Potato Leaf Dataset PlantVillage

Transfer Learning models (VGG19, GoogLeNet, ResNet50)

Inspiration taken from: https://www.kaggle.com/code/sakthimurugavel/potato-leaf-disease-classifier-review-ii-final/notebook

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

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

Import all the required dependencies

```
import os
import cv2
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import tensorflow as tf

from tensorflow.keras import models, layers
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.models import load_model, Model
from tensorflow.keras.applications.vgg19 import VGG19
from tensorflow.keras.applications.inception_v3 import InceptionV3
from tensorflow.keras.applications.resnet_v2 import ResNet50V2
from tensorflow.keras.utils import plot_model
```

Define the constants

```
BATCH_SIZE = 32
IMAGE_SIZE = 224
CHANNELS = 3
EPOCHS = 20
```

```
path = "/content/drive/MyDrive/Colab Notebooks/Dissertation/Code/PlantVillage"
```

Creating a copy...

```
ge_dataset_from_directory(path,
                                                  shuffle = True,
                                                  image_size = (IMAGE_SIZE, IMAGE_SIZE),
                                                  batch_size = BATCH_SIZE
)
```

```
Found 2152 files belonging to 3 classes.
```

```
class_names = dataset.class_names
class_names # 0 = early blight, 1 = late blight, 2 = healthy
```

```
['Potato___Early_blight', 'Potato___Late_blight', 'Potato___healthy']
```

```
def DatasetSize(path):
    number_of_images = {} #Dictionary
    for folder in os.listdir(path):
        number_of_images[folder] = len(os.listdir(os.path.join(path, folder)))
    return number_of_images

data_set = DatasetSize(path)
print(data_set)
```

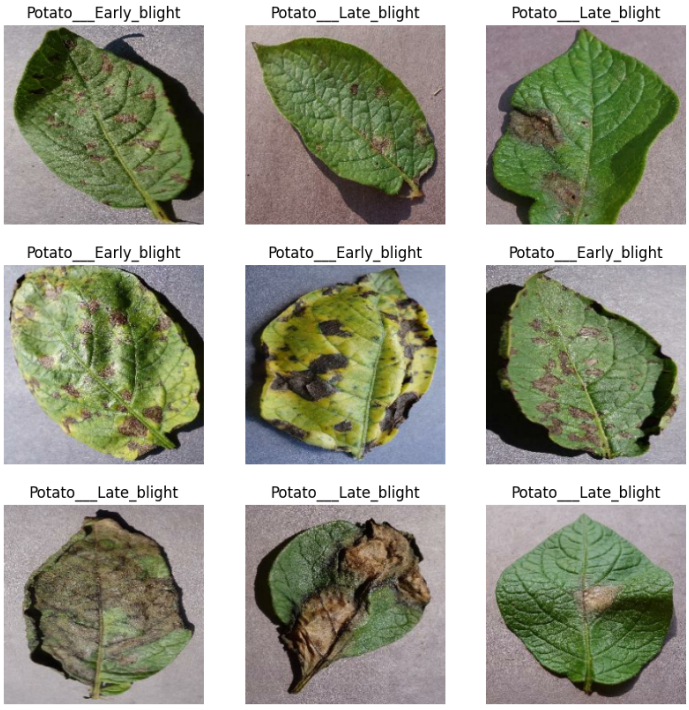
```
{'Potato___healthy': 152, 'Potato___Early_blight': 1000, 'Potato___Late_blight': 1000}
```

```
for image_batch, labels_batch in dataset.take(1):
    print(image_batch.shape)
    print(labels_batch.numpy())
```

```
(32, 224, 224, 3)
[0 1 0 1 0 1 0 1 0 0 0 1 0 0 2 0 0 1 1 1 1 1 0 0 1 0 2 2 0 0 0 1]
```

Visualise the images

```
plt.figure(figsize=(10, 10))
for image_batch, labels_batch in dataset.take(1):
    for i in range(9):
        ax = plt.subplot(3, 3, i+1)
        plt.imshow(image_batch[i].numpy().astype("uint8"))
        plt.title(class_names[labels_batch[i]])
        plt.axis("off")
```



Split the dataset

```
# Use split folders
#splitfolders --ratio .8 .1 .1 --
```

```
!pip install split-folders
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting split-folders
  Downloading split_folders-0.5.1-py3-none-any.whl (8.4 kB)
Installing collected packages: split-folders
Successfully installed split-folders-0.5.1
```

```
import splitfolders
splitfolders.ratio(path, output="output", seed=1337, ratio=(.8, 0.1,0.1))
```

```
Copying files: 2152 files [00:15, 142.54 files/s]
```

Data Preprocessing and Augmentation

```
train_datagen = ImageDataGenerator(
        rescale = 1./255,
        rotation_range = 10,
        horizontal_flip = True
)

train_generator = train_datagen.flow_from_directory("/content/drive/MyDrive/Colab Notebooks/Dissertation/Code/TransferLearning/output/tra
                                                    target_size = (IMAGE_SIZE, IMAGE_SIZE),
                                                    batch_size = 32,
                                                    class_mode = "sparse")
```

```
Found 1721 images belonging to 3 classes.
```

```
train_generator.class_indices
```

```
{'Potato___Early_blight': 0, 'Potato___Late_blight': 1, 'Potato___healthy': 2}
```

```
class_names = list(train_generator.class_indices.keys())
class_names
```

```
['Potato___Early_blight', 'Potato___Late_blight', 'Potato___healthy']
```

```
# Validation

validation_datagen = ImageDataGenerator(
        rescale = 1./255,
        rotation_range = 10,
        horizontal_flip = True
)

validation_generator = validation_datagen.flow_from_directory("/content/drive/MyDrive/Colab Notebooks/Dissertation/Code/TransferLearning/
                                                    target_size = (IMAGE_SIZE, IMAGE_SIZE),
                                                    batch_size = 32,
                                                    class_mode = "sparse")
```

```
Found 215 images belonging to 3 classes.
```

```
# Test

test_datagen = ImageDataGenerator(
        rescale = 1./255,
        rotation_range = 10,
        horizontal_flip = True
)

test_generator = test_datagen.flow_from_directory("/content/drive/MyDrive/Colab Notebooks/Dissertation/Code/TransferLearning/output/test"
                                                    target_size = (IMAGE_SIZE, IMAGE_SIZE),
                                                    batch_size = 32,
                                                    class_mode = "sparse")
```



```
Found 216 images belonging to 3 classes.
```

VGG19

```
input_shape = (BATCH_SIZE, IMAGE_SIZE, IMAGE_SIZE, CHANNELS)
n_classes = 3

def create_model():
    model = models.Sequential()
    model.add(VGG19(include_top = False, weights = 'imagenet', input_shape = (IMAGE_SIZE, IMAGE_SIZE, CHANNELS)))
    model.add(layers.GlobalAveragePooling2D())
    model.add(layers.Flatten())
    model.add(layers.Dense(256, activation = 'relu'))
    model.add(layers.Dropout(0.3))
    model.add(layers.Dense(n_classes, activation='softmax'))

    return model


vgg19_with_aug_model = create_model()
vgg19_with_aug_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kernels_n
80134624/80134624 [==============================] - 1s 0us/step
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
```

```
=================================================================
 vgg19 (Functional)          (None, 7, 7, 512)         20024384

 global_average_pooling2d (G  (None, 512)              0
 lobalAveragePooling2D)

 flatten (Flatten)           (None, 512)               0

 dense (Dense)               (None, 256)               131328

 dropout (Dropout)           (None, 256)               0

 dense_1 (Dense)             (None, 3)                 771

=================================================================
Total params: 20,156,483
Trainable params: 20,156,483
Non-trainable params: 0
_________________________________________________________________
```

Compiling the model and determining the accuracy

```
vgg19_with_aug_model.compile(
                            optimizer=tf.keras.optimizers.Adam(learning_rate=1e-4),
                            loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=False),
                            metrics=['accuracy'])


vgg19_with_aug_history = vgg19_with_aug_model.fit(
    train_generator,
    steps_per_epoch=54,
    batch_size=32,
    validation_data=validation_generator,
    validation_steps=7,
    verbose=1,
    epochs=EPOCHS,
)
```

```
Epoch 1/20
54/54 [==============================] - 443s 8s/step - loss: 0.4212 - accuracy: 0.8367 - val_loss: 0.1704 - val_accuracy: 0.9395
Epoch 2/20
54/54 [==============================] - 25s 455ms/step - loss: 0.4070 - accuracy: 0.8664 - val_loss: 0.1985 - val_accuracy: 0.9023
Epoch 3/20
54/54 [==============================] - 25s 455ms/step - loss: 0.1314 - accuracy: 0.9535 - val_loss: 0.1201 - val_accuracy: 0.9442
Epoch 4/20
54/54 [==============================] - 25s 453ms/step - loss: 0.1130 - accuracy: 0.9692 - val_loss: 0.0777 - val_accuracy: 0.9767
Epoch 5/20
54/54 [==============================] - 25s 457ms/step - loss: 0.0671 - accuracy: 0.9791 - val_loss: 0.1498 - val_accuracy: 0.9535
Creating a copy...
======] - 25s 455ms/step - loss: 0.0789 - accuracy: 0.9739 - val_loss: 0.0681 - val_accuracy: 0.9767
54/54 [==============================] - 25s 455ms/step - loss: 0.0514 - accuracy: 0.9791 - val_loss: 0.0623 - val_accuracy: 0.9767
Epoch 8/20
54/54 [==============================] - 25s 460ms/step - loss: 0.0126 - accuracy: 0.9965 - val_loss: 0.0376 - val_accuracy: 0.9814
Epoch 9/20
54/54 [==============================] - 25s 457ms/step - loss: 0.0135 - accuracy: 0.9965 - val_loss: 0.2553 - val_accuracy: 0.9395
Epoch 10/20
54/54 [==============================] - 25s 453ms/step - loss: 0.0495 - accuracy: 0.9820 - val_loss: 0.1676 - val_accuracy: 0.9395
Epoch 11/20
54/54 [==============================] - 25s 452ms/step - loss: 0.0263 - accuracy: 0.9930 - val_loss: 0.0239 - val_accuracy: 0.9953
Epoch 12/20
54/54 [==============================] - 25s 452ms/step - loss: 0.0027 - accuracy: 0.9988 - val_loss: 0.0458 - val_accuracy: 0.9907
Epoch 13/20
54/54 [==============================] - 24s 451ms/step - loss: 6.0051e-04 - accuracy: 1.0000 - val_loss: 0.0299 - val_accuracy: 0.
Epoch 14/20
54/54 [==============================] - 25s 455ms/step - loss: 0.0735 - accuracy: 0.9756 - val_loss: 0.0350 - val_accuracy: 0.9860
Epoch 15/20
54/54 [==============================] - 25s 456ms/step - loss: 0.0297 - accuracy: 0.9907 - val_loss: 0.0855 - val_accuracy: 0.9721
Epoch 16/20
54/54 [==============================] - 25s 456ms/step - loss: 0.0092 - accuracy: 0.9983 - val_loss: 0.0085 - val_accuracy: 0.9953
Epoch 17/20
54/54 [==============================] - 25s 454ms/step - loss: 0.0022 - accuracy: 0.9994 - val_loss: 0.0131 - val_accuracy: 0.9953
Epoch 18/20
54/54 [==============================] - 25s 456ms/step - loss: 0.0105 - accuracy: 0.9988 - val_loss: 0.0010 - val_accuracy: 1.0000
Epoch 19/20
54/54 [==============================] - 25s 454ms/step - loss: 0.0148 - accuracy: 0.9948 - val_loss: 0.0678 - val_accuracy: 0.9767
Epoch 20/20
54/54 [==============================] - 25s 460ms/step - loss: 0.0072 - accuracy: 0.9977 - val_loss: 0.0595 - val_accuracy: 0.9814
```

Producing the test accuracy and test loss

```
vgg19_with_aug_scores = vgg19_with_aug_model.evaluate(test_generator)
vgg19_with_aug_test_acc = vgg19_with_aug_scores[1]*100
vgg19_with_aug_test_loss = vgg19_with_aug_scores[0]
print("Test Loss: ", vgg19_with_aug_test_loss)
print("Test Accuracy: ", vgg19_with_aug_test_acc)
```

```
7/7 [==============================] - 64s 11s/step - loss: 0.0498 - accuracy: 0.9815
Test Loss:  0.04982779547572136
Test Accuracy:  98.14814925193787
```

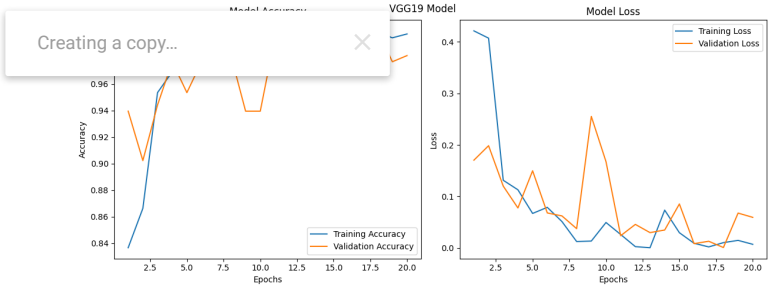
VGG19 plot for accuracy vs loss

```
vgg19_with_aug_history
```

```
<keras.callbacks.History at 0x7fe584b8cd60>
```

```
vgg19_with_aug_acc = vgg19_with_aug_history.history['accuracy']
vgg19_with_aug_val_acc = vgg19_with_aug_history.history['val_accuracy']

vgg19_with_aug_loss = vgg19_with_aug_history.history['loss']
vgg19_with_aug_val_loss = vgg19_with_aug_history.history['val_loss']

n = range(1, EPOCHS+1)
```

```
plt.figure(figsize=(12,5))
plt.subplot(1,2,1)
plt.plot(n, vgg19_with_aug_acc, label='Training Accuracy')
plt.plot(n, vgg19_with_aug_val_acc, label='Validation Accuracy')
plt.legend(loc='best')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Model Accuracy')

plt.subplot(1,2,2)
plt.plot(n, vgg19_with_aug_loss, label='Training Loss')
plt.plot(n, vgg19_with_aug_val_loss, label='Validation Loss')
plt.legend(loc='best')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Model Loss')
plt.tight_layout()
plt.suptitle('VGG19 Model')
plt.savefig("plot_vgg19.png")
plt.show()
```

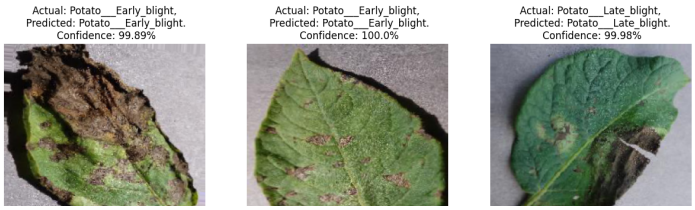


Prediction of images using VGG19

```
def predict(model, img):
    img_array = tf.keras.preprocessing.image.img_to_array(images[i])
    img_array = tf.expand_dims(img_array, 0)
```

```
    predictions = model.predict(img_array)

    predicted_class = class_names[np.argmax(predictions[0])]
    confidence = round(100 * (np.max(predictions[0])), 2)
    return predicted_class, confidence


plt.figure(figsize=(15, 15))
for images, labels in test_generator:
    for i in range(9):
        ax = plt.subplot(3, 3, i + 1)
        plt.imshow(images[i])

        predicted_class, confidence = predict(vgg19_with_aug_model, images[i])
        actual_class = class_names[int(labels[i])]

        plt.title(f"Actual: {actual_class},\n Predicted: {predicted_class}.\n Confidence: {confidence}%")

        plt.axis("off")
    break

plt.savefig("VGG19_prediction images")
plt.show()
```

```
1/1 [==============================] - 0s 479ms/step
1/1 [==============================] - 0s 21ms/step
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 19ms/step
1/1 [==============================] - 0s 22ms/step
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 21ms/step
1/1 [==============================] - 0s 19ms/step
1/1 [==============================] - 0s 18ms/step
```



GoogLeNet (InceptionV3)


```
input_shape = (BATCH_SIZE, IMAGE_SIZE, IMAGE_SIZE, CHANNELS)
n_classes = 3

def create_model():
    model = models.Sequential()
    model.add(InceptionV3(include_top = False, weights = 'imagenet', input_shape = (IMAGE_SIZE, IMAGE_SIZE, CHANNELS)))
    model.add(layers.GlobalAveragePooling2D())
    model.add(layers.Flatten())
    model.add(layers.Dense(256, activation = 'relu'))
    model.add(layers.Dropout(0.3))
    model.add(layers.Dense(n_classes, activation='softmax'))

    return model
```

```
inceptionv3_with_aug_model = create_model()
inceptionv3_with_aug_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_orderin
87910968/87910968 [==============================] - 0s 0us/step
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 inception_v3 (Functional)   (None, 5, 5, 2048)        21802784

 global_average_pooling2d_1   (None, 2048)             0
 (GlobalAveragePooling2D)

                             one, 2048)              0

                             one, 256)               524544

 dropout_1 (Dropout)         (None, 256)               0

 dense_3 (Dense)             (None, 3)                 771

=================================================================
Total params: 22,328,099
Trainable params: 22,293,667
Non-trainable params: 34,432
_________________________________________________________________
```

Creating a copy...

Compiling the model and determining the accuracy

```
inceptionv3_with_aug_model.compile(
                           optimizer=tf.keras.optimizers.Adam(learning_rate=1e-4),
                           loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=False),
                           metrics=['accuracy'])


inceptionv3_with_aug_history = inceptionv3_with_aug_model.fit(train_generator,
                                              steps_per_epoch=54,
                                              batch_size=32,
                                              validation_data=validation_generator,
                                               validation_steps = 7,
                                               verbose=1,
                                               epochs=EPOCHS)
```

```
Epoch 1/20
54/54 [==============================] - 65s 512ms/step - loss: 0.2415 - accuracy: 0.9030 - val_loss: 0.2436 - val_accuracy: 0.9209
```

```
Epoch 2/20
54/54 [==============================] - 25s 457ms/step - loss: 0.0609 - accuracy: 0.9797 - val_loss: 0.0356 - val_accuracy: 0.9907
Epoch 3/20
54/54 [==============================] - 25s 454ms/step - loss: 0.0207 - accuracy: 0.9948 - val_loss: 0.0177 - val_accuracy: 0.9907
Epoch 4/20
54/54 [==============================] - 24s 449ms/step - loss: 0.0221 - accuracy: 0.9959 - val_loss: 0.0453 - val_accuracy: 0.9907
Epoch 5/20
54/54 [==============================] - 24s 447ms/step - loss: 0.0113 - accuracy: 0.9971 - val_loss: 0.0033 - val_accuracy: 1.0000
Epoch 6/20
54/54 [==============================] - 24s 449ms/step - loss: 0.0045 - accuracy: 0.9988 - val_loss: 0.0107 - val_accuracy: 0.9953
Epoch 7/20
54/54 [==============================] - 24s 448ms/step - loss: 0.0115 - accuracy: 0.9965 - val_loss: 0.0062 - val_accuracy: 0.9953
Epoch 8/20
54/54 [==============================] - 25s 456ms/step - loss: 0.0243 - accuracy: 0.9936 - val_loss: 0.0023 - val_accuracy: 1.0000
Epoch 9/20
54/54 [==============================] - 24s 451ms/step - loss: 0.0091 - accuracy: 0.9965 - val_loss: 0.0113 - val_accuracy: 0.9907
Epoch 10/20
54/54 [==============================] - 24s 445ms/step - loss: 0.0036 - accuracy: 0.9994 - val_loss: 0.0032 - val_accuracy: 1.0000
Epoch 11/20
54/54 [==============================] - 24s 449ms/step - loss: 0.0028 - accuracy: 0.9994 - val_loss: 7.7642e-04 - val_accuracy: 1.
Epoch 12/20
54/54 [==============================] - 24s 447ms/step - loss: 0.0084 - accuracy: 0.9977 - val_loss: 0.0011 - val_accuracy: 1.0000
Epoch 13/20
54/54 [==============================] - 24s 450ms/step - loss: 0.0137 - accuracy: 0.9971 - val_loss: 0.0020 - val_accuracy: 1.0000
Epoch 14/20
54/54 [==============================] - 24s 445ms/step - loss: 0.0078 - accuracy: 0.9977 - val_loss: 0.0012 - val_accuracy: 1.0000
Epoch 15/20
54/54 [==============================] - 24s 449ms/step - loss: 0.0029 - accuracy: 0.9994 - val_loss: 6.4993e-04 - val_accuracy: 1.
Epoch 16/20
54/54 [==============================] - 24s 440ms/step - loss: 0.0011 - accuracy: 0.9994 - val_loss: 0.0228 - val_accuracy: 0.9953
Epoch 17/20
54/54 [==============================] - 24s 445ms/step - loss: 0.0032 - accuracy: 0.9988 - val_loss: 0.0070 - val_accuracy: 0.9953
Epoch 18/20
54/54 [==============================] - 24s 445ms/step - loss: 0.0015 - accuracy: 0.9994 - val_loss: 3.2696e-04 - val_accuracy: 1.
Epoch 19/20
54/54 [==============================] - 24s 446ms/step - loss: 7.4828e-04 - accuracy: 1.0000 - val_loss: 0.0036 - val_accuracy: 1.
Epoch 20/20
54/54 [==============================] - 24s 446ms/step - loss: 6.5330e-04 - accuracy: 1.0000 - val_loss: 3.2091e-04 - val_accuracy
```

Producing the test accuracy and test loss

```
inceptionv3_with_aug_scores = inceptionv3_with_aug_model.evaluate(test_generator)
inceptionv3_with_aug_test_acc = inceptionv3_with_aug_scores[1]*100
inceptionv3_with_aug_test_loss = inceptionv3_with_aug_scores[0]
print("Test Loss: ", inceptionv3_with_aug_test_loss)
print("Test Accuracy: ", inceptionv3_with_aug_test_acc)
```

```
7/7 [==============================] - 3s 472ms/step - loss: 0.0367 - accuracy: 0.9954
Test Loss:  0.0367109440267086
Test Accuracy:  99.53488349914551
```

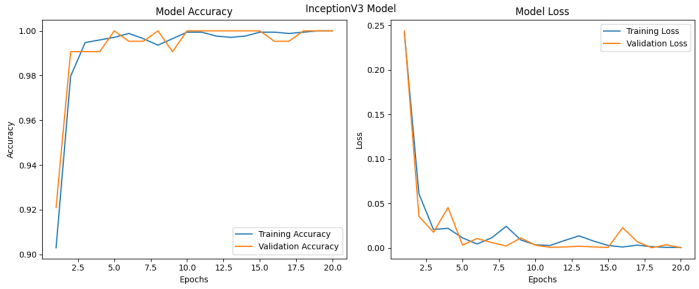

InceptionV3 plot for accuracy vs loss

```
inceptionv3_with_aug_history
```

```
<keras.callbacks.History at 0x7fe4e0f76260>
```

```
inceptionv3_with_aug_acc = inceptionv3_with_aug_history.history['accuracy']
inceptionv3_with_aug_val_acc = inceptionv3_with_aug_history.history['val_accuracy']

inceptionv3_with_aug_loss = inceptionv3_with_aug_history.history['loss']
inceptionv3_with_aug_val_loss = inceptionv3_with_aug_history.history['val_loss']

n = range(1, EPOCHS+1)


plt.figure(figsize=(12,5))
plt.subplot(1,2,1)
plt.plot(n, inceptionv3_with_aug_acc, label='Training Accuracy')
plt.plot(n, inceptionv3_with_aug_val_acc, label='Validation Accuracy')
plt.legend(loc='best')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Model Accuracy')

plt.subplot(1,2,2)
plt.plot(n, inceptionv3_with_aug_loss, label='Training Loss')
plt.plot(n, inceptionv3_with_aug_val_loss, label='Validation Loss')
plt.legend(loc='best')
plt.xlabel('Epochs')
```

```
plt.ylabel('Loss')
plt.title('Model Loss')
plt.tight_layout()
plt.suptitle('InceptionV3 Model')
plt.savefig("plot_inceptionv3.png")
plt.show()
```



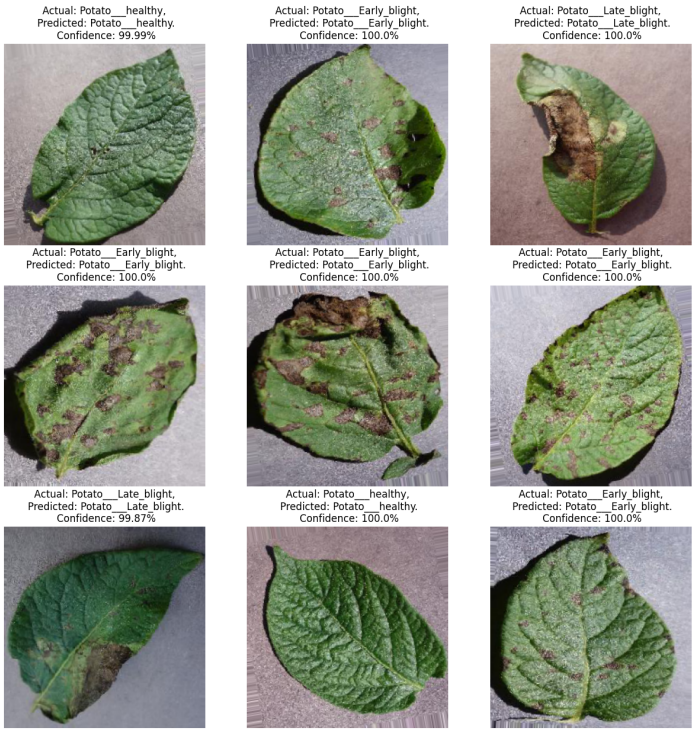
Prediction of images using InceptionV3

```
def predict(model, img):
    img_array = tf.keras.preprocessing.image.img_to_array(images[i])
    img_array = tf.expand_dims(img_array, 0)

    predictions = model.predict(img_array)

    predicted_class = class_names[np.argmax(predictions[0])]
    confidence = round(100 * (np.max(predictions[0])), 2)
    return predicted_class, confidence
```

Creating a copy...

```
    for i in range(9):
        ax = plt.subplot(3, 3, i + 1)
        plt.imshow(images[i])

        predicted_class, confidence = predict(inceptionv3_with_aug_model, images[i])
        actual_class = class_names[int(labels[i])]

        plt.title(f"Actual: {actual_class},\n Predicted: {predicted_class}.\n Confidence: {confidence}%")

        plt.axis("off")
    break

plt.savefig("InceptionV3_prediction images")
```

```
1/1 [==============================] - 2s 2s/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 29ms/step
```



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ResNet50

```
input_shape = (BATCH_SIZE, IMAGE_SIZE, IMAGE_SIZE, CHANNELS)
n_classes = 3

def create_model():
    model = models.Sequential()
    model.add(ResNet50V2(include_top = False, weights = 'imagenet', input_shape = (IMAGE_SIZE, IMAGE_SIZE, CHANNELS)))
    model.add(layers.GlobalAveragePooling2D())
    model.add(layers.Flatten())
    model.add(layers.Dense(256, activation = 'relu'))
    model.add(layers.Dropout(0.3))
    model.add(layers.Dense(n_classes, activation='softmax'))

    return model
```

```
resnet50_with_aug_model = create_model()
resnet50_with_aug_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50v2_weights_tf_dim_ordering_tf_ker
94668760/94668760 [==============================] - 0s 0us/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 resnet50v2 (Functional)     (None, 7, 7, 2048)        23564800

 global_average_pooling2d_2   (None, 2048)            0
 (GlobalAveragePooling2D)

 flatten_2 (Flatten)         (None, 2048)              0

 dense_4 (Dense)             (None, 256)               524544

 dropout_2 (Dropout)         (None, 256)               0

 dense_5 (Dense)             (None, 3)                 771

=================================================================
Total params: 24,090,115
Trainable params: 24,044,675
Non-trainable params: 45,440
_________________________________________________________________
```

Compiling the model and determining the accuracy

```
resnet50_with_aug_model.compile(
                          optimizer=tf.keras.optimizers.Adam(learning_rate=1e-4),
                          loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=False),
                          metrics=['accuracy'])


resnet50_with_aug_history = resnet50_with_aug_model.fit(train_generator,
                                                steps_per_epoch=54,
                                                batch_size=32,
                                                validation_data=validation_generator,
                                                 validation_steps = 7,
                                                 verbose=1,
                                                 epochs=EPOCHS)
```

```
Epoch 1/20
54/54 [==============================] - 58s 487ms/step - loss: 0.2174 - accuracy: 0.9227 - val_loss: 0.1925 - val_accuracy: 0.9256
Epoch 2/20
54/54 [==============================] - 24s 447ms/step - loss: 0.0387 - accuracy: 0.9872 - val_loss: 0.0306 - val_accuracy: 0.9860
```

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```
54/54 [==============================] - 24s 449ms/step - loss: 0.0196 - accuracy: 0.9959 - val_loss: 0.0422 - val_accuracy: 0.9860
54/54 [==============================] - 24s 447ms/step - loss: 0.0237 - accuracy: 0.9913 - val_loss: 0.0102 - val_accuracy: 1.0000
Epoch 5/20
54/54 [==============================] - 24s 449ms/step - loss: 0.0103 - accuracy: 0.9971 - val_loss: 0.0103 - val_accuracy: 0.9953
Epoch 6/20
54/54 [==============================] - 24s 446ms/step - loss: 0.0130 - accuracy: 0.9948 - val_loss: 0.0174 - val_accuracy: 0.9907
Epoch 7/20
54/54 [==============================] - 24s 450ms/step - loss: 0.0125 - accuracy: 0.9965 - val_loss: 0.0085 - val_accuracy: 0.9953
Epoch 8/20
54/54 [==============================] - 24s 442ms/step - loss: 0.0166 - accuracy: 0.9930 - val_loss: 0.0221 - val_accuracy: 0.9907
Epoch 9/20
54/54 [==============================] - 24s 444ms/step - loss: 0.0108 - accuracy: 0.9959 - val_loss: 0.0466 - val_accuracy: 0.9814
Epoch 10/20
54/54 [==============================] - 25s 456ms/step - loss: 0.0142 - accuracy: 0.9971 - val_loss: 0.0180 - val_accuracy: 0.9907
Epoch 11/20
54/54 [==============================] - 24s 450ms/step - loss: 0.0055 - accuracy: 0.9983 - val_loss: 0.0292 - val_accuracy: 0.9860
Epoch 12/20
54/54 [==============================] - 24s 448ms/step - loss: 0.0032 - accuracy: 0.9988 - val_loss: 0.0013 - val_accuracy: 1.0000
Epoch 13/20
54/54 [==============================] - 24s 448ms/step - loss: 0.0011 - accuracy: 1.0000 - val_loss: 0.0149 - val_accuracy: 0.9907
Epoch 14/20
54/54 [==============================] - 24s 444ms/step - loss: 0.0031 - accuracy: 0.9983 - val_loss: 0.0141 - val_accuracy: 0.9953
Epoch 15/20
54/54 [==============================] - 24s 447ms/step - loss: 0.0080 - accuracy: 0.9959 - val_loss: 0.0235 - val_accuracy: 0.9953
Epoch 16/20
54/54 [==============================] - 24s 446ms/step - loss: 0.0090 - accuracy: 0.9971 - val_loss: 0.0866 - val_accuracy: 0.9953
Epoch 17/20
54/54 [==============================] - 24s 448ms/step - loss: 0.0030 - accuracy: 0.9988 - val_loss: 0.0068 - val_accuracy: 0.9953
Epoch 18/20
54/54 [==============================] - 24s 448ms/step - loss: 0.0061 - accuracy: 0.9971 - val_loss: 0.0970 - val_accuracy: 0.9860
Epoch 19/20
54/54 [==============================] - 24s 450ms/step - loss: 0.0038 - accuracy: 0.9988 - val_loss: 0.0432 - val_accuracy: 0.9907
Epoch 20/20
54/54 [==============================] - 24s 447ms/step - loss: 0.0020 - accuracy: 0.9988 - val_loss: 0.0342 - val_accuracy: 0.9953
```

Producing the test accuracy and test loss

```
resnet50_with_aug_scores = resnet50_with_aug_model.evaluate(test_generator)
resnet50_with_aug_test_acc = resnet50_with_aug_scores[1]*100
resnet50_with_aug_test_loss = resnet50_with_aug_scores[0]
print("Test Loss: ", resnet50_with_aug_test_loss)
print("Test Accuracy: ", resnet50_with_aug_test_acc)
```

```
7/7 [==============================] - 3s 432ms/step - loss: 0.0080 - accuracy: 0.9954
Test Loss:  0.007989414036273956
Test Accuracy:  99.53703880310059
```

ResNet50 plot for accuracy vs loss

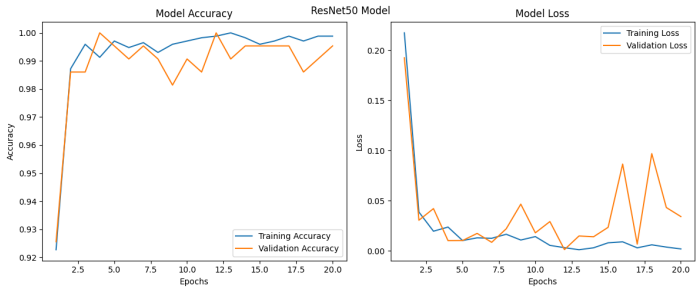
```
resnet50_with_aug_history
```

```
<keras.callbacks.History at 0x7fe483696770>
```

```
resnet50_with_aug_acc = resnet50_with_aug_history.history['accuracy']
resnet50_with_aug_val_acc = resnet50_with_aug_history.history['val_accuracy']

resnet50_with_aug_loss = resnet50_with_aug_history.history['loss']
resnet50_with_aug_val_loss = resnet50_with_aug_history.history['val_loss']

n = range(1, EPOCHS+1)


plt.figure(figsize=(12,5))
plt.subplot(1,2,1)
plt.plot(n, resnet50_with_aug_acc, label='Training Accuracy')
plt.plot(n, resnet50_with_aug_val_acc, label='Validation Accuracy')
plt.legend(loc='best')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Model Accuracy')

plt.subplot(1,2,2)
plt.plot(n, resnet50_with_aug_loss, label='Training Loss')
plt.plot(n, resnet50_with_aug_val_loss, label='Validation Loss')
plt.legend(loc='best')
plt.xlabel('Epochs')
plt.ylabel('Loss')
```



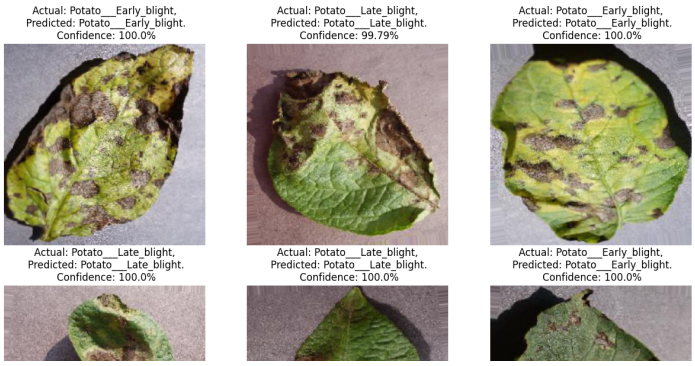
```
plt.savefig("plot_resnet50.png")
plt.show()
```



Prediction of images using ResNet50

```
def predict(model, img):
    img_array = tf.keras.preprocessing.image.img_to_array(images[i])
    img_array = tf.expand_dims(img_array, 0)

    predictions = model.predict(img_array)

    predicted_class = class_names[np.argmax(predictions[0])]
    confidence = round(100 * (np.max(predictions[0])), 2)
    return predicted_class, confidence


plt.figure(figsize=(15, 15))
for images, labels in test_generator:
    for i in range(9):
        ax = plt.subplot(3, 3, i + 1)
        plt.imshow(images[i])

        predicted_class, confidence = predict(resnet50_with_aug_model, images[i])
        actual_class = class_names[int(labels[i])]

        plt.title(f"Actual: {actual_class},\n Predicted: {predicted_class}.\n Confidence: {confidence}%")

        plt.axis("off")
    break

plt.savefig("ResNet50V2_prediction images")
```

```
1/1 [==============================] - 1s 1s/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 22ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 23ms/step
1/1 [==============================] - 0s 23ms/step
1/1 [==============================] - 0s 23ms/step
```



Compare the transfer learning models performances

Comparing the test accuracies

```
algorithms = ['VGG19', 'InceptionV3', 'ResNet50']
accuracy = [vgg19_with_aug_test_acc, inceptionv3_with_aug_test_acc, resnet50_with_aug_test_acc]
accuracy = np.around([i for i in accuracy], 3)
colours = ['red', 'green', 'blue']

fig = plt.figure(figsize=(15,15))

# Plotting the bar chart
bars = plt.bar(algorithms, accuracy, color=colours, width = 0.5)

plt.xlabel("Algorithms Used")
plt.ylabel("Testing Accuracy")
for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x(), yval+2, yval)

plt.title('Comparison of the test accuracies from the models used')
plt.tight_layout()
racies.png')
```

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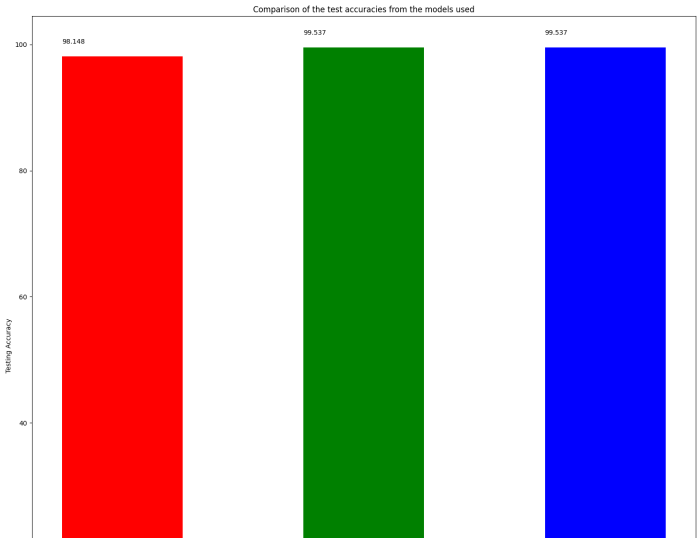

Comparing the test loss

```
algorithms = ['VGG19', 'InceptionV3', 'ResNet50']
loss = [vgg19_with_aug_test_loss, inceptionv3_with_aug_test_loss, resnet50_with_aug_test_loss]
loss = np.around([i for i in loss], 3)
colours = ['red', 'green', 'blue']

fig = plt.figure(figsize=(15,15))

# Plotting the bar chart
bars = plt.bar(algorithms, loss, color=colours, width = 0.5)

plt.xlabel("Algorithms Used")
plt.ylabel("Testing Loss")
for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x(), yval+0.00009, yval)

plt.title('Comparison of the test losses from the models used')
plt.tight_layout()
plt.savefig('comparison_of_test_losses.png')
plt.show()
```

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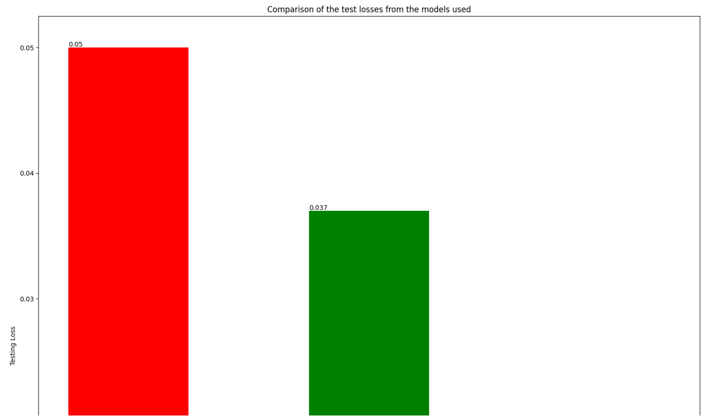


```
!jupyter nbconvert --to html PlantVillageTransferLearning.ipynb
```

```
[NbConvertApp] WARNING | pattern 'PlantVillageTransferLearning.ipynb' matched no files
This application is used to convert notebook files (*.ipynb)
        to various other formats.

        WARNING: THE COMMANDLINE INTERFACE MAY CHANGE IN FUTURE RELEASES.

Options
=======
The options below are convenience aliases to configurable class-options,
as listed in the "Equivalent to" description-line of the aliases.
To see all configurable class-options for some <cmd>, use:
    <cmd> --help-all

--debug
    set log level to logging.DEBUG (maximize logging output)
    Equivalent to: [--Application.log_level=10]
--show-config
    Show the application's configuration (human-readable format)
    Equivalent to: [--Application.show_config=True]
--show-config-json
    Show the application's configuration (json format)
    Equivalent to: [--Application.show_config_json=True]
--generate-config
    generate default config file
    Equivalent to: [--JupyterApp.generate_config=True]
-y
    Answer yes to any questions instead of prompting.
    Equivalent to: [--JupyterApp.answer_yes=True]
--execute
    Execute the notebook prior to export.
    Equivalent to: [--ExecutePreprocessor.enabled=True]
--allow-errors
                            even if one of the cells throws an error and include the error message in the cell output (the d
Creating a copy...          eprocessor.allow_errors=True]

    read a single notebook file from stdin. Write the resulting notebook with default basename 'notebook.*'
    Equivalent to: [--NbConvertApp.from_stdin=True]
--stdout
    Write notebook output to stdout instead of files.
    Equivalent to: [--NbConvertApp.writer_class=StdoutWriter]
--inplace
    Run nbconvert in place, overwriting the existing notebook (only
            relevant when converting to notebook format)
    Equivalent to: [--NbConvertApp.use_output_suffix=False --NbConvertApp.export_format=notebook --FilesWriter.build_directory=]
--clear-output
    Clear output of current file and save in place,
            overwriting the existing notebook.
    Equivalent to: [--NbConvertApp.use_output_suffix=False --NbConvertApp.export_format=notebook --FilesWriter.build_directory=
--no-prompt
    Exclude input and output prompts from converted document.
    Equivalent to: [--TemplateExporter.exclude_input_prompt=True --TemplateExporter.exclude_output_prompt=True]
--no-input
    Exclude input cells and output prompts from converted document.
            This mode is ideal for generating code-free reports.
    Equivalent to: [--TemplateExporter.exclude_output_prompt=True --TemplateExporter.exclude_input=True --TemplateExporter.exclu
--allow-chromium-download
    Whether to allow downloading chromium if no suitable version is found on the system.
```