Garbage Classification Week2

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1 Garbage Classification with EfficientNetV2B2

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1.2 Project Description

In this project, the aim is to develop a sophisticated **garbage classification system** leveraging the **EfficientNetV2B2** architecture. Our primary dataset serves as a foundation for building models that can eventually automate waste segregation, a critical step in optimizing recycling and waste management, ultimately aiding in environmental conservation.

Goal: To develop an accurate and efficient garbage classification model using EfficientNetV2B2 and transfer learning for automated waste sorting.

1.3 Challenges and Scope

Key Challenge: A notable challenge encountered is the inherent **class imbalance** within the dataset.

1.3.1 Core Libraries

- `tensorflow`: For deep learning model building and training.
- `numpy`: For numerical operations and array manipulation.
- `matplotlib.pyplot`: For plotting training curves and results.

```
[1]: import numpy as np  # Importing NumPy for numerical operations and array
      ↪manipulations
     import matplotlib.pyplot as plt  # Importing Matplotlib for plotting graphs and
      ↪visualizations
     import seaborn as sns  # Importing Seaborn for statistical data visualization,
      ↪built on top of Matplotlib
     import tensorflow as tf  # Importing TensorFlow for building and training
      ↪machine learning models
     from tensorflow import keras  # Importing Keras, a high-level API for
      ↪TensorFlow, to simplify model building
     from tensorflow.keras import Layer  # Importing Layer class for creating custom
      ↪layers in Keras
```

```python
from tensorflow.keras.models import Sequential  # Importing Sequential model
  ↪for building neural networks layer-by-layer
from tensorflow.keras.layers import Rescaling , GlobalAveragePooling2D
from tensorflow.keras import layers, optimizers, callbacks  # Importing various
  ↪modules for layers, optimizers, and callbacks in Keras
from sklearn.utils.class_weight import compute_class_weight  # Importing
  ↪function to compute class weights for imbalanced datasets
from tensorflow.keras.applications import EfficientNetV2B2  # Importing
  ↪EfficientNetV2S model for transfer learning
from sklearn.metrics import confusion_matrix, classification_report  #
  ↪Importing functions to evaluate model performance
import gradio as gr  # Importing Gradio for creating interactive web interfaces
  ↪for machine learning models
```

1.4 1. Exploring and Understanding the Data.

- Loading image dataset using tools like `image_dataset_from_directory`.
- Visualizing sample images from each class.
- Check the number of images per class to ensure balance.
- Understand image dimensions, color channels, and class labels.

```python
[2]: dataset_dir= r"C:\Users\Pranesh\OneDrive\Desktop\LMS\AICTE
     ↪Internship\TrashType_Image_Dataset"
     image_size = (124, 124)
     batch_size = 32
     seed = 42
```

```python
[3]: train_ds = tf.keras.utils.image_dataset_from_directory(
         dataset_dir,
         validation_split=0.2,
         subset="training",
         seed=seed,
         shuffle = True,
         image_size=image_size,
         batch_size=batch_size
     )
```

```
Found 2527 files belonging to 6 classes.
Using 2022 files for training.
```

```python
[4]: val_ds = tf.keras.utils.image_dataset_from_directory(
         dataset_dir,
         validation_split=0.2,
         subset="validation",
         seed=seed,
         shuffle = True,
         image_size=image_size,
         batch_size=batch_size
```

```
)
val_class= val_ds.class_names
```

```
Found 2527 files belonging to 6 classes.
Using 505 files for validation.
```

[5]:
```python
# Get the total number of batches in the validation dataset
val_batches = tf.data.experimental.cardinality(val_ds)

# Split the validation dataset into two equal parts:
# First half becomes the test dataset
test_ds = val_ds.take(val_batches // 2)

# Second half remains as the validation dataset
val_dat = val_ds.skip(val_batches // 2)

# Optimize test dataset by caching and prefetching to improve performance
test_ds_eval = test_ds.cache().prefetch(tf.data.AUTOTUNE)
```

[6]:
```python
print(train_ds.class_names)
print(val_class)
print(len(train_ds.class_names))
```

```
['cardboard', 'glass', 'metal', 'paper', 'plastic', 'trash']
['cardboard', 'glass', 'metal', 'paper', 'plastic', 'trash']
6
```

1.4.1 Visualization of sample images from each class.

[7]:
```python
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 10))
for images, labels in train_ds.take(1):
  for i in range(12):
    ax = plt.subplot(4, 3, i + 1)
    plt.imshow(images[i].numpy().astype("uint8"))
    plt.title(train_ds.class_names[labels[i]])
    plt.axis("off")
```

-

1.5 Checking the number of images per class to ensure balance.

-

1.6 Understanding image properties like Image dimensions, Class labels.

```python
[8]: def count_distribution(dataset, class_names):
         total = 0
         counts = {name: 0 for name in class_names}

         for _, labels in dataset:
             for label in labels.numpy():
                 class_name = class_names[label]
                 counts[class_name] += 1
                 total += 1

         for k in counts:
             counts[k] = round((counts[k] / total) * 100, 2)  # Convert to percentage
         return counts
```

```python
[9]: # Plot class distribution
     def simple_bar_plot(dist, title):
         plt.bar(dist.keys(), dist.values(), color='cornflowerblue')
         plt.title(title)
         plt.ylabel('Percentage (%)')
         plt.xticks(rotation=45)
         plt.ylim(0, 100)
         plt.tight_layout()
         plt.show()
```

```python
[10]: class_names = train_ds.class_names

      # Get class distributions
      train_dist = count_distribution(train_ds, class_names)
      val_dist = count_distribution(val_ds, class_names)
      test_dist = count_distribution(test_ds, class_names)
      overall_dist = {}
      for k in class_names:
          overall_dist[k] = round((train_dist[k] + val_dist[k]) / 2, 2)

      print(train_dist)
      print(val_dist)
      print(test_dist)
      print(overall_dist)
```

```
{'cardboard': 16.52, 'glass': 19.73, 'metal': 15.92, 'paper': 23.29, 'plastic':
19.44, 'trash': 5.09}
{'cardboard': 13.66, 'glass': 20.2, 'metal': 17.43, 'paper': 24.36, 'plastic':
17.62, 'trash': 6.73}
{'cardboard': 14.06, 'glass': 17.58, 'metal': 16.8, 'paper': 25.0, 'plastic':
19.14, 'trash': 7.42}
{'cardboard': 15.09, 'glass': 19.96, 'metal': 16.68, 'paper': 23.82, 'plastic':
```

18.53, 'trash': 5.91}

[11]:
```python
# Show visualizations
simple_bar_plot(train_dist, "Training Set Class Distribution (%)")
simple_bar_plot(val_dist, "Validation Set Class Distribution (%)")
simple_bar_plot(test_dist, "Test Set Class Distribution (%)")
simple_bar_plot(overall_dist, "Overall Class Distribution (%)")
```


Training Set Class Distribution (%)

Validation Set Class Distribution (%)

Test Set Class Distribution (%)
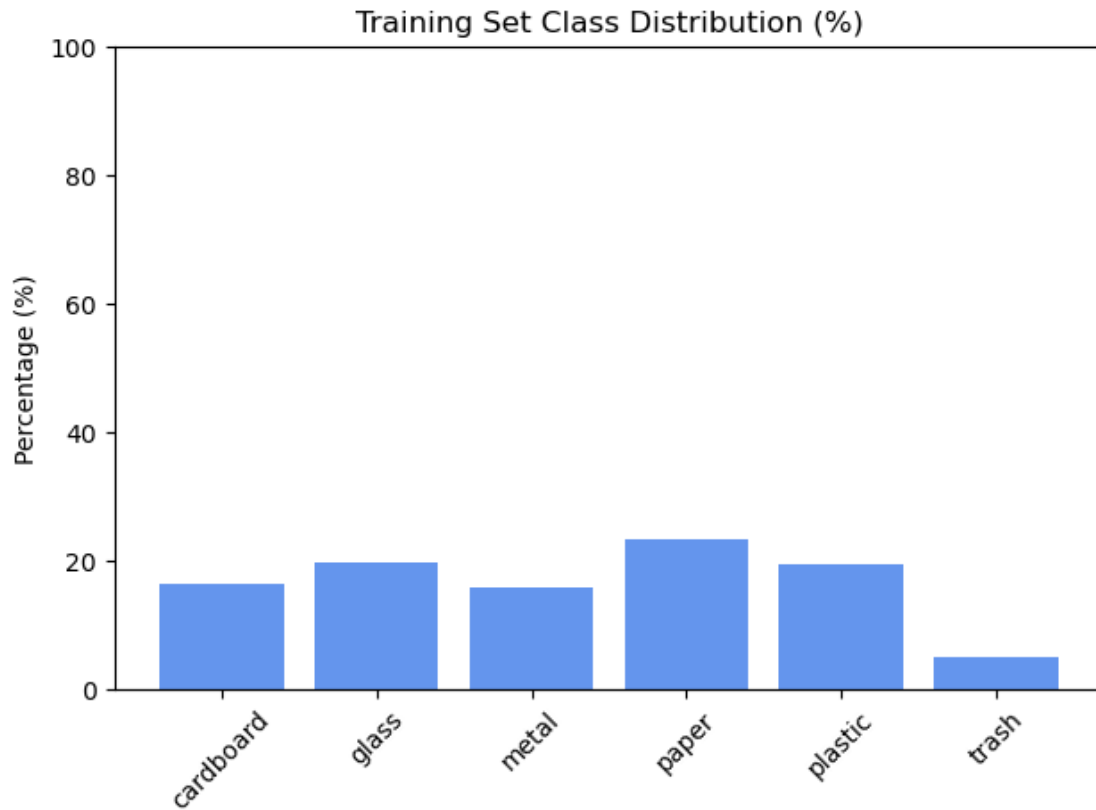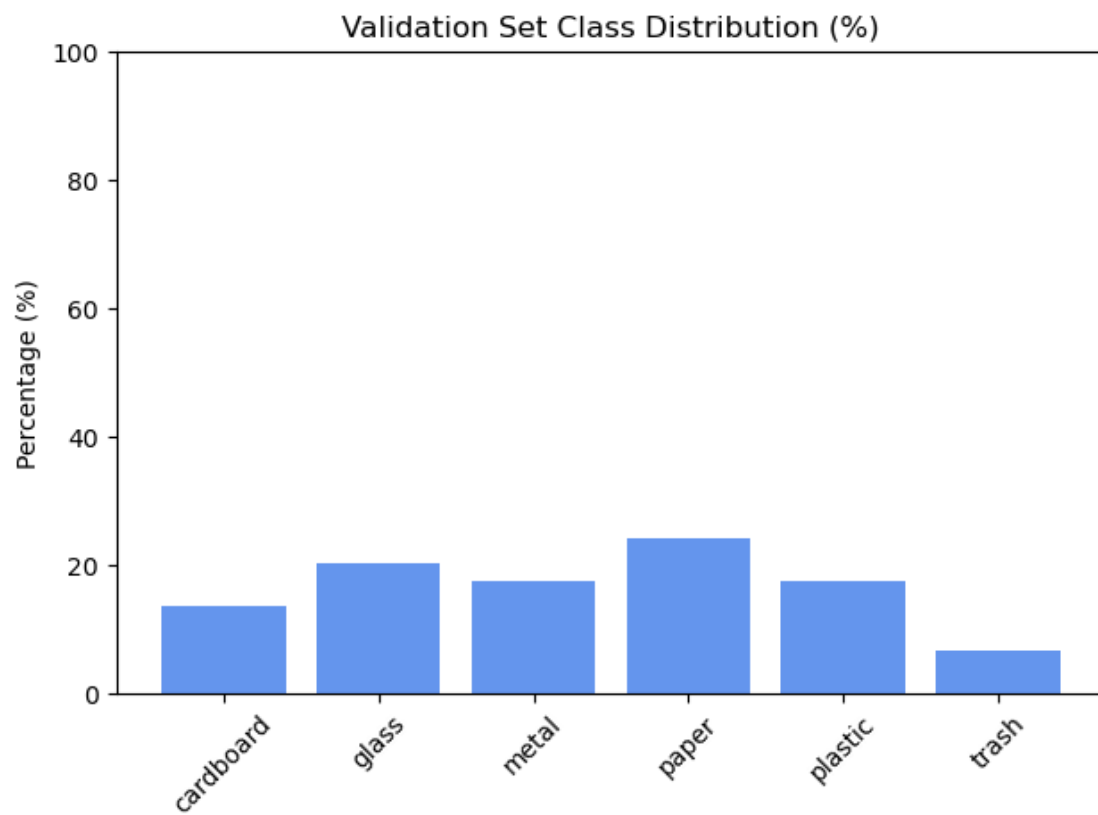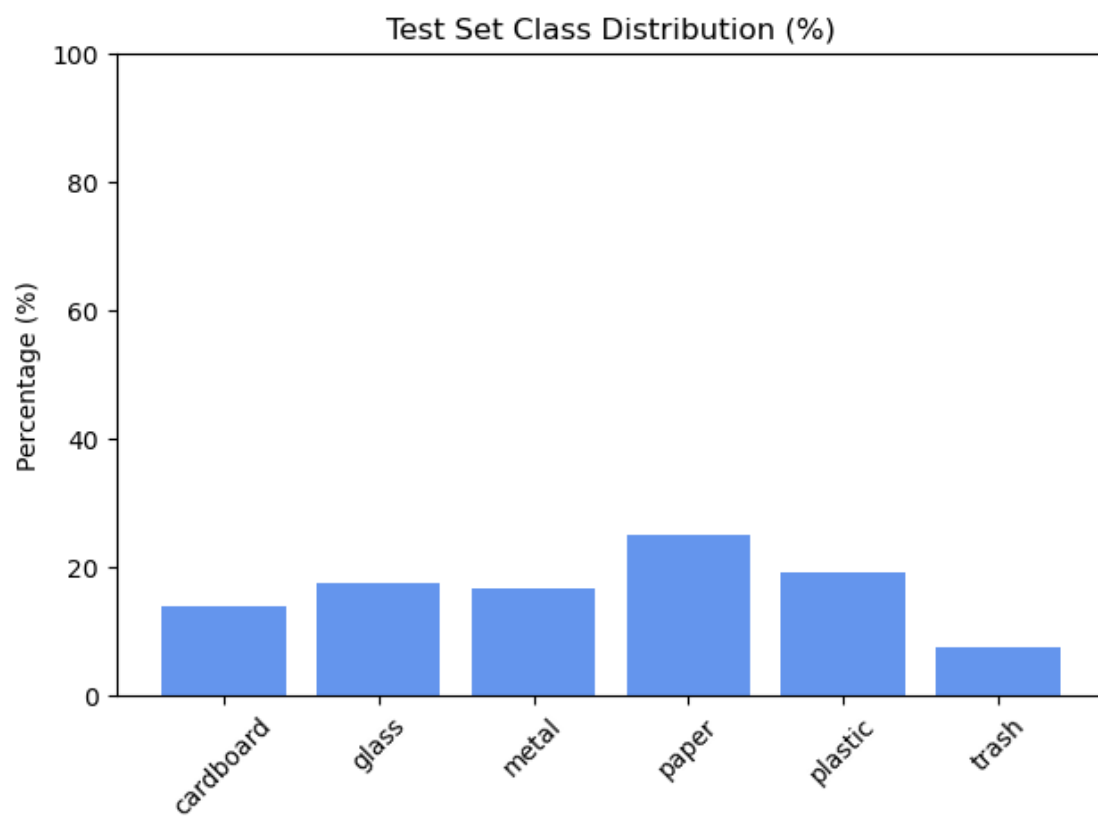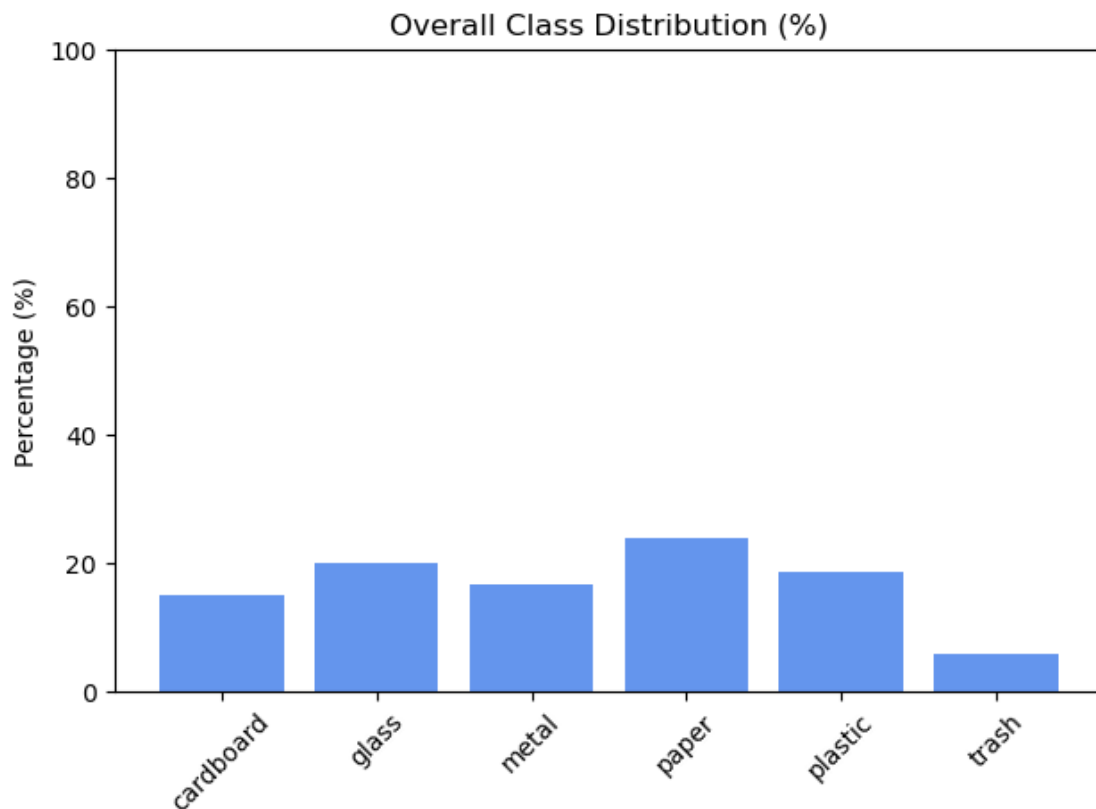
2 Inference on Class Imbalance

The **"Garbage Image Dataset"** reveals a noticeable **imbalance** in the distribution of its image categories:

Category	Image Count	Updated Distribution
Cardboard	403	15.09
Glass	501	19.96
Metal	410	16.68
Paper	594	23.82
Plastic	482	18.53
Trash	137	5.91

2.0.1 Key Problems Caused by Class Imbalance:

1 Bias

- The model may **overpredict common classes** like "paper" and **underpredict rare ones** like "trash".

2 Generalization Issues

- If the real-world distribution is more balanced, the model may **fail to generalize** and **misclassify rare classes**.

3 Accuracy Deception

- The model might appear to have **high overall accuracy** just by **predicting the majority class**, while **failing** on underrepresented ones.

```python
[12]: # Count class occurrences and prepare label list
      class_counts = {i: 0 for i in range(len(class_names))}
      all_labels = []

      for images, labels in train_ds:
          for label in labels.numpy():
              class_counts[label] += 1
              all_labels.append(label)

      # Compute class weights (index aligned)
      class_weights_array = compute_class_weight(
          class_weight='balanced',
          classes=np.arange(len(class_names)),
          y=all_labels
      )

      # Create dictionary mapping class index to weight
      class_weights = {i: w for i, w in enumerate(class_weights_array)}
```

```python
[13]: #  Optional: print results
      print("Class Counts:", class_counts)
      print("Class Weights:", class_weights)
```

```
Class Counts: {0: 334, 1: 399, 2: 322, 3: 471, 4: 393, 5: 103}
Class Weights: {0: 1.0089820359281436, 1: 0.8446115288220551, 2:
1.046583850931677, 3: 0.7154989384288747, 4: 0.8575063613231552, 5:
3.2718446601941746}
```

2.1 Data Preprocessing

```python
[14]: data_augmentation = Sequential([
          layers.RandomFlip("horizontal"),
          layers.RandomRotation(0.1),
          layers.RandomZoom(0.1),
          layers.RandomContrast(0.1),
      ])
```

```python
[16]: base_model = EfficientNetV2B2(include_top=False, input_shape=(124, 124,
      ↪3),include_preprocessing=True, weights='imagenet')


      #  Freeze early layers (to retain general pretrained features)
      base_model.trainable = True
      for layer in base_model.layers[:100]:  # You can adjust this number
          layer.trainable = False
```

```python
[17]: #  Building the final model
      model = Sequential([
          layers.Input(shape=(124, 124, 3)),
          data_augmentation,
          base_model,
          GlobalAveragePooling2D(),
          layers.Dropout(0.3),
          layers.Dense(6, activation='softmax')  # Change to your number of classes
      ])
```

```python
[19]: #  Compiling the model
      model.compile(
          optimizer=optimizers.Adam(learning_rate=1e-4),
          loss='sparse_categorical_crossentropy',
          metrics=['accuracy']
      )
```

```python
[20]: early = tf.keras.callbacks.EarlyStopping(
          monitor='val_loss',               # Metric to monitor (validation loss here)
          patience=3,                       # Number of epochs to wait after last
      ↪improvement before stopping
          restore_best_weights=True      # After stopping, restore the model weights
      ↪from the epoch with the best val_loss
      )
```

Train the model using .fit() with appropriate epochs, batch_size, and callbacks like EarlyStopping.

```python
[22]: epochs = 15  # Number of times the model will go through the entire dataset

      # Train the model using the fit function
      history = model.fit(
          train_ds,                  # Training dataset used to adjust model weights
          validation_data=val_ds,    # Validation dataset to monitor performance on
      ↪unseen data
          epochs=epochs,             # Number of training cycles, referencing the
      ↪variable set earlier
          class_weight=class_weights,  # Handles class imbalances by assigning
      ↪appropriate weights
```

```
    batch_size=32,              # Number of samples processed in each training step
    callbacks=[early]           # Implements early stopping to prevent unnecessary
 ↪training
)
```

```
Epoch 1/15
64/64              42s 658ms/step -
accuracy: 0.9553 - loss: 0.1309 - val_accuracy: 0.8931 - val_loss: 0.2921
Epoch 2/15
64/64              40s 631ms/step -
accuracy: 0.9640 - loss: 0.1169 - val_accuracy: 0.8891 - val_loss: 0.3070
Epoch 3/15
64/64              40s 628ms/step -
accuracy: 0.9726 - loss: 0.0885 - val_accuracy: 0.8891 - val_loss: 0.2985
Epoch 4/15
64/64              40s 630ms/step -
accuracy: 0.9747 - loss: 0.0853 - val_accuracy: 0.9089 - val_loss: 0.2650
Epoch 5/15
64/64              41s 633ms/step -
accuracy: 0.9785 - loss: 0.0714 - val_accuracy: 0.9228 - val_loss: 0.2434
Epoch 6/15
64/64              41s 639ms/step -
accuracy: 0.9872 - loss: 0.0548 - val_accuracy: 0.9188 - val_loss: 0.2385
Epoch 7/15
64/64              41s 635ms/step -
accuracy: 0.9798 - loss: 0.0637 - val_accuracy: 0.9030 - val_loss: 0.2512
Epoch 8/15
64/64              41s 639ms/step -
accuracy: 0.9835 - loss: 0.0567 - val_accuracy: 0.9168 - val_loss: 0.2507
Epoch 9/15
64/64              41s 632ms/step -
accuracy: 0.9850 - loss: 0.0484 - val_accuracy: 0.9149 - val_loss: 0.2586
```

[23]: `model.summary()`

```
Model: "sequential_1"


 Layer (type)                        Output Shape                         ␣
 ↪Param #

 sequential (Sequential)             (None, 124, 124, 3)                         ␣
 ↪   0

 efficientnetv2-b2 (Functional)      (None, 4, 4, 1408)                        ␣
 ↪8,769,374
```

```
global_average_pooling2d              (None, 1408)                            ␣
↳   0
(GlobalAveragePooling2D)                                                      ␣
↳

dropout (Dropout)                     (None, 1408)                            ␣
↳   0

dense (Dense)                         (None, 6)                           ␣
↳8,454
```

Total params: 24,727,114 (94.33 MB)

Trainable params: 7,974,642 (30.42 MB)

Non-trainable params: 803,186 (3.06 MB)

Optimizer params: 15,949,286 (60.84 MB)

[24]: `base_model.summary()` *# Print the architecture summary of the base model*

Model: "efficientnetv2-b2"

```
Layer (type)                  Output Shape                    Param #  ␣
↳Connected to

input_layer_1 (InputLayer)    (None, 124, 124, 3)                 0   -  ␣
↳

rescaling_1 (Rescaling)       (None, 124, 124, 3)                 0   ␣
↳input_layer_1[0][0]

normalization_1               (None, 124, 124, 3)                 0   ␣
↳rescaling_1[0][0]
(Normalization)                                                       ␣
↳

stem_conv (Conv2D)            (None, 62, 62, 32)                864   ␣
↳normalization_1[0][0]

stem_bn (BatchNormalization)  (None, 62, 62, 32)                128   ␣
↳stem_conv[0][0]
```

```
stem_activation (Activation)      (None, 62, 62, 32)                    0 ⊔
↪stem_bn[0][0]

block1a_project_conv (Conv2D)     (None, 62, 62, 16)                4,608 ⊔
↪stem_activation[0][0]

block1a_project_bn                (None, 62, 62, 16)                   64 ⊔
↪block1a_project_conv[0][0]
(BatchNormalization)                                                     ⊔
↪

block1a_project_activation        (None, 62, 62, 16)                    0 ⊔
↪block1a_project_bn[0][0]
(Activation)                                                             ⊔
↪

block1b_project_conv (Conv2D)     (None, 62, 62, 16)                2,304 ⊔
↪block1a_project_activatio…

block1b_project_bn                (None, 62, 62, 16)                   64 ⊔
↪block1b_project_conv[0][0]
(BatchNormalization)                                                     ⊔
↪

block1b_project_activation        (None, 62, 62, 16)                    0 ⊔
↪block1b_project_bn[0][0]
(Activation)                                                             ⊔
↪

block1b_drop (Dropout)            (None, 62, 62, 16)                    0 ⊔
↪block1b_project_activatio…

block1b_add (Add)                 (None, 62, 62, 16)                    0 ⊔
↪block1b_drop[0][0],
                                                                         ⊔
↪block1a_project_activatio…

block2a_expand_conv (Conv2D)      (None, 31, 31, 64)                9,216 ⊔
↪block1b_add[0][0]

block2a_expand_bn                 (None, 31, 31, 64)                  256 ⊔
↪block2a_expand_conv[0][0]
(BatchNormalization)                                                     ⊔
↪
```

```
block2a_expand_activation        (None, 31, 31, 64)                    0  ␣
↪block2a_expand_bn[0][0]
(Activation)                                                              ␣
↪

block2a_project_conv (Conv2D)    (None, 31, 31, 32)                2,048  ␣
↪block2a_expand_activation…

block2a_project_bn               (None, 31, 31, 32)                  128  ␣
↪block2a_project_conv[0][0]
(BatchNormalization)                                                      ␣
↪

block2b_expand_conv (Conv2D)     (None, 31, 31, 128)              36,864  ␣
↪block2a_project_bn[0][0]

block2b_expand_bn                (None, 31, 31, 128)                 512  ␣
↪block2b_expand_conv[0][0]
(BatchNormalization)                                                      ␣
↪

block2b_expand_activation        (None, 31, 31, 128)                   0  ␣
↪block2b_expand_bn[0][0]
(Activation)                                                              ␣
↪

block2b_project_conv (Conv2D)    (None, 31, 31, 32)                4,096  ␣
↪block2b_expand_activation…

block2b_project_bn               (None, 31, 31, 32)                  128  ␣
↪block2b_project_conv[0][0]
(BatchNormalization)                                                      ␣
↪

block2b_drop (Dropout)           (None, 31, 31, 32)                    0  ␣
↪block2b_project_bn[0][0]

block2b_add (Add)                (None, 31, 31, 32)                    0  ␣
↪block2b_drop[0][0],
                                                                          ␣
↪block2a_project_bn[0][0]

block2c_expand_conv (Conv2D)     (None, 31, 31, 128)              36,864  ␣
↪block2b_add[0][0]
```

block2c_expand_bn ↪block2c_expand_conv[0][0] (BatchNormalization) ↪	(None, 31, 31, 128)	512 ⊔ ⊔ ⊔
block2c_expand_activation ↪block2c_expand_bn[0][0] (Activation) ↪	(None, 31, 31, 128)	0 ⊔ ⊔ ⊔
block2c_project_conv (Conv2D) ↪block2c_expand_activation…	(None, 31, 31, 32)	4,096 ⊔
block2c_project_bn ↪block2c_project_conv[0][0] (BatchNormalization) ↪	(None, 31, 31, 32)	128 ⊔ ⊔
block2c_drop (Dropout) ↪block2c_project_bn[0][0]	(None, 31, 31, 32)	0 ⊔
block2c_add (Add) ↪block2c_drop[0][0], ↪block2b_add[0][0]	(None, 31, 31, 32)	0 ⊔ ⊔
block3a_expand_conv (Conv2D) ↪block2c_add[0][0]	(None, 16, 16, 128)	36,864 ⊔
block3a_expand_bn ↪block3a_expand_conv[0][0] (BatchNormalization) ↪	(None, 16, 16, 128)	512 ⊔ ⊔
block3a_expand_activation ↪block3a_expand_bn[0][0] (Activation) ↪	(None, 16, 16, 128)	0 ⊔ ⊔
block3a_project_conv (Conv2D) ↪block3a_expand_activation…	(None, 16, 16, 56)	7,168 ⊔
block3a_project_bn ↪block3a_project_conv[0][0] (BatchNormalization) ↪	(None, 16, 16, 56)	224 ⊔ ⊔

```
block3b_expand_conv (Conv2D)      (None, 16, 16, 224)              112,896  ␣
↪block3a_project_bn[0][0]

block3b_expand_bn                 (None, 16, 16, 224)                  896  ␣
↪block3b_expand_conv[0][0]
(BatchNormalization)                                                       ␣
↪

block3b_expand_activation         (None, 16, 16, 224)                    0  ␣
↪block3b_expand_bn[0][0]
(Activation)                                                               ␣
↪

block3b_project_conv (Conv2D)     (None, 16, 16, 56)               12,544  ␣
↪block3b_expand_activation…

block3b_project_bn                (None, 16, 16, 56)                  224  ␣
↪block3b_project_conv[0][0]
(BatchNormalization)                                                       ␣
↪

block3b_drop (Dropout)            (None, 16, 16, 56)                    0  ␣
↪block3b_project_bn[0][0]

block3b_add (Add)                 (None, 16, 16, 56)                    0  ␣
↪block3b_drop[0][0],
                                                                           ␣
↪block3a_project_bn[0][0]

block3c_expand_conv (Conv2D)      (None, 16, 16, 224)              112,896  ␣
↪block3b_add[0][0]

block3c_expand_bn                 (None, 16, 16, 224)                  896  ␣
↪block3c_expand_conv[0][0]
(BatchNormalization)                                                       ␣
↪

block3c_expand_activation         (None, 16, 16, 224)                    0  ␣
↪block3c_expand_bn[0][0]
(Activation)                                                               ␣
↪

block3c_project_conv (Conv2D)     (None, 16, 16, 56)               12,544  ␣
↪block3c_expand_activation…
```

block3c_project_bn ↪block3c_project_conv[0][0] (BatchNormalization) ↪	(None, 16, 16, 56)	224 ⊔ ⊔
block3c_drop (Dropout) ↪block3c_project_bn[0][0]	(None, 16, 16, 56)	0 ⊔
block3c_add (Add) ↪block3c_drop[0][0], ↪block3b_add[0][0]	(None, 16, 16, 56)	0 ⊔ ⊔
block4a_expand_conv (Conv2D) ↪block3c_add[0][0]	(None, 16, 16, 224)	12,544 ⊔
block4a_expand_bn ↪block4a_expand_conv[0][0] (BatchNormalization) ↪	(None, 16, 16, 224)	896 ⊔ ⊔
block4a_expand_activation ↪block4a_expand_bn[0][0] (Activation) ↪	(None, 16, 16, 224)	0 ⊔ ⊔
block4a_dwconv2 ↪block4a_expand_activation… (DepthwiseConv2D) ↪	(None, 8, 8, 224)	2,016 ⊔ ⊔
block4a_bn ↪block4a_dwconv2[0][0] (BatchNormalization) ↪	(None, 8, 8, 224)	896 ⊔ ⊔
block4a_activation ↪block4a_bn[0][0] (Activation) ↪	(None, 8, 8, 224)	0 ⊔ ⊔
block4a_se_squeeze ↪block4a_activation[0][0] (GlobalAveragePooling2D) ↪	(None, 224)	0 ⊔ ⊔

block4a_se_reshape (Reshape) ↪block4a_se_squeeze[0][0]	(None, 1, 1, 224)	0 ⊔
block4a_se_reduce (Conv2D) ↪block4a_se_reshape[0][0]	(None, 1, 1, 14)	3,150 ⊔
block4a_se_expand (Conv2D) ↪block4a_se_reduce[0][0]	(None, 1, 1, 224)	3,360 ⊔
block4a_se_excite (Multiply) ↪block4a_activation[0][0], ↪block4a_se_expand[0][0]	(None, 8, 8, 224)	0 ⊔ ⊔
block4a_project_conv (Conv2D) ↪block4a_se_excite[0][0]	(None, 8, 8, 104)	23,296 ⊔
block4a_project_bn ↪block4a_project_conv[0][0] (BatchNormalization) ↪	(None, 8, 8, 104)	416 ⊔ ⊔
block4b_expand_conv (Conv2D) ↪block4a_project_bn[0][0]	(None, 8, 8, 416)	43,264 ⊔
block4b_expand_bn ↪block4b_expand_conv[0][0] (BatchNormalization) ↪	(None, 8, 8, 416)	1,664 ⊔ ⊔
block4b_expand_activation ↪block4b_expand_bn[0][0] (Activation) ↪	(None, 8, 8, 416)	0 ⊔ ⊔
block4b_dwconv2 ↪block4b_expand_activation… (DepthwiseConv2D) ↪	(None, 8, 8, 416)	3,744 ⊔ ⊔
block4b_bn ↪block4b_dwconv2[0][0] (BatchNormalization) ↪	(None, 8, 8, 416)	1,664 ⊔ ⊔

```
block4b_activation                (None, 8, 8, 416)                              0 ␣
↪block4b_bn[0][0]
(Activation)                                                                       ␣
↪

block4b_se_squeeze                (None, 416)                                    0 ␣
↪block4b_activation[0][0]
(GlobalAveragePooling2D)                                                          ␣
↪

block4b_se_reshape (Reshape)      (None, 1, 1, 416)                              0 ␣
↪block4b_se_squeeze[0][0]

block4b_se_reduce (Conv2D)        (None, 1, 1, 26)                          10,842 ␣
↪block4b_se_reshape[0][0]

block4b_se_expand (Conv2D)        (None, 1, 1, 416)                         11,232 ␣
↪block4b_se_reduce[0][0]

block4b_se_excite (Multiply)      (None, 8, 8, 416)                              0 ␣
↪block4b_activation[0][0],

                                                                                   ␣
↪block4b_se_expand[0][0]

block4b_project_conv (Conv2D)     (None, 8, 8, 104)                         43,264 ␣
↪block4b_se_excite[0][0]

block4b_project_bn                (None, 8, 8, 104)                            416 ␣
↪block4b_project_conv[0][0]
(BatchNormalization)                                                              ␣
↪

block4b_drop (Dropout)            (None, 8, 8, 104)                              0 ␣
↪block4b_project_bn[0][0]

block4b_add (Add)                 (None, 8, 8, 104)                              0 ␣
↪block4b_drop[0][0],

                                                                                   ␣
↪block4a_project_bn[0][0]

block4c_expand_conv (Conv2D)      (None, 8, 8, 416)                         43,264 ␣
↪block4b_add[0][0]

block4c_expand_bn                 (None, 8, 8, 416)                          1,664 ␣
↪block4c_expand_conv[0][0]
```

```
(BatchNormalization)                                                                    ⊔
↪

block4c_expand_activation          (None, 8, 8, 416)                              0 ⊔
↪block4c_expand_bn[0][0]
(Activation)                                                                            ⊔
↪

block4c_dwconv2                    (None, 8, 8, 416)                          3,744 ⊔
↪block4c_expand_activation…
(DepthwiseConv2D)                                                                       ⊔
↪

block4c_bn                         (None, 8, 8, 416)                          1,664 ⊔
↪block4c_dwconv2[0][0]
(BatchNormalization)                                                                    ⊔
↪

block4c_activation                 (None, 8, 8, 416)                              0 ⊔
↪block4c_bn[0][0]
(Activation)                                                                            ⊔
↪

block4c_se_squeeze                 (None, 416)                                    0 ⊔
↪block4c_activation[0][0]
(GlobalAveragePooling2D)                                                                ⊔
↪

block4c_se_reshape (Reshape)       (None, 1, 1, 416)                              0 ⊔
↪block4c_se_squeeze[0][0]

block4c_se_reduce (Conv2D)         (None, 1, 1, 26)                           10,842 ⊔
↪block4c_se_reshape[0][0]

block4c_se_expand (Conv2D)         (None, 1, 1, 416)                          11,232 ⊔
↪block4c_se_reduce[0][0]

block4c_se_excite (Multiply)       (None, 8, 8, 416)                              0 ⊔
↪block4c_activation[0][0],

                                                                                        ⊔
↪block4c_se_expand[0][0]

block4c_project_conv (Conv2D)      (None, 8, 8, 104)                          43,264 ⊔
↪block4c_se_excite[0][0]
```

```
block4c_project_bn              (None, 8, 8, 104)                   416  ⌴
↪block4c_project_conv[0][0]
(BatchNormalization)                                                    ⌴
↪

block4c_drop (Dropout)          (None, 8, 8, 104)                     0  ⌴
↪block4c_project_bn[0][0]

block4c_add (Add)               (None, 8, 8, 104)                     0  ⌴
↪block4c_drop[0][0],
                                                                        ⌴
↪block4b_add[0][0]

block4d_expand_conv (Conv2D)    (None, 8, 8, 416)                43,264  ⌴
↪block4c_add[0][0]

block4d_expand_bn               (None, 8, 8, 416)                 1,664  ⌴
↪block4d_expand_conv[0][0]
(BatchNormalization)                                                    ⌴
↪

block4d_expand_activation       (None, 8, 8, 416)                     0  ⌴
↪block4d_expand_bn[0][0]
(Activation)                                                            ⌴
↪

block4d_dwconv2                 (None, 8, 8, 416)                 3,744  ⌴
↪block4d_expand_activation…
(DepthwiseConv2D)                                                       ⌴
↪

block4d_bn                      (None, 8, 8, 416)                 1,664  ⌴
↪block4d_dwconv2[0][0]
(BatchNormalization)                                                    ⌴
↪

block4d_activation              (None, 8, 8, 416)                     0  ⌴
↪block4d_bn[0][0]
(Activation)                                                            ⌴
↪

block4d_se_squeeze              (None, 416)                          0  ⌴
↪block4d_activation[0][0]
(GlobalAveragePooling2D)                                                ⌴
↪
```

```
block4d_se_reshape (Reshape)    (None, 1, 1, 416)                    0 ⎵
↪block4d_se_squeeze[0][0]

block4d_se_reduce (Conv2D)      (None, 1, 1, 26)                10,842 ⎵
↪block4d_se_reshape[0][0]

block4d_se_expand (Conv2D)      (None, 1, 1, 416)               11,232 ⎵
↪block4d_se_reduce[0][0]

block4d_se_excite (Multiply)    (None, 8, 8, 416)                    0 ⎵
↪block4d_activation[0][0],

                                                                     ⎵
↪block4d_se_expand[0][0]

block4d_project_conv (Conv2D)   (None, 8, 8, 104)               43,264 ⎵
↪block4d_se_excite[0][0]

block4d_project_bn              (None, 8, 8, 104)                  416 ⎵
↪block4d_project_conv[0][0]
(BatchNormalization)                                                 ⎵
↪

block4d_drop (Dropout)          (None, 8, 8, 104)                    0 ⎵
↪block4d_project_bn[0][0]

block4d_add (Add)               (None, 8, 8, 104)                    0 ⎵
↪block4d_drop[0][0],

                                                                     ⎵
↪block4c_add[0][0]

block5a_expand_conv (Conv2D)    (None, 8, 8, 624)               64,896 ⎵
↪block4d_add[0][0]

block5a_expand_bn               (None, 8, 8, 624)                2,496 ⎵
↪block5a_expand_conv[0][0]
(BatchNormalization)                                                 ⎵
↪

block5a_expand_activation       (None, 8, 8, 624)                    0 ⎵
↪block5a_expand_bn[0][0]
(Activation)                                                         ⎵
↪

block5a_dwconv2                 (None, 8, 8, 624)                5,616 ⎵
↪block5a_expand_activation…
```

(DepthwiseConv2D)

block5a_bn ↪block5a_dwconv2[0][0] (BatchNormalization)	(None, 8, 8, 624)	2,496
block5a_activation ↪block5a_bn[0][0] (Activation)	(None, 8, 8, 624)	0
block5a_se_squeeze ↪block5a_activation[0][0] (GlobalAveragePooling2D)	(None, 624)	0
block5a_se_reshape (Reshape) ↪block5a_se_squeeze[0][0]	(None, 1, 1, 624)	0
block5a_se_reduce (Conv2D) ↪block5a_se_reshape[0][0]	(None, 1, 1, 26)	16,250
block5a_se_expand (Conv2D) ↪block5a_se_reduce[0][0]	(None, 1, 1, 624)	16,848
block5a_se_excite (Multiply) ↪block5a_activation[0][0], ↪block5a_se_expand[0][0]	(None, 8, 8, 624)	0
block5a_project_conv (Conv2D) ↪block5a_se_excite[0][0]	(None, 8, 8, 120)	74,880
block5a_project_bn ↪block5a_project_conv[0][0] (BatchNormalization)	(None, 8, 8, 120)	480
block5b_expand_conv (Conv2D) ↪block5a_project_bn[0][0]	(None, 8, 8, 720)	86,400
block5b_expand_bn ↪block5b_expand_conv[0][0]	(None, 8, 8, 720)	2,880

```
(BatchNormalization)                                                              ␣
↪

block5b_expand_activation        (None, 8, 8, 720)                            0  ␣
↪block5b_expand_bn[0][0]
(Activation)                                                                     ␣
↪

block5b_dwconv2                  (None, 8, 8, 720)                        6,480  ␣
↪block5b_expand_activation…
(DepthwiseConv2D)                                                                ␣
↪

block5b_bn                       (None, 8, 8, 720)                        2,880  ␣
↪block5b_dwconv2[0][0]
(BatchNormalization)                                                             ␣
↪

block5b_activation               (None, 8, 8, 720)                            0  ␣
↪block5b_bn[0][0]
(Activation)                                                                     ␣
↪

block5b_se_squeeze               (None, 720)                                  0  ␣
↪block5b_activation[0][0]
(GlobalAveragePooling2D)                                                         ␣
↪

block5b_se_reshape (Reshape)     (None, 1, 1, 720)                            0  ␣
↪block5b_se_squeeze[0][0]

block5b_se_reduce (Conv2D)       (None, 1, 1, 30)                        21,630  ␣
↪block5b_se_reshape[0][0]

block5b_se_expand (Conv2D)       (None, 1, 1, 720)                       22,320  ␣
↪block5b_se_reduce[0][0]

block5b_se_excite (Multiply)     (None, 8, 8, 720)                            0  ␣
↪block5b_activation[0][0],

                                                                                 ␣
↪block5b_se_expand[0][0]

block5b_project_conv (Conv2D)    (None, 8, 8, 120)                       86,400  ␣
↪block5b_se_excite[0][0]
```

block5b_project_bn ↪block5b_project_conv[0][0] (BatchNormalization) ↪	(None, 8, 8, 120)	480	␣ ␣ ␣
block5b_drop (Dropout) ↪block5b_project_bn[0][0]	(None, 8, 8, 120)	0	␣
block5b_add (Add) ↪block5b_drop[0][0], ↪block5a_project_bn[0][0]	(None, 8, 8, 120)	0	␣ ␣
block5c_expand_conv (Conv2D) ↪block5b_add[0][0]	(None, 8, 8, 720)	86,400	␣
block5c_expand_bn ↪block5c_expand_conv[0][0] (BatchNormalization) ↪	(None, 8, 8, 720)	2,880	␣ ␣
block5c_expand_activation ↪block5c_expand_bn[0][0] (Activation) ↪	(None, 8, 8, 720)	0	␣ ␣
block5c_dwconv2 ↪block5c_expand_activation… (DepthwiseConv2D) ↪	(None, 8, 8, 720)	6,480	␣ ␣
block5c_bn ↪block5c_dwconv2[0][0] (BatchNormalization) ↪	(None, 8, 8, 720)	2,880	␣ ␣
block5c_activation ↪block5c_bn[0][0] (Activation) ↪	(None, 8, 8, 720)	0	␣ ␣
block5c_se_squeeze ↪block5c_activation[0][0] (GlobalAveragePooling2D) ↪	(None, 720)	0	␣ ␣

```
block5c_se_reshape (Reshape)      (None, 1, 1, 720)                        0
↪block5c_se_squeeze[0][0]

block5c_se_reduce (Conv2D)        (None, 1, 1, 30)                    21,630
↪block5c_se_reshape[0][0]

block5c_se_expand (Conv2D)        (None, 1, 1, 720)                   22,320
↪block5c_se_reduce[0][0]

block5c_se_excite (Multiply)      (None, 8, 8, 720)                        0
↪block5c_activation[0][0],

↪block5c_se_expand[0][0]

block5c_project_conv (Conv2D)     (None, 8, 8, 120)                   86,400
↪block5c_se_excite[0][0]

block5c_project_bn                (None, 8, 8, 120)                      480
↪block5c_project_conv[0][0]
(BatchNormalization)
↪

block5c_drop (Dropout)            (None, 8, 8, 120)                        0
↪block5c_project_bn[0][0]

block5c_add (Add)                 (None, 8, 8, 120)                        0
↪block5c_drop[0][0],

↪block5b_add[0][0]

block5d_expand_conv (Conv2D)      (None, 8, 8, 720)                   86,400
↪block5c_add[0][0]

block5d_expand_bn                 (None, 8, 8, 720)                    2,880
↪block5d_expand_conv[0][0]
(BatchNormalization)
↪

block5d_expand_activation         (None, 8, 8, 720)                        0
↪block5d_expand_bn[0][0]
(Activation)
↪

block5d_dwconv2                   (None, 8, 8, 720)                    6,480
↪block5d_expand_activation…
```

```
(DepthwiseConv2D)                                                                ␣
↪

block5d_bn                        (None, 8, 8, 720)                    2,880 ␣
↪block5d_dwconv2[0][0]
(BatchNormalization)                                                             ␣
↪

block5d_activation                (None, 8, 8, 720)                        0 ␣
↪block5d_bn[0][0]
(Activation)                                                                     ␣
↪

block5d_se_squeeze                (None, 720)                              0 ␣
↪block5d_activation[0][0]
(GlobalAveragePooling2D)                                                         ␣
↪

block5d_se_reshape (Reshape)      (None, 1, 1, 720)                        0 ␣
↪block5d_se_squeeze[0][0]

block5d_se_reduce (Conv2D)        (None, 1, 1, 30)                     21,630 ␣
↪block5d_se_reshape[0][0]

block5d_se_expand (Conv2D)        (None, 1, 1, 720)                    22,320 ␣
↪block5d_se_reduce[0][0]

block5d_se_excite (Multiply)      (None, 8, 8, 720)                        0 ␣
↪block5d_activation[0][0],
                                                                                 ␣
↪block5d_se_expand[0][0]

block5d_project_conv (Conv2D)     (None, 8, 8, 120)                    86,400 ␣
↪block5d_se_excite[0][0]

block5d_project_bn                (None, 8, 8, 120)                      480 ␣
↪block5d_project_conv[0][0]
(BatchNormalization)                                                             ␣
↪

block5d_drop (Dropout)            (None, 8, 8, 120)                        0 ␣
↪block5d_project_bn[0][0]

block5d_add (Add)                 (None, 8, 8, 120)                        0 ␣
↪block5d_drop[0][0],
```

```
                                                                          ⌞
 ↪block5c_add[0][0]

block5e_expand_conv (Conv2D)    (None, 8, 8, 720)               86,400  ⌞
 ↪block5d_add[0][0]

block5e_expand_bn               (None, 8, 8, 720)                2,880  ⌞
 ↪block5e_expand_conv[0][0]
 (BatchNormalization)                                                      ⌞
 ↪

block5e_expand_activation       (None, 8, 8, 720)                    0  ⌞
 ↪block5e_expand_bn[0][0]
 (Activation)                                                              ⌞
 ↪

block5e_dwconv2                 (None, 8, 8, 720)                6,480  ⌞
 ↪block5e_expand_activation…
 (DepthwiseConv2D)                                                         ⌞
 ↪

block5e_bn                      (None, 8, 8, 720)                2,880  ⌞
 ↪block5e_dwconv2[0][0]
 (BatchNormalization)                                                      ⌞
 ↪

block5e_activation              (None, 8, 8, 720)                    0  ⌞
 ↪block5e_bn[0][0]
 (Activation)                                                              ⌞
 ↪

block5e_se_squeeze              (None, 720)                          0  ⌞
 ↪block5e_activation[0][0]
 (GlobalAveragePooling2D)                                                  ⌞
 ↪

block5e_se_reshape (Reshape)    (None, 1, 1, 720)                    0  ⌞
 ↪block5e_se_squeeze[0][0]

block5e_se_reduce (Conv2D)      (None, 1, 1, 30)                21,630  ⌞
 ↪block5e_se_reshape[0][0]

block5e_se_expand (Conv2D)      (None, 1, 1, 720)               22,320  ⌞
 ↪block5e_se_reduce[0][0]
```

```
block5e_se_excite (Multiply)     (None, 8, 8, 720)              0  ⊔
↪block5e_activation[0][0],

                                                                  ⊔

↪block5e_se_expand[0][0]

block5e_project_conv (Conv2D)    (None, 8, 8, 120)         86,400  ⊔
↪block5e_se_excite[0][0]

block5e_project_bn               (None, 8, 8, 120)            480  ⊔
↪block5e_project_conv[0][0]
(BatchNormalization)                                              ⊔
↪

block5e_drop (Dropout)           (None, 8, 8, 120)              0  ⊔
↪block5e_project_bn[0][0]

block5e_add (Add)                (None, 8, 8, 120)              0  ⊔
↪block5e_drop[0][0],

                                                                  ⊔

↪block5d_add[0][0]

block5f_expand_conv (Conv2D)     (None, 8, 8, 720)         86,400  ⊔
↪block5e_add[0][0]

block5f_expand_bn                (None, 8, 8, 720)          2,880  ⊔
↪block5f_expand_conv[0][0]
(BatchNormalization)                                              ⊔
↪

block5f_expand_activation        (None, 8, 8, 720)              0  ⊔
↪block5f_expand_bn[0][0]
(Activation)                                                      ⊔
↪

block5f_dwconv2                  (None, 8, 8, 720)          6,480  ⊔
↪block5f_expand_activation…
(DepthwiseConv2D)                                                 ⊔
↪

block5f_bn                       (None, 8, 8, 720)          2,880  ⊔
↪block5f_dwconv2[0][0]
(BatchNormalization)                                              ⊔
↪

block5f_activation               (None, 8, 8, 720)              0  ⊔
↪block5f_bn[0][0]
```

```
(Activation)                                                           ␣
↪

block5f_se_squeeze                       (None, 720)                        0 ␣
↪block5f_activation[0][0]
(GlobalAveragePooling2D)                                                ␣
↪

block5f_se_reshape (Reshape)    (None, 1, 1, 720)                      0 ␣
↪block5f_se_squeeze[0][0]

block5f_se_reduce (Conv2D)      (None, 1, 1, 30)                  21,630 ␣
↪block5f_se_reshape[0][0]

block5f_se_expand (Conv2D)      (None, 1, 1, 720)                 22,320 ␣
↪block5f_se_reduce[0][0]

block5f_se_excite (Multiply)    (None, 8, 8, 720)                      0 ␣
↪block5f_activation[0][0],

                                                                       ␣
↪block5f_se_expand[0][0]

block5f_project_conv (Conv2D)   (None, 8, 8, 120)                 86,400 ␣
↪block5f_se_excite[0][0]

block5f_project_bn              (None, 8, 8, 120)                    480 ␣
↪block5f_project_conv[0][0]
(BatchNormalization)                                                   ␣
↪

block5f_drop (Dropout)          (None, 8, 8, 120)                      0 ␣
↪block5f_project_bn[0][0]

block5f_add (Add)               (None, 8, 8, 120)                      0 ␣
↪block5f_drop[0][0],

                                                                       ␣
↪block5e_add[0][0]

block6a_expand_conv (Conv2D)    (None, 8, 8, 720)                 86,400 ␣
↪block5f_add[0][0]

block6a_expand_bn               (None, 8, 8, 720)                  2,880 ␣
↪block6a_expand_conv[0][0]
(BatchNormalization)                                                   ␣
↪
```

```
block6a_expand_activation        (None, 8, 8, 720)                    0  ␣
↪block6a_expand_bn[0][0]
(Activation)                                                            ␣
↪

block6a_dwconv2                  (None, 4, 4, 720)                6,480  ␣
↪block6a_expand_activation…
(DepthwiseConv2D)                                                       ␣
↪

block6a_bn                       (None, 4, 4, 720)                2,880  ␣
↪block6a_dwconv2[0][0]
(BatchNormalization)                                                    ␣
↪

block6a_activation               (None, 4, 4, 720)                    0  ␣
↪block6a_bn[0][0]
(Activation)                                                            ␣
↪

block6a_se_squeeze               (None, 720)                          0  ␣
↪block6a_activation[0][0]
(GlobalAveragePooling2D)                                                ␣
↪

block6a_se_reshape (Reshape)     (None, 1, 1, 720)                    0  ␣
↪block6a_se_squeeze[0][0]

block6a_se_reduce (Conv2D)       (None, 1, 1, 30)                21,630  ␣
↪block6a_se_reshape[0][0]

block6a_se_expand (Conv2D)       (None, 1, 1, 720)               22,320  ␣
↪block6a_se_reduce[0][0]

block6a_se_excite (Multiply)     (None, 4, 4, 720)                    0  ␣
↪block6a_activation[0][0],
                                                                        ␣
↪block6a_se_expand[0][0]

block6a_project_conv (Conv2D)    (None, 4, 4, 208)              149,760  ␣
↪block6a_se_excite[0][0]

block6a_project_bn               (None, 4, 4, 208)                  832  ␣
↪block6a_project_conv[0][0]
(BatchNormalization)                                                    ␣
↪
```

block6b_expand_conv (Conv2D) ↪block6a_project_bn[0][0]	(None, 4, 4, 1248)	259,584
block6b_expand_bn ↪block6b_expand_conv[0][0] (BatchNormalization) ↪	(None, 4, 4, 1248)	4,992
block6b_expand_activation ↪block6b_expand_bn[0][0] (Activation) ↪	(None, 4, 4, 1248)	0
block6b_dwconv2 ↪block6b_expand_activation… (DepthwiseConv2D) ↪	(None, 4, 4, 1248)	11,232
block6b_bn ↪block6b_dwconv2[0][0] (BatchNormalization) ↪	(None, 4, 4, 1248)	4,992
block6b_activation ↪block6b_bn[0][0] (Activation) ↪	(None, 4, 4, 1248)	0
block6b_se_squeeze ↪block6b_activation[0][0] (GlobalAveragePooling2D) ↪	(None, 1248)	0
block6b_se_reshape (Reshape) ↪block6b_se_squeeze[0][0]	(None, 1, 1, 1248)	0
block6b_se_reduce (Conv2D) ↪block6b_se_reshape[0][0]	(None, 1, 1, 52)	64,948
block6b_se_expand (Conv2D) ↪block6b_se_reduce[0][0]	(None, 1, 1, 1248)	66,144
block6b_se_excite (Multiply) ↪block6b_activation[0][0],	(None, 4, 4, 1248)	0

```
                                                          ␣
↪block6b_se_expand[0][0]

block6b_project_conv (Conv2D)   (None, 4, 4, 208)         259,584  ␣
↪block6b_se_excite[0][0]

block6b_project_bn              (None, 4, 4, 208)             832  ␣
↪block6b_project_conv[0][0]
(BatchNormalization)                                              ␣
↪

block6b_drop (Dropout)          (None, 4, 4, 208)               0  ␣
↪block6b_project_bn[0][0]

block6b_add (Add)               (None, 4, 4, 208)               0  ␣
↪block6b_drop[0][0],

                                                          ␣
↪block6a_project_bn[0][0]

block6c_expand_conv (Conv2D)    (None, 4, 4, 1248)        259,584  ␣
↪block6b_add[0][0]

block6c_expand_bn               (None, 4, 4, 1248)          4,992  ␣
↪block6c_expand_conv[0][0]
(BatchNormalization)                                              ␣
↪

block6c_expand_activation       (None, 4, 4, 1248)              0  ␣
↪block6c_expand_bn[0][0]
(Activation)                                                      ␣
↪

block6c_dwconv2                 (None, 4, 4, 1248)         11,232  ␣
↪block6c_expand_activation…
(DepthwiseConv2D)                                                 ␣
↪

block6c_bn                      (None, 4, 4, 1248)          4,992  ␣
↪block6c_dwconv2[0][0]
(BatchNormalization)                                              ␣
↪

block6c_activation              (None, 4, 4, 1248)              0  ␣
↪block6c_bn[0][0]
(Activation)                                                      ␣
↪
```

```
block6c_se_squeeze            (None, 1248)                           0  ␣
↪block6c_activation[0][0]
(GlobalAveragePooling2D)                                               ␣
↪

block6c_se_reshape (Reshape)  (None, 1, 1, 1248)                     0  ␣
↪block6c_se_squeeze[0][0]

block6c_se_reduce (Conv2D)    (None, 1, 1, 52)                  64,948  ␣
↪block6c_se_reshape[0][0]

block6c_se_expand (Conv2D)    (None, 1, 1, 1248)               66,144  ␣
↪block6c_se_reduce[0][0]

block6c_se_excite (Multiply)  (None, 4, 4, 1248)                    0  ␣
↪block6c_activation[0][0],

↪block6c_se_expand[0][0]                                               ␣

block6c_project_conv (Conv2D) (None, 4, 4, 208)                259,584  ␣
↪block6c_se_excite[0][0]

block6c_project_bn            (None, 4, 4, 208)                    832  ␣
↪block6c_project_conv[0][0]
(BatchNormalization)                                                  ␣
↪

block6c_drop (Dropout)        (None, 4, 4, 208)                     0  ␣
↪block6c_project_bn[0][0]

block6c_add (Add)             (None, 4, 4, 208)                     0  ␣
↪block6c_drop[0][0],

↪block6b_add[0][0]                                                     ␣

block6d_expand_conv (Conv2D)  (None, 4, 4, 1248)               259,584  ␣
↪block6c_add[0][0]

block6d_expand_bn             (None, 4, 4, 1248)                4,992  ␣
↪block6d_expand_conv[0][0]
(BatchNormalization)                                                  ␣
↪

block6d_expand_activation     (None, 4, 4, 1248)                     0  ␣
↪block6d_expand_bn[0][0]
```

```
(Activation)                                                                    ␣
↪

block6d_dwconv2                    (None, 4, 4, 1248)                 11,232  ␣
↪block6d_expand_activation…
(DepthwiseConv2D)                                                               ␣
↪

block6d_bn                        (None, 4, 4, 1248)                  4,992  ␣
↪block6d_dwconv2[0][0]
(BatchNormalization)                                                           ␣
↪

block6d_activation                (None, 4, 4, 1248)                      0  ␣
↪block6d_bn[0][0]
(Activation)                                                                   ␣
↪

block6d_se_squeeze                (None, 1248)                            0  ␣
↪block6d_activation[0][0]
(GlobalAveragePooling2D)                                                       ␣
↪

block6d_se_reshape (Reshape)      (None, 1, 1, 1248)                      0  ␣
↪block6d_se_squeeze[0][0]

block6d_se_reduce (Conv2D)        (None, 1, 1, 52)                    64,948  ␣
↪block6d_se_reshape[0][0]

block6d_se_expand (Conv2D)        (None, 1, 1, 1248)                  66,144  ␣
↪block6d_se_reduce[0][0]

block6d_se_excite (Multiply)      (None, 4, 4, 1248)                      0  ␣
↪block6d_activation[0][0],
                                                                               ␣
↪block6d_se_expand[0][0]

block6d_project_conv (Conv2D)     (None, 4, 4, 208)                  259,584  ␣
↪block6d_se_excite[0][0]

block6d_project_bn                (None, 4, 4, 208)                      832  ␣
↪block6d_project_conv[0][0]
(BatchNormalization)                                                           ␣
↪
```

```
block6d_drop (Dropout)          (None, 4, 4, 208)                            0  ⊔
↪block6d_project_bn[0][0]

block6d_add (Add)               (None, 4, 4, 208)                            0  ⊔
↪block6d_drop[0][0],

                                                                               ⊔
↪block6c_add[0][0]

block6e_expand_conv (Conv2D)    (None, 4, 4, 1248)                     259,584  ⊔
↪block6d_add[0][0]

block6e_expand_bn               (None, 4, 4, 1248)                       4,992  ⊔
↪block6e_expand_conv[0][0]
(BatchNormalization)                                                           ⊔
↪

block6e_expand_activation       (None, 4, 4, 1248)                           0  ⊔
↪block6e_expand_bn[0][0]
(Activation)                                                                   ⊔
↪

block6e_dwconv2                 (None, 4, 4, 1248)                      11,232  ⊔
↪block6e_expand_activation…
(DepthwiseConv2D)                                                              ⊔
↪

block6e_bn                      (None, 4, 4, 1248)                       4,992  ⊔
↪block6e_dwconv2[0][0]
(BatchNormalization)                                                           ⊔
↪

block6e_activation              (None, 4, 4, 1248)                           0  ⊔
↪block6e_bn[0][0]
(Activation)                                                                   ⊔
↪

block6e_se_squeeze              (None, 1248)                                 0  ⊔
↪block6e_activation[0][0]
(GlobalAveragePooling2D)                                                       ⊔
↪

block6e_se_reshape (Reshape)    (None, 1, 1, 1248)                           0  ⊔
↪block6e_se_squeeze[0][0]

block6e_se_reduce (Conv2D)      (None, 1, 1, 52)                        64,948  ⊔
↪block6e_se_reshape[0][0]
```

```
block6e_se_expand (Conv2D)      (None, 1, 1, 1248)           66,144  ␣
↪block6e_se_reduce[0][0]

block6e_se_excite (Multiply)    (None, 4, 4, 1248)                0  ␣
↪block6e_activation[0][0],

                                                                     ␣
↪block6e_se_expand[0][0]

block6e_project_conv (Conv2D)   (None, 4, 4, 208)           259,584  ␣
↪block6e_se_excite[0][0]

block6e_project_bn              (None, 4, 4, 208)               832  ␣
↪block6e_project_conv[0][0]
(BatchNormalization)                                                 ␣
↪

block6e_drop (Dropout)          (None, 4, 4, 208)                0  ␣
↪block6e_project_bn[0][0]

block6e_add (Add)               (None, 4, 4, 208)                0  ␣
↪block6e_drop[0][0],

                                                                     ␣
↪block6d_add[0][0]

block6f_expand_conv (Conv2D)    (None, 4, 4, 1248)          259,584  ␣
↪block6e_add[0][0]

block6f_expand_bn               (None, 4, 4, 1248)            4,992  ␣
↪block6f_expand_conv[0][0]
(BatchNormalization)                                                 ␣
↪

block6f_expand_activation       (None, 4, 4, 1248)                0  ␣
↪block6f_expand_bn[0][0]
(Activation)                                                         ␣
↪

block6f_dwconv2                 (None, 4, 4, 1248)           11,232  ␣
↪block6f_expand_activation…
(DepthwiseConv2D)                                                    ␣
↪

block6f_bn                      (None, 4, 4, 1248)            4,992  ␣
↪block6f_dwconv2[0][0]
```

```
(BatchNormalization)                                                                   ⨆
↪

block6f_activation             (None, 4, 4, 1248)                              0  ⨆
↪block6f_bn[0][0]
(Activation)                                                                           ⨆
↪

block6f_se_squeeze             (None, 1248)                                    0  ⨆
↪block6f_activation[0][0]
(GlobalAveragePooling2D)                                                               ⨆
↪

block6f_se_reshape (Reshape)   (None, 1, 1, 1248)                             0  ⨆
↪block6f_se_squeeze[0][0]

block6f_se_reduce (Conv2D)     (None, 1, 1, 52)                          64,948  ⨆
↪block6f_se_reshape[0][0]

block6f_se_expand (Conv2D)     (None, 1, 1, 1248)                        66,144  ⨆
↪block6f_se_reduce[0][0]

block6f_se_excite (Multiply)   (None, 4, 4, 1248)                             0  ⨆
↪block6f_activation[0][0],

                                                                                       ⨆
↪block6f_se_expand[0][0]

block6f_project_conv (Conv2D)  (None, 4, 4, 208)                        259,584  ⨆
↪block6f_se_excite[0][0]

block6f_project_bn             (None, 4, 4, 208)                            832  ⨆
↪block6f_project_conv[0][0]
(BatchNormalization)                                                                   ⨆
↪

block6f_drop (Dropout)         (None, 4, 4, 208)                              0  ⨆
↪block6f_project_bn[0][0]

block6f_add (Add)              (None, 4, 4, 208)                              0  ⨆
↪block6f_drop[0][0],

                                                                                       ⨆
↪block6e_add[0][0]

block6g_expand_conv (Conv2D)   (None, 4, 4, 1248)                       259,584  ⨆
↪block6f_add[0][0]
```

```
block6g_expand_bn              (None, 4, 4, 1248)              4,992  ␣
↪block6g_expand_conv[0][0]
(BatchNormalization)                                                 ␣
↪

block6g_expand_activation      (None, 4, 4, 1248)                  0  ␣
↪block6g_expand_bn[0][0]
(Activation)                                                         ␣
↪

block6g_dwconv2                (None, 4, 4, 1248)             11,232  ␣
↪block6g_expand_activation…
(DepthwiseConv2D)                                                    ␣
↪

block6g_bn                     (None, 4, 4, 1248)              4,992  ␣
↪block6g_dwconv2[0][0]
(BatchNormalization)                                                 ␣
↪

block6g_activation             (None, 4, 4, 1248)                  0  ␣
↪block6g_bn[0][0]
(Activation)                                                         ␣
↪

block6g_se_squeeze             (None, 1248)                        0  ␣
↪block6g_activation[0][0]
(GlobalAveragePooling2D)                                             ␣
↪

block6g_se_reshape (Reshape)   (None, 1, 1, 1248)                  0  ␣
↪block6g_se_squeeze[0][0]

block6g_se_reduce (Conv2D)     (None, 1, 1, 52)               64,948  ␣
↪block6g_se_reshape[0][0]

block6g_se_expand (Conv2D)     (None, 1, 1, 1248)             66,144  ␣
↪block6g_se_reduce[0][0]

block6g_se_excite (Multiply)   (None, 4, 4, 1248)                  0  ␣
↪block6g_activation[0][0],

↪block6g_se_expand[0][0]

block6g_project_conv (Conv2D)  (None, 4, 4, 208)             259,584  ␣
↪block6g_se_excite[0][0]
```

block6g_project_bn → block6g_project_conv[0][0] (BatchNormalization) →	(None, 4, 4, 208)	832	
block6g_drop (Dropout) → block6g_project_bn[0][0]	(None, 4, 4, 208)	0	
block6g_add (Add) → block6g_drop[0][0], → block6f_add[0][0]	(None, 4, 4, 208)	0	
block6h_expand_conv (Conv2D) → block6g_add[0][0]	(None, 4, 4, 1248)	259,584	
block6h_expand_bn → block6h_expand_conv[0][0] (BatchNormalization) →	(None, 4, 4, 1248)	4,992	
block6h_expand_activation → block6h_expand_bn[0][0] (Activation) →	(None, 4, 4, 1248)	0	
block6h_dwconv2 → block6h_expand_activation… (DepthwiseConv2D) →	(None, 4, 4, 1248)	11,232	
block6h_bn → block6h_dwconv2[0][0] (BatchNormalization) →	(None, 4, 4, 1248)	4,992	
block6h_activation → block6h_bn[0][0] (Activation) →	(None, 4, 4, 1248)	0	
block6h_se_squeeze → block6h_activation[0][0] (GlobalAveragePooling2D) →	(None, 1248)	0	

```
block6h_se_reshape (Reshape)     (None, 1, 1, 1248)                    0  ⊔
↪block6h_se_squeeze[0][0]

block6h_se_reduce (Conv2D)       (None, 1, 1, 52)                 64,948  ⊔
↪block6h_se_reshape[0][0]

block6h_se_expand (Conv2D)       (None, 1, 1, 1248)               66,144  ⊔
↪block6h_se_reduce[0][0]

block6h_se_excite (Multiply)     (None, 4, 4, 1248)                    0  ⊔
↪block6h_activation[0][0],

                                                                        ⊔
↪block6h_se_expand[0][0]

block6h_project_conv (Conv2D)    (None, 4, 4, 208)               259,584  ⊔
↪block6h_se_excite[0][0]

block6h_project_bn               (None, 4, 4, 208)                   832  ⊔
↪block6h_project_conv[0][0]
(BatchNormalization)                                                    ⊔
↪

block6h_drop (Dropout)           (None, 4, 4, 208)                     0  ⊔
↪block6h_project_bn[0][0]

block6h_add (Add)                (None, 4, 4, 208)                     0  ⊔
↪block6h_drop[0][0],

                                                                        ⊔
↪block6g_add[0][0]

block6i_expand_conv (Conv2D)     (None, 4, 4, 1248)              259,584  ⊔
↪block6h_add[0][0]

block6i_expand_bn                (None, 4, 4, 1248)                4,992  ⊔
↪block6i_expand_conv[0][0]
(BatchNormalization)                                                    ⊔
↪

block6i_expand_activation        (None, 4, 4, 1248)                    0  ⊔
↪block6i_expand_bn[0][0]
(Activation)                                                            ⊔
↪

block6i_dwconv2                  (None, 4, 4, 1248)               11,232  ⊔
↪block6i_expand_activation…
```

```
(DepthwiseConv2D)
↪

block6i_bn                      (None, 4, 4, 1248)              4,992
↪block6i_dwconv2[0][0]
(BatchNormalization)
↪

block6i_activation              (None, 4, 4, 1248)                  0
↪block6i_bn[0][0]
(Activation)
↪

block6i_se_squeeze              (None, 1248)                        0
↪block6i_activation[0][0]
(GlobalAveragePooling2D)
↪

block6i_se_reshape (Reshape)    (None, 1, 1, 1248)                  0
↪block6i_se_squeeze[0][0]

block6i_se_reduce (Conv2D)      (None, 1, 1, 52)                64,948
↪block6i_se_reshape[0][0]

block6i_se_expand (Conv2D)      (None, 1, 1, 1248)              66,144
↪block6i_se_reduce[0][0]

block6i_se_excite (Multiply)    (None, 4, 4, 1248)                  0
↪block6i_activation[0][0],

↪block6i_se_expand[0][0]

block6i_project_conv (Conv2D)   (None, 4, 4, 208)              259,584
↪block6i_se_excite[0][0]

block6i_project_bn              (None, 4, 4, 208)                  832
↪block6i_project_conv[0][0]
(BatchNormalization)
↪

block6i_drop (Dropout)          (None, 4, 4, 208)                    0
↪block6i_project_bn[0][0]

block6i_add (Add)               (None, 4, 4, 208)                    0
↪block6i_drop[0][0],
```

```
                                                              ↳
                                                      block6h_add[0][0]

block6j_expand_conv (Conv2D)    (None, 4, 4, 1248)            259,584  ↳
↳block6i_add[0][0]

block6j_expand_bn               (None, 4, 4, 1248)              4,992  ↳
↳block6j_expand_conv[0][0]
(BatchNormalization)                                                   ↳
↳

block6j_expand_activation       (None, 4, 4, 1248)                  0  ↳
↳block6j_expand_bn[0][0]
(Activation)                                                           ↳
↳

block6j_dwconv2                 (None, 4, 4, 1248)             11,232  ↳
↳block6j_expand_activation…
(DepthwiseConv2D)                                                      ↳
↳

block6j_bn                      (None, 4, 4, 1248)              4,992  ↳
↳block6j_dwconv2[0][0]
(BatchNormalization)                                                   ↳
↳

block6j_activation              (None, 4, 4, 1248)                  0  ↳
↳block6j_bn[0][0]
(Activation)                                                           ↳
↳

block6j_se_squeeze              (None, 1248)                        0  ↳
↳block6j_activation[0][0]
(GlobalAveragePooling2D)                                               ↳
↳

block6j_se_reshape (Reshape)    (None, 1, 1, 1248)                  0  ↳
↳block6j_se_squeeze[0][0]

block6j_se_reduce (Conv2D)      (None, 1, 1, 52)               64,948  ↳
↳block6j_se_reshape[0][0]

block6j_se_expand (Conv2D)      (None, 1, 1, 1248)             66,144  ↳
↳block6j_se_reduce[0][0]
```

```
block6j_se_excite (Multiply)    (None, 4, 4, 1248)                    0 ␣
↪block6j_activation[0][0],

                                                                       ␣

↪block6j_se_expand[0][0]


block6j_project_conv (Conv2D)   (None, 4, 4, 208)               259,584 ␣
↪block6j_se_excite[0][0]


block6j_project_bn              (None, 4, 4, 208)                   832 ␣
↪block6j_project_conv[0][0]
(BatchNormalization)                                                   ␣
↪


block6j_drop (Dropout)          (None, 4, 4, 208)                     0 ␣
↪block6j_project_bn[0][0]


block6j_add (Add)               (None, 4, 4, 208)                     0 ␣
↪block6j_drop[0][0],

                                                                       ␣

↪block6i_add[0][0]


top_conv (Conv2D)               (None, 4, 4, 1408)              292,864 ␣
↪block6j_add[0][0]


top_bn (BatchNormalization)     (None, 4, 4, 1408)                5,632 ␣
↪top_conv[0][0]


top_activation (Activation)     (None, 4, 4, 1408)                    0 ␣
↪top_bn[0][0]
```

Total params: 8,769,374 (33.45 MB)

Trainable params: 7,966,188 (30.39 MB)

Non-trainable params: 803,186 (3.06 MB)

```
[25]: acc = history.history['accuracy']        # Extract training accuracy from␣
       ↪history
      val_acc = history.history['val_accuracy'] # Extract validation accuracy from␣
       ↪history
      loss = history.history['loss']            # Extract training loss from history
      val_loss = history.history['val_loss']    # Extract validation loss from␣
       ↪history
```

```python
epochs_range = range(len(acc))                    # Define range for epochs based on␣
 ↪accuracy length

plt.figure(figsize=(10,8))                         # Set overall figure size for␣
 ↪visualization

plt.subplot(1,2,1)                                 # Create first subplot (1 row, 2␣
 ↪columns, position 1)
plt.plot(epochs_range, acc, label='Training Accuracy')        # Plot training␣
 ↪accuracy
plt.plot(epochs_range, val_acc, label='Validation Accuracy') # Plot validation␣
 ↪accuracy
plt.legend(loc='lower right')                      # Place legend in lower-right corner
plt.title('Training vs Validation Accuracy') # Add title for accuracy plot

plt.subplot(1,2,2)                                 # Create second subplot (1 row, 2␣
 ↪columns, position 2)
plt.plot(epochs_range, loss, label='Training Loss')           # Plot training loss
plt.plot(epochs_range, val_loss, label='Validation Loss')    # Plot validation␣
 ↪loss
plt.legend(loc='upper right')                      # Place legend in upper-right corner
plt.title('Training vs Validation Loss')   # Add title for loss plot

plt.show()                                         # Display the plots
```
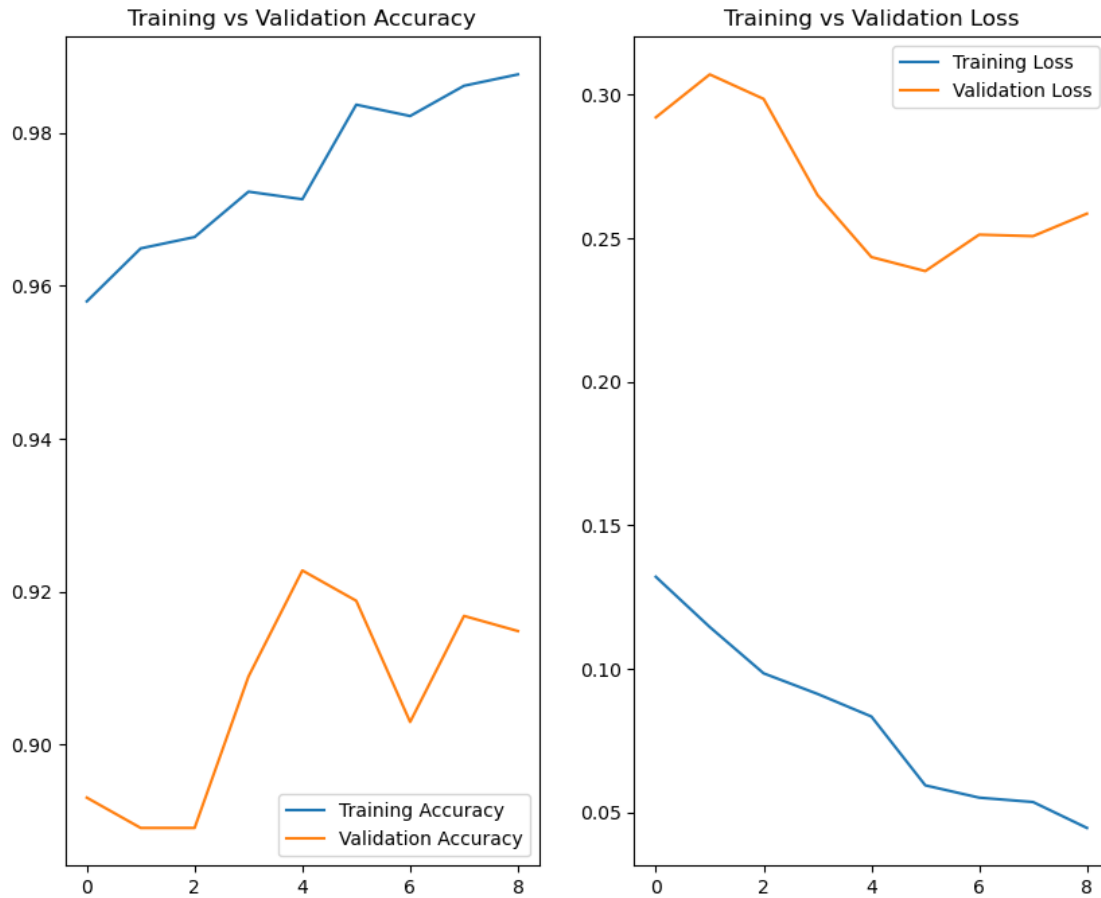
2.2 Model Evaluation

```
[26]: loss, accuracy = model.evaluate(test_ds_eval)
      print(f'Test accuracy is{accuracy:.4f}, Test loss is {loss:.4f}')
```

```
8/8                 2s 212ms/step -
accuracy: 0.9607 - loss: 0.1494
Test accuracy is0.9414, Test loss is 0.1822
```

```
[27]: y_true = np.concatenate([y.numpy() for x, y in test_ds_eval], axis=0)


      y_pred_probs = model.predict(test_ds_eval)


      y_pred = np.argmax(y_pred_probs, axis=1)


      cm = confusion_matrix(y_true, y_pred)
```

```
print(cm)
print(classification_report(y_true, y_pred))
```

```
8/8                5s 200ms/step
[[35  0  0  1  0  0]
 [ 0 52  1  0  3  0]
 [ 0  1 42  0  0  0]
 [ 1  0  1 58  0  4]
 [ 0  1  0  0 36  1]
 [ 0  0  0  1  0 18]]
              precision    recall  f1-score   support

           0       0.97      0.97      0.97        36
           1       0.96      0.93      0.95        56
           2       0.95      0.98      0.97        43
           3       0.97      0.91      0.94        64
           4       0.92      0.95      0.94        38
           5       0.78      0.95      0.86        19

    accuracy                           0.94       256
   macro avg       0.93      0.95      0.94       256
weighted avg       0.94      0.94      0.94       256
```

```python
[28]: plt.figure(figsize=(10,8))

sns.heatmap(cm, annot=True, fmt='d',
            xticklabels=class_names,
            yticklabels=class_names,
            cmap='Blues')

plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

Confusion Matrix
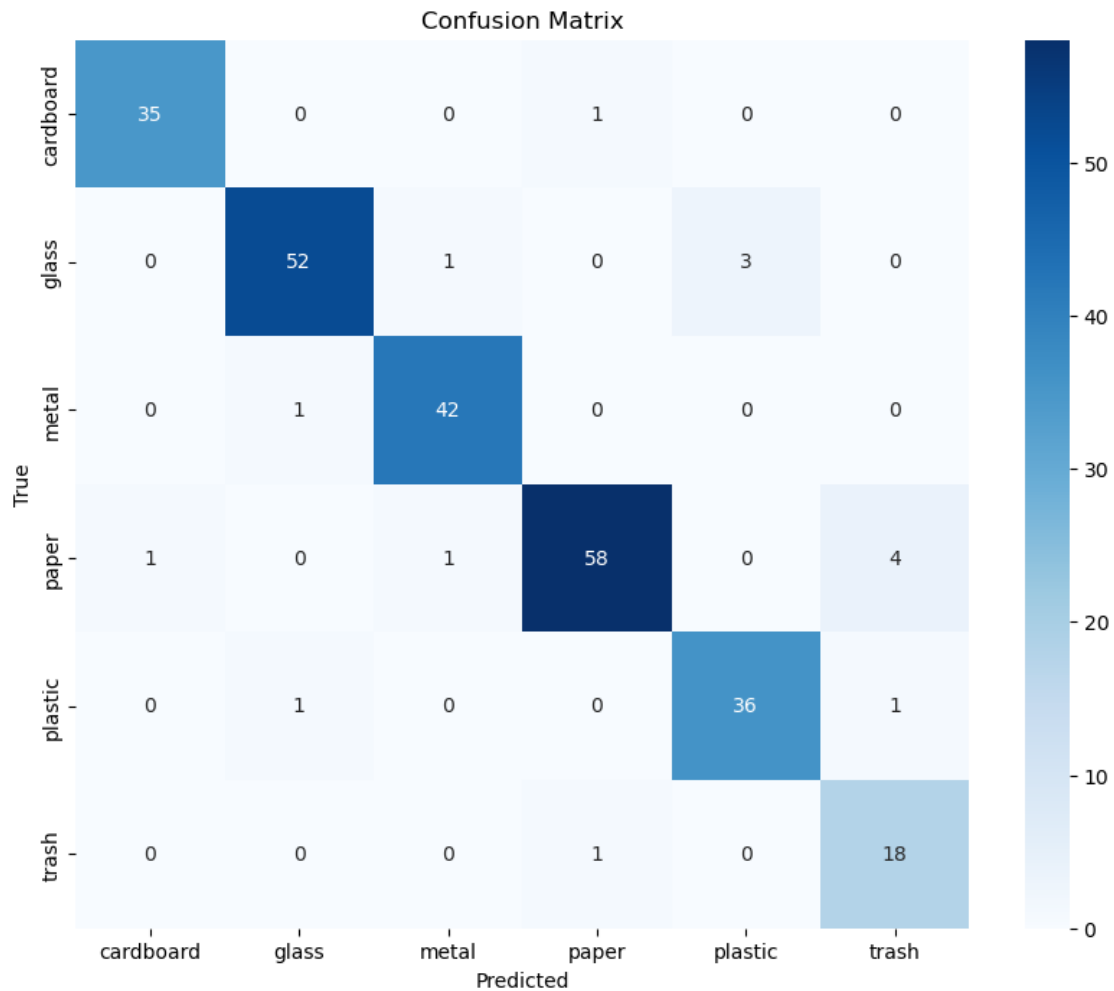
2.3   7. Final Testing and Save the Model

```
[31]: class_names = train_ds.class_names


for images, labels in test_ds_eval.take(1):


    predictions = model.predict(images)


    pred_labels = tf.argmax(predictions, axis=1)


    for i in range(8):
        plt.imshow(images[i].numpy().astype("uint8"))
```

```
        plt.title(f"True: {class_names[labels[i]]}, Pred:␣
↪{class_names[pred_labels[i]]}")
        plt.axis("off")
        plt.show()
```

True: glass, Pred: glass

True: trash, Pred: trash

True: glass, Pred: glass

True: metal, Pred: metal

True: plastic, Pred: plastic

True: cardboard, Pred: cardboard

True: glass, Pred: glass

True: metal, Pred: metal

2.4 Save the trained model using model.save() or save_model() for future inference.

```
[32]: model.save('Effiicientnetv2b2.keras')


      model = tf.keras.models.load_model('Effiicientnetv2b2.keras')
```

2.4.1 Week II Submission

```
[ ]:
```