Task 1

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

```
Mounted at /content/drive
```

Improve the Previous Model

```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

train_datagen = ImageDataGenerator(
    rescale=1./255,
    rotation_range=20,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True,
    fill_mode='nearest'
)

test_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    '/content/drive/MyDrive/AIandML/Worksheet5/FruitinAmazon/FruitinAmazon/train',
    target_size=(224, 224),
    batch_size=32,
    class_mode='categorical'
)

validation_generator = test_datagen.flow_from_directory(
    '/content/drive/MyDrive/AIandML/Worksheet5/FruitinAmazon/FruitinAmazon/test',
    target_size=(224, 224),
    batch_size=32,
    class_mode='categorical'
)
```

```
Found 90 images belonging to 6 classes.
Found 30 images belonging to 6 classes.
```

Build a Deeper CNN Model with Batch Normalization & Dropout

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout, BatchNormalization

model = Sequential([
    Conv2D(32, (3,3), activation='relu', input_shape=(64, 64, 3)),
    BatchNormalization(),
    MaxPooling2D(pool_size=(2,2)),

    Conv2D(64, (3,3), activation='relu'),
    BatchNormalization(),
    MaxPooling2D(pool_size=(2,2)),
    Dropout(0.3),

    Conv2D(128, (3,3), activation='relu'),
    BatchNormalization(),
    MaxPooling2D(pool_size=(2,2)),
    Dropout(0.4),

    Flatten(),
    Dense(256, activation='relu'),
    Dropout(0.5),
    Dense(10, activation='softmax')
])

model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
model.summary()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`inp
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
Model: "sequential"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d (Conv2D)                      │ (None, 62, 62, 32)          │             896 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization                  │ (None, 62, 62, 32)          │             128 │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d (MaxPooling2D)         │ (None, 31, 31, 32)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_1 (Conv2D)                    │ (None, 29, 29, 64)          │          18,496 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization_1                │ (None, 29, 29, 64)          │             256 │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_1 (MaxPooling2D)       │ (None, 14, 14, 64)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout (Dropout)                    │ (None, 14, 14, 64)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_2 (Conv2D)                    │ (None, 12, 12, 128)         │          73,856 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization_2                │ (None, 12, 12, 128)         │             512 │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_2 (MaxPooling2D)       │ (None, 6, 6, 128)           │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_1 (Dropout)                  │ (None, 6, 6, 128)           │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten (Flatten)                    │ (None, 4608)                │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense (Dense)                        │ (None, 256)                 │       1,179,904 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_2 (Dropout)                  │ (None, 256)                 │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_1 (Dense)                      │ (None, 10)                  │           2,570 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,276,618 (4.87 MB)
 Trainable params: 1,276,170 (4.87 MB)
```

Transfer Learning with VGG16

```
from tensorflow.keras.applications import VGG16
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Dense, GlobalAveragePooling2D

# Load VGG16 without the top classification layer
base_model = VGG16(weights='imagenet', include_top=False, input_shape=(224, 224, 3))

# Freeze base model layers
```

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

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop
58889256/58889256 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```

Add Custom Layers

```
num_classes = len(train_generator.class_indices)

x = base_model.output
x = GlobalAveragePooling2D()(x)
x = Dense(1024, activation='relu')(x)
x = Dense(num_classes, activation='softmax')(x)
model = Model(inputs=base_model.input, outputs=x)
```

Compile & Train the Model

```
from tensorflow.keras.optimizers import Adam

model.compile(optimizer=Adam(), loss='categorical_crossentropy', metrics=['accuracy'])

history = model.fit(train_generator, epochs=10, validation_data=validation_generator)
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121: UserWarning: Your `PyDataset` class
  self._warn_if_super_not_called()
Epoch 1/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 54s 18s/step - accuracy: 0.1865 - loss: 1.8096 - val_accuracy: 0.4000 - val_loss: 1.6733
Epoch 2/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 31s 605ms/step - accuracy: 0.3470 - loss: 1.6162 - val_accuracy: 0.4667 - val_loss: 1.5452
Epoch 3/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 578ms/step - accuracy: 0.6265 - loss: 1.4294 - val_accuracy: 0.4333 - val_loss: 1.5507
Epoch 4/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 660ms/step - accuracy: 0.6060 - loss: 1.2728 - val_accuracy: 0.3667 - val_loss: 1.4750
Epoch 5/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 578ms/step - accuracy: 0.6135 - loss: 1.1824 - val_accuracy: 0.6667 - val_loss: 1.3536
Epoch 6/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 600ms/step - accuracy: 0.7307 - loss: 1.1001 - val_accuracy: 0.5333 - val_loss: 1.3242
Epoch 7/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 610ms/step - accuracy: 0.7319 - loss: 0.9823 - val_accuracy: 0.4000 - val_loss: 1.3343
Epoch 8/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 794ms/step - accuracy: 0.7589 - loss: 0.9183 - val_accuracy: 0.4667 - val_loss: 1.3425
Epoch 9/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 598ms/step - accuracy: 0.8035 - loss: 0.8774 - val_accuracy: 0.6333 - val_loss: 1.2571
Epoch 10/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 634ms/step - accuracy: 0.8953 - loss: 0.7401 - val_accuracy: 0.6000 - val_loss: 1.2084
```

Model Analysis

```
model.summary()
```

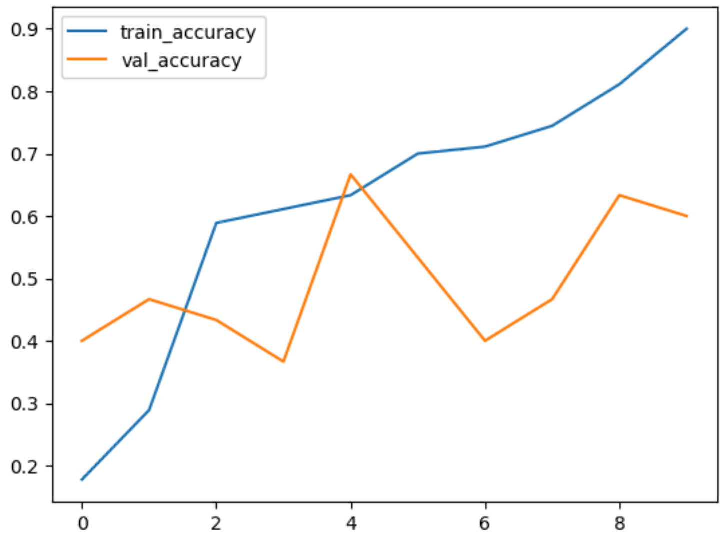
```
Model: "functional_1"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ input_layer_1 (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 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ global_average_pooling2d             │ (None, 512)                 │               0 │
│ (GlobalAveragePooling2D)             │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_2 (Dense)                      │ (None, 1024)                │         525,312 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_3 (Dense)                      │ (None, 6)                   │           6,150 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 16,309,076 (62.21 MB)
 Trainable params: 531,462 (2.03 MB)
```

Visualize Training Performance

```
import matplotlib.pyplot as plt

# history = model.fit(train_generator, epochs=10, validation_data=validation_generator)

plt.plot(history.history['accuracy'], label='train_accuracy')
plt.plot(history.history['val_accuracy'], label='val_accuracy')
plt.legend()
plt.show()
```



Task 2

Data Preparation & Augmentation

```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

train_dir = '/content/drive/MyDrive/AIandML/Worksheet5/FruitinAmazon/FruitinAmazon/train'
val_dir = '/content/drive/MyDrive/AIandML/Worksheet5/FruitinAmazon/FruitinAmazon/test'

# Data augmentation
train_datagen = ImageDataGenerator(
    rescale=1./255,
    rotation_range=20,
    zoom_range=0.2,
    width_shift_range=0.2,
    height_shift_range=0.2,
    horizontal_flip=True
)

val_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='categorical'
)

validation_generator = val_datagen.flow_from_directory(
    val_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='categorical',
    shuffle=False  # Important for inference output
)

num_classes = len(train_generator.class_indices)
```

```
Found 90 images belonging to 6 classes.
Found 30 images belonging to 6 classes.
```

Load VGG16 (Pre-trained) and Freeze Layers

```
from tensorflow.keras.applications import VGG16
from tensorflow.keras.models import Model
from tensorflow.keras.layers import GlobalAveragePooling2D, Dense, Dropout
from tensorflow.keras.optimizers import Adam
```

```
base_model = VGG16(weights='imagenet', include_top=False, input_shape=(224, 224, 3))

# Freeze all layers
for layer in base_model.layers:
    layer.trainable = False
```

Add Custom Layers

```
x = base_model.output
x = GlobalAveragePooling2D()(x)
x = Dense(512, activation='relu')(x)
x = Dropout(0.5)(x)
x = Dense(num_classes, activation='softmax')(x)

model = Model(inputs=base_model.input, outputs=x)
```

Compile & Train the Model

```
model.compile(optimizer=Adam(learning_rate=0.0001), loss='categorical_crossentropy', metrics=['accuracy'])

history = model.fit(
    train_generator,
    epochs=10,
    validation_data=validation_generator
)
```

```
Epoch 1/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 6s 1s/step - accuracy: 0.1293 - loss: 2.1646 - val_accuracy: 0.1667 - val_loss: 1.9615
Epoch 2/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 578ms/step - accuracy: 0.1104 - loss: 2.0926 - val_accuracy: 0.1333 - val_loss: 1.8992
Epoch 3/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 704ms/step - accuracy: 0.1158 - loss: 1.9014 - val_accuracy: 0.1000 - val_loss: 1.8569
Epoch 4/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 3s 792ms/step - accuracy: 0.2099 - loss: 1.8784 - val_accuracy: 0.0667 - val_loss: 1.8298
Epoch 5/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 650ms/step - accuracy: 0.1573 - loss: 1.8747 - val_accuracy: 0.1333 - val_loss: 1.8111
Epoch 6/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 586ms/step - accuracy: 0.1787 - loss: 1.7941 - val_accuracy: 0.2000 - val_loss: 1.7974
Epoch 7/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 585ms/step - accuracy: 0.1425 - loss: 1.8980 - val_accuracy: 0.2333 - val_loss: 1.7872
Epoch 8/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 580ms/step - accuracy: 0.1748 - loss: 1.8456 - val_accuracy: 0.2333 - val_loss: 1.7791
Epoch 9/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 583ms/step - accuracy: 0.1832 - loss: 1.8352 - val_accuracy: 0.2000 - val_loss: 1.7717
Epoch 10/10
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 783ms/step - accuracy: 0.2802 - loss: 1.8221 - val_accuracy: 0.3000 - val_loss: 1.7646
```

Evaluate + Classification Report

```
from sklearn.metrics import classification_report
import numpy as np

# Predict on validation data
y_pred = model.predict(validation_generator)
```