Grapevine_Leaves_Classification

August 12, 2022

1 Grapevine leaves classification u sing d eep c onvolutional neural network

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Final version, Aug 2022.

1.1 Environment Initialization

[ ]:
```
#Loading General Tools and Libraries
import os
import random
import shutil
import sklearn
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import tensorflow as tf
import tensorflow_datasets as tfds
from tensorflow import keras
from keras import layers
plt.style.use('ggplot')
```

1.2 Data Loading

1.2.1 Data Downloading

[ ]:
```
#Loading Dataset
!rm -rf Grapevine_Leaves_Image_Dataset*
!rm -rf Test_Data
!wget https://www.muratkoklu.com/datasets/Grapevine_Leaves_Image_Dataset.zip
!unzip -q Grapevine_Leaves_Image_Dataset.zip
!rm Grapevine_Leaves_Image_Dataset.zip
!ls -lh
```

```
--2022-08-06 06:26:31--
https://www.muratkoklu.com/datasets/Grapevine_Leaves_Image_Dataset.zip
Resolving www.muratkoklu.com (www.muratkoklu.com)… 185.179.25.150
```

```
Connecting to www.muratkoklu.com (www.muratkoklu.com)|185.179.25.150|:443…
connected.
HTTP request sent, awaiting response… 200 OK
Length: 113862245 (109M) [application/zip]
Saving to: ‘Grapevine_Leaves_Image_Dataset.zip’

Grapevine_Leaves_Im 100%[===================>] 108.59M  20.7MB/s    in 6.3s

2022-08-06 06:26:38 (17.4 MB/s) - ‘Grapevine_Leaves_Image_Dataset.zip’ saved
[113862245/113862245]

total 8.0K
drwxr-xr-x 7 root root 4.0K Feb 11 17:53 Grapevine_Leaves_Image_Dataset
drwxr-xr-x 1 root root 4.0K Aug  3 20:21 sample_data
```

1.2.2 Select and Move 20% of Data for OOS (Out Of Sample) Testing

[ ]:
```
Species = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"]
OriginalDataPath = "Grapevine_Leaves_Image_Dataset"
TestDataPath = "Test_Data"
os.mkdir(os.path.join(TestDataPath,""))

for folder_name in Species:
  Percentage = 20/100
  Test_location = os.path.join(TestDataPath,folder_name)
  os.mkdir(Test_location)
  Original_location = os.path.join(OriginalDataPath, folder_name)
  AllImages = os.listdir(Original_location)
  Count = int(Percentage * len(AllImages))
  Selecteds = random.sample(AllImages, Count)
  for file in Selecteds:
    shutil.move(os.path.join(Original_location,file), Test_location)
```

1.2.3 Datasets Loading (Train, Validation, and Test)

[ ]:
```
image_size = (256,256)
batch_size = 32
validation_split = 0.2
seed = 199

train_data = tf.keras.utils.image_dataset_from_directory(
    'Grapevine_Leaves_Image_Dataset',
    class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
    batch_size=batch_size,
    image_size=image_size,
    seed=seed,
    validation_split=validation_split,
```

```
    subset="training"
)

validation_data = tf.keras.utils.image_dataset_from_directory(
    'Grapevine_Leaves_Image_Dataset',
    class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
    batch_size=batch_size,
    image_size=image_size,
    seed=seed,
    validation_split=validation_split,
    subset="validation"
)

test_data = tf.keras.utils.image_dataset_from_directory(
    'Test_Data',
    class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
    image_size=image_size,
    batch_size=100,
    shuffle=False)
```

```
Found 400 files belonging to 5 classes.
Using 320 files for training.
Found 400 files belonging to 5 classes.
Using 80 files for validation.
Found 100 files belonging to 5 classes.
```

1.3 Data Augmentation

1.3.1 Color Transformation

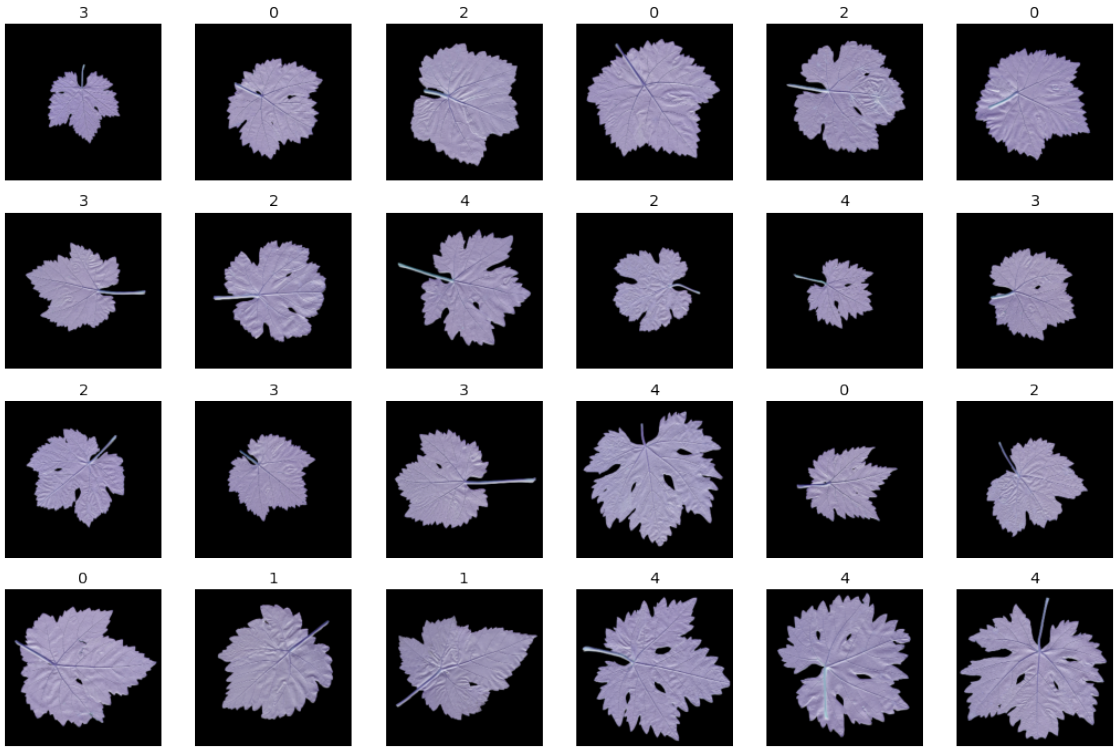
[ ]:
```
train_data2 = train_data.map(lambda x, y: (255-x, y))
validation_data2 = validation_data.map(lambda x, y: (255-x, y))
test_data2 = test_data.map(lambda x, y: (255-x, y))
```

1.3.2 Data Augmentation

[ ]:
```
data_augmentation = keras.Sequential([
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
  ↪2),fill_mode='constant', fill_value=0),
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0)
])

augmented_train_data = train_data2
for i in range(4):
  augmented_train_data = augmented_train_data.concatenate(train_data2.
  ↪map(lambda x, y: (data_augmentation(x, training=True), y)))
```

1.3.3 Showing a random sample

[ ]:
```
plt.figure(figsize=(18, 12))
for images, labels in augmented_train_data.take(1):
    for i in range(24):
        ax = plt.subplot(4, 6, i + 1)
        plt.imshow(images[i].numpy().astype("uint8"))
        plt.title(int(labels[i]))
        plt.axis("off")
```



1.4 My own Convolutional neural network Model

1.4.1 Model Architecture Define

[ ]:
```
MyOwnModel = keras.models.Sequential([
    layers.RandomRotation(0.1, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    layers.Conv2D(16, (3, 3), activation='relu'),
    layers.MaxPooling2D(2, 2),
    layers.Conv2D(32, (3, 3), activation='relu'),
    layers.MaxPooling2D(2, 2),
    layers.Conv2D(64, (3, 3), activation='relu'),
```

```
    layers.MaxPooling2D(2, 2),
    layers.Conv2D(128, (3, 3), activation='relu'),
    layers.MaxPooling2D(2, 2),
    layers.Conv2D(256, (3, 3), activation='relu'),
    layers.MaxPooling2D(2,2),
    layers.Conv2D(512, (3, 3), activation='relu'),
    layers.MaxPooling2D(2,2),
    layers.Flatten(),
    layers.Dense(1024, activation='relu'),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(128, activation='relu'),
    layers.Dense(5, activation='softmax')
])
MyOwnModel.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_1 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_flip_2 (RandomFlip)  (None, 256, 256, 3)       0

 random_flip_3 (RandomFlip)  (None, 256, 256, 3)       0

 conv2d (Conv2D)             (None, 254, 254, 16)      448

 max_pooling2d (MaxPooling2D  (None, 127, 127, 16)     0
 )

 conv2d_1 (Conv2D)           (None, 125, 125, 32)      4640

 max_pooling2d_1 (MaxPooling  (None, 62, 62, 32)       0
 2D)

 conv2d_2 (Conv2D)           (None, 60, 60, 64)        18496

 max_pooling2d_2 (MaxPooling  (None, 30, 30, 64)       0
 2D)

 conv2d_3 (Conv2D)           (None, 28, 28, 128)       73856

 max_pooling2d_3 (MaxPooling  (None, 14, 14, 128)      0
 2D)

 conv2d_4 (Conv2D)           (None, 12, 12, 256)       295168
```

```
max_pooling2d_4 (MaxPooling  (None, 6, 6, 256)        0
2D)

conv2d_5 (Conv2D)            (None, 4, 4, 512)        1180160

max_pooling2d_5 (MaxPooling  (None, 2, 2, 512)        0
2D)

flatten (Flatten)            (None, 2048)             0

dense (Dense)                (None, 1024)             2098176

dense_1 (Dense)              (None, 512)              524800

dense_2 (Dense)              (None, 256)              131328

dense_3 (Dense)              (None, 128)              32896

dense_4 (Dense)              (None, 5)                645

=================================================================
Total params: 4,360,613
Trainable params: 4,360,613
Non-trainable params: 0
_________________________________________________________________
```

1.4.2 Model Creation and Training

[ ]:
```
MyOwnModel.compile(
    optimizer=keras.optimizers.Adam(2*1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"],
)
epochs = 200
history_myown = MyOwnModel.fit(
    train_data2, epochs=epochs,
    validation_data=validation_data2)
MyOwnModel.save('MyOwnModel.h5')
```

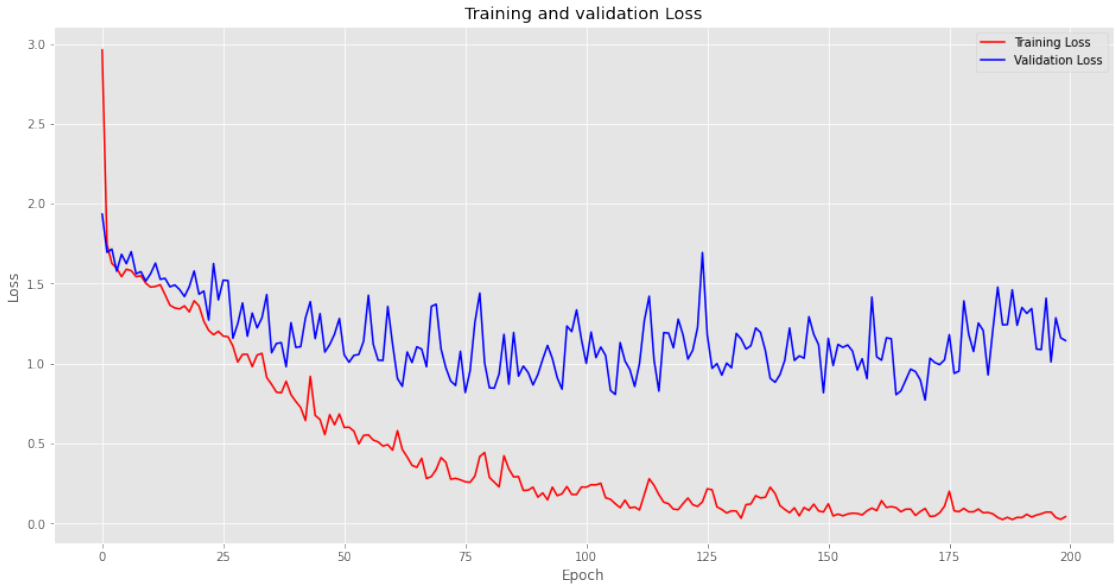
1.4.3 Accuracy Curve

[ ]:
```
MyOwnModel_acc=history_myown.history['accuracy']
MyOwnModel_val_acc=history_myown.history['val_accuracy']
MyOwnModel_loss=history_myown.history['loss']
MyOwnModel_val_loss=history_myown.history['val_loss']
epochs=range(len(MyOwnModel_acc))
```

```
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, MyOwnModel_acc, 'r', label="Training Accuracy")
plt.plot(epochs, MyOwnModel_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
plt.show()
```

1.4.4 Loss Curve

[ ]:
```
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, MyOwnModel_loss, 'r', label="Training Loss")
plt.plot(epochs, MyOwnModel_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



1.4.5 Model Performance Evaluation on Test Data

[ ]:
```
from sklearn.metrics import␣
  ↪accuracy_score,classification_report,confusion_matrix
result = MyOwnModel.predict(test_data2)
y_test = np.concatenate([y for x, y in test_data2], axis=0)
MyOwnModel_y_predict = np.array([i.argmax() for i in result])

MyOwnModel_cm = confusion_matrix(y_test, MyOwnModel_y_predict)
MyOwnModel_ac = accuracy_score(y_test,MyOwnModel_y_predict)

print("confusion matrix on test data :\n",MyOwnModel_cm)
print("accuracy score on test data:\n",MyOwnModel_ac)

print(classification_report(y_test, MyOwnModel_y_predict))
```

```
confusion matrix on test data :
 [[14  3  0  3  0]
 [ 2 15  0  2  1]
 [ 1  1 14  3  1]
 [ 0  2  0 17  1]
 [ 0  0  0  0 20]]
accuracy score on test data:
 0.8
              precision    recall  f1-score   support

           0       0.82      0.70      0.76        20
           1       0.71      0.75      0.73        20
```

```
           2       1.00      0.70      0.82        20
           3       0.68      0.85      0.76        20
           4       0.87      1.00      0.93        20

    accuracy                           0.80       100
   macro avg       0.82      0.80      0.80       100
weighted avg       0.82      0.80      0.80       100
```

[ ]:

1.5 Pre-Trained Models

1.5.1 Training Parameters

[ ]:
```
pre_trained_data = train_data2
pre_trained_epochs = 30
pre_trained_validation_data = validation_data2
```

1.5.2 Xception

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.Xception(
        weights='imagenet',
        include_top=False ,
        input_shape=image_size + (3,))
pretrained_model.trainable = False
Xception_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
Xception_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/xception/xception_weights_tf_dim_ordering_tf_kernels_notop.h5
83689472/83683744 [==============================] - 0s 0us/step
83697664/83683744 [==============================] - 0s 0us/step
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_2 (RandomRo  (None, 256, 256, 3)      0
```

```
 tation)

 random_zoom_1 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_4 (RandomFlip)  (None, 256, 256, 3)       0

 random_flip_5 (RandomFlip)  (None, 256, 256, 3)       0

 xception (Functional)       (None, 8, 8, 2048)        20861480

 flatten_1 (Flatten)         (None, 131072)            0

 dense_5 (Dense)             (None, 512)               67109376

 dense_6 (Dense)             (None, 256)               131328

 dense_7 (Dense)             (None, 5)                 1285

=================================================================
Total params: 88,103,469
Trainable params: 67,241,989
Non-trainable params: 20,861,480
_________________________________________________________________
```

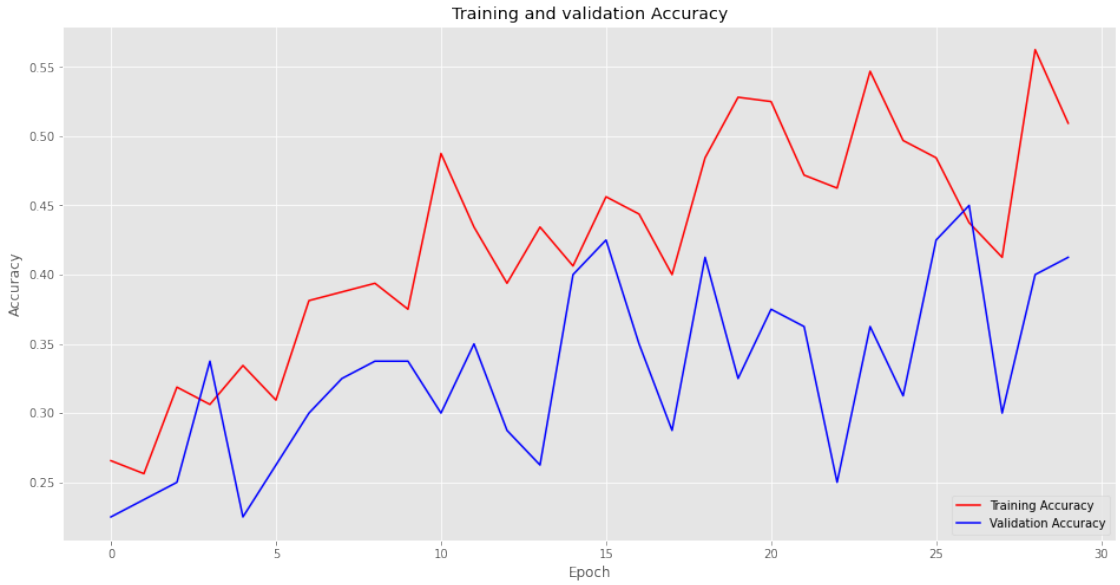
Model Creation and Training

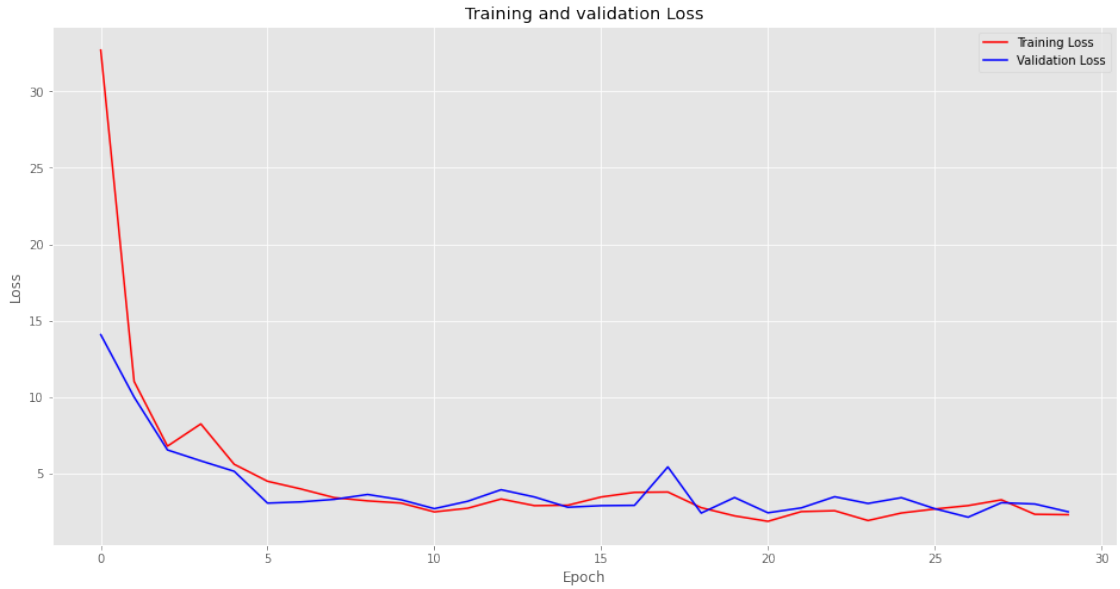
[ ]:
```
Xception_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
Xception_Model_History = Xception_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
Xception_Model_acc = Xception_Model_History.history['accuracy']
Xception_Model_val_acc = Xception_Model_History.history['val_accuracy']
Xception_Model_loss = Xception_Model_History.history['loss']
Xception_Model_val_loss = Xception_Model_History.history['val_loss']
epochs = range(len(Xception_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, Xception_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, Xception_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
```

```
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, Xception_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, Xception_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```





Model Performance Evaluation on Test Data

```
[ ]: result = Xception_Model.predict(test_data2)
Xception_Model_y_predict = np.array([i.argmax() for i in result])

Xception_Model_cm = confusion_matrix(y_test, Xception_Model_y_predict)
Xception_Model_ac = accuracy_score(y_test,Xception_Model_y_predict)

print("confusion matrix on test data :\n",Xception_Model_cm)
print("accuracy score on test data:\n",Xception_Model_ac)

print(classification_report(y_test, Xception_Model_y_predict))
```

```
confusion matrix on test data :
 [[ 6  2  4  4  4]
 [ 1  7  1  4  7]
 [ 0  3 10  1  6]
 [ 0  1  4  8  7]
 [ 1  0  1  3 15]]
accuracy score on test data:
 0.46
              precision    recall  f1-score   support

           0       0.75      0.30      0.43        20
           1       0.54      0.35      0.42        20
           2       0.50      0.50      0.50        20
           3       0.40      0.40      0.40        20
           4       0.38      0.75      0.51        20

    accuracy                           0.46       100
   macro avg       0.51      0.46      0.45       100
weighted avg       0.51      0.46      0.45       100
```

1.5.3 VGG16

Model Architecture Define

```
[ ]: pretrained_model = tf.keras.applications.VGG16(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
    classifier_activation="softmax",
)
pretrained_model.trainable = False
VGG16_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
  ↪input_shape=image_size + (3,)),
```

```
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
VGG16_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58892288/58889256 [==============================] - 0s 0us/step
58900480/58889256 [==============================] - 0s 0us/step
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_3 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_2 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_6 (RandomFlip)  (None, 256, 256, 3)       0

 random_flip_7 (RandomFlip)  (None, 256, 256, 3)       0

 vgg16 (Functional)          (None, 8, 8, 512)         14714688

 flatten_2 (Flatten)         (None, 32768)             0

 dense_8 (Dense)             (None, 512)               16777728

 dense_9 (Dense)             (None, 256)               131328

 dense_10 (Dense)            (None, 5)                 1285

=================================================================
Total params: 31,625,029
Trainable params: 16,910,341
Non-trainable params: 14,714,688
_________________________________________________________________
```

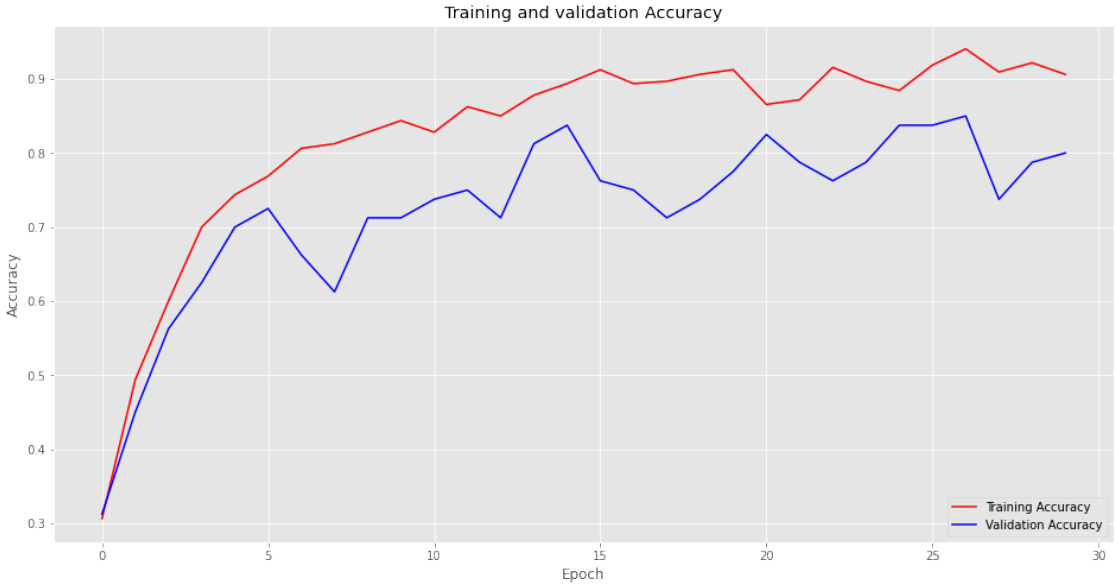
Model Creation and Training

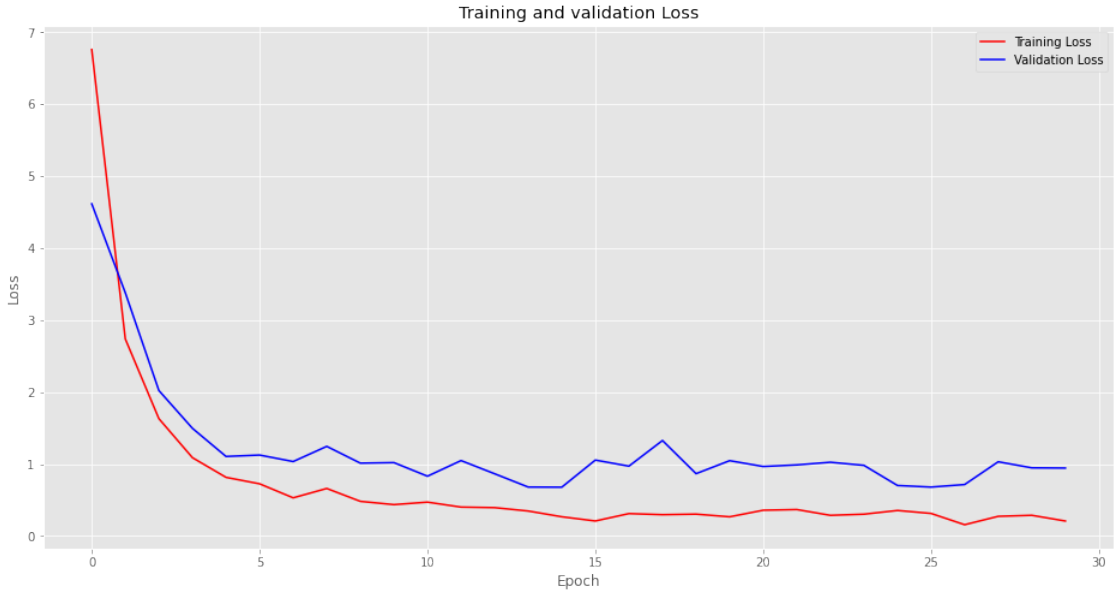
[ ]:
```
VGG16_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
```

```
    metrics=["accuracy"])
VGG16_Model_History = VGG16_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
VGG16_Model_acc = VGG16_Model_History.history['accuracy']
VGG16_Model_val_acc = VGG16_Model_History.history['val_accuracy']
VGG16_Model_loss = VGG16_Model_History.history['loss']
VGG16_Model_val_loss = VGG16_Model_History.history['val_loss']
epochs = range(len(VGG16_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, VGG16_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, VGG16_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, VGG16_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, VGG16_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```





Model Performance Evaluation on Test Data

[ ]:
```
result = VGG16_Model.predict(test_data2)
VGG16_Model_y_predict = np.array([i.argmax() for i in result])

VGG16_Model_cm = confusion_matrix(y_test, VGG16_Model_y_predict)
VGG16_Model_ac = accuracy_score(y_test,VGG16_Model_y_predict)

print("confusion matrix on test data :\n",VGG16_Model_cm)
print("accuracy score on test data:\n",VGG16_Model_ac)

print(classification_report(y_test, VGG16_Model_y_predict))
```

```
confusion matrix on test data :
 [[15  5  0  0  0]
 [ 0 17  2  0  1]
 [ 0  2 17  1  0]
 [ 2  0  2 16  0]
 [ 1  0  0  0 19]]
accuracy score on test data:
 0.84
              precision    recall  f1-score   support

           0       0.83      0.75      0.79        20
           1       0.71      0.85      0.77        20
           2       0.81      0.85      0.83        20
           3       0.94      0.80      0.86        20
           4       0.95      0.95      0.95        20
```

```
    accuracy                           0.84       100
   macro avg       0.85      0.84      0.84       100
weighted avg       0.85      0.84      0.84       100
```

1.5.4 VGG19

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.VGG16(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
    classifier_activation="softmax",
)
pretrained_model.trainable = False
VGG19_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
VGG19_Model.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_4 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_3 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_8 (RandomFlip)  (None, 256, 256, 3)       0

 random_flip_9 (RandomFlip)  (None, 256, 256, 3)       0

 vgg16 (Functional)          (None, 8, 8, 512)         14714688

 flatten_3 (Flatten)         (None, 32768)             0

 dense_11 (Dense)            (None, 512)               16777728
```

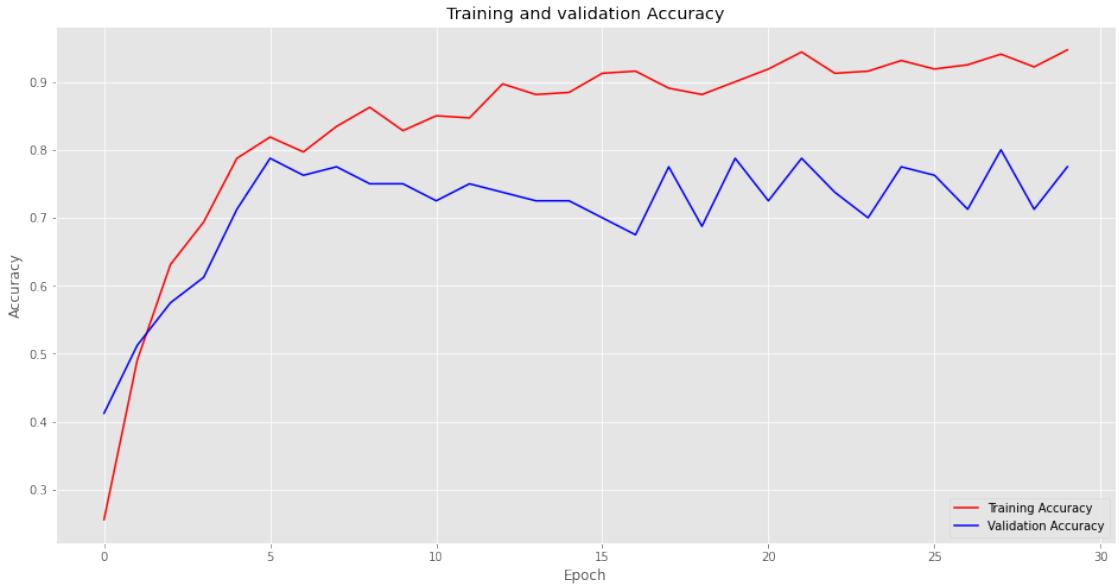
```
 dense_12 (Dense)            (None, 256)               131328

 dense_13 (Dense)            (None, 5)                 1285

=================================================================
Total params: 31,625,029
Trainable params: 16,910,341
Non-trainable params: 14,714,688
_________________________________________________________________
```

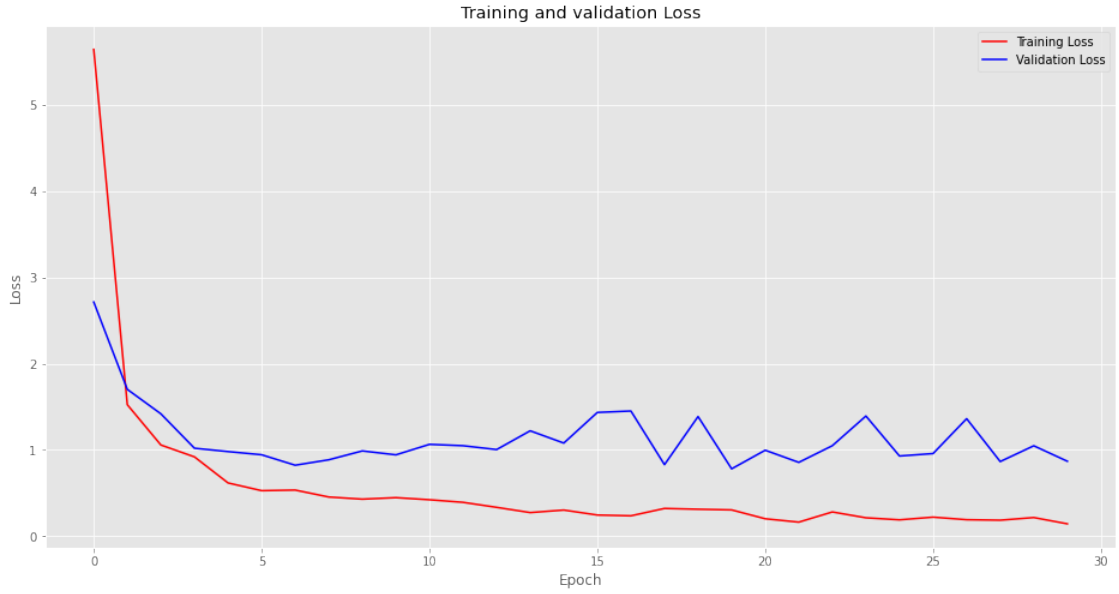
Model Creation and Training

[ ]:
```
VGG19_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
VGG19_Model_History = VGG19_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
VGG19_Model_acc = VGG19_Model_History.history['accuracy']
VGG19_Model_val_acc = VGG19_Model_History.history['val_accuracy']
VGG19_Model_loss = VGG19_Model_History.history['loss']
VGG19_Model_val_loss = VGG19_Model_History.history['val_loss']
epochs = range(len(VGG19_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, VGG19_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, VGG19_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, VGG19_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, VGG19_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```





Model Performance Evaluation on Test Data

[ ]:
```
result = VGG19_Model.predict(test_data2)
VGG19_Model_y_predict = np.array([i.argmax() for i in result])

VGG19_Model_cm = confusion_matrix(y_test, VGG19_Model_y_predict)
VGG19_Model_ac = accuracy_score(y_test,VGG19_Model_y_predict)
```

```
print("confusion matrix on test data :\n",VGG19_Model_cm)
print("accuracy score on test data:\n",VGG19_Model_ac)

print(classification_report(y_test, VGG19_Model_y_predict))
```

```
confusion matrix on test data :
 [[17  3  0  0  0]
 [ 1 16  3  0  0]
 [ 0  2 18  0  0]
 [ 2  0  3 15  0]
 [ 2  1  2  0 15]]
accuracy score on test data:
 0.81
              precision    recall  f1-score   support

           0       0.77      0.85      0.81        20
           1       0.73      0.80      0.76        20
           2       0.69      0.90      0.78        20
           3       1.00      0.75      0.86        20
           4       1.00      0.75      0.86        20

    accuracy                           0.81       100
   macro avg       0.84      0.81      0.81       100
weighted avg       0.84      0.81      0.81       100
```

1.5.5 ResNet50

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.ResNet50(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
)
pretrained_model.trainable = False
ResNet50_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
ResNet50_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/resnet/resnet50_weights_tf_dim_ordering_tf_kernels_notop.h5
94773248/94765736 [==============================] - 0s 0us/step
94781440/94765736 [==============================] - 0s 0us/step
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_5 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_4 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_10 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_11 (RandomFlip)  (None, 256, 256, 3)      0

 resnet50 (Functional)       (None, 8, 8, 2048)        23587712

 flatten_4 (Flatten)         (None, 131072)            0

 dense_14 (Dense)            (None, 512)               67109376

 dense_15 (Dense)            (None, 256)               131328

 dense_16 (Dense)            (None, 5)                 1285

=================================================================
Total params: 90,829,701
Trainable params: 67,241,989
Non-trainable params: 23,587,712
_________________________________________________________________
```

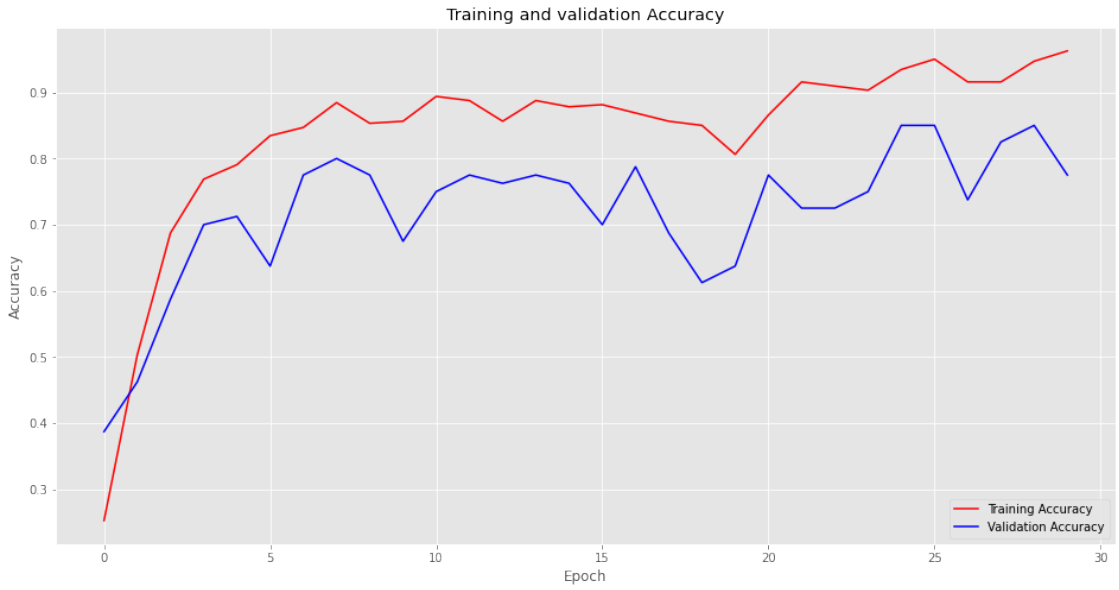
Model Creation and Training

[ ]:
```
ResNet50_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
ResNet50_Model_History = ResNet50_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
ResNet50_Model_acc = ResNet50_Model_History.history['accuracy']
ResNet50_Model_val_acc = ResNet50_Model_History.history['val_accuracy']
ResNet50_Model_loss = ResNet50_Model_History.history['loss']
```

```
ResNet50_Model_val_loss = ResNet50_Model_History.history['val_loss']
epochs = range(len(ResNet50_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, ResNet50_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, ResNet50_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, ResNet50_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, ResNet50_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



Model Performance Evaluation on Test Data

[ ]:
```
result = ResNet50_Model.predict(test_data2)
ResNet50_Model_y_predict = np.array([i.argmax() for i in result])

ResNet50_Model_cm = confusion_matrix(y_test, ResNet50_Model_y_predict)
ResNet50_Model_ac = accuracy_score(y_test,ResNet50_Model_y_predict)

print("confusion matrix on test data :\n",ResNet50_Model_cm)
print("accuracy score on test data:\n",ResNet50_Model_ac)

print(classification_report(y_test, ResNet50_Model_y_predict))
```

```
WARNING:tensorflow:5 out of the last 5 calls to <function
Model.make_predict_function.<locals>.predict_function at 0x7ff9b0116170>
triggered tf.function retracing. Tracing is expensive and the excessive number
of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2)
passing tensors with different shapes, (3) passing Python objects instead of
tensors. For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has experimental_relax_shapes=True option that relaxes argument
shapes that can avoid unnecessary retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.
confusion matrix on test data :
 [[18  0  1  0  1]
 [ 4 13  2  0  1]
 [ 2  0 17  1  0]
 [ 2  0  1 14  3]
 [ 1  0  0  0 19]]
```

```
accuracy score on test data:
 0.81
              precision    recall  f1-score   support

           0       0.67      0.90      0.77        20
           1       1.00      0.65      0.79        20
           2       0.81      0.85      0.83        20
           3       0.93      0.70      0.80        20
           4       0.79      0.95      0.86        20

    accuracy                           0.81       100
   macro avg       0.84      0.81      0.81       100
weighted avg       0.84      0.81      0.81       100
```

1.5.6 ResNet101

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.ResNet101(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
)
pretrained_model.trainable = False
ResNet101_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
ResNet101_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/resnet/resnet101_weights_tf_dim_ordering_tf_kernels_notop.h5
171450368/171446536 [==============================] - 1s 0us/step
171458560/171446536 [==============================] - 1s 0us/step
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_6 (RandomRo  (None, 256, 256, 3)      0
 tation)
```

```
 random_zoom_5 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_12 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_13 (RandomFlip)  (None, 256, 256, 3)      0

 resnet101 (Functional)      (None, 8, 8, 2048)        42658176

 flatten_5 (Flatten)         (None, 131072)            0

 dense_17 (Dense)            (None, 512)               67109376

 dense_18 (Dense)            (None, 256)               131328

 dense_19 (Dense)            (None, 5)                 1285

=================================================================
Total params: 109,900,165
Trainable params: 67,241,989
Non-trainable params: 42,658,176
_________________________________________________________________
```

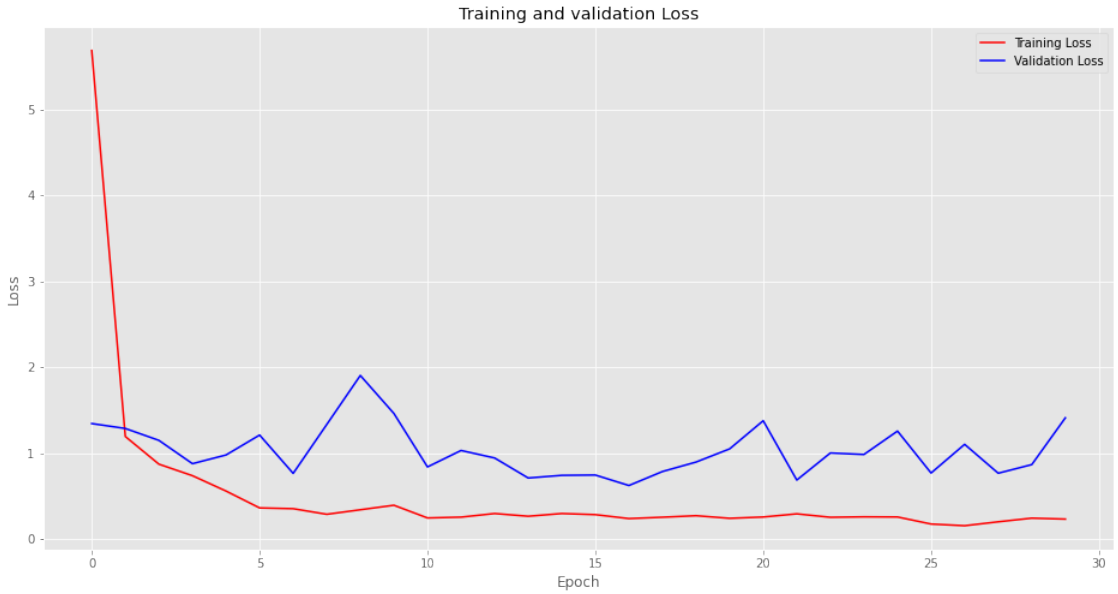
Model Creation and Training

[ ]:
```
ResNet101_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
ResNet101_Model_History = ResNet101_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
ResNet101_Model_acc = ResNet101_Model_History.history['accuracy']
ResNet101_Model_val_acc = ResNet101_Model_History.history['val_accuracy']
ResNet101_Model_loss = ResNet101_Model_History.history['loss']
ResNet101_Model_val_loss = ResNet101_Model_History.history['val_loss']
epochs = range(len(ResNet101_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, ResNet101_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, ResNet101_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
```

```
plt.plot(epochs, ResNet101_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, ResNet101_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



Model Performance Evaluation on Test Data

```
[ ]: result = ResNet101_Model.predict(test_data2)
ResNet101_Model_y_predict = np.array([i.argmax() for i in result])

ResNet101_Model_cm = confusion_matrix(y_test, ResNet101_Model_y_predict)
ResNet101_Model_ac = accuracy_score(y_test,ResNet101_Model_y_predict)

print("confusion matrix on test data :\n",ResNet101_Model_cm)
print("accuracy score on test data:\n",ResNet101_Model_ac)

print(classification_report(y_test, ResNet101_Model_y_predict))
```

```
WARNING:tensorflow:6 out of the last 6 calls to <function
Model.make_predict_function.<locals>.predict_function at 0x7ff82cf69d40>
triggered tf.function retracing. Tracing is expensive and the excessive number
of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2)
passing tensors with different shapes, (3) passing Python objects instead of
tensors. For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has experimental_relax_shapes=True option that relaxes argument
shapes that can avoid unnecessary retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.
confusion matrix on test data :
 [[18  0  0  0  2]
 [ 1 11  3  0  5]
 [ 3  1 14  0  2]
 [ 5  0  0  8  7]
 [ 0  0  0  0 20]]
accuracy score on test data:
 0.71
              precision    recall  f1-score   support

           0       0.67      0.90      0.77        20
           1       0.92      0.55      0.69        20
           2       0.82      0.70      0.76        20
           3       1.00      0.40      0.57        20
           4       0.56      1.00      0.71        20

    accuracy                           0.71       100
   macro avg       0.79      0.71      0.70       100
weighted avg       0.79      0.71      0.70       100
```

1.5.7 ResNet152

Model Architecture Define

```
[ ]: pretrained_model = tf.keras.applications.ResNet152(
    include_top=False,
```

```
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
)
pretrained_model.trainable = False
ResNet152_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
ResNet152_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/resnet/resnet152_weights_tf_dim_ordering_tf_kernels_notop.h5
234700800/234698864 [==============================] - 1s 0us/step
234708992/234698864 [==============================] - 1s 0us/step
Model: "sequential_7"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_7 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_6 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_14 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_15 (RandomFlip)  (None, 256, 256, 3)      0

 resnet152 (Functional)      (None, 8, 8, 2048)        58370944

 flatten_6 (Flatten)         (None, 131072)            0

 dense_20 (Dense)            (None, 512)               67109376

 dense_21 (Dense)            (None, 256)               131328

 dense_22 (Dense)            (None, 5)                 1285

=================================================================
Total params: 125,612,933
```

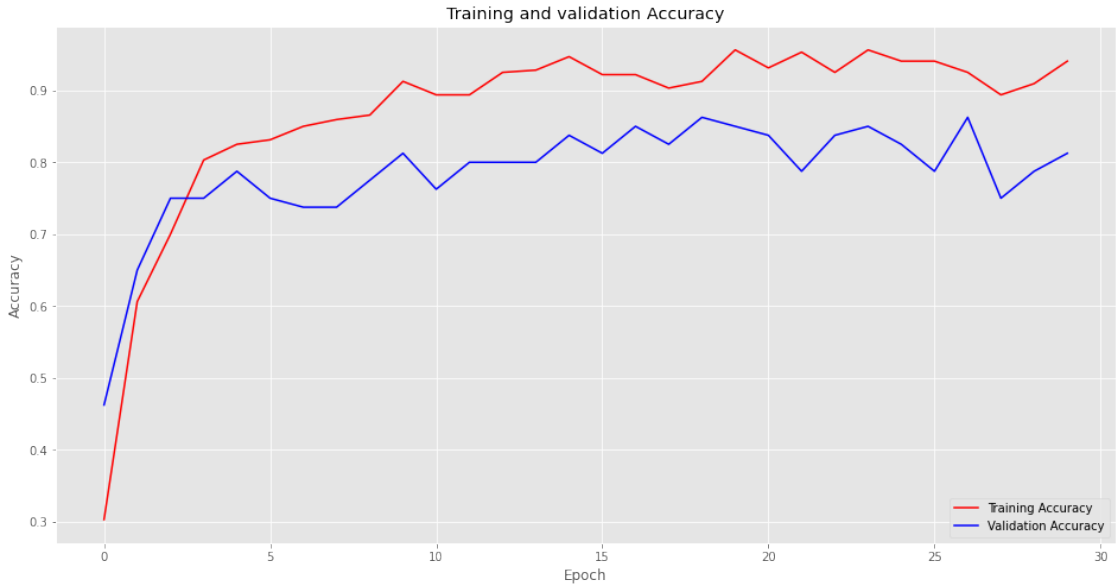
```
Trainable params: 67,241,989
Non-trainable params: 58,370,944
_________________________________________________________________
```

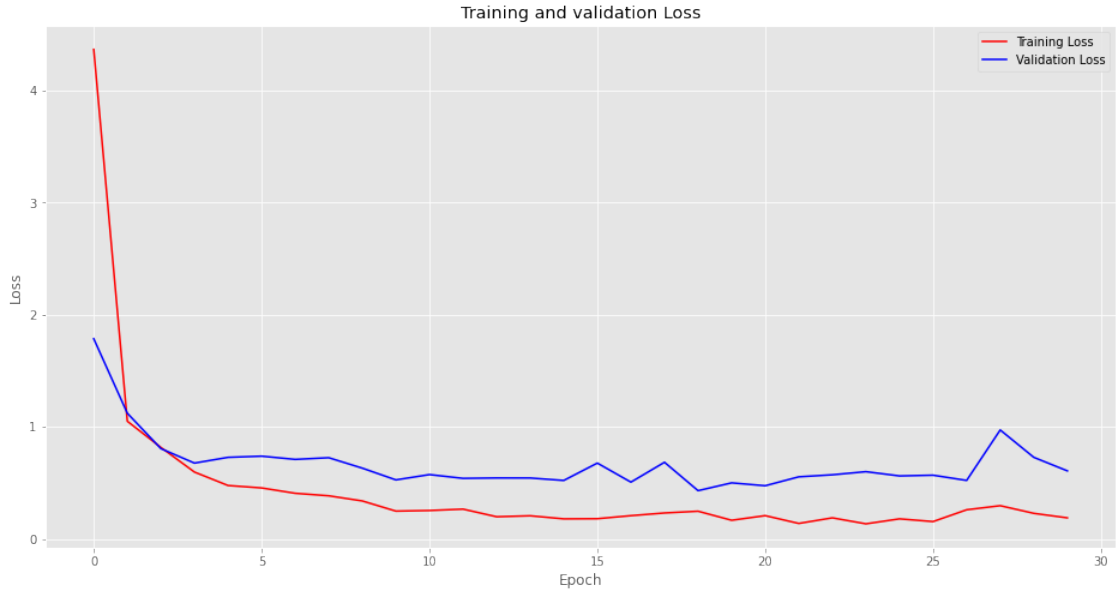
Model Creation and Training

[ ]:
```
ResNet152_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
ResNet152_Model_History = ResNet152_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
ResNet152_Model_acc = ResNet152_Model_History.history['accuracy']
ResNet152_Model_val_acc = ResNet152_Model_History.history['val_accuracy']
ResNet152_Model_loss = ResNet152_Model_History.history['loss']
ResNet152_Model_val_loss = ResNet152_Model_History.history['val_loss']
epochs = range(len(ResNet152_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, ResNet152_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, ResNet152_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, ResNet152_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, ResNet152_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```





Model Performance Evaluation on Test Data

[ ]:
```
result = ResNet152_Model.predict(test_data2)
ResNet152_Model_y_predict = np.array([i.argmax() for i in result])

ResNet152_Model_cm = confusion_matrix(y_test, ResNet152_Model_y_predict)
ResNet152_Model_ac = accuracy_score(y_test,ResNet152_Model_y_predict)
```

```
print("confusion matrix on test data :\n",ResNet152_Model_cm)
print("accuracy score on test data:\n",ResNet152_Model_ac)

print(classification_report(y_test, ResNet152_Model_y_predict))
```

```
confusion matrix on test data :
 [[17  1  1  1  0]
 [ 2 16  0  0  2]
 [ 1  2 15  0  2]
 [ 0  0  1 17  2]
 [ 0  0  1  0 19]]
accuracy score on test data:
 0.84
              precision    recall  f1-score   support

           0       0.85      0.85      0.85        20
           1       0.84      0.80      0.82        20
           2       0.83      0.75      0.79        20
           3       0.94      0.85      0.89        20
           4       0.76      0.95      0.84        20

    accuracy                           0.84       100
   macro avg       0.85      0.84      0.84       100
weighted avg       0.85      0.84      0.84       100
```

1.5.8 InceptionV3

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.InceptionV3(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
    classifier_activation="softmax",
)
pretrained_model.trainable = False
InceptionV3_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
```

```
InceptionV3_Model.summary()
```

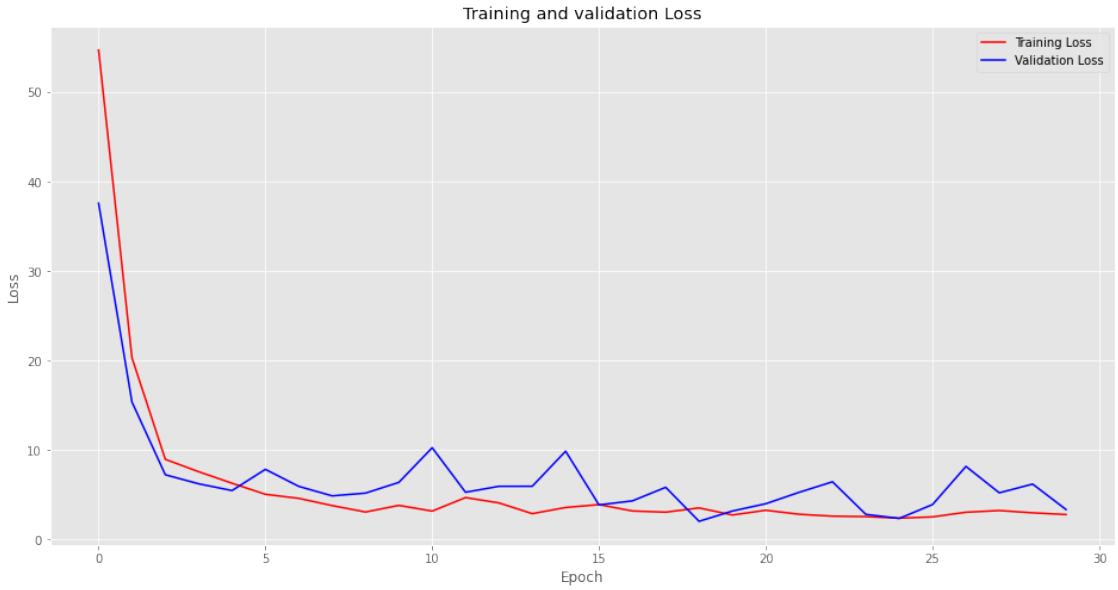
```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicatio
ns/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
87916544/87910968 [==============================] - 0s 0us/step
87924736/87910968 [==============================] - 0s 0us/step
Model: "sequential_8"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_8 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_7 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_16 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_17 (RandomFlip)  (None, 256, 256, 3)      0

 inception_v3 (Functional)   (None, 6, 6, 2048)        21802784

 flatten_7 (Flatten)         (None, 73728)             0

 dense_23 (Dense)            (None, 512)               37749248

 dense_24 (Dense)            (None, 256)               131328

 dense_25 (Dense)            (None, 5)                 1285

=================================================================
Total params: 59,684,645
Trainable params: 37,881,861
Non-trainable params: 21,802,784
_________________________________________________________________
```

Model Creation and Training

[ ]:
```
InceptionV3_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
InceptionV3_Model_History = InceptionV3_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

```
[ ]: InceptionV3_Model_acc = InceptionV3_Model_History.history['accuracy']
InceptionV3_Model_val_acc = InceptionV3_Model_History.history['val_accuracy']
InceptionV3_Model_loss = InceptionV3_Model_History.history['loss']
InceptionV3_Model_val_loss = InceptionV3_Model_History.history['val_loss']
epochs = range(len(InceptionV3_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, InceptionV3_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, InceptionV3_Model_val_acc, 'b', label="Validation Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, InceptionV3_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, InceptionV3_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



Model Performance Evaluation on Test Data

[ ]:
```
result = InceptionV3_Model.predict(test_data2)
InceptionV3_Model_y_predict = np.array([i.argmax() for i in result])

InceptionV3_Model_cm = confusion_matrix(y_test, InceptionV3_Model_y_predict)
InceptionV3_Model_ac = accuracy_score(y_test,InceptionV3_Model_y_predict)

print("confusion matrix on test data :\n",InceptionV3_Model_cm)
print("accuracy score on test data:\n",InceptionV3_Model_ac)

print(classification_report(y_test, InceptionV3_Model_y_predict))
```

```
confusion matrix on test data :
 [[ 0  5  3 11  1]
 [ 0  6  2  8  4]
 [ 0  1  6  9  4]
 [ 0  2  0 14  4]
 [ 0  1  0  6 13]]
accuracy score on test data:
 0.39
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        20
           1       0.40      0.30      0.34        20
           2       0.55      0.30      0.39        20
           3       0.29      0.70      0.41        20
           4       0.50      0.65      0.57        20
```

```
    accuracy                           0.39       100
   macro avg       0.35      0.39      0.34       100
weighted avg       0.35      0.39      0.34       100
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are 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, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are 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, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are 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, msg_start, len(result))
```

1.5.9 InceptionResNetV2

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.InceptionResNetV2(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
    classifier_activation="softmax",
)
pretrained_model.trainable = False
InceptionResNetV2_Model = tf.keras.Sequential([
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
 ↪input_shape=image_size + (3,)),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    pretrained_model, layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(5, activation='softmax')])
InceptionResNetV2_Model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applicatio
ns/inception_resnet_v2/inception_resnet_v2_weights_tf_dim_ordering_tf_kernels_no
top.h5
219062272/219055592 [==============================] - 1s 0us/step
```

```
219070464/219055592 [==============================] - 1s 0us/step
Model: "sequential_9"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_9 (RandomRo  (None, 256, 256, 3)      0
 tation)

 random_zoom_8 (RandomZoom)  (None, 256, 256, 3)       0

 random_flip_18 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_19 (RandomFlip)  (None, 256, 256, 3)      0

 inception_resnet_v2 (Functi  (None, 6, 6, 1536)       54336736
 onal)

 flatten_8 (Flatten)         (None, 55296)             0

 dense_26 (Dense)            (None, 512)               28312064

 dense_27 (Dense)            (None, 256)               131328

 dense_28 (Dense)            (None, 5)                 1285

=================================================================
Total params: 82,781,413
Trainable params: 28,444,677
Non-trainable params: 54,336,736
_________________________________________________________________
```

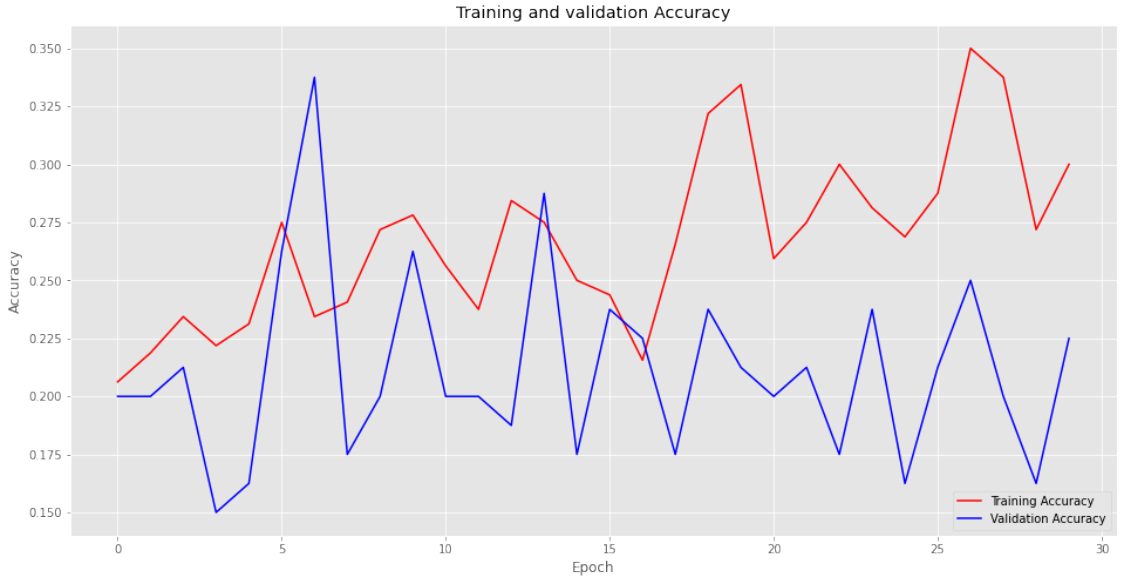
Model Creation and Training

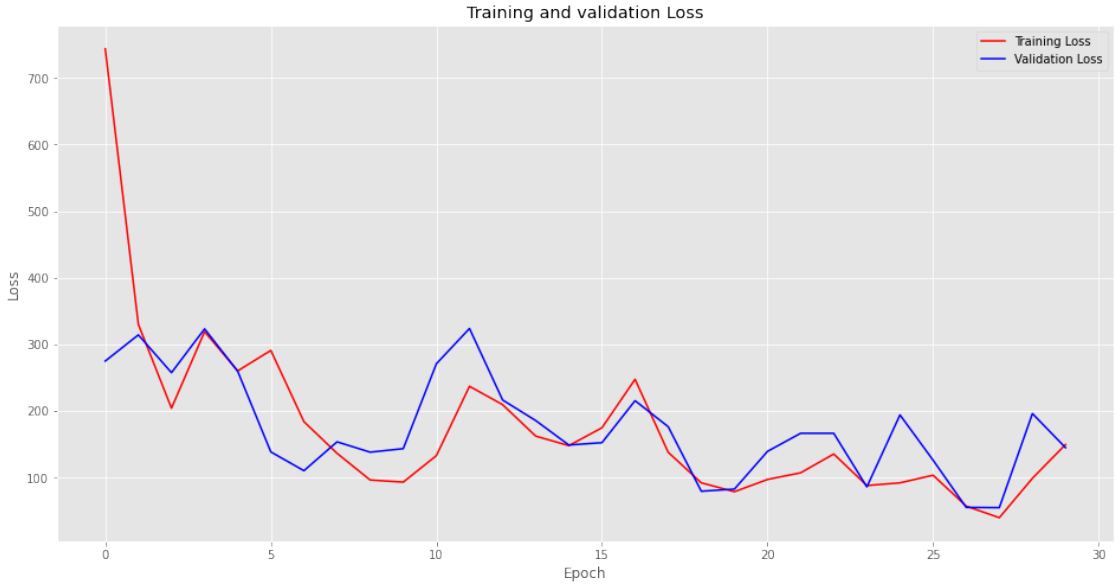
[ ]:
```
InceptionResNetV2_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
InceptionResNetV2_Model_History = InceptionResNetV2_Model.fit(
    pre_trained_data,
    epochs = pre_trained_epochs,
    validation_data = pre_trained_validation_data)
```

Accuracy and Loss Curves

[ ]:
```
InceptionResNetV2_Model_acc = InceptionResNetV2_Model_History.
 ↪history['accuracy']
InceptionResNetV2_Model_val_acc = InceptionResNetV2_Model_History.
 ↪history['val_accuracy']
InceptionResNetV2_Model_loss = InceptionResNetV2_Model_History.history['loss']
```

```
InceptionResNetV2_Model_val_loss = InceptionResNetV2_Model_History.
 ↪history['val_loss']
epochs = range(len(InceptionResNetV2_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, InceptionResNetV2_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, InceptionResNetV2_Model_val_acc, 'b', label="Validation␣
 ↪Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, InceptionResNetV2_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, InceptionResNetV2_Model_val_loss, 'b', label="Validation Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```





Model Performance Evaluation on Test Data

[ ]:
```
result = InceptionResNetV2_Model.predict(test_data2)
InceptionResNetV2_Model_y_predict = np.array([i.argmax() for i in result])

InceptionResNetV2_Model_cm = confusion_matrix(y_test,␣
 ↪InceptionResNetV2_Model_y_predict)
InceptionResNetV2_Model_ac =␣
 ↪accuracy_score(y_test,InceptionResNetV2_Model_y_predict)

print("confusion matrix on test data :\n",InceptionResNetV2_Model_cm)
print("accuracy score on test data:\n",InceptionResNetV2_Model_ac)

print(classification_report(y_test, InceptionResNetV2_Model_y_predict))
```

```
confusion matrix on test data :
 [[ 0  1 16  3  0]
 [ 0  0 17  3  0]
 [ 0  1 18  1  0]
 [ 0  0 19  1  0]
 [ 0  3 14  3  0]]
accuracy score on test data:
 0.19
```

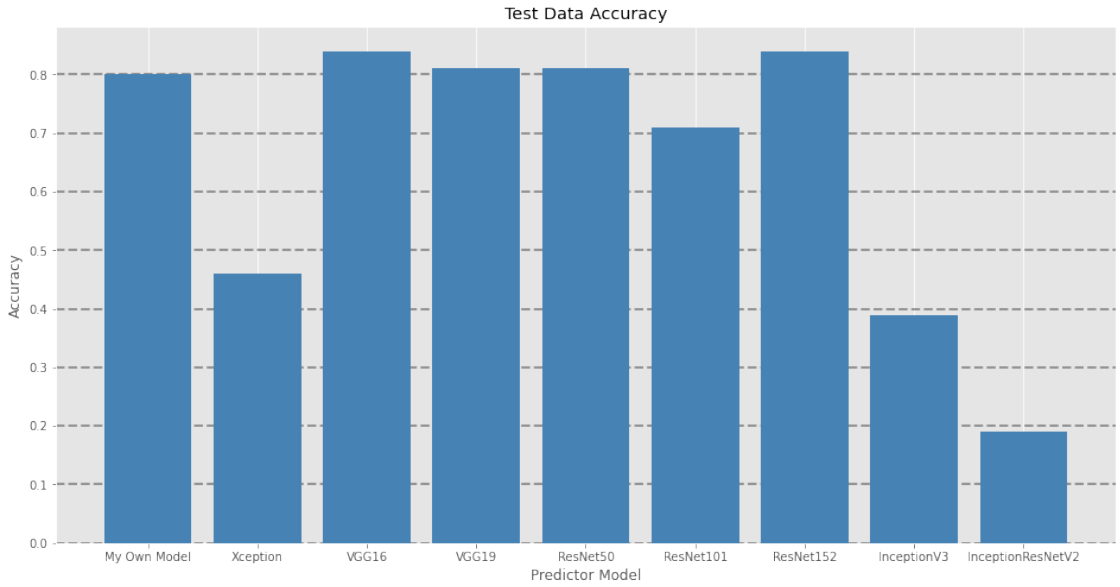
	precision	recall	f1-score	support
0	0.00	0.00	0.00	20
1	0.00	0.00	0.00	20
2	0.21	0.90	0.35	20
3	0.09	0.05	0.06	20

```
           4       0.00      0.00      0.00        20

    accuracy                           0.19       100
   macro avg       0.06      0.19      0.08       100
weighted avg       0.06      0.19      0.08       100
```

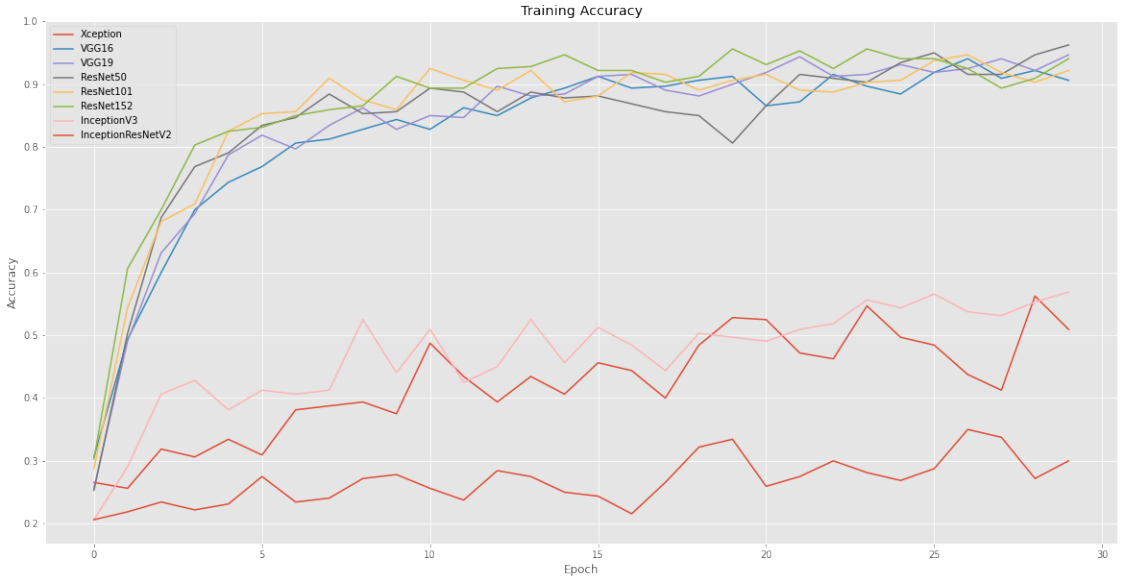
```
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are 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, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision and F-score are 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, msg_start, len(result))
```

1.5.10 Comparing Pre-Trained Models

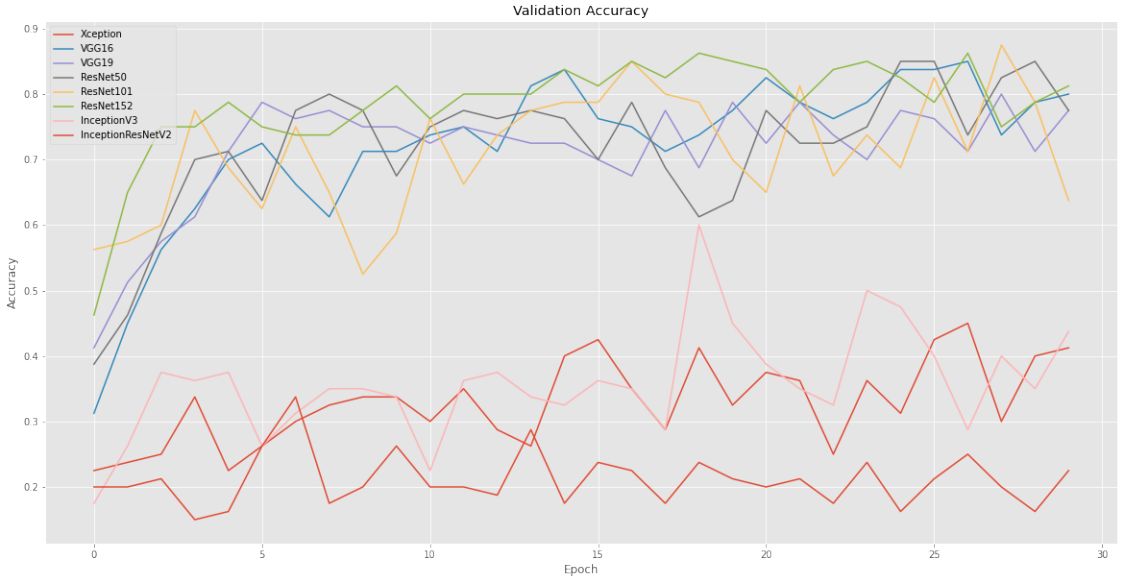
[ ]:
```
Models_Names = ["My Own Model", "Xception", "VGG16", "VGG19",
                "ResNet50", "ResNet101", "ResNet152",
                "InceptionV3", "InceptionResNetV2"]
Models_test_acc = [MyOwnModel_ac, Xception_Model_ac, VGG16_Model_ac,␣
 ↪VGG19_Model_ac,
                   ResNet50_Model_ac, ResNet101_Model_ac, ResNet152_Model_ac,
                   InceptionV3_Model_ac, InceptionResNetV2_Model_ac]

fig = plt.figure(figsize=(16,8))
plt.bar(Models_Names, Models_test_acc, color='steelblue')
plt.grid(color='gray', linestyle='--', linewidth=2, axis='y', alpha=0.8)
plt.xlabel('Predictor Model')
plt.ylabel('Accuracy')
plt.title('Test Data Accuracy')
plt.show()
```



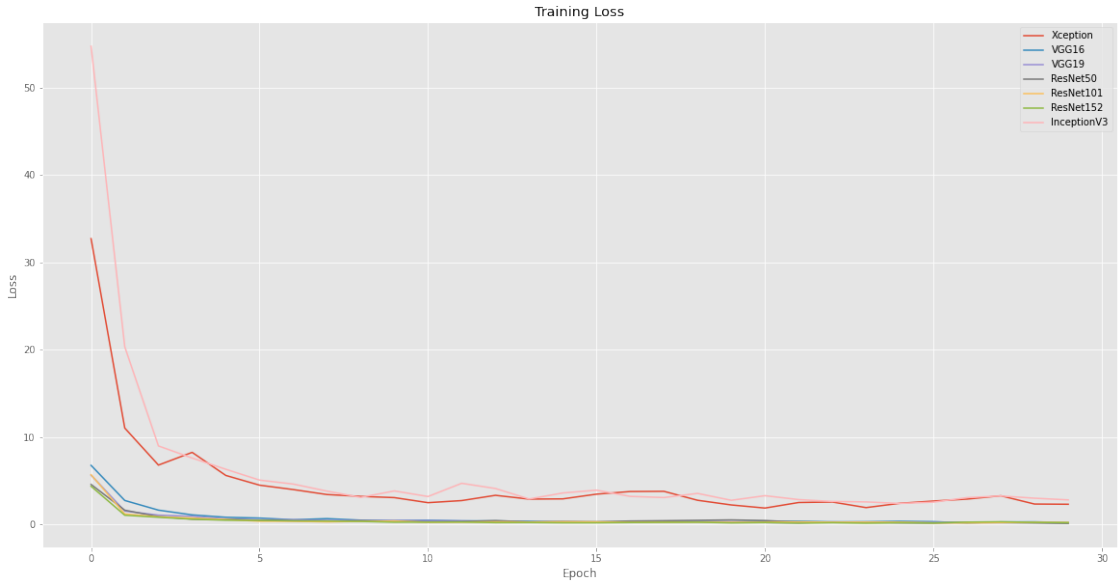
[ ]:
```
fig = plt.figure(figsize=(20,10))
plt.plot(epochs, Xception_Model_acc, label="Xception")
plt.plot(epochs, VGG16_Model_acc, label="VGG16")
plt.plot(epochs, VGG19_Model_acc, label="VGG19")
plt.plot(epochs, ResNet50_Model_acc, label="ResNet50")
plt.plot(epochs, ResNet101_Model_acc, label="ResNet101")
plt.plot(epochs, ResNet152_Model_acc, label="ResNet152")
plt.plot(epochs, InceptionV3_Model_acc, label="InceptionV3")
plt.plot(epochs, InceptionResNetV2_Model_acc, label="InceptionResNetV2")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training Accuracy')
plt.legend(loc='upper left')
plt.show()
```



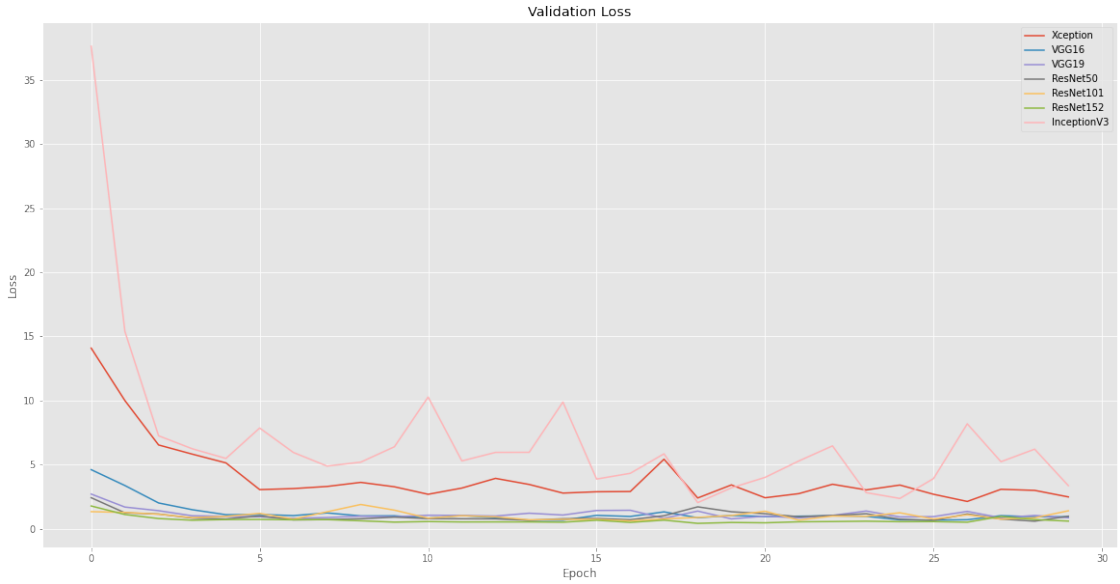
[ ]:
```
fig = plt.figure(figsize=(20,10))
plt.plot(epochs, Xception_Model_val_acc, label="Xception")
plt.plot(epochs, VGG16_Model_val_acc, label="VGG16")
plt.plot(epochs, VGG19_Model_val_acc, label="VGG19")
plt.plot(epochs, ResNet50_Model_val_acc, label="ResNet50")
plt.plot(epochs, ResNet101_Model_val_acc, label="ResNet101")
plt.plot(epochs, ResNet152_Model_val_acc, label="ResNet152")
plt.plot(epochs, InceptionV3_Model_val_acc, label="InceptionV3")
plt.plot(epochs, InceptionResNetV2_Model_val_acc, label="InceptionResNetV2")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Validation Accuracy')
plt.legend(loc='upper left')
plt.show()
```



[ ]:
```
fig = plt.figure(figsize=(20,10))
plt.plot(epochs, Xception_Model_loss, label="Xception")
plt.plot(epochs, VGG16_Model_loss, label="VGG16")
plt.plot(epochs, VGG19_Model_loss, label="VGG19")
plt.plot(epochs, ResNet50_Model_loss, label="ResNet50")
plt.plot(epochs, ResNet101_Model_loss, label="ResNet101")
plt.plot(epochs, ResNet152_Model_loss, label="ResNet152")
plt.plot(epochs, InceptionV3_Model_loss, label="InceptionV3")
#plt.plot(epochs, InceptionResNetV2_Model_loss, label="InceptionResNetV2")
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training Loss')
plt.legend(loc='upper right')
plt.show()
```



[ ]:
```
fig = plt.figure(figsize=(20,10))
plt.plot(epochs, Xception_Model_val_loss, label="Xception")
plt.plot(epochs, VGG16_Model_val_loss, label="VGG16")
plt.plot(epochs, VGG19_Model_val_loss, label="VGG19")
plt.plot(epochs, ResNet50_Model_val_loss, label="ResNet50")
plt.plot(epochs, ResNet101_Model_val_loss, label="ResNet101")
plt.plot(epochs, ResNet152_Model_val_loss, label="ResNet152")
plt.plot(epochs, InceptionV3_Model_val_loss, label="InceptionV3")
#plt.plot(epochs, InceptionResNetV2_Model_val_loss, label="InceptionResNetV2")
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Validation Loss')
plt.legend(loc='upper right')
plt.show()
```



1.6 Exploiting Autoencoder Networks

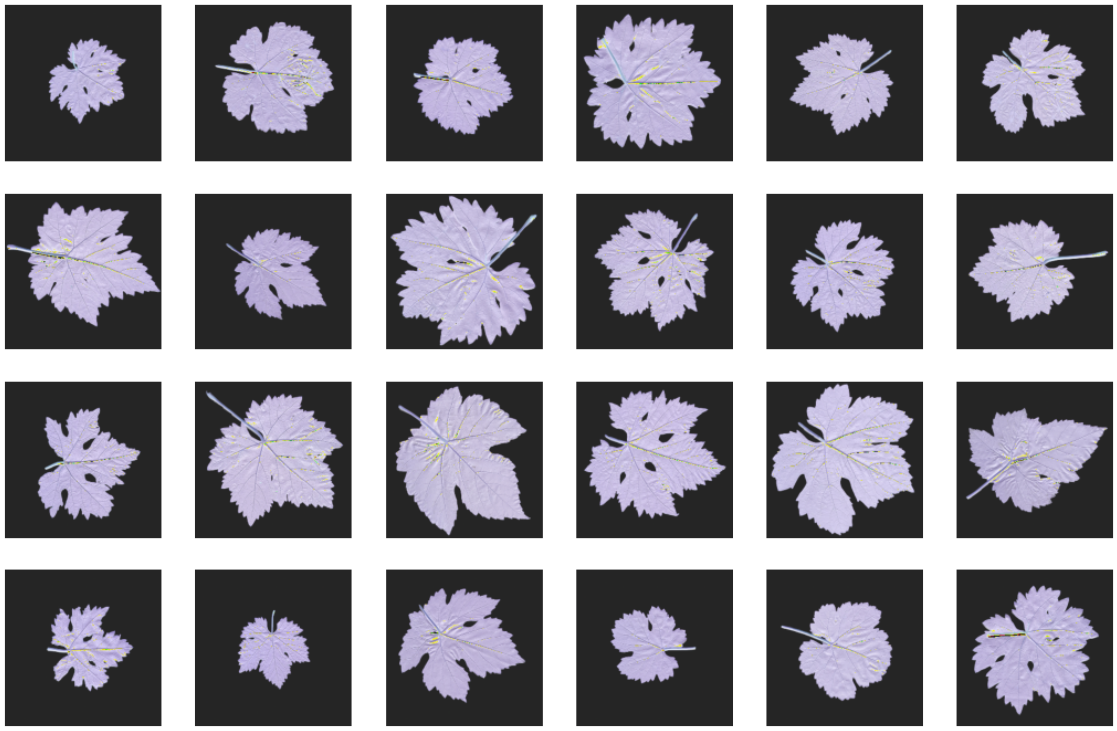
1.6.1 Denoising Autoencoder

Noisy Data Generation

[ ]:
```
Noise_Factor = 0.3
Noise_Mean = 0.5 * 255

train_data_denoising = augmented_train_data.map(lambda x, y: (x + Noise_Factor␣
 ↪* np.random.normal(loc=Noise_Mean, scale=1.0, size=image_size + (3,)), x))
validation_data_denoising = validation_data2.map(lambda x, y: (x + Noise_Factor␣
 ↪* np.random.normal(loc=Noise_Mean, scale=1.0, size=image_size + (3,)), x))
test_data_denoising = test_data2.map(lambda x, y: (x + Noise_Factor * np.random.
 ↪normal(loc=Noise_Mean, scale=1.0, size=image_size + (3,)), x))
```

Random Sample

[ ]:
```
plt.figure(figsize=(18, 12))
for images, labels in train_data_denoising.take(1):
    for i in range(24):
        ax = plt.subplot(4, 6, i + 1)
        plt.imshow(images[i].numpy().astype("uint8"))
        plt.axis("off")
```



Model Architecture Define

[ ]:
```
Denoising_Model = keras.models.Sequential([
    layers.Input(shape = image_size + (3,)),

    layers.Conv2D(16, (3, 3), activation='relu', padding="same"),
    layers.MaxPooling2D((2, 2), strides = (2, 2), padding="same"),

    layers.Conv2D(32, (3, 3), activation='relu', padding="same"),
    layers.MaxPooling2D((2, 2), strides = (2, 2), padding="same"),

    layers.Conv2D(64, (3, 3), activation='relu', padding="same"),
    layers.MaxPooling2D((2, 2), strides = (2, 2), padding="same"),

    layers.Conv2D(128, (3, 3), activation='relu', padding="same"),
    layers.MaxPooling2D((2, 2), strides = (2, 2), padding="same"),

    layers.Conv2D(256, (3, 3), activation='relu', padding="same"),
    layers.MaxPooling2D((2, 2), strides = (2, 2), padding="same"),

    layers.Conv2DTranspose(256, (3, 3), strides = 2, activation="relu",␣
↪padding="same"),
```

```
    layers.Conv2DTranspose(128, (3, 3), strides = 2, activation="relu",␣
 ↪padding="same"),

    layers.Conv2DTranspose(64, (3, 3), strides = 2, activation="relu",␣
 ↪padding="same"),

    layers.Conv2DTranspose(32, (3, 3), strides = 2, activation="relu",␣
 ↪padding="same"),

    layers.Conv2DTranspose(16, (3, 3), strides = 2, activation="relu",␣
 ↪padding="same"),

    layers.Conv2D(3, (3, 3), activation="sigmoid", padding="same"),
    layers.Rescaling(scale = 255.0/1, offset = 0.0)
    ])
Denoising_Model.summary()
```

```
Model: "sequential_10"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_307 (Conv2D)         (None, 256, 256, 16)      448

 max_pooling2d_14 (MaxPoolin  (None, 128, 128, 16)     0
 g2D)

 conv2d_308 (Conv2D)         (None, 128, 128, 32)      4640

 max_pooling2d_15 (MaxPoolin  (None, 64, 64, 32)       0
 g2D)

 conv2d_309 (Conv2D)         (None, 64, 64, 64)        18496

 max_pooling2d_16 (MaxPoolin  (None, 32, 32, 64)       0
 g2D)

 conv2d_310 (Conv2D)         (None, 32, 32, 128)       73856

 max_pooling2d_17 (MaxPoolin  (None, 16, 16, 128)      0
 g2D)

 conv2d_311 (Conv2D)         (None, 16, 16, 256)       295168

 max_pooling2d_18 (MaxPoolin  (None, 8, 8, 256)        0
 g2D)

 conv2d_transpose (Conv2DTra  (None, 16, 16, 256)      590080
```

```
nspose)

conv2d_transpose_1 (Conv2DT  (None, 32, 32, 128)      295040
ranspose)

conv2d_transpose_2 (Conv2DT  (None, 64, 64, 64)       73792
ranspose)

conv2d_transpose_3 (Conv2DT  (None, 128, 128, 32)     18464
ranspose)

conv2d_transpose_4 (Conv2DT  (None, 256, 256, 16)     4624
ranspose)

conv2d_312 (Conv2D)          (None, 256, 256, 3)      435

rescaling (Rescaling)        (None, 256, 256, 3)      0

=================================================================
Total params: 1,375,043
Trainable params: 1,375,043
Non-trainable params: 0
_________________________________________________________________
```

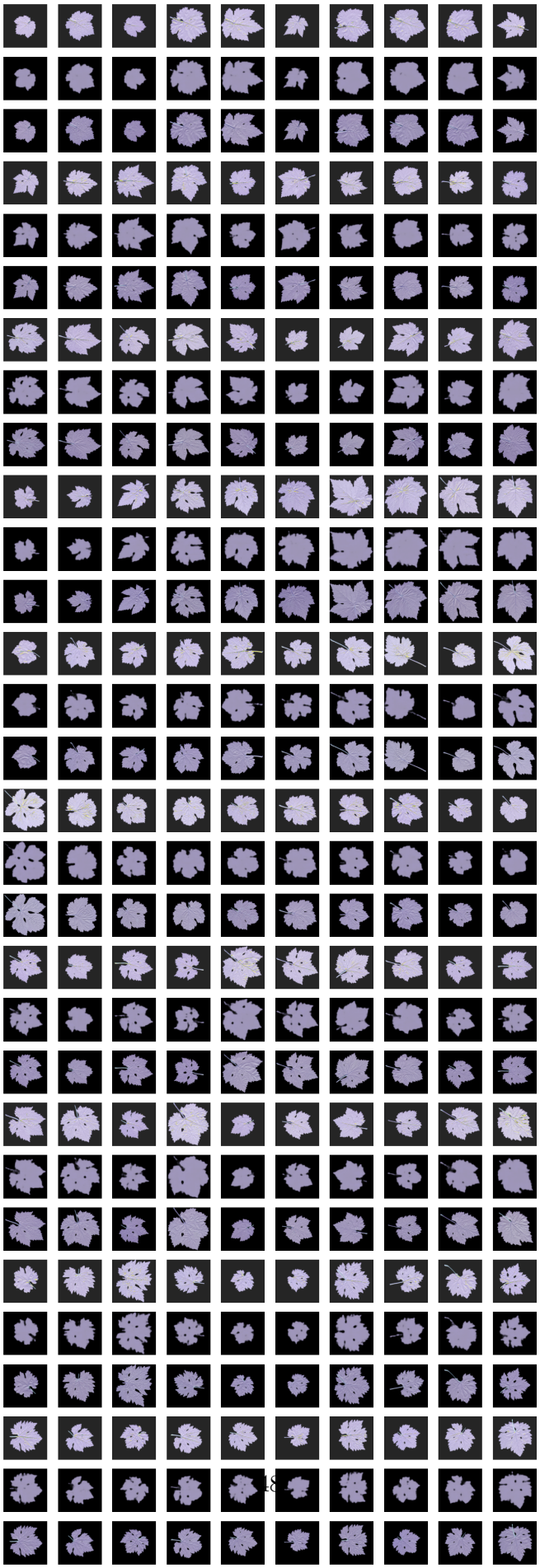
Model Creation and Training

[ ]:
```
Denoising_Model.compile(
    optimizer=keras.optimizers.Adam(1e-3),
    loss=keras.losses.MeanSquaredError(),
    metrics=["accuracy"],
)
history_Denosing = Denoising_Model.fit(
    train_data_denoising,
    epochs=30,
    validation_data=validation_data_denoising)
Denoising_Model.save('Denoising_Model.h5')
```

Model Performance Evaluation on Test Data

[ ]:
```
Denoising_Output = Denoising_Model.predict(test_data_denoising).round()

plt.figure(figsize=(20, 60))
for images, labels in test_data_denoising:
  for rows in range(10):
    for i in range(10):
      ax = plt.subplot(30, 10, rows*30 + i + 1)
      plt.imshow(images[rows*10+i].numpy().astype("uint8"))
      plt.axis("off")
      ax = plt.subplot(30, 10, rows*30 + 10 + i + 1)
```

```
    plt.imshow(Denoising_Output[rows*10+i].astype("uint8"))
    plt.axis("off")
    ax = plt.subplot(30, 10, rows*30 + 20 + i + 1)
    plt.imshow(labels[rows*10+i].numpy().astype("uint8"))
    plt.axis("off")
```



Denosing and Classifier Models Merging

Model Architecture Define

[ ]:
```
pretrained_model = tf.keras.applications.ResNet152(
    include_top=False,
    weights="imagenet",
    input_shape=image_size + (3,),
    classes=1000,
)

Denoising_Model.trainable = False
pretrained_model.trainable = False

Denoised_ResNet152_Model = keras.models.Sequential([
    layers.Input(shape = image_size + (3,)),
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    Denoising_Model,
    pretrained_model,
    layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(5, activation='softmax')])

Denoised_ResNet152_Model.summary()
```

```
Model: "sequential_27"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_23 (RandomR  (None, 256, 256, 3)      0
 otation)

 random_zoom_22 (RandomZoom)  (None, 256, 256, 3)      0

 random_flip_46 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_47 (RandomFlip)  (None, 256, 256, 3)      0

 sequential_10 (Sequential)  (None, 256, 256, 3)       1375043
```

```
resnet152 (Functional)      (None, 8, 8, 2048)        58370944

flatten_22 (Flatten)        (None, 131072)            0

dense_82 (Dense)            (None, 512)               67109376

dense_83 (Dense)            (None, 256)               131328

dense_84 (Dense)            (None, 256)               65792

dense_85 (Dense)            (None, 5)                 1285

=================================================================
Total params: 127,053,768
Trainable params: 67,307,781
Non-trainable params: 59,745,987
_________________________________________________________________
```

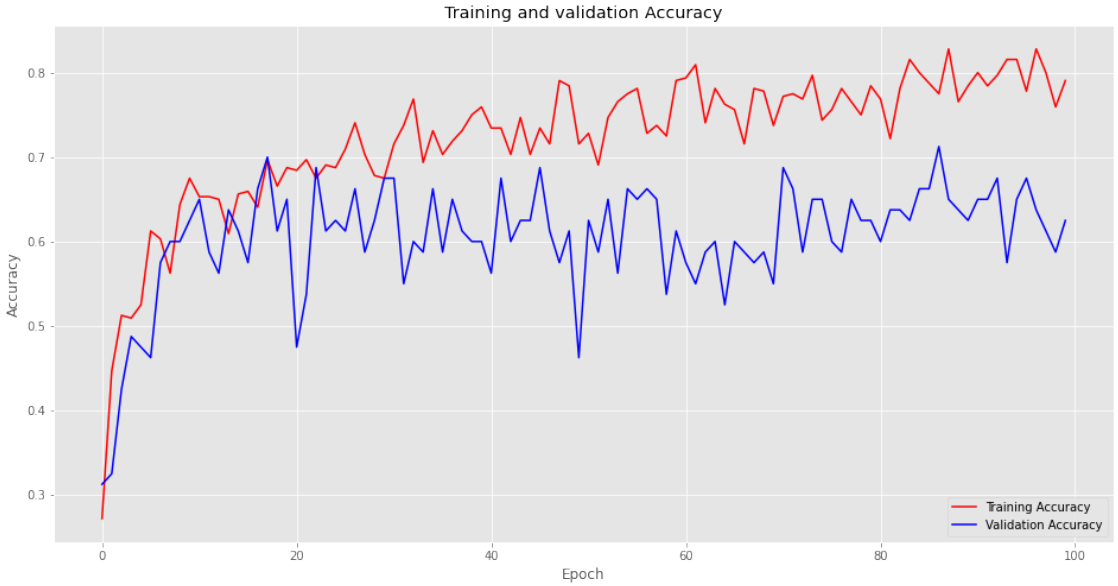
Model Creation and Training

[ ]:
```
Denoised_ResNet152_Model.compile(
    optimizer=keras.optimizers.Adam(1e-4),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
Denoised_ResNet152_Model_History = Denoised_ResNet152_Model.fit(
    train_data2,
    epochs = 100,
    validation_data = validation_data2)
Denoised_ResNet152_Model.save('Denoised_ResNet152_Model.h5')
```

Accuracy and Loss Curves

[ ]:
```
Denoised_ResNet152_Model_acc = Denoised_ResNet152_Model_History.
 ↪history['accuracy']
Denoised_ResNet152_Model_val_acc = Denoised_ResNet152_Model_History.
 ↪history['val_accuracy']
Denoised_ResNet152_Model_loss = Denoised_ResNet152_Model_History.history['loss']
Denoised_ResNet152_Model_val_loss = Denoised_ResNet152_Model_History.
 ↪history['val_loss']
epochs = range(len(Denoised_ResNet152_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, Denoised_ResNet152_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, Denoised_ResNet152_Model_val_acc, 'b', label="Validation␣
 ↪Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
fig2 = plt.figure(figsize=(16,8))
```

```
plt.plot(epochs, Denoised_ResNet152_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, Denoised_ResNet152_Model_val_loss, 'b', label="Validation␣
 ↪Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



Model Performance Evaluation on Test Data

```
[ ]: result = Denoised_ResNet152_Model.predict(test_data2)
Denoised_ResNet152_Model_y_predict = np.array([i.argmax() for i in result])

Denoised_ResNet152_Model_cm = confusion_matrix(y_test,␣
 ↪Denoised_ResNet152_Model_y_predict)
Denoised_ResNet152_Model_ac =␣
 ↪accuracy_score(y_test,Denoised_ResNet152_Model_y_predict)

print("confusion matrix on test data :\n",Denoised_ResNet152_Model_cm)
print("accuracy score on test data:\n",Denoised_ResNet152_Model_ac)

print(classification_report(y_test, Denoised_ResNet152_Model_y_predict))
```

```
confusion matrix on test data :
 [[ 9  1  2  3  5]
 [ 3  9  1  3  4]
 [ 0  2 11  6  1]
 [ 0  0  1 19  0]
 [ 0  0  0  4 16]]
accuracy score on test data:
 0.64
              precision    recall  f1-score   support

           0       0.75      0.45      0.56        20
           1       0.75      0.45      0.56        20
           2       0.73      0.55      0.63        20
           3       0.54      0.95      0.69        20
           4       0.62      0.80      0.70        20

    accuracy                           0.64       100
   macro avg       0.68      0.64      0.63       100
weighted avg       0.68      0.64      0.63       100
```

1.6.2 Dimension Reduction Autoencoder

Input Dataset Generation

```
[ ]: train_data_dimension_reduction = augmented_train_data.map(lambda x, y: (x, x))
validation_data_dimension_reduction = validation_data2.map(lambda x, y: (x, x))
test_data_dimension_reduction = test_data2.map(lambda x, y: (x, x))
```

Model Architecture Define

```
[ ]: Encoder_Model = keras.models.Sequential([
    layers.Resizing(128, 128),
    layers.Flatten(),
    layers.Dense(512, activation='relu'),
    layers.Dense(512, activation='relu'),
```

```
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
])
Decoder_Model = keras.models.Sequential([
    layers.Dense(512, activation='relu'),
    layers.Dense(512, activation='relu'),
    layers.Dense(512, activation='relu'),
    layers.Dense(128*128*3, activation='relu'),
    layers.Reshape((128,128,3)),
    layers.Resizing(256, 256),
    ])
AutoEncoder_Model = keras.models.Sequential([
    layers.Input(shape = image_size + (3,)),
    Encoder_Model,
    Decoder_Model,
    ])
AutoEncoder_Model.summary()
```

```
Model: "sequential_14"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 sequential_12 (Sequential)  (None, 256)               25822976

 sequential_13 (Sequential)  (None, 256, 256, 3)       25871872

=================================================================
Total params: 51,694,848
Trainable params: 51,694,848
Non-trainable params: 0
_________________________________________________________________
```

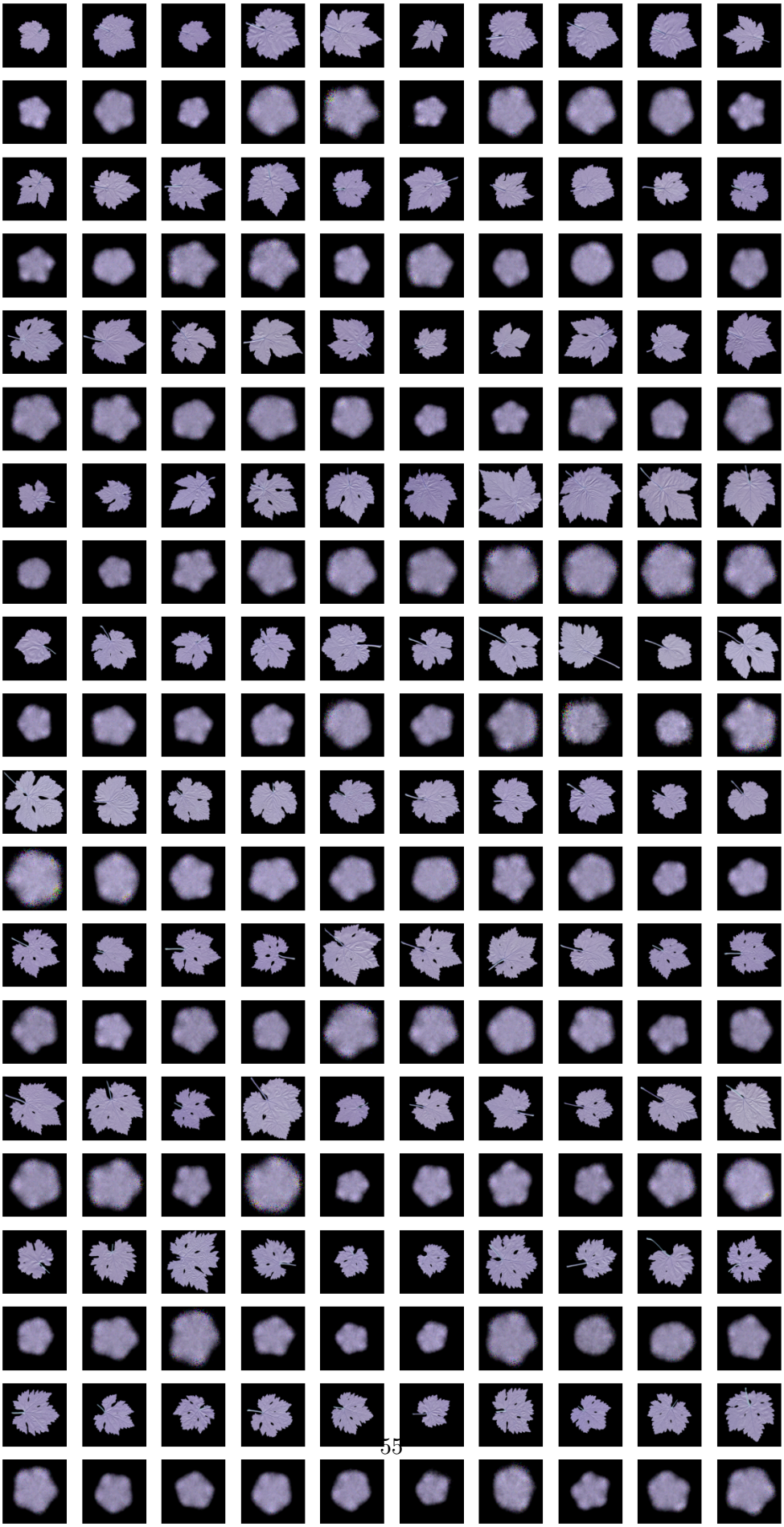
Model Creation and Training

[ ]:
```
AutoEncoder_Model.compile(
    optimizer=keras.optimizers.Adam(1e-3),
    loss=tf.keras.losses.MeanSquaredError(),
    metrics=["accuracy"])
AutoEncoder_Model_History = AutoEncoder_Model.fit(
    train_data_dimension_reduction,
    epochs = 30,
    validation_data = validation_data_dimension_reduction)
AutoEncoder_Model.save('AutoEncoder_Model.h5')
```

Model Performance Evaluation on Test Data

[ ]:
```
AutoEncoder_Output = AutoEncoder_Model.predict(test_data_dimension_reduction).
  ↪round()
```

```
plt.figure(figsize=(20, 40))
for images, labels in test_data_dimension_reduction:
  for rows in range(10):
    for i in range(10):
      ax = plt.subplot(20, 10, rows*20 + i + 1)
      plt.imshow(images[rows*10+i].numpy().astype("uint8"))
      plt.axis("off")
      ax = plt.subplot(20, 10, rows*20 + 10 + i + 1)
      plt.imshow(AutoEncoder_Output[rows*10+i].astype("uint8"))
      plt.axis("off")
```



Dimension Reduction and Classifier Models Merging

Model Architecture Define

[ ]:
```
Encoder_Model.trainable = False

Dimension_Reduction_Model = keras.models.Sequential([
    layers.Input(shape = image_size + (3,)),
    layers.RandomRotation(0.3, fill_mode='constant', fill_value=0),
    layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
 ↪2),fill_mode='constant', fill_value=0),
    layers.RandomFlip("horizontal"),
    layers.RandomFlip("vertical"),
    Encoder_Model,
    layers.Dense(512, activation='relu'),
    layers.Dense(1024, activation='relu'),
    layers.Dense(2048, activation='relu'),
    layers.Dense(1024, activation='relu'),
    layers.Dense(512, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(128, activation='relu'),
    layers.Dense(5, activation='softmax')
    ])

Dimension_Reduction_Model.summary()
```

```
Model: "sequential_15"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 random_rotation_11 (RandomR  (None, 256, 256, 3)      0
 otation)

 random_zoom_10 (RandomZoom)  (None, 256, 256, 3)      0

 random_flip_22 (RandomFlip)  (None, 256, 256, 3)      0

 random_flip_23 (RandomFlip)  (None, 256, 256, 3)      0

 sequential_12 (Sequential)  (None, 256)               25822976

 dense_41 (Dense)            (None, 512)               131584

 dense_42 (Dense)            (None, 1024)              525312

 dense_43 (Dense)            (None, 2048)              2099200
```

```
 dense_44 (Dense)            (None, 1024)              2098176

 dense_45 (Dense)            (None, 512)               524800

 dense_46 (Dense)            (None, 256)               131328

 dense_47 (Dense)            (None, 128)               32896

 dense_48 (Dense)            (None, 5)                 645

=================================================================
Total params: 31,366,917
Trainable params: 5,543,941
Non-trainable params: 25,822,976
_________________________________________________________________
```

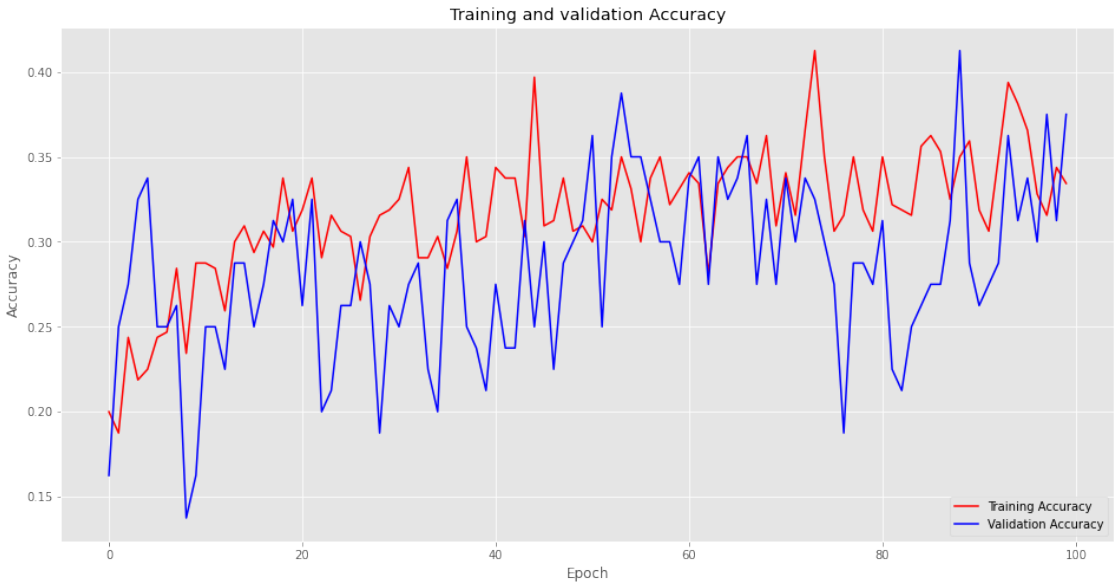
Model Creation and Training

[ ]:
```
Dimension_Reduction_Model.compile(
    optimizer=keras.optimizers.Adam(1e-3),
    loss=tf.keras.losses.SparseCategoricalCrossentropy(),
    metrics=["accuracy"])
Dimension_Reduction_Model_History = Dimension_Reduction_Model.fit(
    train_data2,
    epochs = 100,
    validation_data = validation_data2)
Dimension_Reduction_Model.save('Dimension_Reduction_Model.h5')
```

Accuracy and Loss Curves

[ ]:
```
Dimension_Reduction_Model_acc = Dimension_Reduction_Model_History.
 ↪history['accuracy']
Dimension_Reduction_Model_val_acc = Dimension_Reduction_Model_History.
 ↪history['val_accuracy']
Dimension_Reduction_Model_loss = Dimension_Reduction_Model_History.
 ↪history['loss']
Dimension_Reduction_Model_val_loss = Dimension_Reduction_Model_History.
 ↪history['val_loss']
epochs = range(len(Dimension_Reduction_Model_acc))
fig = plt.figure(figsize=(16,8))
plt.plot(epochs, Dimension_Reduction_Model_acc, 'r', label="Training Accuracy")
plt.plot(epochs, Dimension_Reduction_Model_val_acc, 'b', label="Validation␣
 ↪Accuracy")
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and validation Accuracy')
plt.legend(loc='lower right')
```

```
fig2 = plt.figure(figsize=(16,8))
plt.plot(epochs, Dimension_Reduction_Model_loss, 'r', label="Training Loss")
plt.plot(epochs, Dimension_Reduction_Model_val_loss, 'b', label="Validation␣
 ↪Loss")
plt.legend(loc='upper right')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training and validation Loss')
plt.show()
```



Model Performance Evaluation on Test Data

```
[ ]: result = Dimension_Reduction_Model.predict(test_data2)
Dimension_Reduction_Model_y_predict = np.array([i.argmax() for i in result])

Dimension_Reduction_Model_cm = confusion_matrix(y_test,␣
 ↪Dimension_Reduction_Model_y_predict)
Dimension_Reduction_Model_ac =␣
 ↪accuracy_score(y_test,Dimension_Reduction_Model_y_predict)

print("confusion matrix on test data :\n",Dimension_Reduction_Model_cm)
print("accuracy score on test data:\n",Dimension_Reduction_Model_ac)

print(classification_report(y_test, Dimension_Reduction_Model_y_predict))
```

```
confusion matrix on test data :
 [[11  1  3  4  1]
 [ 3  6  1  4  6]
 [ 7  1  4  3  5]
 [ 5  5  1  2  7]
 [ 3  1  1  8  7]]
accuracy score on test data:
 0.3
              precision    recall  f1-score   support

           0       0.38      0.55      0.45        20
           1       0.43      0.30      0.35        20
           2       0.40      0.20      0.27        20
           3       0.10      0.10      0.10        20
           4       0.27      0.35      0.30        20

    accuracy                           0.30       100
   macro avg       0.31      0.30      0.29       100
weighted avg       0.31      0.30      0.29       100
```

1.7 10 Different Seeds

```
[ ]: def load_by_conf(seed = 199, image_size = (256,256), batch_size = 32,␣
 ↪validation_split = 0.2):
    train_data = tf.keras.utils.image_dataset_from_directory(
        'Grapevine_Leaves_Image_Dataset',
        class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
        batch_size=batch_size,
        image_size=image_size,
        seed=seed,
        validation_split=validation_split,
```

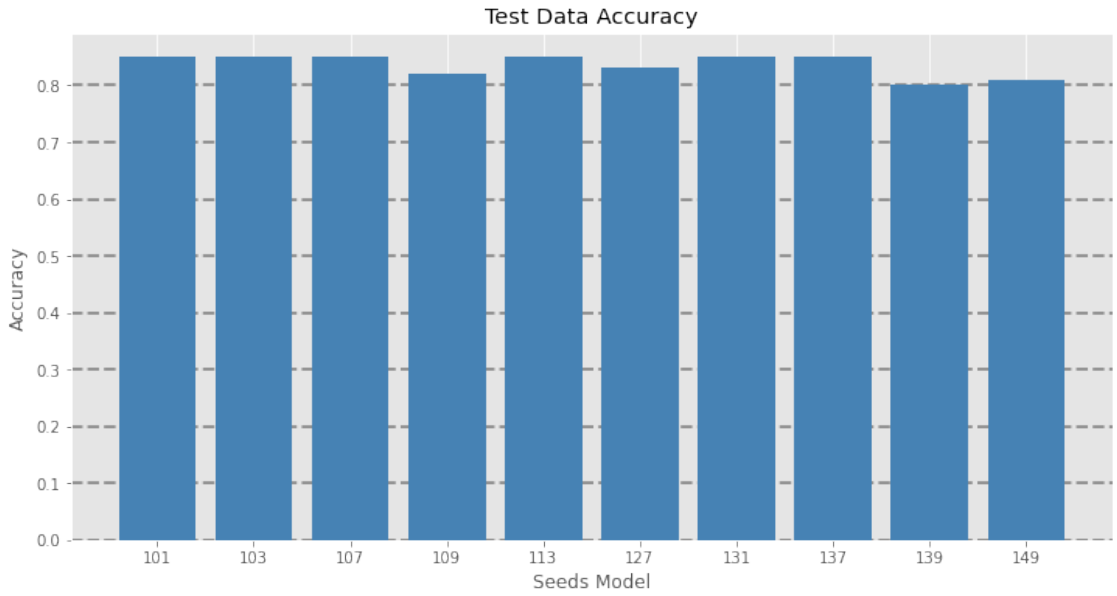
```
        subset="training"
    )
    validation_data = tf.keras.utils.image_dataset_from_directory(
        'Grapevine_Leaves_Image_Dataset',
        class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
        batch_size=batch_size,
        image_size=image_size,
        seed=seed,
        validation_split=validation_split,
        subset="validation"
    )
    test_data = tf.keras.utils.image_dataset_from_directory(
        'Test_Data',
        class_names = ["Ak", "Ala_Idris", "Buzgulu", "Dimnit", "Nazli"],
        image_size=image_size,
        batch_size=100,
        shuffle=False,
    )
    train_data_transposed = train_data.map(lambda x, y: (255-x, y))
    validation_data_transposed = validation_data.map(lambda x, y: (255-x, y))
    test_data_transposed = test_data.map(lambda x, y: (255-x, y))
    return([train_data_transposed, validation_data_transposed,␣
↪test_data_transposed])
```

[ ]:
```
def best_model_train(data, epochs = 2):
    pretrained_model = tf.keras.applications.ResNet152(
        include_top=False,
        weights="imagenet",
        input_shape=image_size + (3,),
        classes=1000)
    pretrained_model.trainable = False

    Best_Model = tf.keras.Sequential([
        layers.RandomRotation(0.3, fill_mode='constant', fill_value=0,␣
↪input_shape=image_size + (3,)),
        layers.RandomZoom(height_factor=(-0.2,0.2), width_factor=(-0.2,0.
↪2),fill_mode='constant', fill_value=0),
        layers.RandomFlip("horizontal"),
        layers.RandomFlip("vertical"),
        pretrained_model, layers.Flatten(),
        layers.Dense(512, activation='relu'),
        layers.Dense(256, activation='relu'),
        tf.keras.layers.Dense(5, activation='softmax')])
    Best_Model.compile(
        optimizer=keras.optimizers.Adam(1e-4),
        loss=tf.keras.losses.SparseCategoricalCrossentropy(),
        metrics=["accuracy"])
```

```
    Best_Model_History = Best_Model.fit(
        data[0],
        epochs = epochs,
        validation_data = data[1],
        verbose=2)

    result = Best_Model.predict(data[2])
    Best_Model_y_predict = np.array([i.argmax() for i in result])
    y_test = np.concatenate([y for x, y in data[2]], axis=0)
    Best_Model_cm = confusion_matrix(y_test, Best_Model_y_predict)
    Best_Model_ac = accuracy_score(y_test,Best_Model_y_predict)
    res = [Best_Model_ac, Best_Model_cm, classification_report(y_test,␣
 ↪Best_Model_y_predict)]
    return(res)
```

[ ]:
```
seeds = [101, 103, 107, 109, 113, 127, 131, 137, 139, 149]
results = []
for s in seeds:
    print("*"*40)
    print("For Seed = ", s)
    print("*"*40)
    new_data = load_by_conf(seed = s)
    new_res = best_model_train(new_data, epochs = 30)
    results.append(new_res)
    print("*"*40)
    print("\n"*2)
accs = []
cfmxs = []
clfrep = []
for i in results:
    accs.append(i[0])
    cfmxs.append(i[1])
    clfrep.append(i[2])
```

[ ]:
```
fig = plt.figure(figsize=(12,6))
plt.bar([str(i) for i in seeds], accs, color='steelblue')
plt.grid(color='gray', linestyle='--', linewidth=2, axis='y', alpha=0.8)
plt.xlabel('Seeds Model')
plt.ylabel('Accuracy')
plt.title('Test Data Accuracy')
plt.show()
print("*"*100)
print("accuracies : ", accs)
print("Mean accuracy : ",np.array(accs).mean())
print("Best Model Classification Report :")
print(clfrep[np.array(accs).argmax()])
```




```
**********************************************************************************
********************
accuracies :  [0.85, 0.85, 0.85, 0.82, 0.85, 0.83, 0.85, 0.85, 0.8, 0.81]
Mean accuracy :  0.836
Best Model Classification Report :
              precision    recall  f1-score   support

           0       0.67      0.90      0.77        20
           1       1.00      0.80      0.89        20
           2       0.90      0.95      0.93        20
           3       1.00      0.70      0.82        20
           4       0.82      0.90      0.86        20

    accuracy                           0.85       100
   macro avg       0.88      0.85      0.85       100
weighted avg       0.88      0.85      0.85       100
```