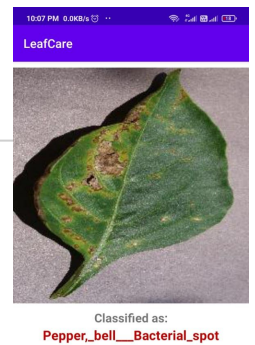


Development of a Deep Learning Model for Automated Detection and Diagnosis of Plant Diseases

In []:

```
1 import pandas as pd
2 import pathlib
3 import tensorflow as tf
4 import matplotlib.pyplot as plt
5 import numpy as np
6 import os
7 import PIL
8 import glob
9 from tensorflow import keras
10 from tensorflow.keras import layers
11 from tensorflow.keras.models import Sequential
12 from tensorflow.keras.preprocessing import image_dataset_from_directory
13 from tensorflow.keras.layers import Conv2D, MaxPooling2D, Activation, Flatten, Dense,
14 from tensorflow.keras.losses import SparseCategoricalCrossentropy
15 from tensorflow.keras.regularizers import l2
16 import os
17
18 %matplotlib inline
19 from glob import glob
20 import seaborn as sns
21 from PIL import Image
22 np.random.seed(11)
23 from sklearn.preprocessing import StandardScaler
24 from sklearn.model_selection import train_test_split, KFold, cross_val_score, GridSearchCV
25 from sklearn.metrics import accuracy_score
26 import itertools
27
28 import keras
29 from keras.utils.np_utils import to_categorical
30 from keras.models import Sequential, Model
31 from keras.layers import Dense, Dropout, Flatten, Conv2D, MaxPool2D
32 from keras import backend as K
33 from tensorflow.keras.layers import BatchNormalization
34 from tensorflow.keras.optimizers import Adam, RMSprop
35 from keras.preprocessing.image import ImageDataGenerator
36 from keras.callbacks import ReduceLROnPlateau
37 from keras.wrappers.scikit_learn import KerasClassifier
38 from keras.applications.inception_v3 import InceptionV3
39 from keras import backend as K
40 import random
41 import urllib.request
42 import matplotlib.image as mpimg
43
44 from skimage.filters import rank, threshold_otsu
45 from skimage import io
46 from skimage.color import rgb2gray
47 from sklearn.cluster import KMeans
48 from skimage.morphology import closing, square, disk
```



Loading Data

In [2]:

```
1 data_dir = pathlib.Path("../input/plantvillage-dataset/color")
2 train='../input/plantvillage-dataset/color'
```

In [3]:

```
1 dataset_path_train = os.listdir(data_dir)
2 print(dataset_path_train)
3 print("Types of classes labels found: ", len(dataset_path_train))
```

```
['Tomato__Late_blight', 'Tomato__healthy', 'Grape__healthy', 'Orange__
Haunglongbing_(Citrus_greening)', 'Soybean__healthy', 'Squash__Powdery_m
ildew', 'Potato__healthy', 'Corn_(maize)__Northern_Leaf_Blight', 'Tomato
__Early_blight', 'Tomato__Septoria_leaf_spot', 'Corn_(maize)__Cercospor
a_leaf_spot Gray_leaf_spot', 'Strawberry__Leaf_scorch', 'Peach__health
y', 'Apple__Apple_scab', 'Tomato__Tomato_Yellow_Leaf_Curl_Virus', 'Tomat
o__Bacterial_spot', 'Apple__Black_rot', 'Blueberry__healthy', 'Cherry_
(including_sour)__Powdery_mildew', 'Peach__Bacterial_spot', 'Apple__Ced
ar_apple_rust', 'Tomato__Target_Spot', 'Pepper,_bell__healthy', 'Grape__
_Leaf_blight_(Isariopsis_Leaf_Spot)', 'Potato__Late_blight', 'Tomato__To
mato_mosaic_virus', 'Strawberry__healthy', 'Apple__healthy', 'Grape__Bl
ack_rot', 'Potato__Early_blight', 'Cherry_(including_sour)__healthy', 'C
orn_(maize)__Common_rust_', 'Grape__Esca_(Black_Measles)', 'Raspberry__
healthy', 'Tomato__Leaf_Mold', 'Tomato__Spider_mites Two-spotted_spider_
mite', 'Pepper,_bell__Bacterial_spot', 'Corn_(maize)__healthy']
Types of classes labels found: 38
```

In [4]:

```
1 image_count_train = len(list(data_dir.glob('*/*.JPG')))
2 print("The number of Train data:", image_count_train)
```

The number of Train data: 52803

In [5]:

```
1 # This Parameter we can use it in the network and model
2 batch_size = 32
3 img_height = 224
4 img_width = 224
```

In [6]:

```
1 #train data set
2 train_ds = image_dataset_from_directory(data_dir,
3                                         seed = 123,
4                                         image_size=(img_height, img_width),
5                                         validation_split=0.2,
6                                         subset='training')
```

Found 54305 files belonging to 38 classes.
Using 43444 files for training.

In [7]:

```
1 #validate data
2 val_ds = image_dataset_from_directory(data_dir,
3                                     seed = 123,
4                                     image_size=(img_height, img_width),
5                                     validation_split=0.2,
6                                     subset='validation')
```

Found 54305 files belonging to 38 classes.
Using 10861 files for validation.

In [8]:

```
1 # test data
2 test = image_dataset_from_directory(data_dir,
3                                     seed = 123,
4                                     image_size=(img_height, img_width),
5                                     validation_split=None)
```

Found 54305 files belonging to 38 classes.

In [9]:

```
1 # Here We give the name of the data the we found the Benign dataset and malignant
2 class_names = train_ds.class_names
3 print(len(class_names))
4 print(class_names)
5
```

```
38
['Apple__Apple_scab', 'Apple__Black_rot', 'Apple__Cedar_apple_rust', 'A
pple__healthy', 'Blueberry__healthy', 'Cherry_(including_sour)__Powdery
_mildew', 'Cherry_(including_sour)__healthy', 'Corn_(maize)__Cercospora_
leaf_spot Gray_leaf_spot', 'Corn_(maize)__Common_rust_', 'Corn_(maize)__
Northern_Leaf_Blight', 'Corn_(maize)__healthy', 'Grape__Black_rot', 'Gra
pe__Esca_(Black_Measles)', 'Grape__Leaf_blight_(Isariopsis_Leaf_Spot)',
'Grape__healthy', 'Orange__Haunglongbing_(Citrus_greening)', 'Peach__Ba
cterial_spot', 'Peach__healthy', 'Pepper_bell__Bacterial_spot', 'Peppe
r_bell__healthy', 'Potato__Early_blight', 'Potato__Late_blight', 'Pota
to__healthy', 'Raspberry__healthy', 'Soybean__healthy', 'Squash__Powde
ry_mildew', 'Strawberry__Leaf_scorch', 'Strawberry__healthy', 'Tomato__
Bacterial_spot', 'Tomato__Early_blight', 'Tomato__Late_blight', 'Tomato_
__Leaf_Mold', 'Tomato__Septoria_leaf_spot', 'Tomato__Spider_mites Two-sp
otted_spider_mite', 'Tomato__Target_Spot', 'Tomato__Tomato_Yellow_Leaf_C
url_Virus', 'Tomato__Tomato_mosaic_virus', 'Tomato__healthy']
```

In [10]:

```
1 for image_batch, labels_batch in train_ds.take(1):
2     print(image_batch.shape)
3     print(labels_batch.shape)
```

```
(32, 224, 224, 3)
(32,)
```

Creat Model

In [11]:

```
1 num_classes = 38
2
3 model = Sequential()
4 model.add(layers.experimental.preprocessing.Rescaling(1./255, input_shape=(img_height, img_width)))
5 model.add(Conv2D(16, 3, padding='same'))
6 model.add(Activation('relu'))
7 model.add(MaxPooling2D())
8
9 model.add(Conv2D(32, 3, padding='same'))
10 model.add(Activation('relu'))
11 model.add(MaxPooling2D())
12
13 model.add(Conv2D(64, 3, padding='same'))
14 model.add(Activation('relu'))
15 model.add(MaxPooling2D())
16 model.add(Dropout(0.15))
17
18 model.add(Flatten())
19 model.add(Dense(128))
20 model.add(Activation('Softmax'))
21 model.add(Dense(num_classes))
```

In [12]:

```
1 # Compile the model
2 model.compile(optimizer='adam',
3               loss=SparseCategoricalCrossentropy(from_logits=True),
4               metrics=['accuracy'])
```

In [13]:

```
1 model.summary()
```

Model: "sequential"

| Layer (type) | Output Shape | Param # |
|--------------------------------|----------------------|---------|
| ===== | ===== | ===== |
| rescaling (Rescaling) | (None, 224, 224, 3) | 0 |
| conv2d (Conv2D) | (None, 224, 224, 16) | 448 |
| activation (Activation) | (None, 224, 224, 16) | 0 |
| max_pooling2d (MaxPooling2D) | (None, 112, 112, 16) | 0 |
| conv2d_1 (Conv2D) | (None, 112, 112, 32) | 4640 |
| activation_1 (Activation) | (None, 112, 112, 32) | 0 |
| max_pooling2d_1 (MaxPooling2D) | (None, 56, 56, 32) | 0 |
| conv2d_2 (Conv2D) | (None, 56, 56, 64) | 18496 |
| activation_2 (Activation) | (None, 56, 56, 64) | 0 |
| max_pooling2d_2 (MaxPooling2D) | (None, 28, 28, 64) | 0 |
| dropout (Dropout) | (None, 28, 28, 64) | 0 |
| flatten (Flatten) | (None, 50176) | 0 |
| dense (Dense) | (None, 128) | 6422656 |
| activation_3 (Activation) | (None, 128) | 0 |
| dense_1 (Dense) | (None, 38) | 4902 |
| ===== | ===== | ===== |
| Total params: 6,451,142 | | |
| Trainable params: 6,451,142 | | |
| Non-trainable params: 0 | | |

In [15]:

```
1 epochs = 10
2
3 history = model.fit(
4     train_ds,
5     validation_data=val_ds,
6     epochs=epochs
7 )
```

Epoch 1/10

1186/1358 [=====>....] - ETA: 1:06 - loss: 1.0078 - accuracy: 0.7149

Cleanup called...

1358/1358 [=====] - 567s 417ms/step - loss: 0.9479 - accuracy: 0.7303 - val_loss: 0.4355 - val_accuracy: 0.8683

Epoch 2/10

1186/1358 [=====>....] - ETA: 1:04 - loss: 0.3279 - accuracy: 0.8966

Cleanup called...

1358/1358 [=====] - 543s 400ms/step - loss: 0.3206 - accuracy: 0.8987 - val_loss: 0.3058 - val_accuracy: 0.9056

Epoch 3/10

1186/1358 [=====>....] - ETA: 1:04 - loss: 0.1712 - accuracy: 0.9454

Cleanup called...

1358/1358 [=====] - 544s 400ms/step - loss: 0.1678 - accuracy: 0.9460 - val_loss: 0.3885 - val_accuracy: 0.8882

Epoch 4/10

1186/1358 [=====>....] - ETA: 1:03 - loss: 0.1138 - accuracy: 0.9613

Cleanup called...

1358/1358 [=====] - 540s 398ms/step - loss: 0.1093 - accuracy: 0.9631 - val_loss: 0.3530 - val_accuracy: 0.9100

Epoch 5/10

1186/1358 [=====>....] - ETA: 1:04 - loss: 0.0895 - accuracy: 0.9697

Cleanup called...

1358/1358 [=====] - 542s 399ms/step - loss: 0.0899 - accuracy: 0.9698 - val_loss: 0.4175 - val_accuracy: 0.8948

Epoch 6/10

1186/1358 [=====>....] - ETA: 1:03 - loss: 0.0747 - accuracy: 0.9751

Cleanup called...

1358/1358 [=====] - 540s 397ms/step - loss: 0.0756 - accuracy: 0.9754 - val_loss: 0.3449 - val_accuracy: 0.9175

Epoch 7/10

1186/1358 [=====>....] - ETA: 1:04 - loss: 0.0560 - accuracy: 0.9820

Cleanup called...

1358/1358 [=====] - 541s 398ms/step - loss: 0.0574 - accuracy: 0.9816 - val_loss: 0.3413 - val_accuracy: 0.9188
Epoch 8/10
1186/1358 [=====>....] - ETA: 1:04 - loss: 0.0547 - accuracy: 0.9823

Cleanup called...

1358/1358 [=====] - 546s 402ms/step - loss: 0.0527 - accuracy: 0.9830 - val_loss: 0.3569 - val_accuracy: 0.9200
Epoch 9/10
1186/1358 [=====>....] - ETA: 1:04 - loss: 0.0501 - accuracy: 0.9843

Cleanup called...

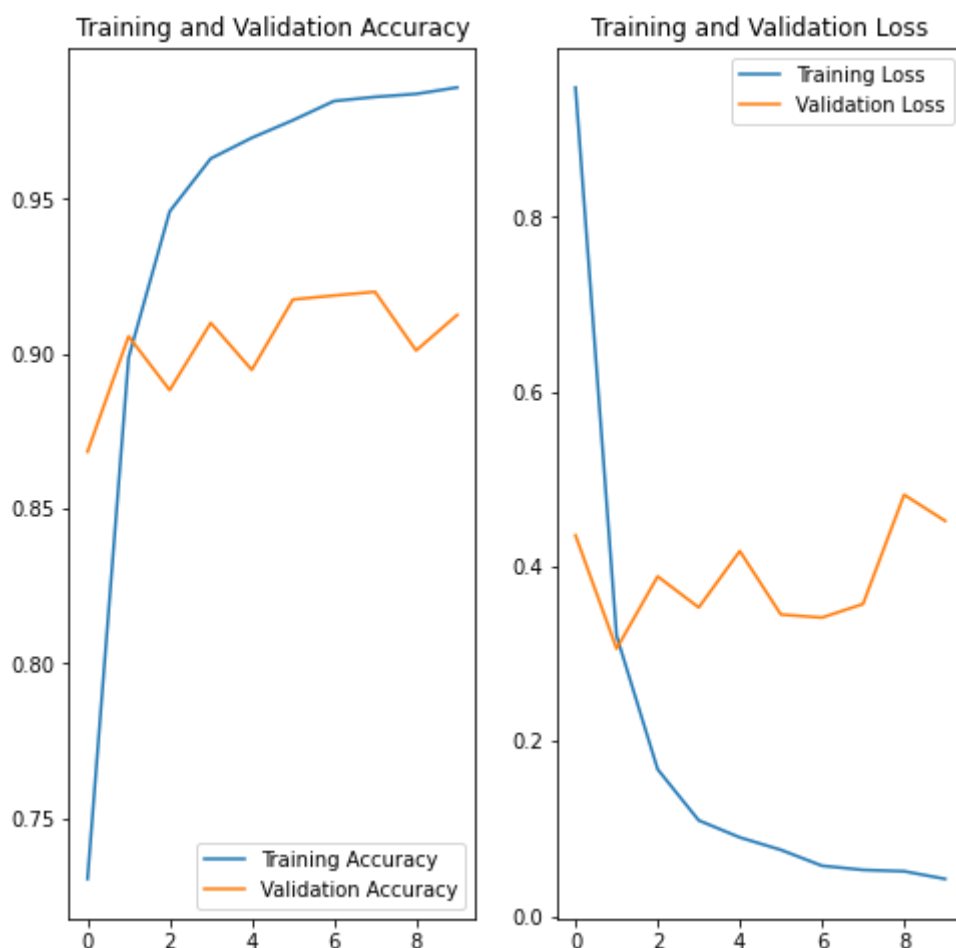
1358/1358 [=====] - 547s 403ms/step - loss: 0.0511 - accuracy: 0.9839 - val_loss: 0.4819 - val_accuracy: 0.9010
Epoch 10/10
1186/1358 [=====>....] - ETA: 1:04 - loss: 0.0461 - accuracy: 0.9847

Cleanup called...

1358/1358 [=====] - 544s 401ms/step - loss: 0.0423 - accuracy: 0.9860 - val_loss: 0.4520 - val_accuracy: 0.9125

In [16]:

```
1 acc = history.history['accuracy']
2 val_acc = history.history['val_accuracy']
3
4 loss = history.history['loss']
5 val_loss = history.history['val_loss']
6
7 epochs_range = range(epochs)
8
9 plt.figure(figsize=(8, 8))
10 plt.subplot(1, 2, 1)
11 plt.plot(epochs_range, acc, label='Training Accuracy')
12 plt.plot(epochs_range, val_acc, label='Validation Accuracy')
13 plt.legend(loc='lower right')
14 plt.title('Training and Validation Accuracy')
15
16 plt.subplot(1, 2, 2)
17 plt.plot(epochs_range, loss, label='Training Loss')
18 plt.plot(epochs_range, val_loss, label='Validation Loss')
19 plt.legend(loc='upper right')
20 plt.title('Training and Validation Loss')
21 plt.show()
```



In [17]:

```
1 preformance = model.evaluate(val_ds)
```

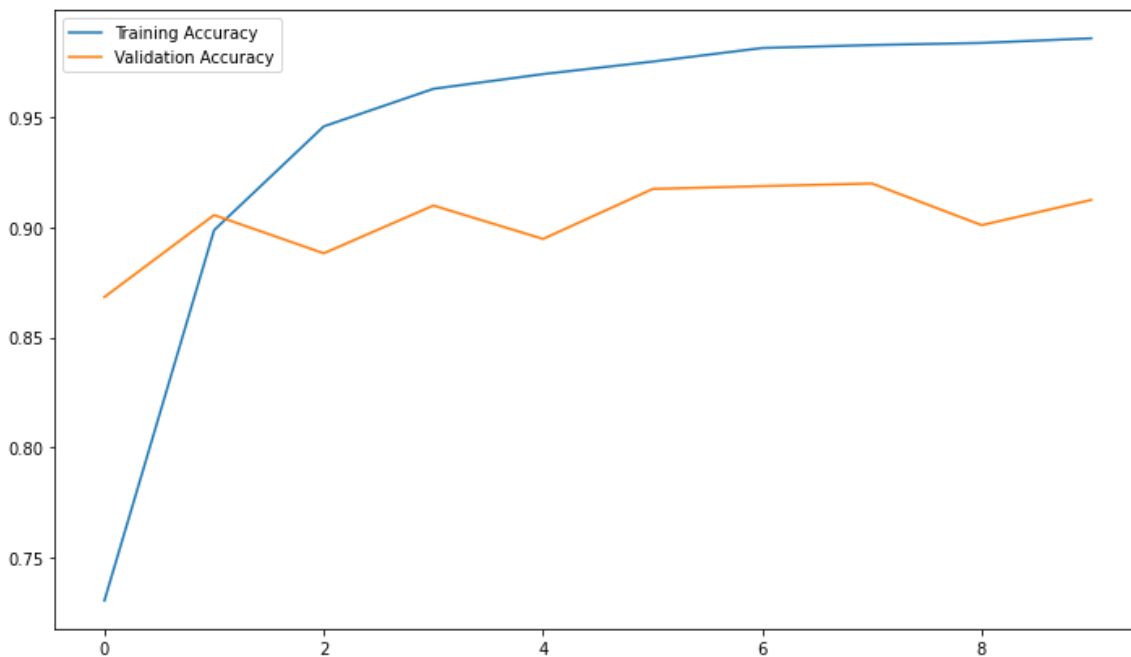
340/340 [=====] - 37s 108ms/step - loss: 0.4520 - accuracy: 0.9125

In []:

```
1 preformance
```

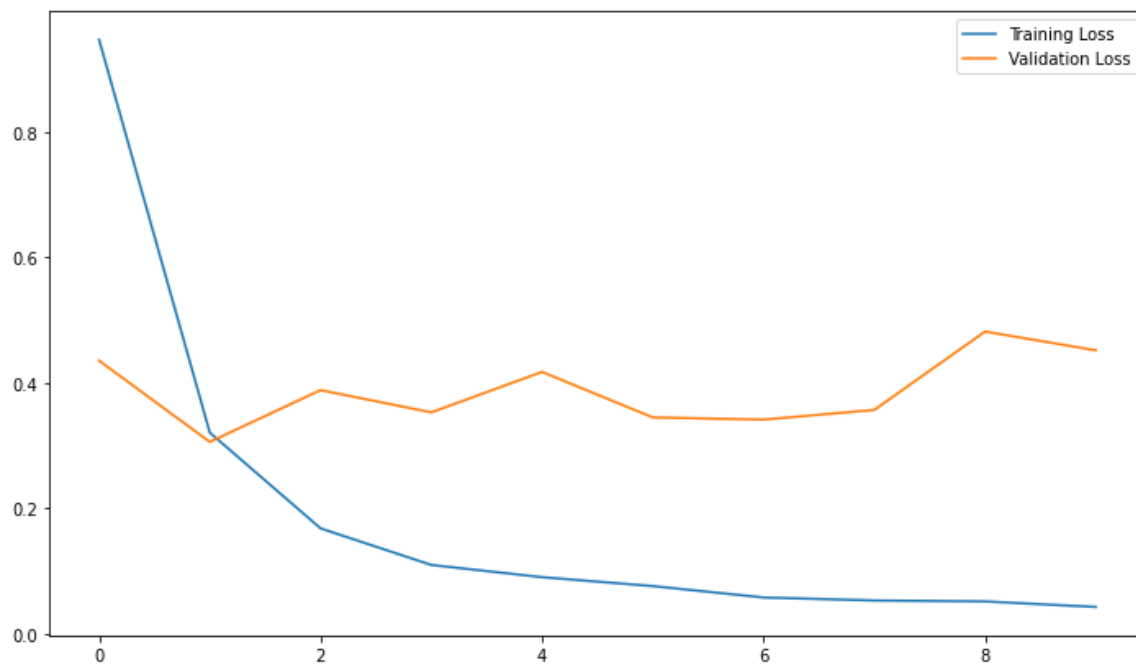
In [18]:

```
1 acc = history.history['accuracy']
2 val_acc = history.history['val_accuracy']
3
4 loss = history.history['loss']
5 val_loss = history.history['val_loss']
6 no_of_epochs = history.params['epochs']
7 len(history.history['accuracy']) == no_of_epochs
8 plt.figure(figsize=(12, 7))
9
10 plt.plot(range(no_of_epochs), acc, label='Training Accuracy')
11 plt.plot(range(no_of_epochs), val_acc, label='Validation Accuracy')
12
13 plt.legend()
14 plt.show()
```



In [19]:

```
1 plt.figure(figsize=(12, 7))
2
3 plt.plot(range(no_of_epochs), loss, label='Training Loss')
4 plt.plot(range(no_of_epochs), val_loss, label='Validation Loss')
5
6 plt.legend()
7 plt.show()
```



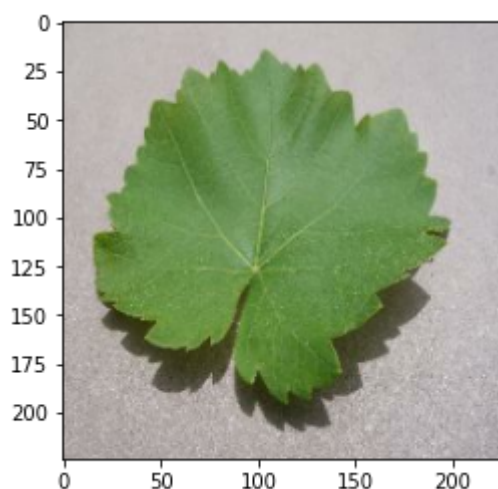
In []:

1

In [20]:

```
1 labels = train_ds.class_names
2 labels
3 for images_batch, labels_batch in test.take(1):
4
5     image = images_batch[0].numpy().astype('uint8')
6     label = labels_batch[0].numpy()
7
8     plt.imshow(image)
9     print("actual label:", labels[label])
10
11     batch_prediction = model.predict(images_batch)
12     print("predicted label:", labels[np.argmax(batch_prediction[0])])
```

actual label: Grape__healthy
predicted label: Grape__healthy



In [22]:

```
1 from tensorflow import expand_dims, newaxis
2
3 def predict(model, img):
4
5     img_array = img.numpy()
6     img_array = expand_dims(img_array, 0)
7
8     predictions = model.predict(img_array)
9
10    predicted_class = labels[np.argmax(predictions[0])]
11    confidence = round( (np.max(predictions[0])), 2)
12
13    return predicted_class, confidence
```

In [23]:

```

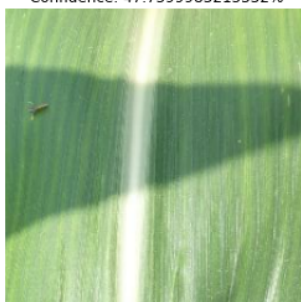
1 plt.figure(figsize=(15, 15))
2
3 for images, lbs in val_ds.take(1):
4     for i in range(9):
5
6         plt.subplot(3, 3, i + 1)
7         plt.imshow(images[i].numpy().astype("uint32"))
8
9         predicted_class, confidence = predict(model, images[i])
10        actual_class = labels[lbs[i]]
11
12        plt.title(f"Actual: {actual_class},\n Predicted: {predicted_class}.\n Confidence: {confidence}")
13
14        plt.axis("off")

```

Actual: Tomato__Tomato_Yellow_Leaf_Curl_Virus,
Predicted: Tomato__Tomato_Yellow_Leaf_Curl_Virus.
Confidence: 36.45000076293945%



Actual: Corn_(maize)__healthy,
Predicted: Corn_(maize)__healthy.
Confidence: 47.7599983215332%



Actual: Tomato__Tomato_Yellow_Leaf_Curl_Virus,
Predicted: Tomato__Tomato_Yellow_Leaf_Curl_Virus.
Confidence: 68.31999969482422%



Actual: Tomato__healthy,
Predicted: Tomato__healthy.
Confidence: 45.4900016784668%



Actual: Pepper_bell__healthy,
Predicted: Pepper_bell__healthy.
Confidence: 20.56999969482422%



Actual: Orange__Haunglongbing_(Citrus_greening),
Predicted: Orange__Haunglongbing_(Citrus_greening).
Confidence: 27.690000534057617%



Actual: Potato__Early_blight,
Predicted: Pepper_bell__Bacterial_spot.
Confidence: 29.489999771118164%



Actual: Orange__Haunglongbing_(Citrus_greening),
Predicted: Orange__Haunglongbing_(Citrus_greening).
Confidence: 21.469999313354492%



Actual: Tomato__Tomato_Yellow_Leaf_Curl_Virus,
Predicted: Tomato__Tomato_Yellow_Leaf_Curl_Virus.
Confidence: 27.040000915527344%

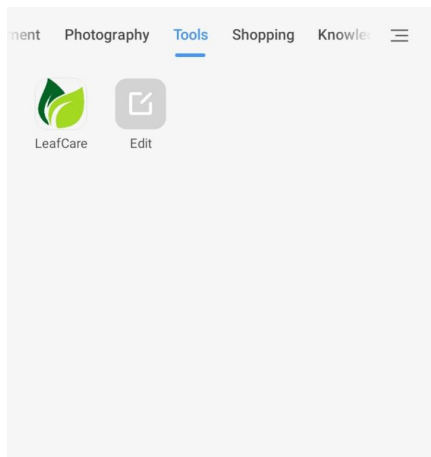


In [25]:

```
1 model.save("leafModel.h5")
```

In []:

```
1
```



App Logo

