MobileNet V2 & V3 Image Classification

Notebook adapted from the Image Classification (MobileNetV2, ImageNet) and Rock Paper Scissors (using MobileNetV2 network) notebooks.
Modified by: Gábor Major
Last Modified date: 2025-03-21

Import libraries.

```
import tensorflow as tf
import tensorflow_datasets as tfds
import matplotlib.pyplot as plt
import numpy as np
import platform
import pathlib
import os
import tensorflow.keras.backend as K

print('Python version:', platform.python_version())
print('Tensorflow version:', tf.__version__)
print('Keras version:', tf.keras.__version__)
```

```
2025-03-21 13:05:58.061781: I
external/local_xla/xla/tsl/cuda/cudart_stub.cc:32] Could not find cuda
drivers on your machine, GPU will not be used.
2025-03-21 13:05:58.064943: I
external/local_xla/xla/tsl/cuda/cudart_stub.cc:32] Could not find cuda
drivers on your machine, GPU will not be used.
2025-03-21 13:05:58.074939: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to
register cuFFT factory: Attempting to register factory for plugin
cuFFT when one has already been registered
WARNING: All log messages before absl::InitializeLog() is called are
written to STDERR
E0000 00:00:1742562358.091401    2261 cuda_dnn.cc:8579] Unable to
register cuDNN factory: Attempting to register factory for plugin
cuDNN when one has already been registered
E0000 00:00:1742562358.096257    2261 cuda_blas.cc:1407] Unable to
register cuBLAS factory: Attempting to register factory for plugin
cuBLAS when one has already been registered
W0000 00:00:1742562358.108553    2261 computation_placer.cc:177]
computation placer already registered. Please check linkage and avoid
linking the same target more than once.
W0000 00:00:1742562358.108570    2261 computation_placer.cc:177]
computation placer already registered. Please check linkage and avoid
linking the same target more than once.
W0000 00:00:1742562358.108572    2261 computation_placer.cc:177]
```

```
computation placer already registered. Please check linkage and avoid
linking the same target more than once.
W0000 00:00:1742562358.108573    2261 computation_placer.cc:177]
computation placer already registered. Please check linkage and avoid
linking the same target more than once.
2025-03-21 13:05:58.112660: I
tensorflow/core/platform/cpu_feature_guard.cc:210] This TensorFlow
binary is optimized to use available CPU instructions in performance-
critical operations.
To enable the following instructions: AVX2 FMA, in other operations,
rebuild TensorFlow with the appropriate compiler flags.

Python version: 3.12.5
Tensorflow version: 2.19.0
Keras version: 3.9.0
```

Load in Datasets

Load the CIFAR 10 and CIFAR 100 datasets to be used to train the models.
First the CIFAR 10 data set is going to be used to train a model, afterwards the 100 will be used.
The dataset is originally from CS Toronto.
The 10 version has 60,000 32 by 32 colour images in 10 classes, and the 100 version has 100 classes with 600 images in each.

```
# See available datasets
tfds.list_builders()

2025-03-21 13:06:00.685854: W
external/local_xla/xla/tsl/platform/cloud/google_auth_provider.cc:184]
All attempts to get a Google authentication bearer token failed,
returning an empty token. Retrieving token from files failed with
"NOT_FOUND: Could not locate the credentials file.". Retrieving token
from GCE failed with "FAILED_PRECONDITION: Error executing an HTTP
request: libcurl code 6 meaning 'Could not resolve hostname', error
details: Could not resolve host: metadata.google.internal".

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DATASET_NAME = 'cifar100'

(dataset_train_raw, dataset_test_raw), dataset_info = tfds.load(
    name=DATASET_NAME,
    data_dir='tmp',
    with_info=True,
    as_supervised=True,
    split=[tfds.Split.TRAIN, tfds.Split.TEST],
)

print('Raw train dataset:', dataset_train_raw)
print('Raw train dataset size:', len(list(dataset_train_raw)), '\n')
print('Raw test dataset:', dataset_test_raw)
print('Raw test dataset size:', len(list(dataset_test_raw)), '\n')

Raw train dataset: <_PrefetchDataset
element_spec=(TensorSpec(shape=(32, 32, 3), dtype=tf.uint8,
name=None), TensorSpec(shape=(), dtype=tf.int64, name=None))>
Raw train dataset size: 50000

Raw test dataset: <_PrefetchDataset
element_spec=(TensorSpec(shape=(32, 32, 3), dtype=tf.uint8,
name=None), TensorSpec(shape=(), dtype=tf.int64, name=None))>
Raw test dataset size: 10000


2025-03-21 14:02:18.742828: I
tensorflow/core/framework/local_rendezvous.cc:407] Local rendezvous is
aborting with status: OUT_OF_RANGE: End of sequence

print(dataset_info)

tfds.core.DatasetInfo(
    name='cifar100',
    full_name='cifar100/3.0.2',
    description="""
    This dataset is just like the CIFAR-10, except it has 100 classes
containing 600 images each. There are 500 training images and 100
testing images per class. The 100 classes in the CIFAR-100 are grouped
into 20 superclasses. Each image comes with a "fine" label (the class
to which it belongs) and a "coarse" label (the superclass to which it
belongs).
    """,
    homepage='https://www.cs.toronto.edu/~kriz/cifar.html',
```

```
    data_dir='tmp/cifar100/3.0.2',
    file_format=tfrecord,
    download_size=160.71 MiB,
    dataset_size=132.03 MiB,
    features=FeaturesDict({
        'coarse_label': ClassLabel(shape=(), dtype=int64,
num_classes=20),
        'id': Text(shape=(), dtype=string),
        'image': Image(shape=(32, 32, 3), dtype=uint8),
        'label': ClassLabel(shape=(), dtype=int64, num_classes=100),
    }),
    supervised_keys=('image', 'label'),
    disable_shuffling=False,
    nondeterministic_order=False,
    splits={
        'test': <SplitInfo num_examples=10000, num_shards=1>,
        'train': <SplitInfo num_examples=50000, num_shards=1>,
    },
    citation="""@TECHREPORT{Krizhevsky09learningmultiple,
        author = {Alex Krizhevsky},
        title = {Learning multiple layers of features from tiny
images},
        institution = {},
        year = {2009}
    }""",
)

NUM_TRAIN_EXAMPLES = dataset_info.splits['train'].num_examples
NUM_TEST_EXAMPLES = dataset_info.splits['test'].num_examples
NUM_CLASSES = dataset_info.features['label'].num_classes

print('Number of TRAIN examples:', NUM_TRAIN_EXAMPLES)
print('Number of TEST examples:', NUM_TEST_EXAMPLES)
print('Number of label classes:', NUM_CLASSES)

Number of TRAIN examples: 50000
Number of TEST examples: 10000
Number of label classes: 100
```

No need to resize images as they are 32 by 32 pixels, which is the minimum for MobileNet.

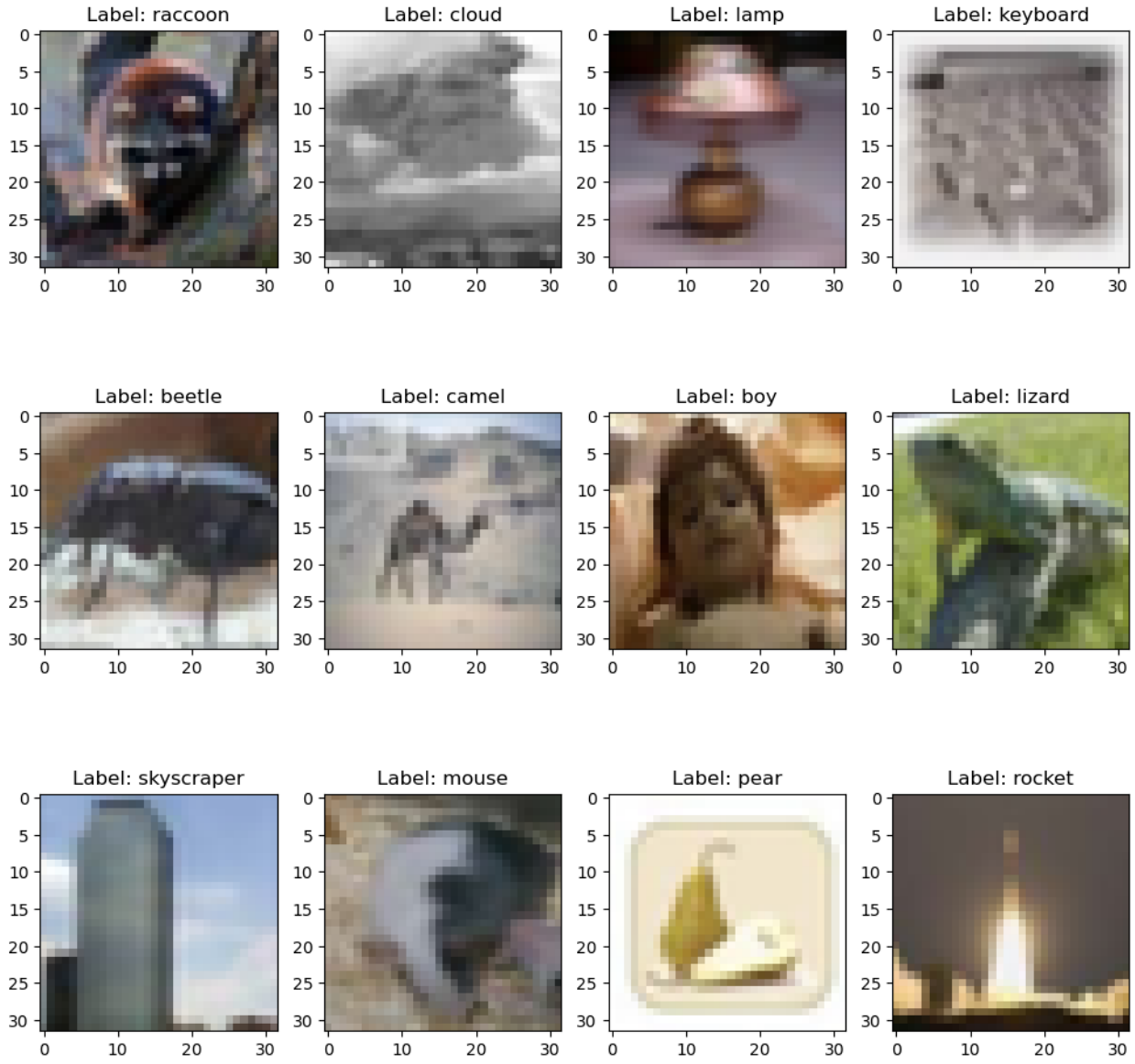
```
INPUT_IMG_SIZE = dataset_info.features['image'].shape[0]
INPUT_IMG_SHAPE = dataset_info.features['image'].shape

print('Input image size:', INPUT_IMG_SIZE)
print('Input image shape:', INPUT_IMG_SHAPE)

Input image size: 32
Input image shape: (32, 32, 3)
```

```
# Function to convert label ID to labels string.
get_label_name = dataset_info.features['label'].int2str

print(get_label_name(0))
print(get_label_name(1))
```

```
apple
aquarium_fish
```

Explore Data

```
def preview_dataset(dataset):
    plt.figure(figsize=(12, 12))
    plot_index = 0
    for features in dataset.take(12):
        (image, label) = features
        plot_index += 1
        plt.subplot(3, 4, plot_index)
        # plt.axis('Off')
        label = get_label_name(label.numpy())
        plt.title('Label: %s' % label)
        plt.imshow(image.numpy())

# Explore raw training dataset images.
preview_dataset(dataset_train_raw)
```




```
# Explore what values are used to represent the image.
(first_image, first_lable) = list(dataset_train_raw.take(1))[0]
print('Label:', first_lable.numpy(), '\n')
print('Image shape:', first_image.numpy().shape, '\n')
print(first_image.numpy())
```

```
Label: 66

Image shape: (32, 32, 3)

[[[151 154 145]
  [144 147 135]
  [141 143 134]
  ...
  [ 44  38  39]
```

```
  [112 100  96]
  [145 127 120]]

 [[153 156 150]
  [141 144 135]
  [139 142 136]
  ...
  [ 68  59  59]
  [131 113 106]
  [121 101  94]]

 [[163 165 161]
  [150 153 145]
  [147 149 144]
  ...
  [ 75  66  60]
  [101  86  77]
  [ 83  77  73]]

 ...

 [[150 150 162]
  [ 51  52  67]
  [ 46  42  56]
  ...
  [ 60  59  48]
  [ 71  73  56]
  [ 58  62  44]]

 [[146 158 168]
  [ 92 106 116]
  [ 73  77  85]
  ...
  [ 54  55  40]
  [ 59  66  41]
  [ 52  56  28]]

 [[ 92  95 105]
  [ 86  90 100]
  [ 77  74  82]
  ...
  [ 59  61  44]
  [ 44  49  26]
  [ 51  53  27]]]
```

Pre-Process Data

```
def format_example(image, label):
    # Make image colour values to be float.
    image = tf.cast(image, tf.float32)
```

```
    # Make image colour values to be in [0..1] range.
    image = image / 255.
    return image, label

dataset_train = dataset_train_raw.map(format_example)
dataset_test = dataset_test_raw.map(format_example)

# Explore what values are used to represent the image.
(first_image, first_lable) = list(dataset_train.take(1))[0]
print('Label:', first_lable.numpy(), '\n')
print('Image shape:', first_image.numpy().shape, '\n')
print(first_image.numpy())
```

```
Label: 66

Image shape: (32, 32, 3)

[[[0.5921569  0.6039216  0.5686275 ]
  [0.5647059  0.5764706  0.5294118 ]
  [0.5529412  0.56078434 0.5254902 ]
  ...
  [0.17254902 0.14901961 0.15294118]
  [0.4392157  0.39215687 0.3764706 ]
  [0.5686275  0.49803922 0.47058824]]

 [[0.6        0.6117647  0.5882353 ]
  [0.5529412  0.5647059  0.5294118 ]
  [0.54509807 0.5568628  0.53333336]
  ...
  [0.26666668 0.23137255 0.23137255]
  [0.5137255  0.44313726 0.41568628]
  [0.4745098  0.39607844 0.36862746]]

 [[0.6392157  0.64705884 0.6313726 ]
  [0.5882353  0.6        0.5686275 ]
  [0.5764706  0.58431375 0.5647059 ]
  ...
  [0.29411766 0.25882354 0.23529412]
  [0.39607844 0.3372549  0.3019608 ]
  [0.3254902  0.3019608  0.28627452]]

 ...

 [[0.5882353  0.5882353  0.63529414]
  [0.2        0.20392157 0.2627451 ]
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  ...
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```

```
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  [0.28627452 0.3019608  0.33333334]
  ...
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  [0.23137255 0.25882354 0.16078432]
  [0.20392157 0.21960784 0.10980392]]

 [[0.36078432 0.37254903 0.4117647 ]
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  [0.3019608  0.2901961  0.32156864]
  ...
  [0.23137255 0.23921569 0.17254902]
  [0.17254902 0.19215687 0.10196079]
  [0.2        0.20784314 0.10588235]]]
```
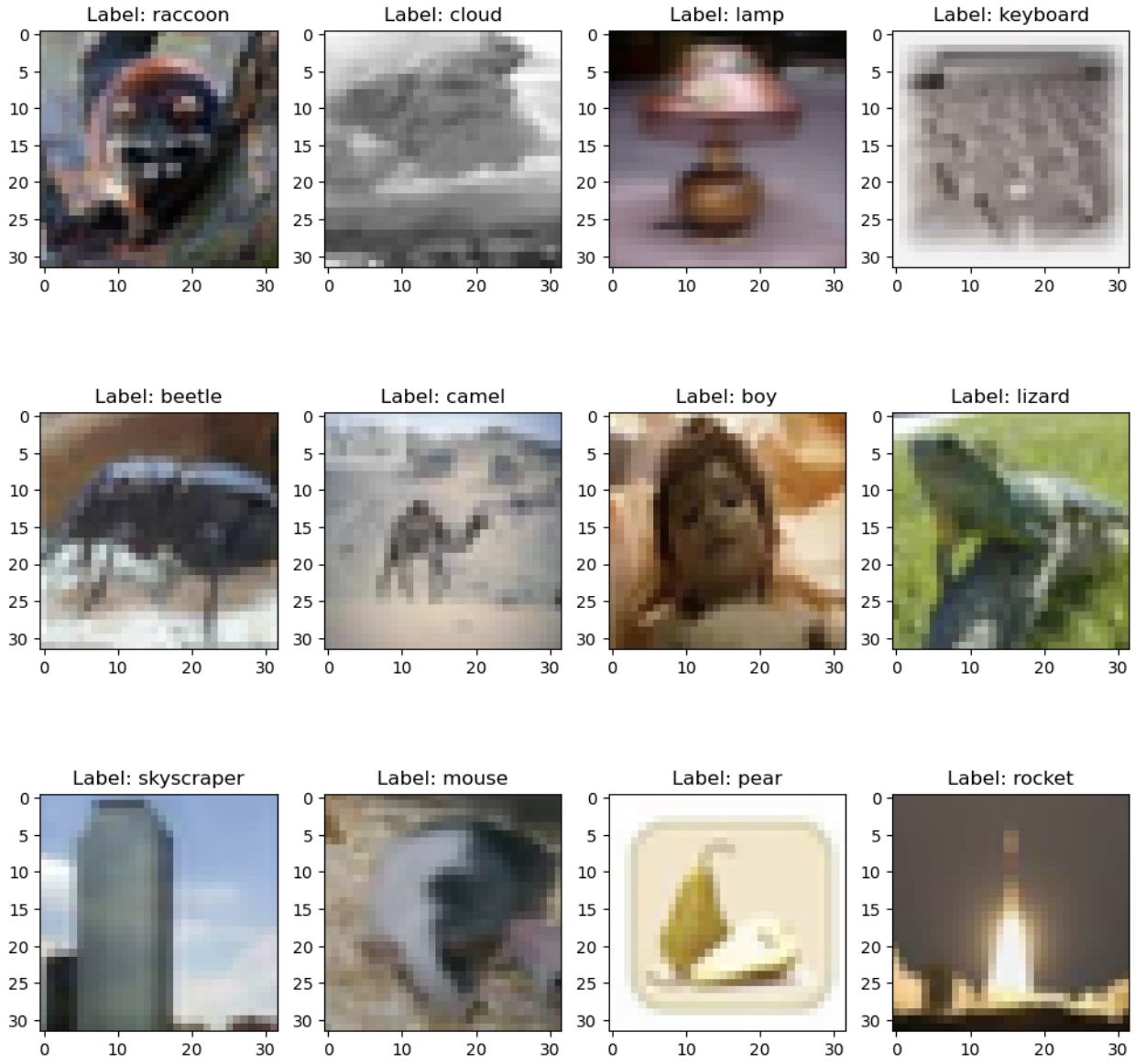

```
# Explore preprocessed training dataset images.
preview_dataset(dataset_train)
```



Shuffle and Batch Data

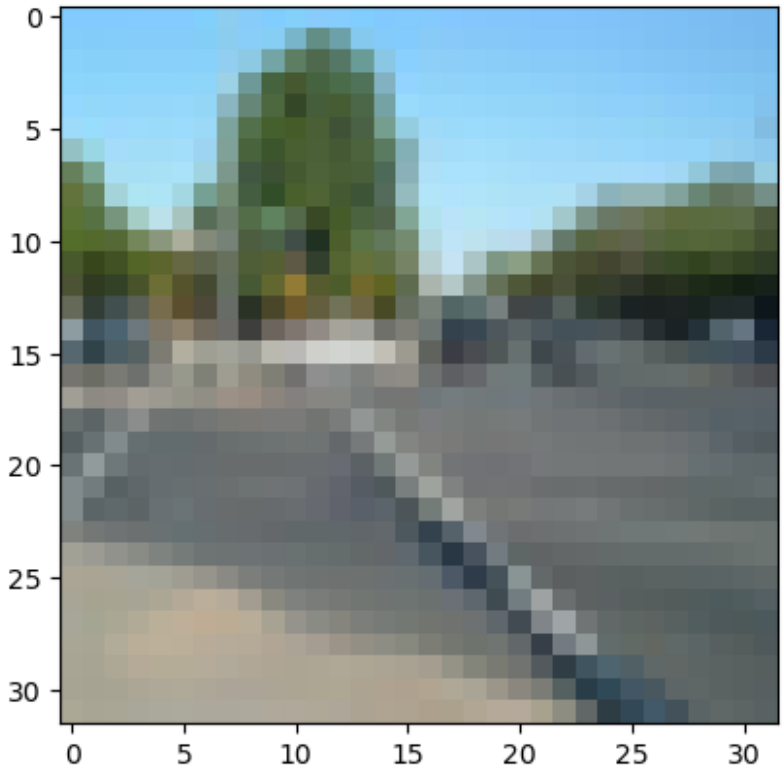
```
BATCH_SIZE = 800

dataset_train_shuffled = dataset_train.shuffle(
    buffer_size=NUM_TRAIN_EXAMPLES
)

dataset_train_shuffled = dataset_train_shuffled.batch(
    batch_size=BATCH_SIZE
)

# Prefetch will enable the input pipeline to asynchronously fetch
batches while your model is training.
dataset_train_shuffled = dataset_train_shuffled.prefetch(
```

```
    buffer_size=tf.data.experimental.AUTOTUNE
)

dataset_test_shuffled = dataset_test.batch(BATCH_SIZE)

# Debugging the batches using conversion to Numpy arrays.
batches = tfds.as_numpy(dataset_train_shuffled)
for batch in batches:
    image_batch, label_batch = batch
    print('Label batch shape:', label_batch.shape, '\n')
    print('Image batch shape:', image_batch.shape, '\n')
    print('Label batch:', label_batch, '\n')

    for batch_item_index in range(len(image_batch)):
        print('First batch image:', image_batch[batch_item_index], '\
n')
        plt.imshow(image_batch[batch_item_index])
        plt.show()
        # Break to shorten the output.
        break
    # Break to shorten the output.
    break
```

```
Label batch shape: (800,)

Image batch shape: (800, 32, 32, 3)

Label batch: [68  5 65 32  0  0 70 70 49 45 52 70 29 55 46 90 15 73 47
59  4 87  4 49
 36 79 69 98 12 47  7 14 10 48 18 86 14 76 92 86 73 48 92 85 61 20 13
91
  1 53 64 61 36 41 87 43 60 99 46 57 19 60 92 96 23 86 68 21 71 51 45
72
 49 89 40 44 85 54 27 87 90  9 17  6 51 91 42 39 50 62 36 20 36 68 76
60
 83 85 81 89 40 57 34 57 67 44 57 36 49 56 48  1 53 81 94 96 57 45 92
13
 15 75 65 28 22 51 17 22 63 22 60 16 14  4 90  2 37  7 27 50 43 29 90
49
 13 92 11 19 13 75 38 94 50 26 42 85 26 78 92 82 58 40 80 10 89 73  8
53
 80 82 92 72  8 14 49 77  7 86 38 11 63 21 29 54  6 86 76 68 90 12  1
16
 58 41 76 29 64 17 84 91  8 75 37 18 45 52 94  2  3 69 57 59 48 43 33
24
 95  9 78 26 23 67 71 32 75  0 86 84 24 87 42 68 26 56 36 29 52 29 93
0
 16 13 13 22 92 30 55 12 10 44 26 21 43  5 50 34 99 97 17 23 14 14 90
28
 70 15 37 14 81 81 52  6 65 45 47 94 71 82  7 74 31  2 50 52 42  7 78
```

```
25
 73 86  1 41 49 20 40 48  6 60 41 91 75 57 31 51 37 20 94 68 92 12 60
43
  7 91 26 88 14 36 39 40 35 17 34 76 85  4 96  5 87 30 98 62  3 80 77
35
 71  7 23 34 44 73  2 36 98 24 57 45 39 84 80 41 80 11 91  4 49 60 57
93
 24  9 34 20  0 41 35 92 51 59 33 11  1 28 81 14 25 52 36 22 16 70 22
47
  9 26 82  5 92 84 54 15 62 87 74 53 71 11 45 95  0 86 16 21 68 87 87
21
 21 49 50 13 14 88 26 85 62 27 29 86 62 66 75 66 34 14 63 58 31 72 18
94
 86  6 38 68  8 39 56 74 75 71 72 47 65 84 44 74 53 22 73 76 81  7 86
3
 14 38 15  5 27 20 11 80  0 52 94 10 39 42  1 49 60 64 50 37 20 34 50
71
 44 53 80 30  9 68 14 82 90 58 46  7 45 43 31 82 68 15 31 63 98 42 70
84
 28 51 95 56 54 80 91 87 37 67 52 82 97 99  9 90 51 20 89 79 86 12 12
96
 88 20 15  5 11 15 47  9 85 51 47 72  1 88 26 32 88 33 53 81 78 10 50
58
 61 99 54 82 57 46 11  4 65 64 29  1 40 83 94 59 64 68 40 22 62 98 45
89
 29 51 28 23 45 65 46 22 22 76 22 18 27 45 47 50 89 39 80 42 50 79 41
53
 35 46 31 63 14 73 86 33 21 40 24 17 28 38 10 60 63 92  9 93  4 84 27
20
 86 34  5 40  0 97 77 57 89 80 94 94  1 78 83 52 88 48 65 81 13 36 76
51
 14 87 48 82 70 85 86 14 23 45 14 35 94 26 12 90 43 19 98 95 49 92 77
0
 22 28 80  9 79 57 83 88 51 91  3 36 44 36 67 55 98 98 70 98 83  9 11
31
 62 84 78 25 91 48 55 68 61 94 63 50 88 53  8 43 58 11 54  7 88 60 45
7
 81 22 80  1 30 88 21 26 79 41 10 56 48 87 71 53 42 14 59 74 55 47 72
11
 59 67 74 71 67 48 10  6 16 22 66 85  9 21 63 59 43 78 96 90 30 76 26
71
  4 12 10 20 23 69 63 98 87 12 17 35  7 75 80 93 22  8  8  5 54 10 25
7
  9  7 49 71 90 34 21 64]

First batch image: [[[0.50980395 0.79607844 1.        ]
  [0.50980395 0.79607844 0.99607843]
  [0.5137255  0.79607844 1.        ]
  ...
```

```
  [0.47843137 0.7411765  0.9490196 ]
  [0.4745098  0.73333335 0.94509804]
  [0.46666667 0.7294118  0.9411765 ]]

 [[0.5176471  0.8039216  0.9843137 ]
  [0.5137255  0.8        0.9764706 ]
  [0.5176471  0.8        0.98039216]
  ...
  [0.48235294 0.7411765  0.9411765 ]
  [0.47843137 0.7372549  0.9372549 ]
  [0.47058824 0.7294118  0.92941177]]

 [[0.53333336 0.8235294  0.9843137 ]
  [0.5254902  0.8156863  0.9764706 ]
  [0.5294118  0.8156863  0.9764706 ]
  ...
  [0.49803922 0.75686276 0.94509804]
  [0.49411765 0.7529412  0.9411765 ]
  [0.4862745  0.74509805 0.93333334]]

 ...

 [[0.65882355 0.64705884 0.5803922 ]
  [0.654902   0.6431373  0.5764706 ]
  [0.6784314  0.65882355 0.5882353 ]
  ...
  [0.3529412  0.3882353  0.38431373]
  [0.34509805 0.38039216 0.3764706 ]
  [0.3372549  0.37254903 0.3647059 ]]

 [[0.654902   0.6431373  0.5764706 ]
  [0.6509804  0.6392157  0.57254905]
  [0.654902   0.6431373  0.5764706 ]
  ...
  [0.3529412  0.3882353  0.38431373]
  [0.34509805 0.38039216 0.3764706 ]
  [0.34509805 0.37254903 0.3764706 ]]

 [[0.67058825 0.65882355 0.5882353 ]
  [0.6627451  0.64705884 0.5803922 ]
  [0.6627451  0.6509804  0.5882353 ]
  ...
  [0.37254903 0.40784314 0.40392157]
  [0.36078432 0.39607844 0.39215687]
  [0.34901962 0.38431373 0.38431373]]]
```



Load Models

Load in the MobileNet V2 and V3 models from Keras.
These models are based on CNN.
As the number of classes is different from the base 1000, CIFAR 10 uses 10 and CIFAR 100 uses 100, the model itself is frozen and only the feature extraction is trained.

```
MODEL_TYPE = 'mobilenet_v3_large'
if MODEL_TYPE == 'mobilenet_v2':
    base_model = tf.keras.applications.MobileNetV2(
      input_shape=INPUT_IMG_SHAPE,
      include_top=False,
      weights='imagenet',
      pooling='avg'
    )
elif MODEL_TYPE == 'mobilenet_v3_small':
    base_model = tf.keras.applications.MobileNetV3Small(
      input_shape=INPUT_IMG_SHAPE,
      include_top=False,
      weights='imagenet',
      pooling='avg'
    )
elif MODEL_TYPE == 'mobilenet_v3_large':
    base_model = tf.keras.applications.MobileNetV3Large(
      input_shape=INPUT_IMG_SHAPE,
```

```
      include_top=False,
      weights='imagenet',
      pooling='avg'
    )

base_model.trainable = False
```

Analyse the Model

```
base_model.summary()
```

```
Model: "MobileNetV3Large"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━┓
┃ Layer (type)              ┃ Output Shape           ┃       Param # ┃ Connected to              ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━┩
│ input_layer_10            │ (None, 32, 32, 3)      │             0 │ -                         │
│ (InputLayer)              │                        │               │                           │
├───────────────────────────┼────────────────────────┼───────────────┼───────────────────────────┤
│ rescaling_3               │ (None, 32, 32, 3)      │             0 │ input_layer_10[0…         │
│ (Rescaling)               │                        │               │                           │
├───────────────────────────┼────────────────────────┼───────────────┼───────────────────────────┤
│ conv (Conv2D)             │ (None, 16, 16,         │           432 │ rescaling_3[0][0]         │
│                           │ 16)                    │               │                           │
├───────────────────────────┼────────────────────────┼───────────────┼───────────────────────────┤
│ conv_bn                   │ (None, 16, 16,         │            64 │ conv[0][0]                │
│ (BatchNormalizatio…       │ 16)                    │               │                           │
├───────────────────────────┼────────────────────────┼───────────────┼───────────────────────────┤
│ activation_56             │ (None, 16, 16,         │             0 │ conv_bn[0][0]             │
│ (Activation)              │ 16)                    │               │                           │
├───────────────────────────┼────────────────────────┼───────────────┼───────────────────────────┤
│ expanded_conv_dept…       │ (None, 16, 16,         │           144 │                           │
```

```
activation_56[0]… │
│ (DepthwiseConv2D)   │ 16)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_dept… │ (None, 16, 16,     │          64 │
expanded_conv_de… │
│ (BatchNormalizatio… │ 16)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ re_lu_47 (ReLU)     │ (None, 16, 16,     │           0 │
expanded_conv_de… │
│                     │ 16)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_proj… │ (None, 16, 16,     │         256 │ re_lu_47[0]
[0]    │
│ (Conv2D)            │ 16)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_proj… │ (None, 16, 16,     │          64 │
expanded_conv_pr… │
│ (BatchNormalizatio… │ 16)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_add   │ (None, 16, 16,     │           0 │
activation_56[0]… │
│ (Add)               │ 16)                │             │
expanded_conv_pr… │
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_1_ex… │ (None, 16, 16,     │       1,024 │
expanded_conv_ad… │
│ (Conv2D)            │ 64)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_1_ex… │ (None, 16, 16,     │         256 │
expanded_conv_1_… │
│ (BatchNormalizatio… │ 64)                │             │
│
├─────────────────────┼────────────────────┼─────────────┼──────────────────
──────┤
│ re_lu_48 (ReLU)     │ (None, 16, 16,     │           0 │
expanded_conv_1_… │
```

```
|                      | 64)                 |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_1_de… | (None, 17, 17,      |           0 | re_lu_48[0]
[0]    |
| (ZeroPadding2D)      | 64)                 |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_1_de… | (None, 8, 8, 64)    |         576 |
expanded_conv_1_… |
| (DepthwiseConv2D)    |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_1_de… | (None, 8, 8, 64)    |         256 |
expanded_conv_1_… |
| (BatchNormalizatio… |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| re_lu_49 (ReLU)      | (None, 8, 8, 64)    |           0 |
expanded_conv_1_… |
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_1_pr… | (None, 8, 8, 24)    |       1,536 | re_lu_49[0]
[0]    |
| (Conv2D)             |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_1_pr… | (None, 8, 8, 24)    |          96 |
expanded_conv_1_… |
| (BatchNormalizatio… |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_2_ex… | (None, 8, 8, 72)    |       1,728 |
expanded_conv_1_… |
| (Conv2D)             |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_2_ex… | (None, 8, 8, 72)    |         288 |
expanded_conv_2_… |
| (BatchNormalizatio… |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
```

```
──────┤
| re_lu_50 (ReLU)      | (None, 8, 8, 72)  |          0 |
expanded_conv_2_… |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_2_de… | (None, 8, 8, 72)  |        648 | re_lu_50[0]
[0]    |
| (DepthwiseConv2D)    |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_2_de… | (None, 8, 8, 72)  |        288 |
expanded_conv_2_… |
| (BatchNormalizatio… |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| re_lu_51 (ReLU)      | (None, 8, 8, 72)  |          0 |
expanded_conv_2_… |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_2_pr… | (None, 8, 8, 24)  |      1,728 | re_lu_51[0]
[0]    |
| (Conv2D)             |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_2_pr… | (None, 8, 8, 24)  |         96 |
expanded_conv_2_… |
| (BatchNormalizatio… |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_2_add | (None, 8, 8, 24)  |          0 |
expanded_conv_1_… |
| (Add)                |                   |            |
expanded_conv_2_… |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_3_ex… | (None, 8, 8, 72)  |      1,728 |
expanded_conv_2_… |
| (Conv2D)             |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_3_ex… | (None, 8, 8, 72)  |        288 |
expanded_conv_3_… |
| (BatchNormalizatio… |                   |            |
|
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ re_lu_52 (ReLU)      │ (None, 8, 8, 72)     │            0 │
expanded_conv_3_… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_de… │ (None, 11, 11,       │            0 │ re_lu_52[0]
[0]    │
│ (ZeroPadding2D)      │ 72)                  │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_de… │ (None, 4, 4, 72)     │        1,800 │
expanded_conv_3_… │
│ (DepthwiseConv2D)    │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_de… │ (None, 4, 4, 72)     │          288 │
expanded_conv_3_… │
│ (BatchNormalizatio… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ re_lu_53 (ReLU)      │ (None, 4, 4, 72)     │            0 │
expanded_conv_3_… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_sq… │ (None, 1, 1, 72)     │            0 │ re_lu_53[0]
[0]    │
│ (GlobalAveragePool… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_sq… │ (None, 1, 1, 24)     │        1,752 │
expanded_conv_3_… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_sq… │ (None, 1, 1, 24)     │            0 │
expanded_conv_3_… │
│ (ReLU)               │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────
──────┤
│ expanded_conv_3_sq… │ (None, 1, 1, 72)     │        1,800 │
expanded_conv_3_… │
│ (Conv2D)             │                      │              │
```

```
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ add_26 (Add)          │ (None, 1, 1, 72)   │            0 │
expanded_conv_3_… │
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ re_lu_54 (ReLU)       │ (None, 1, 1, 72)   │            0 │ add_26[0][0]
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ multiply_26           │ (None, 1, 1, 72)   │            0 │ re_lu_54[0]
[0]       │
│ (Multiply)            │                    │              │
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ expanded_conv_3_sq…   │ (None, 4, 4, 72)   │            0 │ re_lu_53[0]
[0],      │
│ (Multiply)            │                    │              │
multiply_26[0][0] │
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ expanded_conv_3_pr…   │ (None, 4, 4, 40)   │        2,880 │
expanded_conv_3_… │
│ (Conv2D)              │                    │              │
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ expanded_conv_3_pr…   │ (None, 4, 4, 40)   │          160 │
expanded_conv_3_… │
│ (BatchNormalizatio…   │                    │              │
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ expanded_conv_4_ex…   │ (None, 4, 4, 120)  │        4,800 │
expanded_conv_3_… │
│ (Conv2D)              │                    │              │
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ expanded_conv_4_ex…   │ (None, 4, 4, 120)  │          480 │
expanded_conv_4_… │
│ (BatchNormalizatio…   │                    │              │
│
├───────────────────────┼────────────────────┼──────────────┼──────────────
───────┤
│ re_lu_55 (ReLU)       │ (None, 4, 4, 120)  │            0 │
expanded_conv_4_… │
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_de… │ (None, 4, 4, 120) │      3,000 │ re_lu_55[0]
[0]    │
│ (DepthwiseConv2D)    │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_de… │ (None, 4, 4, 120) │        480 │
expanded_conv_4_… │
│ (BatchNormalizatio… │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ re_lu_56 (ReLU)      │ (None, 4, 4, 120) │          0 │
expanded_conv_4_… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_sq… │ (None, 1, 1, 120) │          0 │ re_lu_56[0]
[0]    │
│ (GlobalAveragePool… │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_sq… │ (None, 1, 1, 32)  │      3,872 │
expanded_conv_4_… │
│ (Conv2D)             │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_sq… │ (None, 1, 1, 32)  │          0 │
expanded_conv_4_… │
│ (ReLU)               │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_4_sq… │ (None, 1, 1, 120) │      3,960 │
expanded_conv_4_… │
│ (Conv2D)             │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ add_27 (Add)         │ (None, 1, 1, 120) │          0 │
expanded_conv_4_… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ re_lu_57 (ReLU)      │ (None, 1, 1, 120) │          0 │ add_27[0][0]
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
```

```
──────┤
| multiply_27          | (None, 1, 1, 120) |          0 | re_lu_57[0]
[0]    |
| (Multiply)           |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_4_sq… | (None, 4, 4, 120) |          0 | re_lu_56[0]
[0],   |
| (Multiply)           |                   |            |
multiply_27[0][0] |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_4_pr… | (None, 4, 4, 40)  |      4,800 |
expanded_conv_4_… |
| (Conv2D)             |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_4_pr… | (None, 4, 4, 40)  |        160 |
expanded_conv_4_… |
| (BatchNormalizatio… |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_4_add | (None, 4, 4, 40)  |          0 |
expanded_conv_3_… |
| (Add)                |                   |            |
expanded_conv_4_… |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_5_ex… | (None, 4, 4, 120) |      4,800 |
expanded_conv_4_… |
| (Conv2D)             |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_5_ex… | (None, 4, 4, 120) |        480 |
expanded_conv_5_… |
| (BatchNormalizatio… |                   |            |
|
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| re_lu_58 (ReLU)      | (None, 4, 4, 120) |          0 |
expanded_conv_5_… |
├──────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_5_de… | (None, 4, 4, 120) |      3,000 | re_lu_58[0]
[0]    |
```

(DepthwiseConv2D)			
expanded_conv_5_de…	(None, 4, 4, 120)	480	expanded_conv_5_…
(BatchNormalizatio…			
re_lu_59 (ReLU)	(None, 4, 4, 120)	0	expanded_conv_5_…
expanded_conv_5_sq…	(None, 1, 1, 120)	0	re_lu_59[0][0]
(GlobalAveragePool…			
expanded_conv_5_sq…	(None, 1, 1, 32)	3,872	expanded_conv_5_…
(Conv2D)			
expanded_conv_5_sq…	(None, 1, 1, 32)	0	expanded_conv_5_…
(ReLU)			
expanded_conv_5_sq…	(None, 1, 1, 120)	3,960	expanded_conv_5_…
(Conv2D)			
add_28 (Add)	(None, 1, 1, 120)	0	expanded_conv_5_…
re_lu_60 (ReLU)	(None, 1, 1, 120)	0	add_28[0][0]
multiply_28	(None, 1, 1, 120)	0	re_lu_60[0][0]
(Multiply)			

```
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_5_sq… │ (None, 4, 4, 120) │             0 │ re_lu_59[0]
[0],    │
│ (Multiply)            │                    │               │
multiply_28[0][0] │
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_5_pr… │ (None, 4, 4, 40)  │         4,800 │
expanded_conv_5_… │
│ (Conv2D)              │                    │               │
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_5_pr… │ (None, 4, 4, 40)  │           160 │
expanded_conv_5_… │
│ (BatchNormalizatio… │                    │               │
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_5_add │ (None, 4, 4, 40)  │             0 │
expanded_conv_4_… │
│ (Add)                 │                    │               │
expanded_conv_5_… │
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_6_ex… │ (None, 4, 4, 240) │         9,600 │
expanded_conv_5_… │
│ (Conv2D)              │                    │               │
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_6_ex… │ (None, 4, 4, 240) │           960 │
expanded_conv_6_… │
│ (BatchNormalizatio… │                    │               │
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ activation_57         │ (None, 4, 4, 240) │             0 │
expanded_conv_6_… │
│ (Activation)          │                    │               │
│
├───────────────────────┼────────────────────┼───────────────┼───────────────
──────┤
│ expanded_conv_6_de… │ (None, 5, 5, 240) │             0 │
activation_57[0]… │
│ (ZeroPadding2D)       │                    │               │
│
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_6_de… │ (None, 2, 2, 240) │       2,160 │
expanded_conv_6_… │
│ (DepthwiseConv2D)    │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_6_de… │ (None, 2, 2, 240) │         960 │
expanded_conv_6_… │
│ (BatchNormalizatio… │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ activation_58        │ (None, 2, 2, 240) │           0 │
expanded_conv_6_… │
│ (Activation)         │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_6_pr… │ (None, 2, 2, 80)  │      19,200 │
activation_58[0]… │
│ (Conv2D)             │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_6_pr… │ (None, 2, 2, 80)  │         320 │
expanded_conv_6_… │
│ (BatchNormalizatio… │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_7_ex… │ (None, 2, 2, 200) │      16,000 │
expanded_conv_6_… │
│ (Conv2D)             │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_7_ex… │ (None, 2, 2, 200) │         800 │
expanded_conv_7_… │
│ (BatchNormalizatio… │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ activation_59        │ (None, 2, 2, 200) │           0 │
expanded_conv_7_… │
│ (Activation)         │                      │             │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
```

```
| expanded_conv_7_de… | (None, 2, 2, 200) |      1,800 |
activation_59[0]… |
| (DepthwiseConv2D)   |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_7_de… | (None, 2, 2, 200) |        800 |
expanded_conv_7_… |
| (BatchNormalizatio… |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| activation_60       | (None, 2, 2, 200) |          0 |
expanded_conv_7_… |
| (Activation)        |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_7_pr… | (None, 2, 2, 80)  |     16,000 |
activation_60[0]… |
| (Conv2D)            |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_7_pr… | (None, 2, 2, 80)  |        320 |
expanded_conv_7_… |
| (BatchNormalizatio… |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_7_add | (None, 2, 2, 80)  |          0 |
expanded_conv_6_… |
| (Add)               |                   |            |
expanded_conv_7_… |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_8_ex… | (None, 2, 2, 184) |     14,720 |
expanded_conv_7_… |
| (Conv2D)            |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_8_ex… | (None, 2, 2, 184) |        736 |
expanded_conv_8_… |
| (BatchNormalizatio… |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| activation_61       | (None, 2, 2, 184) |          0 |
```

```
expanded_conv_8_… |
| (Activation)         |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_8_de… | (None, 2, 2, 184) |       1,656 |
activation_61[0]… |
| (DepthwiseConv2D)   |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_8_de… | (None, 2, 2, 184) |         736 |
expanded_conv_8_… |
| (BatchNormalizatio… |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| activation_62        | (None, 2, 2, 184) |           0 |
expanded_conv_8_… |
| (Activation)         |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_8_pr… | (None, 2, 2, 80)  |      14,720 |
activation_62[0]… |
| (Conv2D)             |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_8_pr… | (None, 2, 2, 80)  |         320 |
expanded_conv_8_… |
| (BatchNormalizatio… |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_8_add | (None, 2, 2, 80)  |           0 |
expanded_conv_7_… |
| (Add)                |                     |             |
expanded_conv_8_… |
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_9_ex… | (None, 2, 2, 184) |      14,720 |
expanded_conv_8_… |
| (Conv2D)             |                     |             |
|
├──────────────────────┼─────────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_9_ex… | (None, 2, 2, 184) |         736 |
expanded_conv_9_… |
```

```
| (BatchNormalizatio… |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| activation_63       | (None, 2, 2, 184) |          0 |
expanded_conv_9_… |
| (Activation)        |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_9_de… | (None, 2, 2, 184) |      1,656 |
activation_63[0]… |
| (DepthwiseConv2D)   |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_9_de… | (None, 2, 2, 184) |        736 |
expanded_conv_9_… |
| (BatchNormalizatio… |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| activation_64       | (None, 2, 2, 184) |          0 |
expanded_conv_9_… |
| (Activation)        |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_9_pr… | (None, 2, 2, 80)  |     14,720 |
activation_64[0]… |
| (Conv2D)            |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_9_pr… | (None, 2, 2, 80)  |        320 |
expanded_conv_9_… |
| (BatchNormalizatio… |                   |            |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_9_add | (None, 2, 2, 80)  |          0 |
expanded_conv_8_… |
| (Add)               |                   |            |
expanded_conv_9_… |
├─────────────────────┼───────────────────┼────────────┼──────────────────
──────┤
| expanded_conv_10_e… | (None, 2, 2, 480) |     38,400 |
expanded_conv_9_… |
| (Conv2D)            |                   |            |
```

```
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_e… │ (None, 2, 2, 480) │      1,920 │
expanded_conv_10… │
│ (BatchNormalizatio… │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ activation_65       │ (None, 2, 2, 480) │          0 │
expanded_conv_10… │
│ (Activation)        │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_d… │ (None, 2, 2, 480) │      4,320 │
activation_65[0]… │
│ (DepthwiseConv2D)   │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_d… │ (None, 2, 2, 480) │      1,920 │
expanded_conv_10… │
│ (BatchNormalizatio… │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ activation_66       │ (None, 2, 2, 480) │          0 │
expanded_conv_10… │
│ (Activation)        │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_s… │ (None, 1, 1, 480) │          0 │
activation_66[0]… │
│ (GlobalAveragePool… │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_s… │ (None, 1, 1, 120) │     57,720 │
expanded_conv_10… │
│ (Conv2D)            │                   │            │
│
├───────────────────────────┼────────────────────────┼─────────────────┼─────────────────
──────┤
│ expanded_conv_10_s… │ (None, 1, 1, 120) │          0 │
expanded_conv_10… │
│ (ReLU)              │                   │            │
│
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_10_s… │ (None, 1, 1, 480) │     58,080 │
expanded_conv_10… │
│ (Conv2D)             │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ add_29 (Add)         │ (None, 1, 1, 480) │          0 │
expanded_conv_10… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ re_lu_61 (ReLU)      │ (None, 1, 1, 480) │          0 │ add_29[0][0]
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ multiply_29          │ (None, 1, 1, 480) │          0 │ re_lu_61[0]
[0]    │
│ (Multiply)           │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_10_s… │ (None, 2, 2, 480) │          0 │
activation_66[0]… │
│ (Multiply)           │                      │            │
multiply_29[0][0] │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_10_p… │ (None, 2, 2, 112) │     53,760 │
expanded_conv_10… │
│ (Conv2D)             │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_10_p… │ (None, 2, 2, 112) │        448 │
expanded_conv_10… │
│ (BatchNormalizatio… │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_11_e… │ (None, 2, 2, 672) │     75,264 │
expanded_conv_10… │
│ (Conv2D)             │                      │            │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_11_e… │ (None, 2, 2, 672) │      2,688 │
expanded_conv_11… │
│ (BatchNormalizatio… │                      │            │
```

```
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ activation_67       │ (None, 2, 2, 672) │          0 │
expanded_conv_11… │
│ (Activation)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_d… │ (None, 2, 2, 672) │      6,048 │
activation_67[0]… │
│ (DepthwiseConv2D)   │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_d… │ (None, 2, 2, 672) │      2,688 │
expanded_conv_11… │
│ (BatchNormalizatio… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ activation_68       │ (None, 2, 2, 672) │          0 │
expanded_conv_11… │
│ (Activation)        │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_s… │ (None, 1, 1, 672) │          0 │
activation_68[0]… │
│ (GlobalAveragePool… │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_s… │ (None, 1, 1, 168) │    113,064 │
expanded_conv_11… │
│ (Conv2D)            │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_s… │ (None, 1, 1, 168) │          0 │
expanded_conv_11… │
│ (ReLU)              │                   │            │
│
├─────────────────────┼───────────────────┼────────────┼─────────────
──────┤
│ expanded_conv_11_s… │ (None, 1, 1, 672) │    113,568 │
expanded_conv_11… │
│ (Conv2D)            │                   │            │
│
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ add_30 (Add)         │ (None, 1, 1, 672)    │            0 │
expanded_conv_11… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ re_lu_62 (ReLU)      │ (None, 1, 1, 672)    │            0 │ add_30[0][0]
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ multiply_30          │ (None, 1, 1, 672)    │            0 │ re_lu_62[0]
[0]    │
│ (Multiply)           │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_11_s… │ (None, 2, 2, 672)    │            0 │
activation_68[0]… │
│ (Multiply)           │                      │              │
multiply_30[0][0] │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_11_p… │ (None, 2, 2, 112)    │       75,264 │
expanded_conv_11… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_11_p… │ (None, 2, 2, 112)    │          448 │
expanded_conv_11… │
│ (BatchNormalizatio… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_11_a… │ (None, 2, 2, 112)    │            0 │
expanded_conv_10… │
│ (Add)                │                      │              │
expanded_conv_11… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_e… │ (None, 2, 2, 672)    │       75,264 │
expanded_conv_11… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_e… │ (None, 2, 2, 672)    │        2,688 │
expanded_conv_12… │
│ (BatchNormalizatio… │                      │              │
```

```
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ activation_69           │ (None, 2, 2, 672)      │             0 │
expanded_conv_12… │
│ (Activation)            │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_d…     │ (None, 5, 5, 672)      │             0 │
activation_69[0]… │
│ (ZeroPadding2D)         │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_d…     │ (None, 1, 1, 672)      │        16,800 │
expanded_conv_12… │
│ (DepthwiseConv2D)       │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_d…     │ (None, 1, 1, 672)      │         2,688 │
expanded_conv_12… │
│ (BatchNormalizatio…     │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ activation_70           │ (None, 1, 1, 672)      │             0 │
expanded_conv_12… │
│ (Activation)            │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_s…     │ (None, 1, 1, 672)      │             0 │
activation_70[0]… │
│ (GlobalAveragePool…     │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_s…     │ (None, 1, 1, 168)      │       113,064 │
expanded_conv_12… │
│ (Conv2D)                │                        │               │
│
├─────────────────────────┼────────────────────────┼───────────────┼─────────────────
───────┤
│ expanded_conv_12_s…     │ (None, 1, 1, 168)      │             0 │
expanded_conv_12… │
│ (ReLU)                  │                        │               │
│
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_s… │ (None, 1, 1, 672) │    113,568 │
expanded_conv_12… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ add_31 (Add)         │ (None, 1, 1, 672) │          0 │
expanded_conv_12… │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ re_lu_63 (ReLU)      │ (None, 1, 1, 672) │          0 │ add_31[0][0]
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ multiply_31          │ (None, 1, 1, 672) │          0 │ re_lu_63[0]
[0]    │
│ (Multiply)           │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_s… │ (None, 1, 1, 672) │          0 │
activation_70[0]… │
│ (Multiply)           │                      │              │
multiply_31[0][0] │
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_p… │ (None, 1, 1, 160) │    107,520 │
expanded_conv_12… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_12_p… │ (None, 1, 1, 160) │        640 │
expanded_conv_12… │
│ (BatchNormalizatio… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_13_e… │ (None, 1, 1, 960) │    153,600 │
expanded_conv_12… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────────
──────┤
│ expanded_conv_13_e… │ (None, 1, 1, 960) │      3,840 │
expanded_conv_13… │
│ (BatchNormalizatio… │                      │              │
```

```
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ activation_71             │ (None, 1, 1, 960)      │              0 │
expanded_conv_13… │
│ (Activation)              │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_d…       │ (None, 1, 1, 960)      │         24,000 │
activation_71[0]… │
│ (DepthwiseConv2D)         │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_d…       │ (None, 1, 1, 960)      │          3,840 │
expanded_conv_13… │
│ (BatchNormalizatio…       │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ activation_72             │ (None, 1, 1, 960)      │              0 │
expanded_conv_13… │
│ (Activation)              │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_s…       │ (None, 1, 1, 960)      │              0 │
activation_72[0]… │
│ (GlobalAveragePool…       │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_s…       │ (None, 1, 1, 240)      │        230,640 │
expanded_conv_13… │
│ (Conv2D)                  │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_s…       │ (None, 1, 1, 240)      │              0 │
expanded_conv_13… │
│ (ReLU)                    │                        │                │
│
├───────────────────────────┼────────────────────────┼────────────────┼─────────────────
───────┤
│ expanded_conv_13_s…       │ (None, 1, 1, 960)      │        231,360 │
expanded_conv_13… │
│ (Conv2D)                  │                        │                │
│
```

```
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ add_32 (Add)         │ (None, 1, 1, 960) │           0 │
expanded_conv_13… │
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ re_lu_64 (ReLU)      │ (None, 1, 1, 960) │           0 │ add_32[0][0]
│
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ multiply_32          │ (None, 1, 1, 960) │           0 │ re_lu_64[0]
[0]    │
│ (Multiply)           │                      │             │
│
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_13_s… │ (None, 1, 1, 960) │           0 │
activation_72[0]… │
│ (Multiply)           │                      │             │
multiply_32[0][0] │
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_13_p… │ (None, 1, 1, 160) │     153,600 │
expanded_conv_13… │
│ (Conv2D)             │                      │             │
│
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_13_p… │ (None, 1, 1, 160) │         640 │
expanded_conv_13… │
│ (BatchNormalizatio… │                      │             │
│
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_13_a… │ (None, 1, 1, 160) │           0 │
expanded_conv_12… │
│ (Add)                │                      │             │
expanded_conv_13… │
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_14_e… │ (None, 1, 1, 960) │     153,600 │
expanded_conv_13… │
│ (Conv2D)             │                      │             │
│
├──────────────────────┼──────────────────────┼─────────────┼──────────────────
──────┤
│ expanded_conv_14_e… │ (None, 1, 1, 960) │       3,840 │
expanded_conv_14… │
│ (BatchNormalizatio… │                      │             │
│
```

```
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ activation_73        │ (None, 1, 1, 960)    │            0 │
expanded_conv_14… │
│ (Activation)         │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_d… │ (None, 1, 1, 960)    │       24,000 │
activation_73[0]… │
│ (DepthwiseConv2D)    │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_d… │ (None, 1, 1, 960)    │        3,840 │
expanded_conv_14… │
│ (BatchNormalizatio… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ activation_74        │ (None, 1, 1, 960)    │            0 │
expanded_conv_14… │
│ (Activation)         │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_s… │ (None, 1, 1, 960)    │            0 │
activation_74[0]… │
│ (GlobalAveragePool… │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_s… │ (None, 1, 1, 240)    │      230,640 │
expanded_conv_14… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_s… │ (None, 1, 1, 240)    │            0 │
expanded_conv_14… │
│ (ReLU)               │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
──────┤
│ expanded_conv_14_s… │ (None, 1, 1, 960)    │      231,360 │
expanded_conv_14… │
│ (Conv2D)             │                      │              │
│
├──────────────────────┼──────────────────────┼──────────────┼──────────────────
```

```
──────┤
| add_33 (Add)         | (None, 1, 1, 960) |           0 |
expanded_conv_14… |
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| re_lu_65 (ReLU)      | (None, 1, 1, 960) |           0 | add_33[0][0]
|
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| multiply_33          | (None, 1, 1, 960) |           0 | re_lu_65[0]
[0]    |
| (Multiply)           |                   |             |
|
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_14_s… | (None, 1, 1, 960) |           0 |
activation_74[0]… |
| (Multiply)           |                   |             |
multiply_33[0][0] |
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_14_p… | (None, 1, 1, 160) |     153,600 |
expanded_conv_14… |
| (Conv2D)             |                   |             |
|
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_14_p… | (None, 1, 1, 160) |         640 |
expanded_conv_14… |
| (BatchNormalizatio… |                   |             |
|
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| expanded_conv_14_a… | (None, 1, 1, 160) |           0 |
expanded_conv_13… |
| (Add)                |                   |             |
expanded_conv_14… |
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| conv_1 (Conv2D)      | (None, 1, 1, 960) |     153,600 |
expanded_conv_14… |
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
| conv_1_bn            | (None, 1, 1, 960) |       3,840 | conv_1[0][0]
|
| (BatchNormalizatio… |                   |             |
|
├──────────────────────┼───────────────────┼─────────────┼──────────────────
──────┤
```

```
| activation_75       | (None, 1, 1, 960) |          0 | conv_1_bn[0]
[0]   |
| (Activation)        |                   |            |
|
├─────────────────────┼───────────────────┼────────────┼──────────────
──────┤
| avg_pool            | (None, 960)       |          0 |
activation_75[0]… |
| (GlobalAveragePool… |                   |            |
|
└─────────────────────┴───────────────────┴────────────┴──────────────
──────┘

 Total params: 2,996,352 (11.43 MB)

 Trainable params: 0 (0.00 B)

 Non-trainable params: 2,996,352 (11.43 MB)
```

Add Classification Head

```
model = tf.keras.models.Sequential()
model.add(base_model)
model.add(tf.keras.layers.Dropout(0.5))
model.add(tf.keras.layers.Dense(
    units=NUM_CLASSES,
    activation=tf.keras.activations.softmax,
    kernel_regularizer=tf.keras.regularizers.l2(l2=0.01)
))

model.summary()
```

```
Model: "sequential_5"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━
━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━
━━━┩
| MobileNetV3Large (Functional)   | (None, 960)            |
2,996,352 |
├─────────────────────────────────┼────────────────────────┼──────────────
──────┤
| dropout_5 (Dropout)             | (None, 960)            |
0 |
├─────────────────────────────────┼────────────────────────┼──────────────
──────┤
| dense_5 (Dense)                 | (None, 100)            |
96,100 |
```

```
└─────────────────────────────────────┴──────────────────────────────┴──────────
──────┘

 Total params: 3,092,452 (11.80 MB)

 Trainable params: 96,100 (375.39 KB)

 Non-trainable params: 2,996,352 (11.43 MB)
```

Compiling Model

```
adam_optimizer = tf.keras.optimizers.Adam(learning_rate=0.001)

model.compile(
    optimizer=adam_optimizer,
    loss=tf.keras.losses.sparse_categorical_crossentropy,
    metrics=['accuracy']
)
```

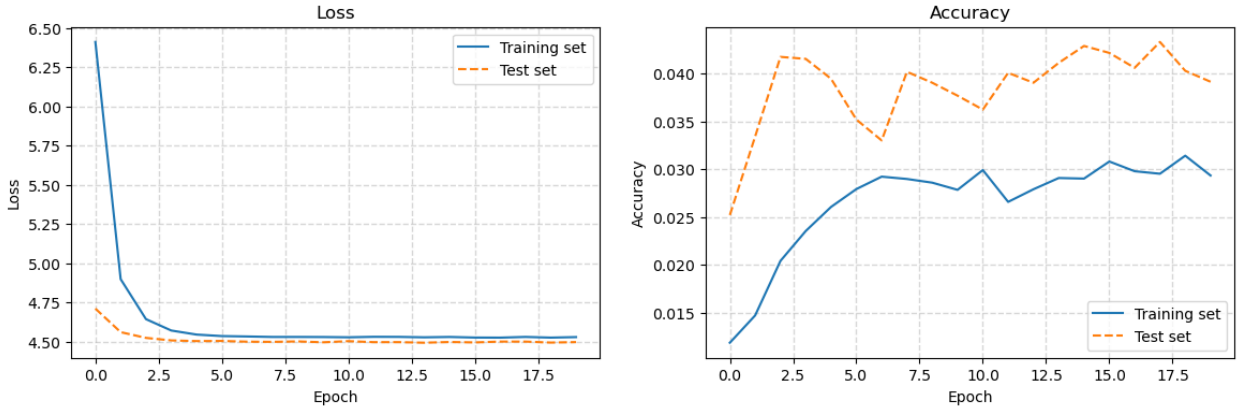
Training the Models with CIFAR 10

```
initial_epochs = 20
steps_per_epoch = NUM_TRAIN_EXAMPLES // BATCH_SIZE
validation_steps = NUM_TEST_EXAMPLES // BATCH_SIZE if
NUM_TEST_EXAMPLES // BATCH_SIZE else 1

print('steps_per_epoch:', steps_per_epoch)
print('validation_steps:', validation_steps)

steps_per_epoch: 62
validation_steps: 12

training_history = model.fit(
    x=dataset_train_shuffled.repeat(),
    validation_data=dataset_test_shuffled.repeat(),
    epochs=initial_epochs,
    steps_per_epoch=steps_per_epoch,
    validation_steps=validation_steps,
    verbose=1
)

Epoch 1/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 27s 334ms/step - accuracy: 0.0111 - loss:
7.4007 - val_accuracy: 0.0252 - val_loss: 4.7113
Epoch 2/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 20s 329ms/step - accuracy: 0.0130 - loss:
5.0190 - val_accuracy: 0.0334 - val_loss: 4.5612
Epoch 3/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 345ms/step - accuracy: 0.0186 - loss:
4.6729 - val_accuracy: 0.0418 - val_loss: 4.5246
```

```
Epoch 4/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 344ms/step - accuracy: 0.0231 - loss:
4.5831 - val_accuracy: 0.0416 - val_loss: 4.5085
Epoch 5/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 24s 387ms/step - accuracy: 0.0261 - loss:
4.5479 - val_accuracy: 0.0395 - val_loss: 4.5042
Epoch 6/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 23s 372ms/step - accuracy: 0.0268 - loss:
4.5408 - val_accuracy: 0.0352 - val_loss: 4.5051
Epoch 7/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 23s 369ms/step - accuracy: 0.0290 - loss:
4.5340 - val_accuracy: 0.0330 - val_loss: 4.5004
Epoch 8/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 22s 363ms/step - accuracy: 0.0280 - loss:
4.5316 - val_accuracy: 0.0402 - val_loss: 4.4992
Epoch 9/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 346ms/step - accuracy: 0.0289 - loss:
4.5291 - val_accuracy: 0.0391 - val_loss: 4.5022
Epoch 10/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 334ms/step - accuracy: 0.0275 - loss:
4.5304 - val_accuracy: 0.0377 - val_loss: 4.4965
Epoch 11/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 337ms/step - accuracy: 0.0302 - loss:
4.5302 - val_accuracy: 0.0362 - val_loss: 4.5038
Epoch 12/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 336ms/step - accuracy: 0.0260 - loss:
4.5341 - val_accuracy: 0.0401 - val_loss: 4.4974
Epoch 13/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 334ms/step - accuracy: 0.0274 - loss:
4.5303 - val_accuracy: 0.0391 - val_loss: 4.4975
Epoch 14/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 336ms/step - accuracy: 0.0296 - loss:
4.5283 - val_accuracy: 0.0411 - val_loss: 4.4937
Epoch 15/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 22s 356ms/step - accuracy: 0.0295 - loss:
4.5254 - val_accuracy: 0.0429 - val_loss: 4.4985
Epoch 16/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 339ms/step - accuracy: 0.0308 - loss:
4.5289 - val_accuracy: 0.0422 - val_loss: 4.4957
Epoch 17/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 332ms/step - accuracy: 0.0285 - loss:
4.5276 - val_accuracy: 0.0406 - val_loss: 4.5010
Epoch 18/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 342ms/step - accuracy: 0.0289 - loss:
4.5329 - val_accuracy: 0.0433 - val_loss: 4.5010
Epoch 19/20
62/62 ━━━━━━━━━━━━━━━━━━━━ 21s 335ms/step - accuracy: 0.0315 - loss:
4.5221 - val_accuracy: 0.0403 - val_loss: 4.4947
Epoch 20/20
```

```
62/62 ━━━━━━━━━━━━━━━━━━━━ 22s 349ms/step - accuracy: 0.0290 - loss:
4.5309 - val_accuracy: 0.0392 - val_loss: 4.4978
```

```python
def render_training_history(training_history):
    loss = training_history.history['loss']
    val_loss = training_history.history['val_loss']

    accuracy = training_history.history['accuracy']
    val_accuracy = training_history.history['val_accuracy']

    plt.figure(figsize=(14, 4))

    plt.subplot(1, 2, 1)
    plt.title('Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.plot(loss, label='Training set')
    plt.plot(val_loss, label='Test set', linestyle='--')
    plt.legend()
    plt.grid(linestyle='--', linewidth=1, alpha=0.5)

    plt.subplot(1, 2, 2)
    plt.title('Accuracy')
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.plot(accuracy, label='Training set')
    plt.plot(val_accuracy, label='Test set', linestyle='--')
    plt.legend()
    plt.grid(linestyle='--', linewidth=1, alpha=0.5)

    plt.show()

render_training_history(training_history)
```



Fine Tune Model

```
# Un-freeze the top layers of the models
base_model.trainable = True

print("Number of layers in the base model: ", len(base_model.layers))
```

```
Number of layers in the base model:  188
```

```
# Freeze all the layers before the specified layer
for layer in base_model.layers[:round(len(base_model.layers) * 0.05)]:
    layer.trainable =  False

# Compile the model using a much-lower training rate.
adam_optimizer = tf.keras.optimizers.Adam(learning_rate=0.0001)

model.compile(
    optimizer = adam_optimizer,
    loss=tf.keras.losses.sparse_categorical_crossentropy,
    metrics=['accuracy']
)

model.summary()
```

```
Model: "sequential_5"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ MobileNetV3Large (Functional)        │ (None, 960)                 │       2,996,352 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_5 (Dropout)                  │ (None, 960)                 │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_5 (Dense)                      │ (None, 100)                 │          96,100 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
```

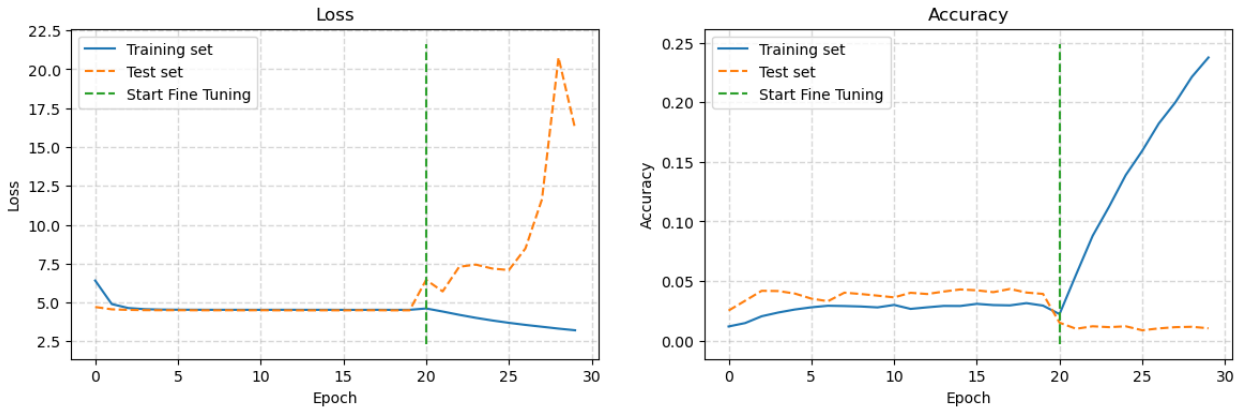
```
 Total params: 3,092,452 (11.80 MB)

 Trainable params: 3,067,156 (11.70 MB)

 Non-trainable params: 25,296 (98.81 KB)
```

```
# The number of additional epochs during which we're going to fine
tune the model.
fine_tuning_epochs = 10

training_history_fine = model.fit(
    x=dataset_train_shuffled.repeat(),
    validation_data=dataset_test_shuffled.repeat(),
    epochs=initial_epochs + fine_tuning_epochs,
    initial_epoch=initial_epochs,
    steps_per_epoch=steps_per_epoch,
    validation_steps=validation_steps,
    verbose=1
)
```

```
Epoch 21/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 111s 1s/step - accuracy: 0.0162 - loss:
4.6685 - val_accuracy: 0.0150 - val_loss: 6.4522
Epoch 22/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 87s 1s/step - accuracy: 0.0486 - loss:
4.4617 - val_accuracy: 0.0099 - val_loss: 5.7148
Epoch 23/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 83s 1s/step - accuracy: 0.0824 - loss:
4.2483 - val_accuracy: 0.0120 - val_loss: 7.2985
Epoch 24/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 84s 1s/step - accuracy: 0.1071 - loss:
4.0533 - val_accuracy: 0.0113 - val_loss: 7.4375
Epoch 25/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 85s 1s/step - accuracy: 0.1323 - loss:
3.8730 - val_accuracy: 0.0120 - val_loss: 7.1843
Epoch 26/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 83s 1s/step - accuracy: 0.1578 - loss:
3.7210 - val_accuracy: 0.0086 - val_loss: 7.0858
Epoch 27/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 85s 1s/step - accuracy: 0.1787 - loss:
3.5846 - val_accuracy: 0.0102 - val_loss: 8.4749
Epoch 28/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 86s 1s/step - accuracy: 0.1922 - loss:
3.4708 - val_accuracy: 0.0113 - val_loss: 11.6396
Epoch 29/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 83s 1s/step - accuracy: 0.2172 - loss:
3.3534 - val_accuracy: 0.0116 - val_loss: 20.7594
Epoch 30/30
62/62 ━━━━━━━━━━━━━━━━━━━━ 89s 1s/step - accuracy: 0.2309 - loss:
3.2481 - val_accuracy: 0.0103 - val_loss: 16.1973
```

```
def render_training_history_fine(training_history,
training_history_fine):
    loss = training_history.history['loss'] +
training_history_fine.history['loss']
    val_loss = training_history.history['val_loss'] +
```

```
training_history_fine.history['val_loss']

    accuracy = training_history.history['accuracy'] +
training_history_fine.history['accuracy']
    val_accuracy = training_history.history['val_accuracy'] +
training_history_fine.history['val_accuracy']

    plt.figure(figsize=(14, 4))

    plt.subplot(1, 2, 1)
    plt.title('Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.plot(loss, label='Training set')
    plt.plot(val_loss, label='Test set', linestyle='--')
    plt.plot(
    [initial_epochs, initial_epochs],
    plt.ylim(),
    label='Start Fine Tuning',
    linestyle='--'
    )
    plt.legend()
    plt.grid(linestyle='--', linewidth=1, alpha=0.5)

    plt.subplot(1, 2, 2)
    plt.title('Accuracy')
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.plot(accuracy, label='Training set')
    plt.plot(val_accuracy, label='Test set', linestyle='--')
    plt.plot(
    [initial_epochs, initial_epochs],
    plt.ylim(),
    label='Start Fine Tuning',
    linestyle='--'
    )
    plt.legend()
    plt.grid(linestyle='--', linewidth=1, alpha=0.5)

    plt.show()

render_training_history_fine(training_history, training_history_fine)
```



Evaluate Model

```
def eval_model(model):
    train_loss, train_accuracy = model.evaluate(
        x=dataset_train.batch(BATCH_SIZE).take(NUM_TRAIN_EXAMPLES)
    )

    test_loss, test_accuracy = model.evaluate(
        x=dataset_test.batch(BATCH_SIZE).take(NUM_TEST_EXAMPLES)
    )
    print('Training loss: ', train_loss)
    print('Training accuracy: ', train_accuracy)
    print('\n')
    print('Test loss: ', test_loss)
    print('Test accuracy: ', test_accuracy)

eval_model(model)
```

```
63/63 ━━━━━━━━━━━━━━━━━━━━ 23s 368ms/step - accuracy: 0.0098 - loss:
16.2303
13/13 ━━━━━━━━━━━━━━━━━━━━ 5s 360ms/step - accuracy: 0.0101 - loss:
16.2583
Training loss:  16.23200798034668
Training accuracy:  0.010040000081062317


Test loss:  16.2645263671875
Test accuracy:  0.010400000028312206
```

Save Model

```
model.save(f'models/{DATASET_NAME}_{MODEL_TYPE}.keras')
```