Importing necessary libaries and tools

```
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```

```
import os
import random
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout, BatchNormalization
from tensorflow.keras.preprocessing.image import load_img, ImageDataGenerator
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping, ReduceLROnPlateau
from tensorflow.keras.regularizers import l2
from sklearn.metrics import classification_report
from tensorflow.keras.applications import MobileNetV2
from tensorflow.keras.layers import GlobalAveragePooling2D, Input
from tensorflow.keras.models import Model
```

Task-1

```
train_dir = "/content/drive/MyDrive/Artificial intelligence and Machine learning/week-6/FruitinAmazon/train"
test_dir = "/content/drive/MyDrive/Artificial intelligence and Machine learning/week-6/FruitinAmazon/test"
```

```
class_names = os.listdir(train_dir)
print(f"Classes: {class_names}")
```

```
Classes: ['acai', 'pupunha', 'cupuacu', 'tucuma', 'guarana', 'graviola']
```

```
[ ]  def visualize_images(train_dir, class_names):
         fig, axes = plt.subplots(2, len(class_names) // 2, figsize=(12, 6))
         axes = axes.flatten()
         for i, class_name in enumerate(class_names):
             class_path = os.path.join(train_dir, class_name)
             img_name = random.choice(os.listdir(class_path))
             img_path = os.path.join(class_path, img_name)
             img = load_img(img_path)
             axes[i].imshow(img)
             axes[i].set_title(class_name)
             axes[i].axis("off")
         plt.show()

     visualize_images(train_dir, class_names)
```

```
[ ] damagedImages = []
    for class_name in class_names:
        class_path = os.path.join(train_dir, class_name)
        for img_name in os.listdir(class_path):
            img_path = os.path.join(class_path, img_name)
            try:
                img = load_img(img_path)  # Try opening the image
            except (IOError, SyntaxError):
                damagedImages.append(img_path)
                os.remove(img_path)
                print(f"Damaged image removed: {img_path}")

    if not damagedImages:
        print("No Damaged Images Found.")
```

```
No Damaged Images Found.
```

```
img_height, img_width = 128, 128
batch_size = 32
validation_split = 0.2
```

```
[ ] train_datagen = ImageDataGenerator(
        rescale=1./255,
        validation_split=validation_split,
        rotation_range=30,
        width_shift_range=0.2,
        height_shift_range=0.2,
        zoom_range=0.2,
        horizontal_flip=True,
        brightness_range=[0.8, 1.2]
    )

    val_datagen = ImageDataGenerator(rescale=1./255, validation_split=validation_split)
```

```
train_ds = train_datagen.flow_from_directory(
    train_dir,
    target_size=(img_height, img_width),
    batch_size=batch_size,
    class_mode='sparse',
    subset='training',
    shuffle=True,
    seed=123
)
```

```
Found 72 images belonging to 6 classes.
```

```python
num_classes = len(class_names)

model = Sequential([
    Conv2D(32, (3,3), activation='relu', padding='same', kernel_regularizer=l2(0.001), input_shape=(img_height, img_width, 3)),
    BatchNormalization(),
    Conv2D(64, (3,3), activation='relu', padding='same', kernel_regularizer=l2(0.001)),
    BatchNormalization(),
    MaxPooling2D((2,2)),
    Dropout(0.25),

    Conv2D(128, (3,3), activation='relu', padding='same', kernel_regularizer=l2(0.001)),
    BatchNormalization(),
    MaxPooling2D((2,2)),
    Dropout(0.4),

    Flatten(),
    Dense(256, activation='relu', kernel_regularizer=l2(0.001)),
    BatchNormalization(),
    Dropout(0.5),
    Dense(num_classes, activation='softmax')
])

model.summary()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
Model: "sequential"
```

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 128, 128, 32)	896
batch_normalization (BatchNormalization)	(None, 128, 128, 32)	128
conv2d_1 (Conv2D)	(None, 128, 128, 64)	18,496
batch_normalization_1 (BatchNormalization)	(None, 128, 128, 64)	256
max_pooling2d (MaxPooling2D)	(None, 64, 64, 64)	0
dropout (Dropout)	(None, 64, 64, 64)	0
conv2d_2 (Conv2D)	(None, 64, 64, 128)	73,856
batch_normalization_2 (BatchNormalization)	(None, 64, 64, 128)	512
max_pooling2d_1 (MaxPooling2D)	(None, 32, 32, 128)	0
dropout_1 (Dropout)	(None, 32, 32, 128)	0
flatten (Flatten)	(None, 131072)	0
dense (Dense)	(None, 256)	33,554,688
batch_normalization_3 (BatchNormalization)	(None, 256)	1,024
dropout_2 (Dropout)	(None, 256)	0
dense_1 (Dense)	(None, 6)	1,542

```
Total params: 33,651,398 (128.37 MB)
Trainable params: 33,650,438 (128.37 MB)
Non-trainable params: 960 (3.75 KB)
```

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

```python
callbacks = [
    ModelCheckpoint("best_model.h5", save_best_only=True, monitor="val_accuracy", mode="max"),
    EarlyStopping(monitor="val_loss", patience=5, restore_best_weights=True),
    ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=3, min_lr=1e-6)
]
history = model.fit(
    train_ds,
    validation_data=val_ds,
    epochs=30,
    batch_size=16,
    callbacks=callbacks
)
```

```
/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 constructor. `**kwargs` can include `workers`, `use_multiprocessing`, `max_queue_size`. Do not pass these
  self._warn_if_super_not_called()
Epoch 1/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 7s/step - accuracy: 0.1324 - loss: 4.1515WARNING: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 format, e.g. `model.save('m
3/3 ━━━━━━━━━━━━━━━━━━━━ 23s 8s/step - accuracy: 0.1549 - loss: 4.0361 - val_accuracy: 0.2778 - val_loss: 2.9270 - learning_rate: 0.0010
Epoch 2/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 6s/step - accuracy: 0.3944 - loss: 2.7233WARNING: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 format, e.g. `model.save('m
3/3 ━━━━━━━━━━━━━━━━━━━━ 20s 8s/step - accuracy: 0.4104 - loss: 2.7072 - val_accuracy: 0.3333 - val_loss: 2.9193 - learning_rate: 0.0010
Epoch 3/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 16s 7s/step - accuracy: 0.5132 - loss: 2.6731 - val_accuracy: 0.2222 - val_loss: 3.2767 - learning_rate: 0.0010
Epoch 4/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 16s 5s/step - accuracy: 0.4931 - loss: 2.6378 - val_accuracy: 0.2778 - val_loss: 4.7318 - learning_rate: 0.0010
Epoch 5/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 16s 7s/step - accuracy: 0.5465 - loss: 2.7442 - val_accuracy: 0.1667 - val_loss: 7.1288 - learning_rate: 0.0010
Epoch 6/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 16s 5s/step - accuracy: 0.5993 - loss: 2.6190 - val_accuracy: 0.1667 - val_loss: 9.5762 - learning_rate: 5.0000e-04
Epoch 7/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 16s 4s/step - accuracy: 0.5451 - loss: 2.5632 - val_accuracy: 0.1667 - val_loss: 11.0435 - learning_rate: 5.0000e-04
```

```python
test_datagen = ImageDataGenerator(rescale=1./255)
test_ds = test_datagen.flow_from_directory(
    test_dir,
    target_size=(img_height, img_width),
    batch_size=batch_size,
    class_mode='sparse',
    shuffle=False
)
test_loss, test_accuracy = model.evaluate(test_ds)
print(f"Test Accuracy: {test_accuracy * 100:.2f}%")
```

```
Found 30 images belonging to 6 classes.
1/1 ━━━━━━━━━━━━━━━━━━━━ 2s 2s/step - accuracy: 0.3333 - loss: 2.8726
Test Accuracy: 33.33%
```

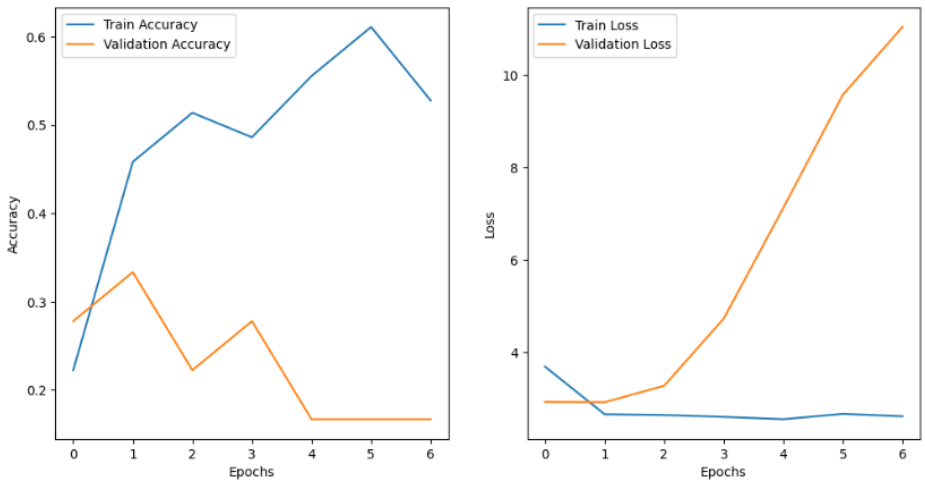
```python
model.save("final_model.h5")
loaded_model = tf.keras.models.load_model("final_model.h5")
```

```
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 format, e.g. `model.save('my_model.keras')` or `keras.saving.save_model(model, 'my_model.keras')
WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
```

```python
y_true = test_ds.classes
y_pred = np.argmax(loaded_model.predict(test_ds), axis=1)

print(classification_report(y_true, y_pred, target_names=class_names))
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 1s/step
              precision    recall  f1-score   support

        acai       0.00      0.00      0.00         5
     pupunha       0.25      1.00      0.40         5
     cupuacu       0.00      0.00      0.00         5
      tucuma       0.00      0.00      0.00         5
     guarana       0.62      1.00      0.77         5
    graviola       0.00      0.00      0.00         5

    accuracy                           0.33        30
   macro avg       0.15      0.33      0.19        30
weighted avg       0.15      0.33      0.19        30

/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

```
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.show()
```



TASK-2

```
[ ] base_model = MobileNetV2(input_shape=(img_height, img_width, 3), include_top=False, weights='imagenet')
    base_model.trainable = False
```

```
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
```

```
[ ] inputs = Input(shape=(img_height, img_width, 3))
    x = base_model(inputs, training=False)
    x = GlobalAveragePooling2D()(x)
    x = Dense(128, activation='relu')(x)
    x = Dropout(0.4)(x)
    outputs = Dense(num_classes, activation='softmax')(x)
    model = Model(inputs, outputs)

    model.summary()
```

Model: "functional_16"

Layer (type)	Output Shape	Param #
input_layer_2 (InputLayer)	(None, 128, 128, 3)	0
mobilenetv2_1.00_128 (Functional)	(None, 4, 4, 1280)	2,257,984
global_average_pooling2d (GlobalAveragePooling2D)	(None, 1280)	0
dense_2 (Dense)	(None, 128)	163,968
dropout_3 (Dropout)	(None, 128)	0
dense_3 (Dense)	(None, 6)	774

Total params: 2,422,726 (9.24 MB)
Trainable params: 164,742 (643.52 KB)
Non-trainable params: 2,257,984 (8.61 MB)

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

```
callbacks = [
    ModelCheckpoint("best_model_t1.h5", save_best_only=True, monitor="val_accuracy", mode="max"),
    EarlyStopping(monitor="val_loss", patience=5, restore_best_weights=True),
    ReduceLROnPlateau(monitor='val_loss', factor=0.5, patience=3, min_lr=1e-6)
]

# Train the model (only top layers)
history = model.fit(
    train_ds,
    validation_data=val_ds,
    epochs=30,
    callbacks=callbacks
)
```

```
Epoch 1/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 648ms/step - accuracy: 0.2657 - loss: 2.3201WARNING: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 format, e.g. `model.sav
3/3 ━━━━━━━━━━━━━━━━━━━━ 12s 2s/step - accuracy: 0.2549 - loss: 2.3198 - val_accuracy: 0.2222 - val_loss: 1.9954 - learning_rate: 0.0010
Epoch 2/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 666ms/step - accuracy: 0.4155 - loss: 1.6917WARNING: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 format, e.g. `model.sav
3/3 ━━━━━━━━━━━━━━━━━━━━ 6s 2s/step - accuracy: 0.4123 - loss: 1.7130 - val_accuracy: 0.4444 - val_loss: 1.4282 - learning_rate: 0.0010
Epoch 3/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 378ms/step - accuracy: 0.3944 - loss: 1.4936WARNING: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 format, e.g. `model.sav
3/3 ━━━━━━━━━━━━━━━━━━━━ 3s 686ms/step - accuracy: 0.4104 - loss: 1.4563 - val_accuracy: 0.5556 - val_loss: 1.2327 - learning_rate: 0.0010
Epoch 4/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 408ms/step - accuracy: 0.5286 - loss: 0.9507 - val_accuracy: 0.5000 - val_loss: 1.1580 - learning_rate: 0.0010
Epoch 5/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 568ms/step - accuracy: 0.7241 - loss: 0.7472WARNING: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 format, e.g. `model.sav
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 841ms/step - accuracy: 0.7236 - loss: 0.7553 - val_accuracy: 0.7222 - val_loss: 0.9767 - learning_rate: 0.0010
Epoch 6/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 770ms/step - accuracy: 0.8531 - loss: 0.5173 - val_accuracy: 0.7222 - val_loss: 0.8294 - learning_rate: 0.0010
Epoch 7/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 3s 898ms/step - accuracy: 0.8345 - loss: 0.5103 - val_accuracy: 0.7222 - val_loss: 0.6791 - learning_rate: 0.0010
Epoch 8/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 0s 761ms/step - accuracy: 0.8657 - loss: 0.4015WARNING: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 format, e.g. `model.sav
3/3 ━━━━━━━━━━━━━━━━━━━━ 4s 1s/step - accuracy: 0.8611 - loss: 0.3997 - val_accuracy: 0.8333 - val_loss: 0.5864 - learning_rate: 0.0010
Epoch 9/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 717ms/step - accuracy: 0.8111 - loss: 0.4936 - val_accuracy: 0.7778 - val_loss: 0.5607 - learning_rate: 0.0010
Epoch 10/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 1s/step - accuracy: 0.9458 - loss: 0.2534 - val_accuracy: 0.7778 - val_loss: 0.5827 - learning_rate: 0.0010
Epoch 11/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 3s 937ms/step - accuracy: 0.9247 - loss: 0.2861 - val_accuracy: 0.8333 - val_loss: 0.6355 - learning_rate: 0.0010
Epoch 12/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 733ms/step - accuracy: 0.9333 - loss: 0.2065 - val_accuracy: 0.8333 - val_loss: 0.6742 - learning_rate: 0.0010
Epoch 13/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 2s 846ms/step - accuracy: 0.9582 - loss: 0.1814 - val_accuracy: 0.8333 - val_loss: 0.6596 - learning_rate: 5.0000e-04
Epoch 14/30
3/3 ━━━━━━━━━━━━━━━━━━━━ 3s 631ms/step - accuracy: 0.9596 - loss: 0.1938 - val_accuracy: 0.8333 - val_loss: 0.6277 - learning_rate: 5.0000e-04
```

```
test_loss, test_accuracy = model.evaluate(test_ds)
print(f"Test Accuracy: {test_accuracy * 100:.2f}%")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 673ms/step - accuracy: 0.9667 - loss: 0.3166
Test Accuracy: 96.67%
```

```
model.save("final_model_t1.h5")

loaded_model = tf.keras.models.load_model("final_model_t1.h5")
```

```
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 format, e.g. `model.save('my_model.keras')` or `keras.saving.save_model(model, 'my_model.keras'
WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
```

```
y_true = test_ds.classes
y_pred_probs = loaded_model.predict(test_ds)
y_pred = np.argmax(y_pred_probs, axis=1)

print("Inference Output: First 20 Samples:")
for i in range(20):
    true_label = class_names[int(y_true[i])]
    pred_label = class_names[int(y_pred[i])]
    print(f"{i+1}. True: {true_label} - Predicted: {pred_label}")
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 2s 2s/step
Inference Output: First 20 Samples:
1. True: acai - Predicted: acai
2. True: acai - Predicted: acai
3. True: acai - Predicted: acai
4. True: acai - Predicted: acai
5. True: acai - Predicted: acai
6. True: pupunha - Predicted: pupunha
7. True: pupunha - Predicted: pupunha
8. True: pupunha - Predicted: pupunha
9. True: pupunha - Predicted: pupunha
10. True: pupunha - Predicted: pupunha
11. True: cupuacu - Predicted: cupuacu
12. True: cupuacu - Predicted: cupuacu
13. True: cupuacu - Predicted: cupuacu
14. True: cupuacu - Predicted: cupuacu
15. True: cupuacu - Predicted: cupuacu
16. True: tucuma - Predicted: tucuma
17. True: tucuma - Predicted: tucuma
18. True: tucuma - Predicted: tucuma
19. True: tucuma - Predicted: tucuma
20. True: tucuma - Predicted: tucuma
```

```
print("Classification Report:")
print(classification_report(y_true, y_pred, target_names=class_names))
```

```
Classification Report:
              precision    recall  f1-score   support

        acai       1.00      1.00      1.00         5
    pupunha       1.00      1.00      1.00         5
    cupuacu       1.00      1.00      1.00         5
     tucuma       0.83      1.00      0.91         5
    guarana       1.00      1.00      1.00         5
   graviola       1.00      0.80      0.89         5
```

```
[ ]
print("Classification Report:")
print(classification_report(y_true, y_pred, target_names=class_names))
```

```
Classification Report:
              precision    recall  f1-score   support

        acai       1.00      1.00      1.00         5
     pupunha       1.00      1.00      1.00         5
     cupuacu       1.00      1.00      1.00         5
      tucuma       0.83      1.00      0.91         5
     guarana       1.00      1.00      1.00         5
    graviola       1.00      0.80      0.89         5

    accuracy                           0.97        30
   macro avg       0.97      0.97      0.97        30
weighted avg       0.97      0.97      0.97        30
```

```
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.show()
```

```
plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.xlabel('Epochs')
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plt.show()
```