TensorFlowISha

June 11, 2025

1 TensorFlow by Isha Borgaonkar

1.1 Installation & Setup

[2]:
```
# Install TensorFlow for deep learning, matplotlib for plotting,
# tensorflow-addons for extra layers/optimizers, and keras-tuner for␣
 ↪hyperparameter search
!pip install tensorflow matplotlib tensorflow-addons keras-tuner
```

```
Requirement already satisfied: tensorflow in c:\users\isha\anaconda3\lib\site-
packages (2.16.1)
Requirement already satisfied: matplotlib in c:\users\isha\anaconda3\lib\site-
packages (3.9.4)
Requirement already satisfied: tensorflow-addons in
c:\users\isha\anaconda3\lib\site-packages (0.22.0)
Requirement already satisfied: keras-tuner in c:\users\isha\anaconda3\lib\site-
packages (1.4.7)
Requirement already satisfied: tensorflow-intel==2.16.1 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow) (2.16.1)
Requirement already satisfied: google-pasta>=0.1.1 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (0.2.0)
Requirement already satisfied: wrapt>=1.11.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (1.14.1)
Requirement already satisfied: h5py>=3.10.0 in c:\users\isha\anaconda3\lib\site-
packages (from tensorflow-intel==2.16.1->tensorflow) (3.11.0)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (0.5.4)
Requirement already satisfied: libclang>=13.0.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (16.0.6)
Requirement already satisfied: setuptools in c:\users\isha\anaconda3\lib\site-
packages (from tensorflow-intel==2.16.1->tensorflow) (63.4.1)
Requirement already satisfied: astunparse>=1.6.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (1.6.3)
```

```
Requirement already satisfied: flatbuffers>=23.5.26 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (23.5.26)
Requirement already satisfied: six>=1.12.0 in c:\users\isha\anaconda3\lib\site-
packages (from tensorflow-intel==2.16.1->tensorflow) (1.16.0)
Requirement already satisfied: ml-dtypes~=0.3.1 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (0.3.2)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (0.31.0)
Requirement already satisfied: opt-einsum>=2.3.2 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (3.3.0)
Requirement already satisfied: numpy<2.0.0,>=1.23.5 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (1.23.5)
Requirement already satisfied: termcolor>=1.1.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (2.3.0)
Requirement already satisfied: requests<3,>=2.21.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (2.32.3)
Requirement already satisfied: keras>=3.0.0 in c:\users\isha\anaconda3\lib\site-
packages (from tensorflow-intel==2.16.1->tensorflow) (3.3.2)
Requirement already satisfied:
protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3
in c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (4.25.8)
Requirement already satisfied: typing-extensions>=3.6.6 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (4.3.0)
Requirement already satisfied: tensorboard<2.17,>=2.16 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (2.16.2)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (1.62.2)
Requirement already satisfied: packaging in c:\users\isha\anaconda3\lib\site-
packages (from tensorflow-intel==2.16.1->tensorflow) (21.3)
Requirement already satisfied: absl-py>=1.0.0 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-
intel==2.16.1->tensorflow) (2.1.0)
Requirement already satisfied: pillow>=8 in c:\users\isha\anaconda3\lib\site-
packages (from matplotlib) (9.2.0)
Requirement already satisfied: kiwisolver>=1.3.1 in
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (1.4.2)
Requirement already satisfied: fonttools>=4.22.0 in
```

```
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (4.25.0)
Requirement already satisfied: importlib-resources>=3.2.0 in
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (6.4.0)
Requirement already satisfied: contourpy>=1.0.1 in
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (1.3.0)
Requirement already satisfied: cycler>=0.10 in c:\users\isha\anaconda3\lib\site-
packages (from matplotlib) (0.11.0)
Requirement already satisfied: python-dateutil>=2.7 in
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (2.9.0.post0)
Requirement already satisfied: pyparsing>=2.3.1 in
c:\users\isha\anaconda3\lib\site-packages (from matplotlib) (3.0.9)
Requirement already satisfied: typeguard<3.0.0,>=2.7 in
c:\users\isha\anaconda3\lib\site-packages (from tensorflow-addons) (2.13.3)
Requirement already satisfied: kt-legacy in c:\users\isha\anaconda3\lib\site-
packages (from keras-tuner) (1.0.5)
Requirement already satisfied: zipp>=3.1.0 in c:\users\isha\anaconda3\lib\site-
packages (from importlib-resources>=3.2.0->matplotlib) (3.8.0)
Requirement already satisfied: optree in c:\users\isha\anaconda3\lib\site-
packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (0.11.0)
Requirement already satisfied: rich in c:\users\isha\anaconda3\lib\site-packages
(from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (13.7.1)
Requirement already satisfied: namex in c:\users\isha\anaconda3\lib\site-
packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (0.0.8)
Requirement already satisfied: certifi>=2017.4.17 in
c:\users\isha\anaconda3\lib\site-packages (from requests<3,>=2.21.0->tensorflow-
intel==2.16.1->tensorflow) (2025.4.26)
Requirement already satisfied: urllib3<3,>=1.21.1 in
c:\users\isha\anaconda3\lib\site-packages (from requests<3,>=2.21.0->tensorflow-
intel==2.16.1->tensorflow) (2.2.3)
Requirement already satisfied: charset-normalizer<4,>=2 in
c:\users\isha\anaconda3\lib\site-packages (from requests<3,>=2.21.0->tensorflow-
intel==2.16.1->tensorflow) (2.0.4)
Requirement already satisfied: idna<4,>=2.5 in c:\users\isha\anaconda3\lib\site-
packages (from requests<3,>=2.21.0->tensorflow-intel==2.16.1->tensorflow) (3.10)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
c:\users\isha\anaconda3\lib\site-packages (from astunparse>=1.6.0->tensorflow-
intel==2.16.1->tensorflow) (0.37.1)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in
c:\users\isha\anaconda3\lib\site-packages (from
tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in
c:\users\isha\anaconda3\lib\site-packages (from
tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (2.0.3)
Requirement already satisfied: markdown>=2.6.8 in
c:\users\isha\anaconda3\lib\site-packages (from
tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (3.3.4)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
c:\users\isha\anaconda3\lib\site-packages (from rich->keras>=3.0.0->tensorflow-
intel==2.16.1->tensorflow) (2.17.2)
Requirement already satisfied: markdown-it-py>=2.2.0 in
c:\users\isha\anaconda3\lib\site-packages (from rich->keras>=3.0.0->tensorflow-
intel==2.16.1->tensorflow) (3.0.0)
Requirement already satisfied: mdurl~=0.1 in c:\users\isha\anaconda3\lib\site-
packages (from markdown-it-py>=2.2.0->rich->keras>=3.0.0->tensorflow-
intel==2.16.1->tensorflow) (0.1.2)
```

1.2 Imports & Environment Check

[4]:

```
# Core TensorFlow imports
import tensorflow as tf                               # Core TensorFlow library
from tensorflow import keras                          # High-level Keras API
from tensorflow.keras import layers, models, callbacks

# Plotting and array utilities
import matplotlib.pyplot as plt                       # For visualizing results
import numpy as np                                    # For numerical operations

# Optional: Keras Tuner for hyperparameter search
try:
    import kerastuner as kt                           # install with: pip install␣
 ↪keras-tuner
    print("Keras Tuner version:", kt.__version__)
except ModuleNotFoundError:
    print("  keras-tuner not found. Install with:\n    pip install keras-tuner")

# Confirm TensorFlow version
print("TensorFlow version:", tf.__version__)
```

```
Keras Tuner version: 1.0.5
TensorFlow version: 2.16.1
```

[5]:

```
# Core TensorFlow imports
import tensorflow as tf                               # Core TensorFlow library
from tensorflow import keras                          # High-level Keras API
from tensorflow.keras import layers, models, callbacks

# Plotting and array utilities
import matplotlib.pyplot as plt                       # For visualizing results
import numpy as np                                    # For numerical operations

# Optional: Keras Tuner for hyperparameter search
try:
    import kerastuner as kt                           # install with: pip install␣
 ↪keras-tuner
    print("Keras Tuner version:", kt.__version__)
except ModuleNotFoundError:
    print("  keras-tuner not found. Install with:\n    pip install keras-tuner")

# Confirm TensorFlow version
print("TensorFlow version:", tf.__version__)
```

```
Keras Tuner version: 1.0.5
TensorFlow version: 2.16.1
```

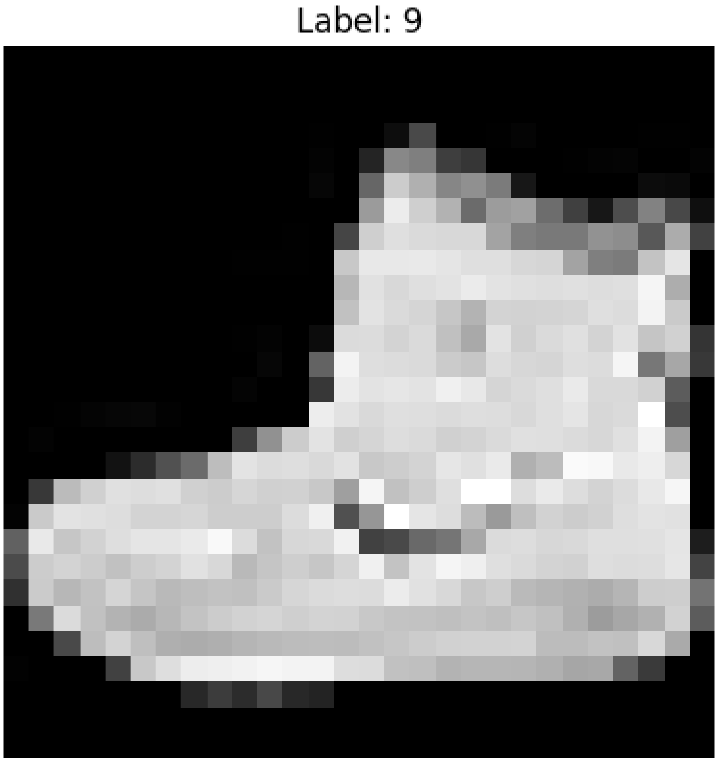
1.3 Loading & Exploring Data

```
[6]: # Load Fashion MNIST: grayscale 28×28 images in 10 classes
(x_train, y_train), (x_test, y_test) = keras.datasets.fashion_mnist.load_data()

# Print shapes to verify dataset dimensions
print(x_train.shape, y_train.shape, x_test.shape, y_test.shape)

# Display the first image with its label
plt.imshow(x_train[0], cmap='gray')            # Show pixel intensities as␣
 ↪grayscale
plt.title("Label: " + str(y_train[0]))          # Show its numeric class label
plt.axis('off')                                 # Hide axis ticks
plt.show()
```

```
(60000, 28, 28) (60000,) (10000, 28, 28) (10000,)
```



1.4 Preprocessing Pipeline

[7]:

```
# Normalize pixel values from [0,255] → [0,1]
x_train = x_train.astype("float32") / 255.0
x_test  = x_test.astype("float32")  / 255.0

# Add channel dimension: (28,28) → (28,28,1) required by Conv2D
x_train = np.expand_dims(x_train, -1)
x_test  = np.expand_dims(x_test,  -1)

# Convert labels to one-hot encoded vectors
num_classes = 10
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test  = keras.utils.to_categorical(y_test,  num_classes)
```

1.5 Building a CNN from Scratch

[9]:

```
def build_cnn():
    model = models.Sequential([
        layers.Conv2D(32, (3,3), activation='relu', input_shape=(28,28,1)),  #␣
 ↪Convolutional layer
        layers.MaxPooling2D((2,2)),                                           #␣
 ↪Max pooling layer
        layers.Conv2D(64, (3,3), activation='relu'),                          #␣
 ↪Another Conv layer
        layers.MaxPooling2D((2,2)),                                           #␣
 ↪Another pooling layer
        layers.Flatten(),                                                     #␣
 ↪Flatten to 1D vector
        layers.Dense(128, activation='relu'),                                 #␣
 ↪Fully connected layer
        layers.Dropout(0.5),                                                  #␣
 ↪Dropout for regularization
        layers.Dense(num_classes, activation='softmax')                       #␣
 ↪Output layer with softmax
    ])
    # Compile model with optimizer, loss, and metric
    model.compile(
        optimizer=keras.optimizers.Adam(learning_rate=1e-3),
        loss='categorical_crossentropy',
        metrics=['accuracy']
    )
    return model

# Instantiate and view model architecture
```

```
cnn = build_cnn()
cnn.summary()
```

```
Model: "sequential_1"


 Layer (type)                          Output Shape                       ␣
↪Param #

 conv2d_2 (Conv2D)                     (None, 26, 26, 32)                   ␣
↪320

 max_pooling2d_2 (MaxPooling2D)        (None, 13, 13, 32)                   ␣
↪  0

 conv2d_3 (Conv2D)                     (None, 11, 11, 64)                 ␣
↪18,496

 max_pooling2d_3 (MaxPooling2D)        (None, 5, 5, 64)                     ␣
↪  0

 flatten_1 (Flatten)                   (None, 1600)                         ␣
↪  0

 dense_2 (Dense)                       (None, 128)                        ␣
↪204,928

 dropout_1 (Dropout)                   (None, 128)                          ␣
↪  0

 dense_3 (Dense)                       (None, 10)                          ␣
↪1,290


 Total params: 225,034 (879.04 KB)

 Trainable params: 225,034 (879.04 KB)

 Non-trainable params: 0 (0.00 B)
```

1.6 Training with Callbacks

[20]:

```
# EarlyStopping: stop training when validation loss stops improving for 3 epochs
early_stop = callbacks.EarlyStopping(
    monitor='val_loss',
    patience=3,
    restore_best_weights=True
)

# TensorBoard: log training metrics and histograms for inspection
tensorboard_cb = callbacks.TensorBoard(
    log_dir="logs",
    histogram_freq=1
)

# ModelCheckpoint: save the best model (in Keras's native format) by validation␣
 ↪accuracy
# Note: Keras now requires the .keras extension for full model saving
mc = callbacks.ModelCheckpoint(
    filepath='best_model.keras',    # Must end in .keras when␣
 ↪save_weights_only=False
    monitor='val_accuracy',         # Which metric to monitor
    save_best_only=True             # Only save when the monitored metric␣
 ↪improves
)

# Train the model with a 10% validation split and the above callbacks
history = cnn.fit(
    x_train,
    y_train,
    epochs=20,
    batch_size=128,
    validation_split=0.1,
    callbacks=[early_stop, tensorboard_cb, mc]
)
```

```
Epoch 1/20
422/422                   16s 32ms/step -
accuracy: 0.6682 - loss: 0.9230 - val_accuracy: 0.8465 - val_loss: 0.4107
Epoch 2/20
422/422                   12s 29ms/step -
accuracy: 0.8411 - loss: 0.4350 - val_accuracy: 0.8757 - val_loss: 0.3348
Epoch 3/20
422/422                   13s 31ms/step -
accuracy: 0.8653 - loss: 0.3777 - val_accuracy: 0.8808 - val_loss: 0.3150
Epoch 4/20
422/422                   12s 29ms/step -
accuracy: 0.8789 - loss: 0.3390 - val_accuracy: 0.8880 - val_loss: 0.2958
```

```
Epoch 5/20
422/422             13s 30ms/step -
accuracy: 0.8867 - loss: 0.3140 - val_accuracy: 0.8917 - val_loss: 0.2889
Epoch 6/20
422/422             12s 28ms/step -
accuracy: 0.8906 - loss: 0.2993 - val_accuracy: 0.8985 - val_loss: 0.2747
Epoch 7/20
422/422             12s 28ms/step -
accuracy: 0.8959 - loss: 0.2828 - val_accuracy: 0.8993 - val_loss: 0.2712
Epoch 8/20
422/422             12s 29ms/step -
accuracy: 0.9030 - loss: 0.2642 - val_accuracy: 0.8965 - val_loss: 0.2637
Epoch 9/20
422/422             12s 28ms/step -
accuracy: 0.9062 - loss: 0.2566 - val_accuracy: 0.9042 - val_loss: 0.2522
Epoch 10/20
422/422             12s 29ms/step -
accuracy: 0.9134 - loss: 0.2370 - val_accuracy: 0.9090 - val_loss: 0.2473
Epoch 11/20
422/422             12s 28ms/step -
accuracy: 0.9154 - loss: 0.2310 - val_accuracy: 0.9115 - val_loss: 0.2418
Epoch 12/20
422/422             12s 29ms/step -
accuracy: 0.9195 - loss: 0.2203 - val_accuracy: 0.9098 - val_loss: 0.2399
Epoch 13/20
422/422             12s 29ms/step -
accuracy: 0.9214 - loss: 0.2125 - val_accuracy: 0.9138 - val_loss: 0.2350
Epoch 14/20
422/422             13s 31ms/step -
accuracy: 0.9228 - loss: 0.2047 - val_accuracy: 0.9177 - val_loss: 0.2327
Epoch 15/20
422/422             13s 30ms/step -
accuracy: 0.9273 - loss: 0.1938 - val_accuracy: 0.9148 - val_loss: 0.2371
Epoch 16/20
422/422             14s 34ms/step -
accuracy: 0.9292 - loss: 0.1859 - val_accuracy: 0.9193 - val_loss: 0.2294
Epoch 17/20
422/422             13s 30ms/step -
accuracy: 0.9322 - loss: 0.1786 - val_accuracy: 0.9157 - val_loss: 0.2372
Epoch 18/20
422/422             12s 29ms/step -
accuracy: 0.9351 - loss: 0.1721 - val_accuracy: 0.9225 - val_loss: 0.2320
Epoch 19/20
422/422             13s 31ms/step -
accuracy: 0.9382 - loss: 0.1663 - val_accuracy: 0.9218 - val_loss: 0.2250
Epoch 20/20
422/422             13s 30ms/step -
accuracy: 0.9402 - loss: 0.1585 - val_accuracy: 0.9195 - val_loss: 0.2379
```

1.7 Visualizing Training with TensorBoard

```
tensorboard --logdir logs
```

1.8 Evaluation & Metrics

[10]:
```
# Evaluate on test set
test_loss, test_acc = cnn.evaluate(x_test, y_test, verbose=0)
print(f"Test Accuracy: {test_acc:.4f}, Test Loss: {test_loss:.4f}")
```

```
Test Accuracy: 0.0950, Test Loss: 2.3203
```

1.9 Data Augmentation

[23]:
```
# Configure image augmentations
datagen = keras.preprocessing.image.ImageDataGenerator(
    rotation_range=15, width_shift_range=0.1, height_shift_range=0.1,
    zoom_range=0.1, horizontal_flip=True
)
datagen.fit(x_train)

# Train with augmented data
aug_cnn = build_cnn()
aug_history = aug_cnn.fit(
    datagen.flow(x_train, y_train, batch_size=128),
    epochs=20,
    validation_data=(x_test, y_test),
    callbacks=[early_stop, mc]
)
```

```
Epoch 1/20
469/469             29s 59ms/step -
accuracy: 0.5498 - loss: 1.2255 - val_accuracy: 0.7745 - val_loss: 0.5772
Epoch 2/20
469/469             29s 61ms/step -
accuracy: 0.7418 - loss: 0.6943 - val_accuracy: 0.8001 - val_loss: 0.5295
Epoch 3/20
469/469             29s 62ms/step -
accuracy: 0.7594 - loss: 0.6299 - val_accuracy: 0.8259 - val_loss: 0.4570
```

1.10 Hyperparameter Tuning with Keras Tuner

[11]:
```
def model_builder(hp):
    # Number of units in dense layer
    hp_units = hp.Int('units', min_value=32, max_value=256, step=32)
    # Learning rate options
    hp_lr = hp.Choice('learning_rate', values=[1e-2, 1e-3, 1e-4])
    model = build_cnn()
    # Modify dense layer units
    model.layers[-2] = layers.Dense(hp_units, activation='relu')
    model.compile(
        optimizer=keras.optimizers.Adam(learning_rate=hp_lr),
        loss='categorical_crossentropy',
        metrics=['accuracy']
    )
    return model

# Run random search
tuner = kt.RandomSearch(model_builder, objective='val_accuracy', max_trials=5,␣
  ↪executions_per_trial=1)
tuner.search(x_train, y_train, epochs=5, validation_split=0.1)
best_model = tuner.get_best_models(num_models=1)[0]
```

```
Reloading Tuner from .\untitled_project\tuner0.json
WARNING:tensorflow:From C:\Users\ISHA\anaconda3\lib\site-
packages\keras\src\backend\common\global_state.py:82: The name
tf.reset_default_graph is deprecated. Please use
tf.compat.v1.reset_default_graph instead.


C:\Users\ISHA\anaconda3\lib\site-packages\keras\src\saving\saving_lib.py:418:
UserWarning: Skipping variable loading for optimizer 'adam', because it has 2
variables whereas the saved optimizer has 18 variables.
  trackable.load_own_variables(weights_store.get(inner_path))
```

1.11 Transfer Learning (Advanced)

[26]:

```
# Load pretrained MobileNetV2 (no top)
base = keras.applications.MobileNetV2(weights='imagenet', include_top=False,␣
  ↪input_shape=(96,96,3))
base.trainable = False  # Freeze base

# Build new model on top
tl_model = models.Sequential([
    layers.UpSampling2D((12,12)),    # Upsample input
    base,                             # Pretrained base
    layers.GlobalAveragePooling2D(),  # Pool features
    layers.Dense(64, activation='relu'),
    layers.Dropout(0.5),
    layers.Dense(num_classes, activation='softmax')
])
tl_model.compile(optimizer='adam', loss='categorical_crossentropy',␣
  ↪metrics=['accuracy'])
tl_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicatio
ns/mobilenet_v2/mobilenet_v2_weights_tf_dim_ordering_tf_kernels_1.0_96_no_top.h5
```

```
9406464/9406464            1s
0us/step
```

```
Model: "sequential_1"
```

```
 Layer (type)                           Output Shape                        ␣
↪Param #

 up_sampling2d (UpSampling2D)           ?                                 0␣
↪(unbuilt)

 mobilenetv2_1.00_96 (Functional)       ?                                  ␣
↪2,257,984

 global_average_pooling2d               ?                                 0␣
↪(unbuilt)
 (GlobalAveragePooling2D)                                                       ␣
↪

 dense_3 (Dense)                        ?                                 0␣
↪(unbuilt)

 dropout_1 (Dropout)                    ?                                 0␣
↪(unbuilt)

 dense_4 (Dense)                        ?                                 0␣
↪(unbuilt)
```

```
 Total params: 2,257,984 (8.61 MB)

 Trainable params: 0 (0.00 B)

 Non-trainable params: 2,257,984 (8.61 MB)
```

1.12 Custom Training Loop with tf.GradientTape

[27]:
```
# Define optimizer and loss
optimizer = keras.optimizers.Adam()
loss_fn = keras.losses.CategoricalCrossentropy()

# Create batched dataset
train_ds = tf.data.Dataset.from_tensor_slices((x_train, y_train)).batch(128)
```

```python

for epoch in range(5):
    for images, labels in train_ds:
        # Record operations
        with tf.GradientTape() as tape:
            preds = cnn(images, training=True)
            loss = loss_fn(labels, preds)
        # Compute gradients
        grads = tape.gradient(loss, cnn.trainable_variables)
        # Apply gradients
        optimizer.apply_gradients(zip(grads, cnn.trainable_variables))
    print(f"Epoch {epoch+1}, Loss: {loss:.4f}")
```

```
Epoch 1, Loss: 0.4342
Epoch 2, Loss: 0.3407
Epoch 3, Loss: 0.3133
Epoch 4, Loss: 0.3123
Epoch 5, Loss: 0.2056
```

1.13 Mixed Precision & Multi-GPU Strategy

[28]:

```python
# Enable mixed precision
tf.keras.mixed_precision.set_global_policy('mixed_float16')

# Use all GPUs
strategy = tf.distribute.MirroredStrategy()
with strategy.scope():
    dist_model = build_cnn()
    dist_model.fit(x_train, y_train, epochs=3, batch_size=256)
```

```
INFO:tensorflow:Using MirroredStrategy with devices
('/job:localhost/replica:0/task:0/device:CPU:0',)
Epoch 1/3
235/235               474s 2s/step -
accuracy: 0.6135 - loss: 1.0769
Epoch 2/3
235/235               380s 2s/step -
accuracy: 0.8250 - loss: 0.4886
Epoch 3/3
235/235               383s 2s/step -
accuracy: 0.8517 - loss: 0.4115
```