Model Development Phase Template

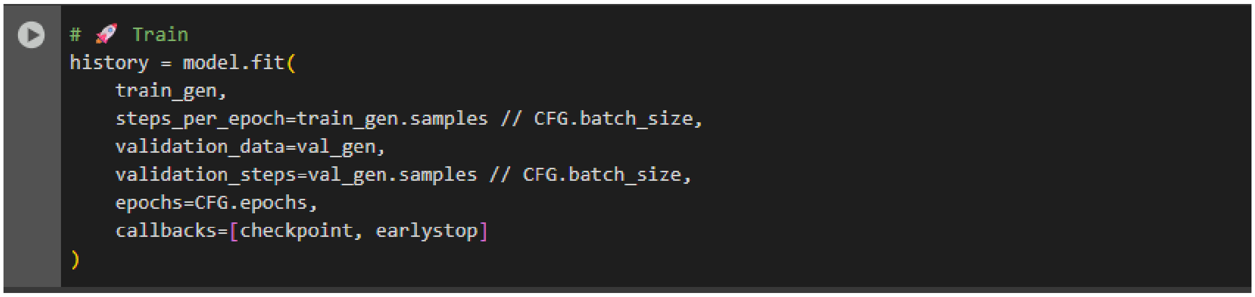
Date	24 June 2025
Team ID	SWTID1750316859
Project Title	ASL - Alphabet Image Recognition
Maximum Marks	10 Marks

Initial Model Training Code, Model Validation and Evaluation Report

The initial model training code will be showcased in the future through a screenshot. The model validation and evaluation report will include a summary and training and validation performance metrics for multiple models, presented through respective screenshots.

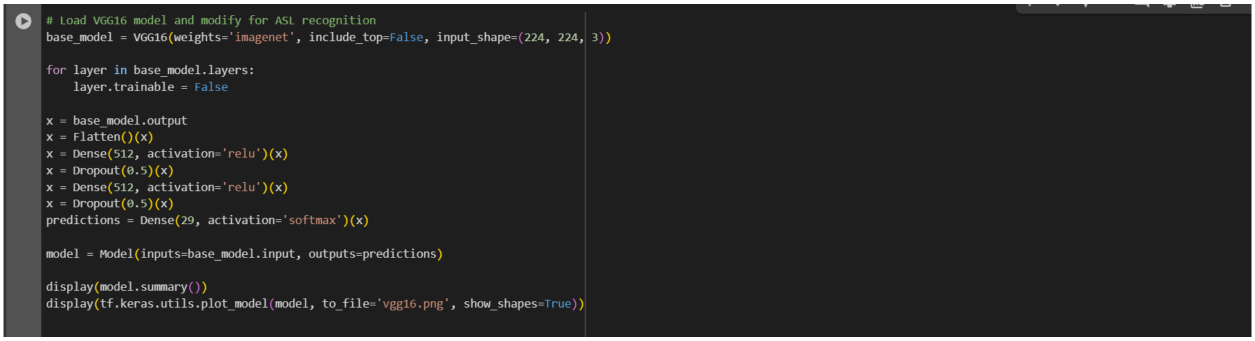
Initial Model Training Code (5 marks):

MobileNet-V2:



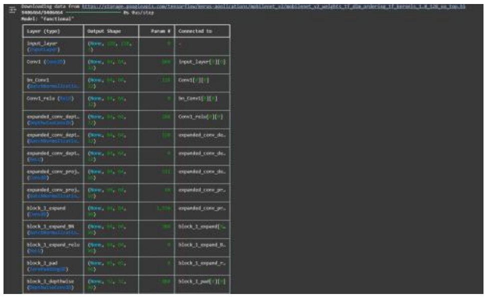
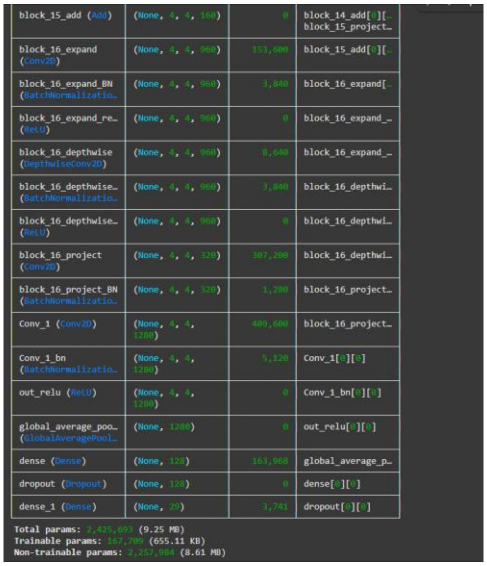
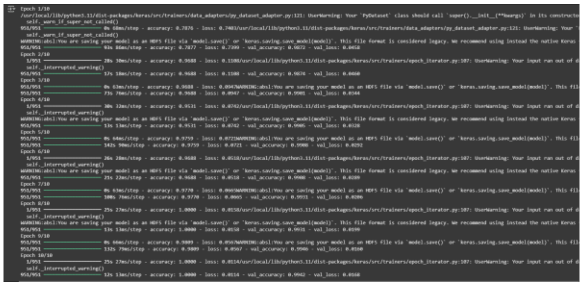
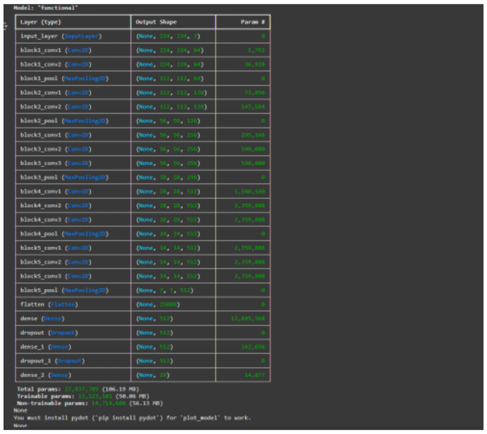
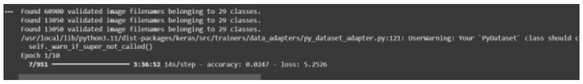
```
# 🚀 Train
history = model.fit(
    train_gen,
    steps_per_epoch=train_gen.samples // CFG.batch_size,
    validation_data=val_gen,
    validation_steps=val_gen.samples // CFG.batch_size,
    epochs=CFG.epochs,
    callbacks=[checkpoint, earlystop]
)
```

VGG16:



```
# Load VGG16 model and modify for ASL recognition
base_model = VGG16(weights='imagenet', include_top=False, input_shape=(224, 224, 3))

for layer in base_model.layers:
    layer.trainable = False

x = base_model.output
x = Flatten()(x)
x = Dense(512, activation='relu')(x)
x = Dropout(0.5)(x)
x = Dense(512, activation='relu')(x)
x = Dropout(0.5)(x)
predictions = Dense(29, activation='softmax')(x)

model = Model(inputs=base_model.input, outputs=predictions)

display(model.summary())
display(tf.keras.utils.plot_model(model, to_file='vgg16.png', show_shapes=True))
```

Model Validation and Evaluation Report (5 marks):

Model	Summary	Training and Validation Performance Metrics
MobileNetV2	 	
VGG16		 AS PER EPOCH TIME IS 4 HOURS AND ACCURACY IS NEGLIGIBLY LOW AFTER WAITING FOR 3 EPOCHS WE DECIDED TO DISCONTINUE THIS MODEL AND FINALIZE MOBILENET-V2.

MobileNetV2 summary:

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_128_no_top.h5
9406464/9406464 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
Model: "functional"
┏━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━┓
┃ Layer (type)        ┃ Output Shape      ┃    Param # ┃ Connected to      ┃
┡━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━┩
│ input_layer         │ (None, [illegible], [illegible], │          0 │ -                 │
│ (InputLayer)        │ 3)                │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ Conv1 (Conv2D)      │ (None, [illegible], [illegible], │ [illegible] │ input_layer[0][0] │
│                     │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ bn_Conv1            │ (None, [illegible], [illegible], │ [illegible] │ Conv1[0][0]       │
│ (BatchNormalizatio… │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ Conv1_relu (ReLU)   │ (None, [illegible], [illegible], │          0 │ bn_Conv1[0][0]    │
│                     │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ expanded_conv_dept… │ (None, [illegible], [illegible], │ [illegible] │ Conv1_relu[0][0]  │
│ (DepthwiseConv2D)   │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ expanded_conv_dept… │ (None, [illegible], [illegible], │ [illegible] │ expanded_conv_de… │
│ (BatchNormalizatio… │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ expanded_conv_dept… │ (None, [illegible], [illegible], │          0 │ expanded_conv_de… │
│ (ReLU)              │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ expanded_conv_proj… │ (None, [illegible], [illegible], │ [illegible] │ expanded_conv_de… │
│ (Conv2D)            │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ expanded_conv_proj… │ (None, [illegible], [illegible], │ [illegible] │ expanded_conv_pr… │
│ (BatchNormalizatio… │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_1_expand      │ (None, [illegible], [illegible], │ [illegible] │ expanded_conv_pr… │
│ (Conv2D)            │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_1_expand_BN   │ (None, [illegible], [illegible], │ [illegible] │ block_1_expand[0… │
│ (BatchNormalizatio… │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_1_expand_relu │ (None, [illegible], [illegible], │          0 │ block_1_expand_B… │
│ (ReLU)              │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_1_pad         │ (None, [illegible], [illegible], │          0 │ block_1_expand_r… │
│ (ZeroPadding2D)     │ [illegible])      │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_1_depthwise   │ (None, [illegible], [illegible], │ [illegible] │ block_1_pad[0][0] │
│ (DepthwiseConv2D)   │ [illegible])      │            │                   │
```

```
│ block_15_add (Add)  │ (None, 4, 4, 160) │          0 │ block_14_add[0][… │
│                     │                   │            │ block_15_project… │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_expand     │ (None, 4, 4, 960) │    153,600 │ block_15_add[0][… │
│ (Conv2D)            │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_expand_BN  │ (None, 4, 4, 960) │      3,840 │ block_16_expand[… │
│ (BatchNormalizatio… │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_expand_re… │ (None, 4, 4, 960) │          0 │ block_16_expand_… │
│ (ReLU)              │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_depthwise  │ (None, 4, 4, 960) │      8,640 │ block_16_expand_… │
│ (DepthwiseConv2D)   │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_depthwise… │ (None, 4, 4, 960) │      3,840 │ block_16_depthwi… │
│ (BatchNormalizatio… │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_depthwise… │ (None, 4, 4, 960) │          0 │ block_16_depthwi… │
│ (ReLU)              │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_project    │ (None, 4, 4, 320) │    307,200 │ block_16_depthwi… │
│ (Conv2D)            │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ block_16_project_BN │ (None, 4, 4, 320) │      1,280 │ block_16_project… │
│ (BatchNormalizatio… │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ Conv_1 (Conv2D)     │ (None, 4, 4,      │    409,600 │ block_16_project… │
│                     │ 1280)             │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ Conv_1_bn           │ (None, 4, 4,      │      5,120 │ Conv_1[0][0]      │
│ (BatchNormalizatio… │ 1280)             │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ out_relu (ReLU)     │ (None, 4, 4,      │          0 │ Conv_1_bn[0][0]   │
│                     │ 1280)             │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ global_average_poo… │ (None, 1280)      │          0 │ out_relu[0][0]    │
│ (GlobalAveragePool… │                   │            │                   │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ dense (Dense)       │ (None, 128)       │    163,968 │ global_average_p… │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ dropout (Dropout)   │ (None, 128)       │          0 │ dense[0][0]       │
├─────────────────────┼───────────────────┼────────────┼───────────────────┤
│ dense_1 (Dense)     │ (None, 29)        │      3,741 │ dropout[0][0]     │
└─────────────────────┴───────────────────┴────────────┴───────────────────┘
 Total params: 2,425,693 (9.25 MB)
 Trainable params: 167,709 (655.11 KB)
 Non-trainable params: 2,257,984 (8.61 MB)
```

MobileNetV2 training log:

```
Epoch 1/10
/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class should call `super().__init__(**kwargs)` in its constructo
  self._warn_if_super_not_called()
951/951 ━━━━━━━━━━━━━━━━━━━━ 0s 68ms/step - accuracy: 0.7876 - loss: 0.7403/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `
  self._warn_if_super_not_called()
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras
951/951 ━━━━━━━━━━━━━━━━━━━━ 93s 86ms/step - accuracy: 0.7877 - loss: 0.7399 - val_accuracy: 0.9872 - val_loss: 0.0458
Epoch 2/10
  1/951 ━━━━━━━━━━━━━━━━━━━━ 28s 30ms/step - accuracy: 0.9688 - loss: 0.1108/usr/local/lib/python3.11/dist-packages/keras/src/trainers/epoch_iterator.py:107: UserWarning: Your input ran out of d
  self._interrupted_warning()
951/951 ━━━━━━━━━━━━━━━━━━━━ 17s 18ms/step - accuracy: 0.9688 - loss: 0.1108 - val_accuracy: 0.9874 - val_loss: 0.0460
Epoch 3/10
951/951 ━━━━━━━━━━━━━━━━━━━━ 0s 63ms/step - accuracy: 0.9688 - loss: 0.0947WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This fil
951/951 ━━━━━━━━━━━━━━━━━━━━ 73s 76ms/step - accuracy: 0.9688 - loss: 0.0947 - val_accuracy: 0.9901 - val_loss: 0.0344
Epoch 4/10
  1/951 ━━━━━━━━━━━━━━━━━━━━ 30s 32ms/step - accuracy: 0.9531 - loss: 0.0742/usr/local/lib/python3.11/dist-packages/keras/src/trainers/epoch_iterator.py:107: UserWarning: Your input ran out of d
  self._interrupted_warning()
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras
951/951 ━━━━━━━━━━━━━━━━━━━━ 13s 13ms/step - accuracy: 0.9531 - loss: 0.0742 - val_accuracy: 0.9905 - val_loss: 0.0328
Epoch 5/10
951/951 ━━━━━━━━━━━━━━━━━━━━ 0s 64ms/step - accuracy: 0.9759 - loss: 0.0721WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This fil
951/951 ━━━━━━━━━━━━━━━━━━━━ 142s 90ms/step - accuracy: 0.9759 - loss: 0.0721 - val_accuracy: 0.9908 - val_loss: 0.0292
Epoch 6/10
  1/951 ━━━━━━━━━━━━━━━━━━━━ 26s 28ms/step - accuracy: 0.9688 - loss: 0.0518/usr/local/lib/python3.11/dist-packages/keras/src/trainers/epoch_iterator.py:107: UserWarning: Your input ran out of d
  self._interrupted_warning()
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras
951/951 ━━━━━━━━━━━━━━━━━━━━ 21s 22ms/step - accuracy: 0.9688 - loss: 0.0518 - val_accuracy: 0.9908 - val_loss: 0.0289
Epoch 7/10
951/951 ━━━━━━━━━━━━━━━━━━━━ 0s 63ms/step - accuracy: 0.9770 - loss: 0.0665WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This fil
951/951 ━━━━━━━━━━━━━━━━━━━━ 100s 76ms/step - accuracy: 0.9770 - loss: 0.0665 - val_accuracy: 0.9931 - val_loss: 0.0206
Epoch 8/10
  1/951 ━━━━━━━━━━━━━━━━━━━━ 25s 27ms/step - accuracy: 1.0000 - loss: 0.0158/usr/local/lib/python3.11/dist-packages/keras/src/trainers/epoch_iterator.py:107: UserWarning: Your input ran out of d
  self._interrupted_warning()
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras
951/951 ━━━━━━━━━━━━━━━━━━━━ 13s 13ms/step - accuracy: 1.0000 - loss: 0.0158 - val_accuracy: 0.9931 - val_loss: 0.0199
Epoch 9/10
951/951 ━━━━━━━━━━━━━━━━━━━━ 0s 66ms/step - accuracy: 0.9809 - loss: 0.0567WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This fil
951/951 ━━━━━━━━━━━━━━━━━━━━ 132s 79ms/step - accuracy: 0.9809 - loss: 0.0567 - val_accuracy: 0.9946 - val_loss: 0.0160
Epoch 10/10
  1/951 ━━━━━━━━━━━━━━━━━━━━ 25s 27ms/step - accuracy: 1.0000 - loss: 0.0114/usr/local/lib/python3.11/dist-packages/keras/src/trainers/epoch_iterator.py:107: UserWarning: Your input ran out of d
  self._interrupted_warning()
951/951 ━━━━━━━━━━━━━━━━━━━━ 12s 13ms/step - accuracy: 1.0000 - loss: 0.0114 - val_accuracy: 0.9942 - val_loss: 0.0168
```

VGG16 summary:

```
Model: "functional"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃       Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━┩
│ input_layer (InputLayer)        │ (None, 224, 224, 3)    │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block1_conv1 (Conv2D)           │ (None, 224, 224, 64)   │         1,792 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block1_conv2 (Conv2D)           │ (None, 224, 224, 64)   │        36,928 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block1_pool (MaxPooling2D)      │ (None, 112, 112, 64)   │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block2_conv1 (Conv2D)           │ (None, 112, 112, 128)  │        73,856 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block2_conv2 (Conv2D)           │ (None, 112, 112, 128)  │       147,584 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block2_pool (MaxPooling2D)      │ (None, 56, 56, 128)    │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block3_conv1 (Conv2D)           │ (None, 56, 56, 256)    │       295,168 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block3_conv2 (Conv2D)           │ (None, 56, 56, 256)    │       590,080 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block3_conv3 (Conv2D)           │ (None, 56, 56, 256)    │       590,080 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block3_pool (MaxPooling2D)      │ (None, 28, 28, 256)    │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block4_conv1 (Conv2D)           │ (None, 28, 28, 512)    │     1,180,160 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block4_conv2 (Conv2D)           │ (None, 28, 28, 512)    │     2,359,808 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block4_conv3 (Conv2D)           │ (None, 28, 28, 512)    │     2,359,808 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block4_pool (MaxPooling2D)      │ (None, 14, 14, 512)    │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block5_conv1 (Conv2D)           │ (None, 14, 14, 512)    │     2,359,808 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block5_conv2 (Conv2D)           │ (None, 14, 14, 512)    │     2,359,808 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block5_conv3 (Conv2D)           │ (None, 14, 14, 512)    │     2,359,808 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ block5_pool (MaxPooling2D)      │ (None, 7, 7, 512)      │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ flatten (Flatten)               │ (None, 25088)          │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dense (Dense)                   │ (None, 512)            │    12,845,568 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dropout (Dropout)               │ (None, 512)            │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dense_1 (Dense)                 │ (None, 512)            │       262,656 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dropout_1 (Dropout)             │ (None, 512)            │             0 │
├─────────────────────────────────┼────────────────────────┼───────────────┤
│ dense_2 (Dense)                 │ (None, 29)             │        14,877 │
└─────────────────────────────────┴────────────────────────┴───────────────┘
 Total params: 27,837,789 (106.19 MB)
 Trainable params: 13,123,101 (50.06 MB)
 Non-trainable params: 14,714,688 (56.13 MB)
None
You must install pydot (`pip install pydot`) for `plot_model` to work.
None
```

VGG16 training log:

```
Found 60900 validated image filenames belonging to 29 classes.
Found 13050 validated image filenames belonging to 29 classes.
Found 13050 validated image filenames belonging to 29 classes.
/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class should c
  self._warn_if_super_not_called()
Epoch 1/10
  7/951 ━━━━━━━━━━━━━━━━━━━━ 3:36:52 14s/step - accuracy: 0.0247 - loss: 5.2526
```