2_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block3_3_conv (Conv2D)	(None, 28, 28, 512)	66,048	conv3_
conv3_block3_out (Add)	(None, 28, 28, 512)	0	conv3_ conv3_
conv3_block4_preact_bn (BatchNormalization)	(None, 28, 28, 512)	2,048	conv3_
conv3_block4_preact_relu (Activation)	(None, 28, 28, 512)	0	conv3_
conv3_block4_1_conv (Conv2D)	(None, 28, 28, 128)	65,536	conv3_
conv3_block4_1_bn (BatchNormalization)	(None, 28, 28, 128)	512	conv3_
conv3_block4_1_relu (Activation)	(None, 28, 28, 128)	0	conv3_
conv3_block4_2_pad (ZeroPadding2D)	(None, 30, 30, 128)	0	conv3_
conv3_block4_2_conv (Conv2D)	(None, 14, 14, 128)	147,456	conv3_

conv3_block4_2_bn (BatchNormalization)	(None, 14, 14, 128)	512	conv3_
conv3_block4_2_relu (Activation)	(None, 14, 14, 128)	0	conv3_
max_pooling2d_4 (MaxPooling2D)	(None, 14, 14, 512)	0	conv3_
conv3_block4_3_conv (Conv2D)	(None, 14, 14, 512)	66,048	conv3_
conv3_block4_out (Add)	(None, 14, 14, 512)	0	max_po conv3_
conv4_block1_preact_bn (BatchNormalization)	(None, 14, 14, 512)	2,048	conv3_
conv4_block1_preact_relu (Activation)	(None, 14, 14, 512)	0	conv4_
conv4_block1_1_conv (Conv2D)	(None, 14, 14, 256)	131,072	conv4_
conv4_block1_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block1_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block1_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block1_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block1_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block1_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block1_0_conv (Conv2D)	(None, 14, 14, 1024)	525,312	conv4_
conv4_block1_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block1_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block2_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_

conv4_block2_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block2_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block2_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block2_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block2_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block2_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block2_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block2_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block2_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block2_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block3_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block3_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block3_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block3_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block3_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block3_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block3_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block3_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_

(BatchNormalization)			
conv4_block3_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block3_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block3_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block4_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block4_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block4_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block4_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block4_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block4_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block4_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block4_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block4_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block4_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block4_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block5_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block5_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block5_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block5_1_bn	(None, 14, 14, 256)	1,024	conv4_

(BatchNormalization)			
conv4_block5_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block5_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block5_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block5_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block5_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block5_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block5_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block6_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block6_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block6_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block6_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block6_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block6_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block6_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block6_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block6_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block6_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block6_out (Add)	(None, 14, 14, 1024)	0	conv4_

conv4_block6_out (Add)	(None, 14, 14, 1024)	0	conv4_
conv4_block7_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block7_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block7_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block7_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block7_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block7_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block7_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block7_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block7_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block7_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block7_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block8_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block8_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block8_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block8_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block8_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block8_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_

conv4_block8_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block8_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block8_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block8_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block8_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block9_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block9_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block9_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block9_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block9_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block9_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block9_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block9_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block9_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block9_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block9_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block10_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block10_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_

conv4_block10_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block10_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block10_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block10_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block10_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block10_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block10_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block10_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block10_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block11_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block11_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block11_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block11_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block11_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block11_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block11_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block11_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block11_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_

conv4_block11_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block11_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block12_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block12_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block12_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block12_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block12_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block12_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block12_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block12_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block12_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block12_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block12_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block13_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block13_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block13_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block13_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block13_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_

conv4_block13_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block13_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block13_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block13_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block13_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block13_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block14_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block14_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block14_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block14_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block14_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block14_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block14_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block14_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block14_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block14_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block14_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block15_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_

(BatchNormalization)			
conv4_block15_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block15_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block15_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block15_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block15_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block15_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block15_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block15_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block15_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block15_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block16_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block16_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block16_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block16_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block16_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block16_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block16_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block16_2_bn	(None, 14, 14, 256)	1,024	conv4_

(BatchNormalization)			
conv4_block16_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block16_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block16_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block17_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block17_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block17_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block17_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block17_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block17_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block17_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block17_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block17_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block17_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block17_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block18_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block18_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block18_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block18_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_

conv4_block18_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block18_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block18_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block18_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block18_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block18_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block18_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block18_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block19_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block19_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block19_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block19_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block19_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block19_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block19_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block19_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block19_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block19_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_

conv4_block19_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block20_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block20_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block20_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block20_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block20_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block20_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block20_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block20_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block20_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block20_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block20_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block21_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block21_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block21_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block21_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block21_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block21_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_

conv4_block21_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block21_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block21_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block21_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block21_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block22_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block22_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_
conv4_block22_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block22_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block22_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block22_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block22_2_conv (Conv2D)	(None, 14, 14, 256)	589,824	conv4_
conv4_block22_2_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block22_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block22_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_
conv4_block22_out (Add)	(None, 14, 14, 1024)	0	conv4_ conv4_
conv4_block23_preact_bn (BatchNormalization)	(None, 14, 14, 1024)	4,096	conv4_
conv4_block23_preact_relu (Activation)	(None, 14, 14, 1024)	0	conv4_

conv4_block23_1_conv (Conv2D)	(None, 14, 14, 256)	262,144	conv4_
conv4_block23_1_bn (BatchNormalization)	(None, 14, 14, 256)	1,024	conv4_
conv4_block23_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_
conv4_block23_2_pad (ZeroPadding2D)	(None, 16, 16, 256)	0	conv4_
conv4_block23_2_conv (Conv2D)	(None, 7, 7, 256)	589,824	conv4_
conv4_block23_2_bn (BatchNormalization)	(None, 7, 7, 256)	1,024	conv4_
conv4_block23_2_relu (Activation)	(None, 7, 7, 256)	0	conv4_
max_pooling2d_5 (MaxPooling2D)	(None, 7, 7, 1024)	0	conv4_
conv4_block23_3_conv (Conv2D)	(None, 7, 7, 1024)	263,168	conv4_
conv4_block23_out (Add)	(None, 7, 7, 1024)	0	max_po conv4_
conv5_block1_preact_bn (BatchNormalization)	(None, 7, 7, 1024)	4,096	conv4_
conv5_block1_preact_relu (Activation)	(None, 7, 7, 1024)	0	conv5_
conv5_block1_1_conv (Conv2D)	(None, 7, 7, 512)	524,288	conv5_
conv5_block1_1_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_
conv5_block1_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block1_2_pad (ZeroPadding2D)	(None, 9, 9, 512)	0	conv5_
conv5_block1_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,296	conv5_
conv5_block1_2_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_

conv5_block1_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block1_0_conv (Conv2D)	(None, 7, 7, 2048)	2,099,200	conv5_
conv5_block1_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_
conv5_block1_out (Add)	(None, 7, 7, 2048)	0	conv5_ conv5_
conv5_block2_preact_bn (BatchNormalization)	(None, 7, 7, 2048)	8,192	conv5_
conv5_block2_preact_relu (Activation)	(None, 7, 7, 2048)	0	conv5_
conv5_block2_1_conv (Conv2D)	(None, 7, 7, 512)	1,048,576	conv5_
conv5_block2_1_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_
conv5_block2_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block2_2_pad (ZeroPadding2D)	(None, 9, 9, 512)	0	conv5_
conv5_block2_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,296	conv5_
conv5_block2_2_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_
conv5_block2_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block2_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_
conv5_block2_out (Add)	(None, 7, 7, 2048)	0	conv5_ conv5_
conv5_block3_preact_bn (BatchNormalization)	(None, 7, 7, 2048)	8,192	conv5_
conv5_block3_preact_relu (Activation)	(None, 7, 7, 2048)	0	conv5_
conv5_block3_1_conv (Conv2D)	(None, 7, 7, 512)	1,048,576	conv5_

(Conv2D)			
conv5_block3_1_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_
conv5_block3_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block3_2_pad (ZeroPadding2D)	(None, 9, 9, 512)	0	conv5_
conv5_block3_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,296	conv5_
conv5_block3_2_bn (BatchNormalization)	(None, 7, 7, 512)	2,048	conv5_
conv5_block3_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_
conv5_block3_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_
conv5_block3_out (Add)	(None, 7, 7, 2048)	0	conv5_ conv5_
post_bn (BatchNormalization)	(None, 7, 7, 2048)	8,192	conv5_
post_relu (Activation)	(None, 7, 7, 2048)	0	post_b
global_average_pooling2d (GlobalAveragePooling2D)	(None, 2048)	0	post_i
batch_normalization (BatchNormalization)	(None, 2048)	8,192	globa
dropout (Dropout)	(None, 2048)	0	batch_
dense (Dense)	(None, 3)	6,147	dropo

Total params: 42,640,901 (162.66 MB)

Trainable params: 10,243 (40.01 KB)

Non-trainable params: 42,630,656 (162.62 MB)

Optimizer params: 2 (12.00 B)

✓ Fine tuning:

- Initial 35% layers as non-trainable

```
train_threshold = int(0.35*(len(model2_FT.layers)-4)) #last 4 layers belong to the
for layer in model2_FT.layers[:train_threshold]:
    layer.trainable = False

for layer in model2_FT.layers[train_threshold:]:
    layer.trainable = True
```

✓ Compile and train the model

```
from tensorflow.keras import regularizers
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import ImageDataGenerator
import numpy as np
```

```
model2_FT.compile(loss='sparse_categorical_crossentropy',
                  optimizer='adam',
                  metrics=['accuracy'])
```

#Use the same data augmentation setup we used for transfer learning

```
datagen = ImageDataGenerator(
    rotation_range=20,
    width_shift_range=0.2,
    height_shift_range=0.2,
    horizontal_flip=True,
    fill_mode='nearest',
    validation_split=0.1
)
```

#Create generators

```
train_generator = datagen.flow(
    X_train_std,
    y_train,
    batch_size=16,
```













```
        subset='training'
    )

validation_generator = datagen.flow(
    X_train_std,
    y_train,
    batch_size=16,
    subset='validation'
)

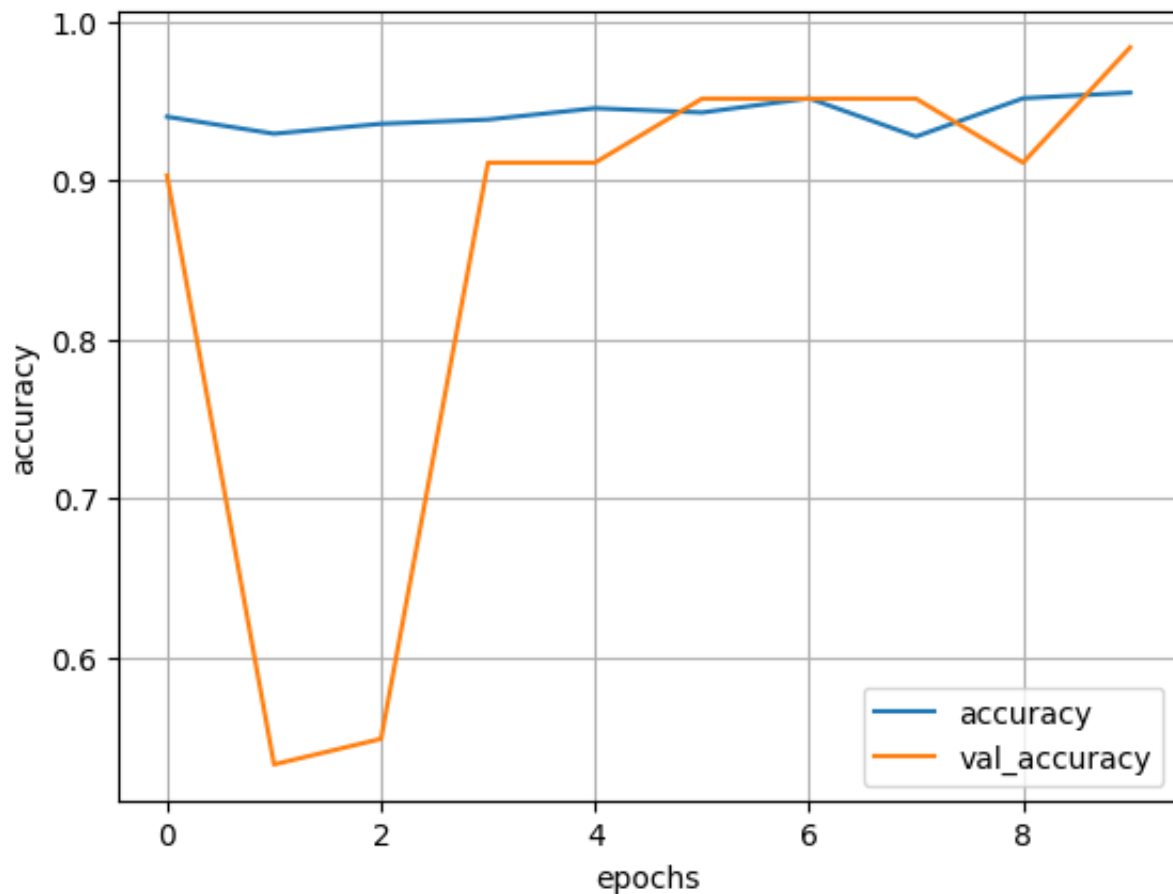
callbacks2_FT = [
    keras.callbacks.ModelCheckpoint(
        "best_resnet_FT.weights.h5",
        monitor='val_accuracy',
        save_weights_only=True,
        save_best_only=True
    ),
]

#Train
history2_FT = model2_FT.fit(
    train_generator,
    validation_data=validation_generator,
    epochs=10,
    callbacks=callbacks2_FT
)
```

↔ Epoch 1/10
71/71  **97s** 602ms/step - accuracy: 0.9448 - loss: 0.2461 -
Epoch 2/10
71/71  **14s** 184ms/step - accuracy: 0.9324 - loss: 0.2308 -
Epoch 3/10
71/71  **14s** 186ms/step - accuracy: 0.9410 - loss: 0.2114 -
Epoch 4/10
71/71  **16s** 212ms/step - accuracy: 0.9426 - loss: 0.1988 -
Epoch 5/10
71/71  **15s** 189ms/step - accuracy: 0.9495 - loss: 0.1717 -
Epoch 6/10
71/71  **16s** 213ms/step - accuracy: 0.9378 - loss: 0.1991 -
Epoch 7/10
71/71  **15s** 189ms/step - accuracy: 0.9533 - loss: 0.1546 -
Epoch 8/10
71/71  **15s** 189ms/step - accuracy: 0.9166 - loss: 0.2732 -
Epoch 9/10
71/71  **15s** 189ms/step - accuracy: 0.9485 - loss: 0.1457 -
Epoch 10/10
71/71  **16s** 212ms/step - accuracy: 0.9564 - loss: 0.1184 -

```
import pandas as pd
#Visualize accuracy
progress = {k:v for k,v in history2_FT.history.items() if k in ['accuracy', 'val_ac

pd.DataFrame(progress).plot()
plt.xlabel("epochs")
plt.ylabel("accuracy")
plt.grid(True)
plt.show()
```



✓ Evaluate Fine tuned model

```
testLoss2_FT, testAccuracy2_FT = model2_FT.evaluate(x = X_test_std, y = y_test)
print("Test-loss: %f, Test-accuracy: %f" % (testLoss2_FT, testAccuracy2_FT))
```



13/13 ————— **8s** 121ms/step – accuracy: 0.9838 – loss: 0.0573
 Test-loss: 0.059052, Test-accuracy: 0.985577

✓ Update model using best weights

```
model2_FT.load_weights("best_resnet_FT.weights.h5")

testLoss2_FT, testAccuracy2_FT = model2_FT.evaluate(x = X_test_std, y = y_test)

print("Test-loss: %f, Test-accuracy: %f" % (testLoss2_FT, testAccuracy2_FT))
```

➞ 13/13 ————— 2s 122ms/step – accuracy: 0.9838 – loss: 0.0573
Test-loss: 0.059052, Test-accuracy: 0.985577

✓ Model performance

```
y_prob = model2_FT.predict(X_test_std)
y_predict = np.argmax(y_prob, axis=-1)
print(y_predict)
```

➞ 13/13 ————— 6s 116ms/step

```
[1 1 0 0 0 0 0 1 0 0 0 1 0 0 0 1 1 1 0 1 1 1 1 0 0 0 1 1 0 1 0 0 0 1
 0 0 0 1 0 1 0 0 1 1 0 0 1 1 1 1 1 0 1 1 1 1 0 0 0 1 0 0 1 1 1 0 0 0 1 0
 0 1 1 0 1 0 1 0 2 1 0 1 0 0 0 0 1 1 1 0 0 1 0 0 1 0 0 0 0 0 1 1 1 1 1 0 0
 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 0 2 0 1 1 1 0 1 0 0 1 1 0 1 1 1 0 1 1 1
 1 0 1 0 1 1 1 1 0 1 1 0 0 1 0 1 1 0 0 0 1 0 0 1 1 1 0 1 0 0 0 0 0 0 0 1 1
 1 0 1 0 0 1 1 0 1 1 0 1 0 2 0 0 0 1 1 1 1 0 0 0 1 0 0 0 1 2 0 0 1 0 0 0 1
 0 1 0 0 0 0 1 0 1 1 0 1 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 0 1 0 1 1 1 0 0 1
 0 1 0 1 0 0 1 1 1 0 0 1 0 0 1 1 1 0 0 0 0 1 0 1 0 1 0 0 1 0 2 1 1 1 1 1 0
 0 2 1 0 0 1 0 1 1 0 0 1 0 1 1 1 0 0 1 1 0 2 1 2 0 0 0 0 1 0 1 0 0 0 1 1 2
 1 0 1 0 1 1 0 0 1 0 1 2 0 1 0 1 1 0 0 0 0 1 1 0 0 0 1 0 1 1 0 1 1 1 1 1 1
 0 0 1 1 0 0 1 0 1 1 1 0 0 0 0 0 1 1 0 1 1 0 2 1 1 1 1 1 1 1 0 1 0 1 1 0 1
 0 1 0 2 1 0 1 0 0]
```

#confusion matrix

```
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_true = y_test, y_pred = y_predict)
```

```
fig, ax = plt.subplots(figsize=(6, 6))
ax.matshow(cm, cmap=plt.cm.Blues, alpha=0.3)
```

```
for i in range(cm.shape[0]):
    for j in range(cm.shape[1]):
```

```
ax.text(x=j, y=i, s=cm[i, j], va='center', ha='center')
```

```
ax.title.set_text('Model 2 FT\n')
```

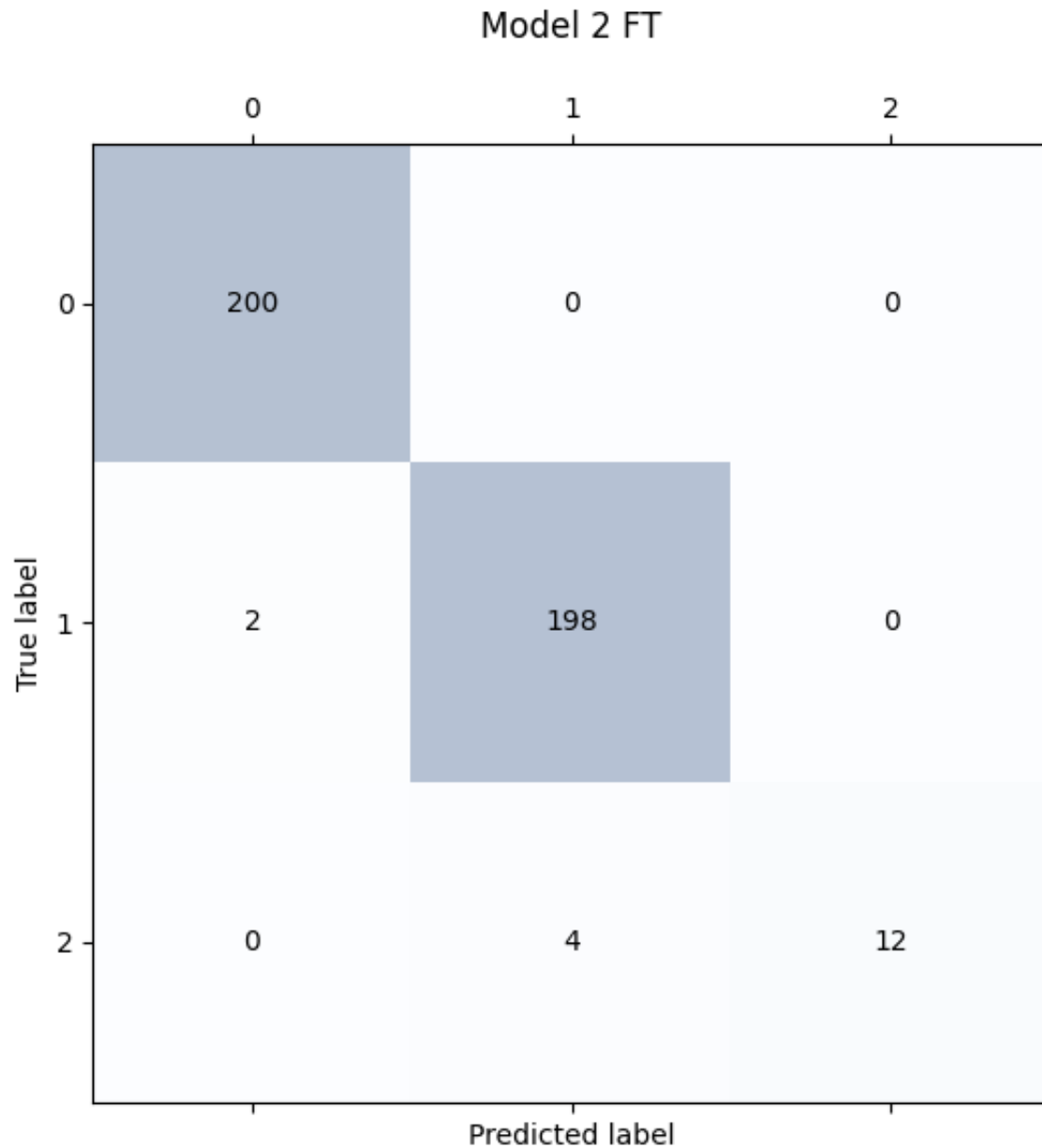
```
plt.xlabel('Predicted label')
```

```
plt.ylabel('True label')
```

```
plt.tight_layout()
```

```
plt.savefig("ConfusionMatrix_ResNet101V2_FT.png", dpi=300, format='png', pad_inches=
```

```
plt.show())
```



```
#classification scores
```

```
from sklearn.metrics import precision_score, recall_score, f1_score
```

```
pScore = precision_score(y_true= y_test, y_pred = y_predict, average = 'weighted')  
print("Precision: ", pScore)
```

```
rScore = recall_score(y_true= y_test, y_pred = y_predict, average = 'weighted')  
print("Recall: ", rScore)
```

```
fScore = f1_score(y_true= y_test, y_pred = y_predict, average = 'weighted')  
print("F1-score: ", fScore)
```

```
⇒ Precision: 0.9857197258187357  
Recall: 0.9855769230769231  
F1-score: 0.9849379476245149
```

✓ Save best model

```
model2_FT.save('/content/gdrive/MyDrive/DL/ResNet101V2_Best_Model_FT.h5')
```

```
⇒ WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `
```

