```
In [1]: import tensorflow as tf
               import numpy
               #imports the TensorFlow library in Python using the alias tf, which is a popular open-source machine learning
               #developed by Google for building and training machine learning models.
               #numpy is another popular Python library used for numerical computing, particularly for handling arrays and mat
               #operations on them.
In [3]: !pip install matplotlib
              #This command will download and install the matplotlib library and its dependencies from the Python Package Ind
              #repository.
              Requirement already satisfied: matplotlib in c:\users\student\miniconda3\envs\tf\lib\site-packages (3.8.3)
              Requirement already satisfied: contourpy>=1.0.1 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from
              matplotlib) (1.2.0)
              Requirement already satisfied: cycler>=0.10 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from matp
              lotlib) (0.12.1)
              Requirement already satisfied: fonttools>=4.22.0 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from
              matplotlib) (4.49.0)
              Requirement already \ satisfied: \ kiwisolver>=1.3.1 \ in \ c:\ wers \ student\ miniconda \ lenvs\ tf\ lib\ site-packages \ (from the conditions of the co
              matplotlib) (1.4.5)
              Requirement already satisfied: numpy<2,>=1.21 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from ma
              tplotlib) (1.26.4)
              Requirement already satisfied: packaging>=20.0 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from m
              atplotlib) (23.1)
              Requirement already satisfied: pillow>=8 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from matplot
              lib) (10.2.0)
              Requirement already satisfied: pyparsing>=2.3.1 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from
              matplotlib) (3.1.2)
              Requirement already satisfied: python-dateutil >= 2.7 in c: \users \land thin in its order of the content of the 
               rom matplotlib) (2.8.2)
              Requirement already satisfied: importlib-resources>=3.2.0 in c:\users\student\miniconda3\envs\tf\lib\site-packa
              ges (from matplotlib) (6.3.0)
              Requirement already satisfied: zipp>=3.1.0 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from impor
              tlib-resources>=3.2.0->matplotlib) (3.17.0)
              Requirement already satisfied: six>=1.5 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from python-d
              ateutil>=2.7->matplotlib) (1.16.0)
In [3]: pip install opencv-python
               #This command installs the opency-python package using pip. OpenCV (Open Source Computer Vision Library) is an
              #computer vision and machine learning software library
              Requirement already satisfied: opency-python in c:\users\student\miniconda3\envs\tf\lib\site-packages (4.5.5.64
              Requirement already satisfied: numpy>=1.14.5 in c:\users\student\miniconda3\envs\tf\lib\site-packages (from ope
              ncv-python) (1.26.4)
              Note: you may need to restart the kernel to use updated packages.
In [4]: import numpy as np
              import matplotlib.pyplot as plt
               # Matplotlib is a plotting library for Python. The pyplot module provides a MATLAB-like interface for creating
               #customizing plots and visualizations.
               import matplotlib.image as mpg
               #This imports the image submodule from Matplotlib, which contains functions for reading, writing, and displayin
              import os
               #The os module provides a portable way to interact with the operating system, such as reading or writing files
               #directories.
               from tensorflow.keras.layers import Conv2D,Conv2DTranspose, Dense, Flatten, Input,BatchNormalization,PReLU,Leak
               from tensorflow.keras.optimizers import Adam
               from tensorflow.keras.models import Model
               from tensorflow.nn import depth to space
               from tensorflow.keras.utils import plot model
               from tensorflow.keras.applications.vgg19 import VGG19
               from tensorflow.math import reduce mean, square
               from tensorflow.keras.losses import MeanSquaredError,BinaryCrossentropy
               from tensorflow.keras import Sequential
                  "tensorflow.keras.layers: Contains various layers used to build neural networks, such as convolutional layers
               tensorflow.keras.optimizers: Provides optimization algorithms to train neural networks, such as Adam (Adam).
               tensorflow.keras.models: Contains tools for building and manipulating neural network models, such as the Model
               tensorflow.nn.depth_to_space: A TensorFlow function for converting depth data into spatial data.
               tensorflow.keras.utils.plot model: Used for visualizing Keras models as graphs.
               tensorflow.keras.applications.vgg19.VGG19: Pre-trained VGG19 model for image classification tasks.
               tensorflow.math.reduce_mean and tensorflow.math.square: TensorFlow mathematical operations.
               tensorflow.keras.losses: Contains loss functions used for training neural networks, such as mean squared error
               tensorflow.keras.Sequential: A linear stack of layers used to build sequential models."""
               import re
               #The re module provides support for working with regular expressions in Python.
               import cv2
               #OpenCV is a popular computer vision library. This import statement imports the Python bindings for OpenCV, all
              #to various computer vision functionalities like image processing, object detection, etc.
```

In [88]: def sift(image):

image= cv2.imread(image)

sift = cv2.SIFT_create()

#We define a function named sift that takes one argument, image

gray_scale= cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

#the function reads the image specified by the image argument using OpenCV's cv2.imread() function

#This line converts the color image loaded in the previous step (image) to grayscale using OpenCV's cv2.cvt

```
#method used for detecting and describing local features and keypoints in images
            keypoints, _= sift.detectAndCompute(image, None)
            #Here, the detectAndCompute() method of the SIFT object is called to find keypoints and compute their descr
            #input image. The keypoints are points of interest in the image. The function returns two values: keypoints,
            #the detected keypoints, and _, which represents the descriptors (feature vectors) associated with the keyp
            sift image = cv2.drawKeypoints(gray scale, keypoints, None)
            #This line draws the detected keypoints on the grayscale image using the cv2.drawKeypoints() function. The
            #with keypoints drawn on it is stored in the variable sift_image.
            plt.imshow(sift_image)
            #Finally, this line displays the image with the keypointson it using Matplotlib's plt.imshow() function.
            plt.axis('off')
            #The plt.axis('off') line is used to turn off the axis lines and labels in the current Matplotlib plot.
            return 'Number of Keypoints in this image are',len(keypoints)
            #return a tuple containing a string indicating the number of keypoints detected in an image and the actual
In [6]: def sorted alphanumeric(data):
            convert = lambda text: int(text) if text.isdigit() else text.lower()
            alphanum_key = lambda key: [convert(c) for c in re.split('([0-9]+)',key)]
            return sorted(data, key = alphanum key)
        low img = []
        path = 'C:/Users/student/Desktop/dataset/Raw Data/low_res'
        files = os.listdir(path)
        files = sorted alphanumeric(files)
In [ ]: #This line defines a function named sorted_alphanumeric that takes one argument, data.
        #convert = lambda text: int(text) if text. isdigit() else text.lower()-This lambda function is used later to ext
        #and non-numeric parts of strings for sorting.
        \#alphanum key = lambda key: [convert(c) for c in re.split('([0-9]+)',key)]-This lambda function is used to gene
        #custom sorting key for strings, where numeric parts are sorted numerically and non-numeric parts are sorted al
        #return sorted(data,key = alphanum_key)-This line returns a sorted version of the input data
In []: '''The code snippet then proceeds to create a list called low img, which seems to contain the
        filenames of images in a directory sorted in alphanumeric order.
        path contains the directory path where the images are located.
        files = os.listdir(path) retrieves the list of filenames in the specified directory.
        files = sorted_alphanumeric(files) sorts the list of filenames using the sorted_alphanumeric function defined e
        After executing this code, low_img will contain the sorted list of filenames.''
In [7]: sample_image=path+"/"+files[13]
        sift(sample_image)
        #This line constructs the full path to a specific low-resolution image by concatenating the directory path (pat
        #and the filename at index 13 from the list files.
```

#This line creates a SIFT (Scale-Invariant Feature Transform) object using OpenCV's cv2.SIFT create() funct

('Number of Keypoints in this image are', 24)



#This line calls the sift() function for the file image we have defined.

```
In []:

def residual_blocks(input):
    x = Conv2D(64,(3,3),padding='same')(input)
    x = BatchNormalization()(x)
    x = ReLU()(x)
    x = Conv2D(64,(3,3),padding='same')(x)
    x = BatchNormalization()(x)
    x = BatchNormalization()(x)
    x = Concatenate()([input,x])
    return x

def subpixel(input):
    x = UpSampling2D()(input)
    x = Conv2D(256,(3,3),padding='same')(x)
```

```
x = ReLU()(x)
  return x
def generator():
  inputs = Input(shape=(64.64.3))
  x1 = Conv2D(64, (9,9), padding='same')(inputs)
  x1 = ReLU()(x1)
  r = residual blocks(x1)
 for _ in range(15):
    r = residual_blocks(r)
  x2 = Conv2D(64,(3,3),padding='same')(r)
  x2 = BatchNormalization()(x2)
  merge = Concatenate()([x2,x1])
 x = subpixel(merge)
  x = subpixel(x)
  output = Conv2D(3,(9,9),padding='same',activation='sigmoid')(x)
  model = Model(inputs,output)
  return model
```

In []: ''''residual_blocks(input): This function implements a series of residual blocks. Residual blocks are crucial i networks for enabling training of very deep networks without vanishing gradients. Each block consists of two co layers with 64 filters, each followed by batch normalization and ReLU activation. The output of the second conv concatenated with the input to the block, thus creating a residual connection.

subpixel(input): This function seems to perform sub-pixel convolution, which is commonly used in super-resoluti It upsamples the input by a factor of 2 using nearest neighbor upsampling, followed by a 3x3 convolution with 2 and ReLU activation.

generator(): This function defines the generator model. It takes an input of shape (64, 64, 3), likely represen resolution image, and passes it through a series of layers. First, a 9x9 convolutional layer with 64 filters is followed by ReLU activation. Then, a stack of 15 residual blocks is applied, using the residual_blocks function residual blocks, another 3x3 convolutional layer with 64 filters is applied, followed by batch normalization. T this convolution is concatenated with the output of the first ReLU layer (x1). Then, the subpixel function is a to gradually increase the resolution of the feature maps. Finally, a 9x9 convolutional layer with 3 filters and activation is applied to generate the high-resolution output image.

Overall, this code defines a generator network for image super-resolution, which takes a low-resolution image a and outputs a high-resolution image.''''

In [9]: g_model = generator()

#This line creates an instance of the generator model by calling the generator() function defined earlier. #The generator model is assigned to the variable g_model . $g_model.summary()$

#This line prints a summary of the generator model. The summary includes information about the architecture of #such as the layers, output shapes, and the number of parameters.

Model: "model"

Layer (type)	Output Shape	Param #	Connected to
<pre>input_1 (InputLayer)</pre>	[(None, 64, 64, 3)]	0	[]
conv2d (Conv2D)	(None, 64, 64, 64)	15616	['input_1[0][0]']
re_lu (ReLU)	(None, 64, 64, 64)	0	['conv2d[0][0]']
conv2d_1 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu[0][0]']
$batch_normalization \ (BatchNormalization)$	(None, 64, 64, 64)	256	['conv2d_1[0][0]']
re_lu_1 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization[0][0]']
conv2d_2 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_1[0][0]']
<pre>batch_normalization_1 (BatchNormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_2[0][0]']
concatenate (Concatenate)	(None, 64, 64, 128)	0	['re_lu[0][0]', 'batch_normalization_1[0][0]']
conv2d_3 (Conv2D)	(None, 64, 64, 64)	73792	['concatenate[0][0]']
<pre>batch_normalization_2 (BatchNormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_3[0][0]']
re_lu_2 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_2[0][0]']
conv2d_4 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_2[0][0]']
<pre>batch_normalization_3 (BatchNormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_4[0][0]']
<pre>concatenate_1 (Concatenate)</pre>	(None, 64, 64, 192)	0	<pre>['concatenate[0][0]', 'batch_normalization_3[0][0]']</pre>

conv2d 5 (Conv2D)	(None, 64, 64, 64)	110656	['concatenate 1[0][0]']
batch normalization 4 (BatchNo		256	['conv2d 5[0][0]']
rmalization)	, , , , ,		
re_lu_3 (ReLU)	(None, 64, 64, 64)	0	<pre>['batch_normalization_4[0][0]']</pre>
conv2d_6 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_3[0][0]']
<pre>batch_normalization_5 (BatchNo rmalization)</pre>	(None, 64, 64, 64)	256	['conv2d_6[0][0]']
<pre>concatenate_2 (Concatenate)</pre>	(None, 64, 64, 256)	0	<pre>['concatenate_1[0][0]', 'batch_normalization_5[0][0]']</pre>
conv2d_7 (Conv2D)	(None, 64, 64, 64)	147520	['concatenate_2[0][0]']
<pre>batch_normalization_6 (BatchNo rmalization)</pre>	(None, 64, 64, 64)	256	['conv2d_7[0][0]']
re_lu_4 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_6[0][0]']
conv2d_8 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_4[0][0]']
<pre>batch_normalization_7 (BatchNo rmalization)</pre>	(None, 64, 64, 64)	256	['conv2d_8[0][0]']
<pre>concatenate_3 (Concatenate)</pre>	(None, 64, 64, 320)	0	<pre>['concatenate_2[0][0]', 'batch_normalization_7[0][0]']</pre>
conv2d_9 (Conv2D)	(None, 64, 64, 64)	184384	['concatenate_3[0][0]']
<pre>batch_normalization_8 (BatchNo rmalization)</pre>	(None, 64, 64, 64)	256	['conv2d_9[0][0]']
re_lu_5 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_8[0][0]']
conv2d_10 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_5[0][0]']
<pre>batch_normalization_9 (BatchNo rmalization)</pre>	(None, 64, 64, 64)	256	['conv2d_10[0][0]']
<pre>concatenate_4 (Concatenate)</pre>	(None, 64, 64, 384)	0	<pre>['concatenate_3[0][0]', 'batch_normalization_9[0][0]']</pre>
conv2d_11 (Conv2D)	(None, 64, 64, 64)	221248	['concatenate_4[0][0]']
<pre>batch_normalization_10 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_11[0][0]']
re_lu_6 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_10[0][0]']
conv2d_12 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_6[0][0]']
<pre>batch_normalization_11 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_12[0][0]']
<pre>concatenate_5 (Concatenate)</pre>	(None, 64, 64, 448)	Θ	<pre>['concatenate_4[0][0]', 'batch_normalization_11[0][0]']</pre>
conv2d_13 (Conv2D)	(None, 64, 64, 64)	258112	['concatenate_5[0][0]']
<pre>batch_normalization_12 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_13[0][0]']
re_lu_7 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_12[0][0]']
conv2d_14 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_7[0][0]']
<pre>batch_normalization_13 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_14[0][0]']
<pre>concatenate_6 (Concatenate)</pre>	(None, 64, 64, 512)	Θ	<pre>['concatenate_5[0][0]', 'batch_normalization_13[0][0]']</pre>
conv2d_15 (Conv2D)	(None, 64, 64, 64)	294976	['concatenate_6[0][0]']
<pre>batch_normalization_14 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_15[0][0]']
re_lu_8 (ReLU)	(None, 64, 64, 64)	0	['batch_normalization_14[0][0]']
conv2d_16 (Conv2D)	(None, 64, 64, 64)	36928	['re_lu_8[0][0]']
<pre>batch_normalization_15 (BatchN ormalization)</pre>	(None, 64, 64, 64)	256	['conv2d_16[0][0]']
<pre>concatenate_7 (Concatenate)</pre>	(None, 64, 64, 576)	0	['concatenate_6[0][0]',

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'batch_normalization_15[0][0]']
conv2d 17 (Conv2D)
                                (None, 64, 64, 64)
                                                      331840
                                                                  ['concatenate_7[0][0]']
batch normalization 16 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_17[0][0]']
ormalization)
re_lu_9 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch_normalization_16[0][0]']
conv2d 18 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re_lu_9[0][0]']
batch normalization 17 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_18[0][0]']
ormalization)
concatenate 8 (Concatenate)
                                (None, 64, 64, 640)
                                                      0
                                                                  ['concatenate 7[0][0]',
                                                                    'batch_normalization_17[0][0]']
conv2d 19 (Conv2D)
                                (None, 64, 64, 64)
                                                      368704
                                                                  ['concatenate 8[0][0]']
batch_normalization_18 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_19[0][0]']
ormalization)
re_lu_10 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch_normalization_18[0][0]']
conv2d 20 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re lu 10[0][0]']
batch_normalization_19 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_20[0][0]']
ormalization)
concatenate_9 (Concatenate)
                                (None, 64, 64, 704)
                                                     0
                                                                  ['concatenate 8[0][0]'
                                                                    'batch normalization 19[0][0]']
conv2d_21 (Conv2D)
                                (None, 64, 64, 64)
                                                      405568
                                                                  ['concatenate_9[0][0]']
batch normalization 20 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d 21[0][0]']
ormalization)
re_lu_11 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch normalization 20[0][0]']
conv2d_22 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re_lu_11[0][0]']
batch normalization 21 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_22[0][0]']
ormalization)
concatenate 10 (Concatenate)
                                (None, 64, 64, 768)
                                                                  ['concatenate_9[0][0]',
                                                                    'batch normalization 21[0][0]']
conv2d 23 (Conv2D)
                                (None, 64, 64, 64)
                                                      442432
                                                                  ['concatenate 10[0][0]']
batch normalization 22 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d 23[0][0]']
ormalization)
re_lu_12 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch normalization 22[0][0]']
conv2d_24 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re lu 12[0][0]']
batch normalization 23 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_24[0][0]']
ormalization)
concatenate 11 (Concatenate)
                                (None, 64, 64, 832)
                                                                  ['concatenate 10[0][0]',
                                                                    'batch normalization 23[0][0]']
conv2d 25 (Conv2D)
                                (None, 64, 64, 64)
                                                      479296
                                                                  ['concatenate 11[0][0]']
                                                      256
                                                                  ['conv2d_25[0][0]']
batch normalization 24 (BatchN (None, 64, 64, 64)
ormalization)
re_lu_13 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch normalization 24[0][0]']
conv2d_26 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re_lu_13[0][0]']
batch normalization 25 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_26[0][0]']
ormalization)
concatenate 12 (Concatenate)
                                (None, 64, 64, 896)
                                                     0
                                                                  ['concatenate_11[0][0]',
                                                                    'batch normalization 25[0][0]']
conv2d 27 (Conv2D)
                                (None, 64, 64, 64)
                                                      516160
                                                                  ['concatenate 12[0][0]']
batch_normalization_26 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_27[0][0]']
ormalization)
re_lu_14 (ReLU)
                                (None, 64, 64, 64)
                                                      0
                                                                  ['batch_normalization_26[0][0]']
conv2d 28 (Conv2D)
                                (None, 64, 64, 64)
                                                      36928
                                                                  ['re_lu_14[0][0]']
batch_normalization_27 (BatchN (None, 64, 64, 64)
                                                      256
                                                                  ['conv2d_28[0][0]']
ormalization)
```

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concatenate_13 (Concatenate)
                              (None, 64, 64, 960)
                                                               ['concatenate_12[0][0]',
                                                                'batch_normalization_27[0][0]']
conv2d 29 (Conv2D)
                               (None, 64, 64, 64)
                                                   553024
                                                               ['concatenate 13[0][0]']
batch_normalization_28 (BatchN (None, 64, 64, 64)
                                                   256
                                                               ['conv2d_29[0][0]']
ormalization)
re_lu_15 (ReLU)
                               (None, 64, 64, 64)
                                                   0
                                                               ['batch_normalization_28[0][0]']
conv2d 30 (Conv2D)
                               (None, 64, 64, 64)
                                                   36928
                                                               ['re lu 15[0][0]']
batch_normalization_29 (BatchN (None, 64, 64, 64)
                                                   256
                                                               ['conv2d_30[0][0]']
ormalization)
concatenate_14 (Concatenate)
                               (None, 64, 64, 1024
                                                               ['concatenate_13[0][0]',
                                                                 batch normalization 29[0][0]']
conv2d_31 (Conv2D)
                                                   589888
                               (None, 64, 64, 64)
                                                               ['concatenate_14[0][0]']
batch normalization 30 (BatchN (None, 64, 64, 64)
                                                               ['conv2d 31[0][0]']
                                                   256
ormalization)
re_lu_16 (ReLU)
                               (None, 64, 64, 64)
                                                               ['batch normalization 30[0][0]']
conv2d_32 (Conv2D)
                               (None, 64, 64, 64)
                                                   36928
                                                               ['re_lu_16[0][0]']
batch normalization 31 (BatchN (None, 64, 64, 64)
                                                               ['conv2d 32[0][0]']
                                                   256
ormalization)
concatenate 15 (Concatenate)
                               (None, 64, 64, 1088
                                                               ['concatenate 14[0][0]'
                                                                'batch normalization 31[0][0]']
conv2d_33 (Conv2D)
                               (None, 64, 64, 64)
                                                   626752
                                                               ['concatenate 15[0][0]']
batch normalization 32 (BatchN (None, 64, 64, 64)
                                                               ['conv2d 33[0][0]']
                                                   256
ormalization)
concatenate 16 (Concatenate)
                               (None, 64, 64, 128) 0
                                                               ['batch_normalization_32[0][0]',
                                                                 're_lu[0][0]']
up_sampling2d (UpSampling2D)
                               (None, 128, 128, 12 0
                                                               ['concatenate_16[0][0]']
conv2d_34 (Conv2D)
                               (None, 128, 128, 25 295168
                                                               ['up_sampling2d[0][0]']
                               6)
re_lu_17 (ReLU)
                               (None, 128, 128, 25 0
                                                               ['conv2d_34[0][0]']
up_sampling2d_1 (UpSampling2D)
                               (None, 256, 256, 25 0
                                                               ['re_lu_17[0][0]']
conv2d 35 (Conv2D)
                               (None, 256, 256, 25 590080
                                                               ['up sampling2d 1[0][0]']
re lu 18 (ReLU)
                               (None, 256, 256, 25 0
                                                               ['conv2d_35[0][0]']
conv2d_36 (Conv2D)
                               (None, 256, 256, 3) 62211
                                                               ['re lu 18[0][0]']
______
Non-trainable params: 4,224
```

Total params: 7,203,651 Trainable params: 7,199,427

```
In [10]:
         def conv block(input,n channels):
           x = Conv2D(n_channels,(3,3),padding='same')(input)
           x = BatchNormalization()(x)
           x = LeakyReLU(0.2)(x)
           x = Conv2D(n_channels, (3,3), padding='same', strides=(2,2))(x)
           x = BatchNormalization()(x)
           x = LeakyReLU(0.2)(x)
           return x
         def discriminator():
           input = Input(shape=(256, 256, 3))
            c1 = Conv2D(64,(3,3),padding='same')(input)
           c1 = LeakyReLU(0.2)(c1)
           c1 = Conv2D(64,(3,3),padding='same',strides=(2,2))(c1)
            c1 = BatchNormalization()(c1)
            c1 = LeakyReLU(0.2)(c1)
           c2 = conv block(c1, 128)
            c3 = conv_block(c2,256)
            c4 = conv_block(c3,512)
           x = Flatten()(c4)
           x = Dense(1024)(x)
```

```
x = LeakyReLU(0.2)(x)
output = Dense(1,activation='sigmoid')(x)
model = Model([input],output)
return model
```

In []: ''''This code defines a discriminator model for use in a GAN (Generative Adversarial Network). Let's break it d

conv block(input, n_channels) function:

This function defines a convolutional block used within the discriminator. It takes an input tensor and the num channels (n_channels) as arguments.

It performs two convolutional operations with 3x3 filters and 'same' padding, followed by batch normalization a activation with a slope of 0.2.

The second convolutional operation uses a stride of (2,2) for downsampling. discriminator() function:

This function defines the discriminator model.

It starts with an input tensor of shape (256, 256, 3), which represents an image with a resolution of 256x256 p color channels (RGB).

The input tensor is passed through two convolutional layers with 64 filters each, followed by LeakyReLU activat downsampling using a stride of (2,2).

Then, it applies three convolutional blocks with increasing numbers of output channels: 128, 256, and 512. After the convolutional blocks, the feature maps are flattened, and a fully connected layer with 1024 units is followed by LeakyReLU activation.

Finally, the output layer consists of a single neuron with sigmoid activation, which outputs a probability indi likelihood that the input image is real.

The discriminator's architecture progressively extracts features from the input image, downsampling it while in the number of channels. The final output is a single probability value indicating the authenticity of the input

```
In [11]: d_model = discriminator()
         d_model.summary()
```

''''This code will provide a detailed overview of the discriminator's architecture, including information about the output shapes, and the number of parameters. If you run this code, you'll get a summary printed in the cons window. Let me know if you need further assistance!

Model: "model_1"		
Layer (type)	Output Shape	Param #
<pre>input_2 (InputLayer)</pre>	[(None, 256, 256, 3)]	0
conv2d_37 (Conv2D)	(None, 256, 256, 64)	1792
<pre>leaky_re_lu (LeakyReLU)</pre>	(None, 256, 256, 64)	0
conv2d_38 (Conv2D)	(None, 128, 128, 64)	36928
<pre>batch_normalization_33 (Bat chNormalization)</pre>	(None, 128, 128, 64)	256
<pre>leaky_re_lu_1 (LeakyReLU)</pre>	(None, 128, 128, 64)	0
conv2d_39 (Conv2D)	(None, 128, 128, 128)	73856
<pre>batch_normalization_34 (Bat chNormalization)</pre>	(None, 128, 128, 128)	512
<pre>leaky_re_lu_2 (LeakyReLU)</pre>	(None, 128, 128, 128)	0
conv2d_40 (Conv2D)	(None, 64, 64, 128)	147584
<pre>batch_normalization_35 (Bat chNormalization)</pre>	(None, 64, 64, 128)	512
<pre>leaky_re_lu_3 (LeakyReLU)</pre>	(None, 64, 64, 128)	0
conv2d_41 (Conv2D)	(None, 64, 64, 256)	295168
<pre>batch_normalization_36 (Bat chNormalization)</pre>	(None, 64, 64, 256)	1024
<pre>leaky_re_lu_4 (LeakyReLU)</pre>	(None, 64, 64, 256)	0
conv2d_42 (Conv2D)	(None, 32, 32, 256)	590080
<pre>batch_normalization_37 (Bat chNormalization)</pre>	(None, 32, 32, 256)	1024
<pre>leaky_re_lu_5 (LeakyReLU)</pre>	(None, 32, 32, 256)	0
conv2d_43 (Conv2D)	(None, 32, 32, 512)	1180160
<pre>batch_normalization_38 (Bat chNormalization)</pre>	(None, 32, 32, 512)	2048
<pre>leaky_re_lu_6 (LeakyReLU)</pre>	(None, 32, 32, 512)	0
conv2d_44 (Conv2D)	(None, 16, 16, 512)	2359808
<pre>batch_normalization_39 (Bat chNormalization)</pre>	(None, 16, 16, 512)	2048
<pre>leaky_re_lu_7 (LeakyReLU)</pre>	(None, 16, 16, 512)	0
flatten (Flatten)	(None, 131072)	0
dense (Dense)	(None, 1024)	134218752
<pre>leaky_re_lu_8 (LeakyReLU)</pre>	(None, 1024)	0
dense_1 (Dense)	(None, 1)	1025

Total params: 138,912,577 Trainable params: 138,908,865 Non-trainable params: 3,712

Layer (Type)					
blocki conv1 (Conv2D) (Mone, 256, 256, 64) 1792 blocki conv1 (Conv2D) (Mone, 128, 128, 64) 0 blocki conv1 (Conv2D) (Mone, 128, 128, 148) 73856 blocki conv1 (Conv2D) (Mone, 128, 128, 128) 73856 blocki conv1 (Conv2D) (Mone, 128, 128, 128) 147594 blocki conv2 (Conv2D) (Mone, 64, 64, 128) 0 blocki conv2 (Conv2D) (Mone, 64, 64, 256) 295168 blocki conv2 (Conv2D) (Mone, 64, 64, 256) 295168 blocki conv2 (Conv2D) (Mone, 64, 64, 256) 596089 Total params 2, 225,569 Trainble params: 0 Mon-trainable params: 1, 235,569 Trainble params: 2, 275,569 Trainble params: 1, 235,569 Trainble p		Layer (type)	Output Shape	Param #	
black1 com/2 (Conv2D) (None, 128, 128, 128) 38928 blackL pool (NawPooling2D) (None, 128, 128, 128) 17856 block2_com/2 (Conv2D) (None, 128, 128, 128) 17856 block2_com/2 (Conv2D) (None, 128, 128, 128) 17856 block2_com/2 (Conv2D) (None, 64, 64, 128) 0 block3 com/2 (Conv2D) (None, 64, 64, 256) 295188 block3_com/2 (Conv2D) (None, 64, 64, 256) 599880 Total parases 2_225_868 Trainable parames 0 Non-trainable parames 2, 225_568 Trainable parames 0 Non-trainable parames 2, 225_5580 Out[12]: Folse In [1]: "**"This code defines a function vag model() which creates a VOG19 model with specified layers, freezes the weil active free model. Then, it instantiates the VOG model, prints its summary, and checks if the model is treated to break of the model is model of treated to break of the WoG19 model with the specified layers. The summary of the model is printed using vog model.summary(), which displays the architecture of the VOG19 model of treated in the model is not trainable. """ In [13]: from tensorflow import odd, dtypes cross fairogs a Blanck-research report of the model is not trainable. """ vog model. framinable is used to check if the entire model is trainable. Since all layers were set to non-trainable vog model. function, this will return false, indicating that the model is not trai		input_3 (InputLayer)	[(None, 256, 256, 3)]	0	
block2_conv1 (Conv2D) (Mone, 128, 128, 64) 0 block2_conv1 (Conv2D) (Mone, 128, 128, 128) 73856 block2_conv1 (Conv2D) (Mone, 128, 128, 128) 147884 block2_conv2 (Conv2D) (Mone, 64, 64, 128) 0 block2_conv2 (Conv2D) (Mone, 64, 64, 256) 293368 block3_conv2 (Conv2D) (Mone, 64, 64, 256) 598080 Total params: 2.225.508 Total params: 2.225.508 Total params: 2.225.508 Total params: 2.235,568 Out[12]: False Out[12]: Total params: 2.235.508		block1_conv1 (Conv2D)	(None, 256, 256, 64)	1792	
block2 conv1 (Conv2D) (Mone, 128, 128, 128) 73856 block2 conv2 (Conv2D) (Mone, 64, 64, 128) 0 block2 conv1 (Conv2D) (Mone, 64, 64, 128) 0 block3 conv1 (Conv2D) (Mone, 64, 64, 256) 295168 block3 conv2 (Conv2D) (Mone, 64, 64, 256) 590880 block3 conv3 (Conv2D) (Mone, 64, 64, 256) 590880 Total params: 2,375,568 Mon-trainable params: 2,325,568 Out[12]; False In [i] """This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the weil and returns the model. Then, I instantiates the VGG model, prints its summary, and checks if the model is to test to be supported by the summary of the model is to test to be supported by the summary of the model is freezes the weil and the summary of the model is printed by setting trainable attribute to False. The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg model. summary(i, which displays the architecture of the VGG19 model with the specified layers. The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg model. summary(i, which displays the architecture of the VGG19 model checking model's trainable is used to check if the entire model is trainable. Since all layers were set to non-trainab vgg model. function, this will return False, indicating that the model is not trainable."" In [13] free tensor(Now Amport add dispuss constitutes the summary of the model is printed using vgg model. function is called to create an instance of the VGG19 model checking model is free tensor(Now Amport and dispuss constitutes the layers were set to non-trainab vgg model. function is called to create an instance of the VGG19 model with the specified layers. In [13] free tensor(Now Amport add dispuss constitutes		block1_conv2 (Conv2D)	(None, 256, 256, 64)	36928	
block2 conv2 (Conv2D) (None, 61, 64, 128) 147584 block2 conv1 (Conv2D) (None, 64, 64, 128) 0 block3 conv2 (Conv2D) (None, 64, 64, 256) 295168 block3 conv2 (Conv2D) (None, 64, 64, 256) 590880 block3 conv3 (Conv2D) (None, 64, 64, 256) 590880 block3 conv4 (Conv2D) (None, 64, 64, 256) 590880 Total params: 2,325,568 Trainable params: 2,325,568 Trainable params: 2,325,568 Out[12]: False In []: '''This code defines a function vgg model() which creates a V6619 model with specified layers, freezes the weil, and returns the model. Then, it instantiates the V66 model, prints its summary, and checks if the model is treatly to break down each part: vgg_model() function: This function creates a V6619 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozom by setting trainable attribute to False. Interturns the model is collect to create an instance of the V6619 model with the specified layers. The vgg_model() function is called to create an instance of the V6619 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the V6619 model created and produced is returnability: vgg_model() function, this will return False, indicating that the model is not trainable.'''' vgg_model() function, this will return False, indicating that the model is not trainable.'''' in [11] from tensorItow import add,dtypes crossfirtney = SimrayCrossentropy() crossfirtney = SimrayCrossentropy() def discriminator, loss(real output, fake output) real loss = crossfirm ropy(valid, real output) real loss = crossform ropy(valid, real output) real loss = crossform ropy(valid, real output) real loss = crossform ropy(valid, real output) real loss = didgen_loss, vgg_loss) return total_loss def generator loss(generated image real hr, barch size): return total_loss return total_loss return total_loss The total_loss = add(gen_loss, vgg_loss) return total_loss The total_loss is add content real_o		<pre>block1_pool (MaxPooling2D)</pre>	(None, 128, 128, 64)	0	
block2 conv1 (Conv20) (None, 64, 64, 128) 6 block3 conv1 (Conv20) (None, 64, 64, 256) 295168 block3 conv2 (Conv20) (None, 64, 64, 256) 590808 block3 conv4 (Conv20) (None, 64, 64, 256) 590808 block3 conv4 (Conv20) (None, 64, 64, 256) 590808 Total params: 2,323,508 Total params: 2,323,508 Total params: 2,323,508 Won-trainable params: 2,325,568 Won-trainable params: 2,325,568 Total params: 2,325,568 Won-trainable params: 2,325,568 Out[12]: Faite In []: '''This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the wei, and returns the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is treater to the season of the vGG19 model with specified layers. In this case, only the layer named 'block3 conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified VGG19 model with only the specified layers. In this case, only the layer named 'block3 conv4' is The weights of all layers are frozen by setting trainable attribute to False. The summary of the model is printed using vgg model. summary(), which displays the architecture of the VGG19 model. Trainable is used to check if the entire model is trainable; '''' vgg_model() function, this will return False, indicating that the model is not trainable; '''' in [13]: from tensorflow import add, dtypes crossfortnoy Simary(rosentroy) order discriminator boss(real_notput_fake_output_batch_size) value = no nose(patch_size_i) real loss = crossfortnoy(rake_fake_output) real loss = crossfortnoy(rake_fake_output_batch_size_i) In [1]: ''''This code defines two loss functions: discri		block2_conv1 (Conv2D)	(None, 128, 128, 128)	73856	
block3_conv2 (Conv2D) (Mone, 64, 64, 256) 293168 block3_conv2 (Conv2D) (Mone, 64, 64, 256) 590800 block3_conv3 (Conv2D) (Mone, 64, 64, 256) 590800 block3_conv4 (Conv2D) (Mone, 64, 64, 256) 590800 Total params: 2,325,560 Total params: 2,325,560 Tranable params: 0 Non-trainable params: 0 Non-trainable params: 2,325,568 Out[12]: False Out[12		block2_conv2 (Conv2D)	(None, 128, 128, 128)	147584	
block3 conv2 (Conv2D) (None, 64, 64, 256) 598888 block3 conv3 (Conv2D) (None, 64, 64, 256) 598888 block3 conv4 (Conv2D) (None, 64, 64, 256) 598888 Total params: 2,325,568 Trainable params: 2,325,568 Trainable params: 2,325,568 Out[12]: False In []: '''This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the wei , and returns the model. hen, it instantiates the VGG model, prints its summary, and checks if the model is treated from each part: vgg model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3 conv4' is The weights of all layers are frozen by setting trainable attribute to false. In terms the model and WGD19 model with only the specified layers. Instantiating the VGG model: The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg model.summary(), which displays the architecture of the VGG19 model checking model's trainability: vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg model.summary(), which displays the architecture of the VGG19 model checking model's trainability: vgg model() function, this will return false, indicating that the model is not trainable.'''' if we encorrflow import add diffupes consistency is fainary crossentropy() mse = MeanSquaredError() def discriminator loss(real output, fake output, batch size): valid = np.ones(lbatch size, 1)) fake = np.zeros(lbatch size, 1) fake np.zer		block2_pool (MaxPooling2D)	(None, 64, 64, 128)	0	
block3 conv3 (Conv2D) (None, 64, 64, 256) 590888 block3_conv4 (Conv2D) (None, 64, 64, 256) 590888 Trainable params: 2,325,568 Trainable params: 2,325,568 Trainable params: 2,325,568 Trainable params: 2,325,568 Out[12]: False In []: ""This code defines a function vgg_model() which creates a VGG19 model with specified layers, freezes the weil, and returns the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is treatly to break down each part: vgg_model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified VGG19 model with only the specified layers. Instantiating the WGG model: The vgg_model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the VGG19 model checking model's trainability: vgg_model() function, this will return False, indicating that the model is not trainable."" In [13]: from tensorflow import add.dtypes crossfarropy = Binary/crossentropy() mse = MeanSquaredError() def discriminator loss/ceal output, fake output, batch size): valid = np.ones((batch.size,1)) fake = np.zers((batch.size,1)) real loss = cfs.f(real_loss + fake_loss) return total_loss = 0.5f(real_loss + fake_loss) return total_loss = 0.5f(real_loss + fake_loss) return total_loss = numerialse image, features, real_image, features) vgg_loss = dtypes.ccst(vgg_loss) returns total_loss = 0.3f(real_loss), respectively. Let's go through each function: discriminator loss/crossfarrop(outpt, dek.p.ones((batch.size,1))) total_loss = 0.3f(real_loss), respectively. Let's go through each function: discriminator loss/crossfarrop(outpt, outpt) of the discriminator for real images), rake_output (output of the for fake/cymerated image); and take images. The total loss is computed as the		block3_conv1 (Conv2D)	(None, 64, 64, 256)	295168	
Total paramer 2,325,588		block3_conv2 (Conv2D)	(None, 64, 64, 256)	590080	
Total params: 2,325,568 Trainable params: 2,325,568 Out[12]: False In []: '''This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the weight of the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is to Let's break down each part: vgg model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the model is dvG19 model with only the specified layers. Instantiating the VGG model: The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg model.summary(), which displays the architecture of the VGG19 model checking model's trainable is used to check if the entire model is trainable. Since all layers were set to non-trainab vgg model() function, this will return False, indicating that the model is not trainable.''' In [13]: from tensorflow import add.dtypes crossEntropy = Binary(rossentropy) med discriminator loss(real output, false output, batch size): valid = np.ones(loatch size, 1) real_loss = crossEntropy(false, false output) fake np.zeros((batch size, 1) real_loss = crossEntropy(rake, false output) real_loss = crossEntropy(rake, false output) total_loss = 0.5 freal_loss + false_loss) return total_loss def generator_loss(generated_image, real_hr,batch_size): fake_image_features = vgg_model(real_hr) vgg_loss = dtypes.cat(vgg_loss,tf.float64) d out fake = d model(generated image) g nloss = (19-s)/crossEntropy(of out_fake,np.ones((batch_size,1))) return total_loss in []: ""This function calculates the loss functions: discriminator loss and generator loss, which are used to calculate the discriminator_loss(real_output, fake_output, batch_size): This fu		block3_conv3 (Conv2D)	(None, 64, 64, 256)	590080	
Total params: 2,325,568 Trainable params: 2,325,568 Trainable params: 2,325,568 Out[22]: In []: '''This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the wei, and returns the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is to Let's break down each part: Vgg model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified VGG19 model with only the specified layers. Instantiating the VGG model: The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the VGG19 mod checking model's trainability: vgg model() function, this will return False, indicating that the model is not trainable.''' In [13]: from tensorflow import add,dtypes crossEntropy = BinaryCrossentropy() mae = MeanSquaredError() def discriminator loss(real output, fake output, batch size): valid = mp.omes((batch Size.1)) real loss = crossEntropy(valid, real output) fake loss = crossEntropy(valid, real output) total loss = 0.5*(real loss + fake loss) return total loss def generator loss(generated image, real hr,batch size): fake image features = vgg model(real hr) vgg loss = dtypes.cast(vgg loss, tf.loat64) d, out fake a did male (speerated image) gan loss = (1e-3)*crossEntropy(d out fake, np.ones((batch_size,1))) total loss = add(gan loss, vgg loss) return total loss In []: '''This code defines two loss functions: discriminator loss and generator loss, which are used to calculate the discriminator and generator models, respectively. Let's go through each function: discriminator loss(real output, fake output, batch size): This function calculates the loss for the discriminator: It takes three arguments: real output (output of the		block3_conv4 (Conv2D)	(None, 64, 64, 256)	590080	
Trainable params: 0 Non-trainable params: 2,325,568 Out[12]; False Out[12];				=========	
In []: '''This code defines a function vgg model() which creates a VGG19 model with specified layers, freezes the weing and returns the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is to Let's break down each part: vgg model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified VGG19 model with only the specified layers. Instantiating the VGG model: The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the VGG19 mod Checking model's trainability: vgg_model.trainable is used to check if the entire model is trainable. Since all layers were set to non-trainab vgg model() function, this will return False, indicating that the model is not trainable.''' In [13]: from tensorflow import add, dtypes crossEntropy = BinaryCrossentropy() mee HeanSquaredError() def discriminator loss(real output, fake output, batch_size): valid = mp.nose((batch_size, 1)) real_loss = crossEntropy(valid, real_output) fake = mp.zeros((batch_size, 1)) real_loss = crossEntropy(valid, real_output) fake loss = crossEntropy(valid, real_output) total_loss = 0.5*(real_loss + fake_loss) return total_loss def generator loss(generated image, real hr, batch size): fake image features = vgg_model(generated image) real_image features = vgg_		Trainable params: 0	568		
<pre>, and returns the model. Then, it instantiates the VGG model, prints its summary, and checks if the model is tr Let's break down each part: vgg model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to false. It returns the modified VGG19 model with only the specified layers. Instantiating the VGG model: The vgg model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the VGG19 mod Checking model's trainability: vgg_model.trainable is used to check if the entire model is trainable. Since all layers were set to non-trainab vgg_model() function, this will return False, indicating that the model is not trainable.'''' In [13]: from tensorflow import add,dtypes crossEntropy = BinaryCrossentropy() mse = MeanSquaredError() def discriminator loss(real_output,fake_output,batch_size): valid = np.nones((batch_size_1)) fake = np.zeros((batch_size_1)) fake = np.zeros((batch_size_1)) real_loss = crossEntropy(valid,real_output) total_loss = crossEntropy(fake_fake_output) total_loss = 0.5*(real_loss + fake_loss) return total_loss def generator_loss(generated_image, real_hr,batch_size): fake_image_features = vgg_model(real_hr) vgg_loss = msetfake_image_features, real_image_features) vgg_loss = dtypes.castivgg_loss_tf.float64) d_out_fake = d_model(generated_image) gan_loss = (le.3)*crossEntropy(d_out_fake,np.ones((batch_size,1))) total_loss = add(gan_loss,vgg_loss) return total_loss In []: This function calculates the loss functions: discriminator loss and generator_loss, which are used to calculate the discriminator_loss(real_output, fake_output, batch_size): This function calculates the loss for the discriminator. It takes three arguments: real output (output of the discriminator for real images), fake_output (output of the for fake/gener</pre>	Out[12]:	False			
vgg_model() function: This function creates a VGG19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified VGG19 model with only the specified layers. Instantiating the VGG model: The vgg_model() function is called to create an instance of the VGG19 model with the specified layers. The summary of the model is printed using vgg_model.summary(), which displays the architecture of the VGG19 mod Checking model's trainability: vgg_model() function, this will return False, indicating that the model is not trainable.'''' In [13]: from tensorflow import add,dtypes crossentropy = BinaryCrossentropy() mse = MeanSquaredError() def discriminator lossireal_output, fake_output,batch_size): valid = np.ones(lbatch_size_1)) fake = np.zeros(lbatch_size_1)) fake = np.zeros(lbatch_size_1)) fake = np.zeros(lbatch_size_1)) fake sp.zeros sp.	In []:	, and returns the model. The			
This function creates a V6G19 model with specified layers. In this case, only the layer named 'block3_conv4' is The weights of all layers are frozen by setting trainable attribute to False. It returns the modified V6G19 model with only the specified layers. Instantiating the V6G model: The vog model() function is called to create an instance of the V6G19 model with the specified layers. The summary of the model is printed using vog_model.summary(), which displays the architecture of the V6G19 mod Checking model's trainability: vgg_model() function, this will return False, indicating that the model is not trainable.''' In [13]: from tensorflow import add,dtypes crossEntropy = BinaryCrossentropy() mse = MeanSquaredError() def discriminator loss(real_output,fake_output,batch_size): valid = np.ceros((batch_size,1)) fake = np.zeros((batch_size,1)) fake = np.zeros((batch_size,1)) real_loss = crossEntropy(rake, fake_output) total_loss = 0.5*(real_loss + fake_loss) return total_loss def generator loss(generated_image,real_hr,batch_size): fake_image_features = vgg_model(generated_image) real_image_features = vgg_model(generated_image) vgg_loss = mse(fake_image_features, real_image_features) vgg_loss = ditypes.cast(vgg_loss, frithoat64) dout_fake = d_model(generated_image) gan_loss = [e-3)*crossEntropy(d_out_fake,np.ones((batch_size,1))) total_loss In []: ''''This code defines two loss functions: discriminator_loss and generator_loss, which are used to calculate the discriminator_loss(real_output, fake_output, batch_size): This function calculates the loss for the discriminator. It takes three arguments: real_output (output of the discriminator for real_images), fake_output (output of the for fake/generated_images), and batch_size. It creates two arrays: valid (an array of ones indicating real_images) and fake (an array of zeros indicating fit calculates the binary cross-entropy loss for the discriminator's predictions on real and fake losses.		·			
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<pre>vgg_model() function, this will return False, indicating that the model is not trainable.'''' from tensorflow import add,dtypes crossEntropy = BinaryCrossentropy() def discriminator loss(real_output,fake_output,batch_size): valid = np.ones((batch_size,1)) fake = np.zeros((batch_size,1)) real_loss = crossEntropy(valid,real_output) fake loss = crossEntropy(valid,real_output) total_loss = crossEntropy(valid,real_output) total_loss = 0.5*(real_loss + fake_loss) return total_loss def generator_loss(generated_image,real_hr,batch_size): fake_image_features = vgg_model(generated_image) real_image_features = vgg_model(generated_image) real_image_features = vgg_model(generated_image) vgg_loss = mse(fake_image_features,real_image_features) vgg_loss = dtypes.cast(vgg_loss,tf.float64) d_out_fake = d_model(generated_image) gan_loss = (1e-3)*crossEntropy(d_out_fake,np.ones((batch_size,1))) total_loss = add(gam_loss,vgg_loss) return_total_loss In []: ''''This code defines two loss functions: discriminator_loss and generator_loss, which are used to calculate the discriminator_loss(real_output, fake_output, batch_size): This function calculates the loss for the discriminator. It takes three arguments: real_output, foutput of the discriminator for real_images), fake_output (output of the for fake/generated_images), and batch_size. It creates two arrays: valid (an array of ones indicating real_images) and fake (an array of zeros indicating f It creates two arrays: valid (an array of ones indicating real_images) and fake (an array of zeros indicating f It closs is computed as the average of the sum of real and fake losses. The total loss is computed as the average of the sum of real and fake losses. </pre>		The summary of the model is	<pre>printed using vgg_model.</pre>		
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<pre>fake_image_features = vgg_model(generated_image) real_image_features = vgg_model(real_hr) vgg_loss = mse(fake_image_features, real_image_features) vgg_loss = dtypes.cast(vgg_loss,tf.float64) d_out_fake = d_model(generated_image) gan_loss = (le-3)*crossEntropy(d_out_fake,np.ones((batch_size,1))) total_loss = add(gan_loss,vgg_loss) return total_loss In []: ''''This code defines two loss functions: discriminator_loss and generator_loss, which are used to calculate the discriminator and generator models, respectively. Let's go through each function: discriminator_loss(real_output, fake_output, batch_size): This function calculates the loss for the discriminator. It takes three arguments: real_output (output of the discriminator for real_images), fake_output (output of the for fake/generated_images), and batch_size. It creates two arrays: valid (an array of ones indicating real_images) and fake (an array of zeros_indicating f It calculates the binary cross-entropy loss for the discriminator's predictions on real_and_fake_images. The total loss is computed as the average of the sum of real_and_fake losses.</pre>	In [13]:	<pre>crossEntropy = BinaryCrossen mse = MeanSquaredError() def discriminator_loss(real_ valid = np.ones((batch_siz) fake = np.zeros((batch_siz) real_loss = crossEntropy(v) fake_loss = crossEntropy(f) total_loss = 0.5*(real_loss)</pre>	<pre>ctropy() output,fake_output,batch e,1)) e,1)) valid,real_output) fake,fake_output)</pre>	_size):	
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		It takes three arguments: refor fake/generated images), It creates two arrays: valid It calculates the binary crown the total loss is computed a	eal_output (output of the and batch_size. I (an array of ones indica ass-entropy loss for the out as the average of the sum	discriminator for real images ating real images) and fake (a discriminator's predictions of of real and fake losses.	an array of zeros indicating f

This function calculates the loss for the generator. It takes three arguments: generated_image (the image generated by the generator), real_hr (the high-resolution

```
This code is designed for training a GAN-based model, where the generator aims to produce realistic images that
          the discriminator, and the discriminator aims to distinguish between real and fake images. The losses are computhe predictions of the discriminator and the features extracted by the VGG network.'''
         lr path ='C:/Users/student/Desktop/dataset/Raw Data/low res'
In [14]:
          hr_path = 'C:/Users/student/Desktop/dataset/Raw Data/high_res'
          for image in sorted(os.listdir(lr path)):
            img_path = os.path.join(lr_path,image)
            img = cv2.imread(img_path)
            img = cv2.cvtColor(img, cv2.COLOR BGR2RGB)
            img = cv2.resize(img, (64, 64))
            img = (img/255)
            img = img.astype('float32')
            lr.append(img)
          hr = [1]
          for image in sorted(os.listdir(hr path)):
            img path = os.path.join(hr path,image)
            img = cv2.imread(img path)
            img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
            img = cv2.resize(img,(256,256))
            img = (img/255)
            img = img.astype('float32')
            hr.append(img)
 In [ ]: ''''
          It appears you're loading a dataset consisting of low-resolution (LR) and high-resolution (HR) images from dire
          specified by lr_path and hr_path, respectively. The images are then resized and normalized before being stored
          and hr. Let me explain the code:
          lr path ='C:/Users/student/Desktop/dataset/Raw Data/low_res'
          hr path ='C:/Users/student/Desktop/dataset/Raw Data/high res'
          These lines define the paths to directories containing the low-resolution (LR) and high-resolution (HR) images.
          Similarly, this loop iterates over each image file in the HR directory and performs the same preprocessing step
          described above, but the images are resized to a target size of 256x256 pixels.
          After executing this code, you'll have two lists: lr, containing the preprocessed LR images, and hr, containing
          preprocessed HR images. These lists can then be used for training your model. If you have any further questions
          additional assistance, feel free to ask!
          This loop iterates over each image file in the LR directory. For each image, it:
          Constructs the full path to the image file.
          Reads the image using OpenCV (cv2.imread()).
          Converts the image from BGR to RGB color space using OpenCV (cv2.cvtColor()).
          Resizes the image to a target size of 64x64 pixels using OpenCV (cv2.resize()).
          Normalizes the pixel values to the range [0, 1].
          Converts the pixel datatype to float32.
          Appends the preprocessed image to the list lr
In [15]: lr[0].shape
          type(lr[0])
          #The code lr[0].shape returns the shape of the first low-resolution image in the lr list, while type(lr[0]) ret
          #type of the first low-resolution image
Out[15]: numpy.ndarray
In [16]: plt.subplot(1,2,1)
          plt.imshow(lr[10])
          plt.title("Low resolution image")
          #Running this code will display the specified low-resolution image with the title "Low resolution image" in the
          \#subplot. If you want to display another image, you can change the index in lr[10] to the index of the desired
          #1r list.
Out[16]: Text(0.5, 1.0, 'Low_resolution_image')
```

It computes the features of the generated and real images using the VGG model (vgg_model).

It calculates the binary cross-entropy loss for the discriminator's output on the generated image.

Then, it calculates the mean squared error (MSE) loss between the features of the generated and real images. Next, it computes the discriminator's output for the generated image using the d model discriminator model.

and batch size.

The total loss is the sum of the GAN loss and VGG loss.

```
In [17]: lr = np.reshape(lr,(len(lr),64,64,3))
         hr = np.reshape(hr, (len(hr), 256, 256, 3))
         lr.shape,hr.shape
Out[17]: ((855, 64, 64, 3), (855, 256, 256, 3))
 In [ ]: This line reshapes the LR image array lr using np.reshape(). The new shape specified is (len(lr), 64, 64, 3), w
         The first dimension (len(lr)) represents the number of images in the LR dataset.
         The second and third dimensions (64, 64) represent the height and width of each LR image after resizing.
         The fourth dimension 3 represents the number of color channels (assuming RGB images).
         This reshaping ensures that each LR image has the correct shape (64, 64, 3) for processing by the neural networ
         Finally, both LR and HR image arrays are reshaped to have the appropriate dimensions, and their shapes are prin
         verification.
 In [ ]: from tensorflow import GradientTape, function
         generator optimizer = Adam(learning rate=0.0001,beta 1=0.9)
         discriminator_optimizer = Adam(learning_rate=0.0001,beta_1=0.9)
         @tf.function
         def train step(lr images,hr images,n samples):
           with GradientTape() as disc_tape:
             generated images = g model(lr images,training=True)
             real output = d model(hr_images,training=True)
             fake_output = d_model(generated_images,training=True)
             d loss = discriminator loss(real output, fake output, n samples)
           gradients of discriminator = disc tape.gradient(d loss, d model.trainable variables)
           discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator, d_model.trainable_variables))
           with tf.GradientTape() as gen tape:
             fake_output = g_model(lr_images)
             g loss = generator loss(fake output, hr images,n samples)
           gradients of generator = gen tape.gradient(g loss, g model.trainable variables)
           generator_optimizer.apply_gradients(zip(gradients_of_generator, g_model.trainable_variables))
           return d loss, g loss
In [18]: #This code defines a training step function train step using TensorFlow's GradientTape
         from tensorflow import GradientTape,function
```

#These lines define Adam optimizers for both the generator and discriminator models. The learning rate is set t

#This line decorates the train_step function with @tf.function, which converts the Python function into a Tenso

generator_optimizer = Adam(learning_rate=0.0001,beta_1=0.9)
discriminator optimizer = Adam(learning_rate=0.0001,beta_1=0.9)

generated images = g model(lr images,training=True)

#and the beta_1 parameter is set to 0.9.

with GradientTape() as disc_tape:

def train step(lr images,hr images,n samples):

#function for faster execution.

@tf.function

```
real output = d model(hr images,training=True)
              fake_output = d_model(generated_images,training=True)
         #Within the gradient tape context for the discriminator (disc tape), it:
         \#Generates fake images using the generator model (g\_model) with LR images as input.
         #Obtains the output of the discriminator (d_model) for both real and fake images.
         #Calculates the discriminator loss (d loss) using discriminator loss function.
             d_loss = discriminator_loss(real_output,fake_output,n_samples)
           gradients of discriminator = disc tape.gradient(d loss, d model.trainable variables)
           discriminator\_optimizer.apply\_gradients(zip(gradients\_of\_discriminator,\ d\_model.trainable\_variables))
         #It computes the gradients of the discriminator loss with respect to the discriminator's trainable variables, a
         #these gradients to update the discriminator's weights using the discriminator optimizer.
           with tf.GradientTape() as gen_tape:
             fake output = q model(lr images)
             g_loss = generator_loss(fake_output, hr_images,n_samples)
         #Within the gradient tape context for the generator (gen tape), it:
         \#Generates fake images using the generator model (g\_model) with LR images as input.
         \#Calculates the generator loss (g_loss) using generator_loss function.
           gradients of generator = gen tape.gradient(g loss, g model.trainable variables)
           generator\_optimizer.apply\_gradients(zip(gradients\_of\_generator, g\_model.trainable\_variables))
         #It computes the gradients of the generator loss with respect to the generator's trainable variables, applies t
         #gradients to update the generator's weights using the generator optimizer'''
            return d loss, q loss
         #Finally, it returns the discriminator and generator losses.
         #This function performs a single training step for the GAN model, updating the weights of both the discriminate
         #generator models based on the calculated losses.''
In [19]: from keras.models import load model #To load a model using Keras, you can use the load model function from kera
 In []: def train(lr images, hr images, epochs=50, n samples=5):
             num images = len(lr images)
              for epoch in range(epochs):
                  for batch_start in range(0, num_images, n_samples):
                      batch end = min(batch start + n samples, num images)
                      input_lr = lr_images[batch_start:batch_end]
                      input hr = hr images[batch start:batch end]
                      d_loss, g_loss = train_step(input_lr, input_hr, n_samples)
                      print(f'Epoch: {epoch + 1} - Batch: {batch_start // n_samples + 1}/{(num_images + n_samples - 1) //
                  if epoch % 10 == 0:
                      file_name = f'generator_model_epoch_{epoch}.h5'
                      g model.save(file name)
         train(lr[:855], hr[:855])
In [89]: #This code defines a training function train for training a GAN model on LR and HR image pairs
         def train(lr_images, hr_images, epochs=50, n_samples=5):
             num\_images = len(lr\_images) #This line calculates the total number of LR images in the dataset.
              for epoch in range(epochs): #This loop iterates over the specified number of epochs.
                  for batch_start in range(0, num_images, n_samples):
                      batch_end = min(batch_start + n_samples, num_images)
                      input lr = lr images[batch start:batch end]
                      input_hr = hr_images[batch_start:batch_end]
                      d_loss, g_loss = train_step(input_lr, input_hr, n_samples)
                      print(f'Epoch: {epoch + 1} - Batch: {batch_start // n_samples + 1}/{(num_images + n_samples - 1) //
                            - - {d_loss}, {g_loss}')
         #This loop iterates over the LR images in batches of size n samples. For each batch:
         #It selects a batch of LR and HR images.
         #It performs a training step using the train step function defined earlier, which updates the weights of the
         #discriminator and generator models.
         #It prints the epoch number, batch number, discriminator loss, and generator loss.
                 if epoch % 10 == 0:
    file_name = f'generator_model_epoch_{epoch}.h5'
                      g model.save(file name)
         #Every 10 epochs, the generator model (g_model) is saved to a file named generator_model_epoch {epoch}.h5.
         #This allows you to monitor the progress of the generator during training
         train(lr[:855], hr[:855])
         #This line calls the train function with the LR and HR image datasets, using the first 855 images from dataset
         Epoch: 1 - Batch: 1/171 - - 12.110645294189453, 22.65062602907128
         Epoch: 1 - Batch: 2/171 - - 2.813004732131958, 25.01518440246582
Epoch: 1 - Batch: 3/171 - - 3.95013194065541e-05, 26.89241410441812
         Epoch: 1 - Batch: 4/171 - - 2.7579721972870175e-06, 28.662347817851224
         Epoch: 1 - Batch: 5/171 - - 1.214034080505371, 19.195042573409086
```

```
Epoch: 1 - Batch: 6/171 - - 4.817137718200684, 24.165274553140485
Epoch: 1 - Batch: 7/171 - - 6.035848491592333e-05, 18.655859799248795
Epoch: 1 - Batch: 8/171 - - 6.535170078277588, 18.347058401521487
Epoch: 1 - Batch: 9/171 - - 1.0010982002032105e-25, 24.63887038376802
Epoch: 1 - Batch: 10/171 - - 0.014539050869643688, 12.89321549942408
Epoch: 1 - Batch: 11/171 - - 0.0001517611090093851, 24.529626552638216
Epoch: 1 - Batch: 12/171 - - 5.9456488088471815e-06, 25.687267010027913
Epoch: 1 - Batch: 13/171 - - 1.8029228448867798, 21.92683804911531
Epoch: 1 - Batch: 14/171 - - 0.0019209595629945397, 17.666535260771145
Epoch: 1 - Batch: 15/171 - - 0.0005182755994610488, 22.45958108167997
Epoch: 1 - Batch: 16/171 - - 1.6992593998566008e-09, 32.13548440045092
Epoch: 1 - Batch: 17/171 - - 0.007367733865976334, 20.81986670230634
Epoch: 1 - Batch: 18/171 - - 0.6792682409286499, 20.31692335831402
Epoch: 1 - Batch: 19/171 - - 0.9109122157096863, 26.39921428943205
Epoch: 1 - Batch: 20/171 - - 8.695641326994519e-07, 23.39826504182264
Epoch: 1 - Batch: 21/171 - - 1.9937798976898193, 17.481069922291496
Epoch: 1 - Batch: 22/171 - - 2.295712064892541e-08, 18.73227146526005
Epoch: 1 - Batch: 23/171 - - 1.1915717124938965, 21.745061502154897
Epoch: 1 - Batch: 24/171 - - 1.8173168116306267e-15, 10.922334679846735
Epoch: 1 - Batch: 25/171 - - 1.2244624801940884e-12, 21.578067781012052
Epoch: 1 - Batch: 26/171 - - 0.1323995441198349, 15.752022599012781
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WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile met
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Epoch: 11 - Batch: 168/171 - - 1.37214994430542, 13.667938232789634
Epoch: 11 - Batch: 169/171 - - 0.11643379926681519, 14.286413192749023
Epoch: 11 - Batch: 170/171 - - 0.3679031729698181, 12.500596815797664
Epoch: 11 - Batch: 171/171 - - 0.6050100922584534, 14.616757246163852
WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_met
rics` will be empty until you train or evaluate the model.
Epoch: 12 - Batch: 1/171 - - 2.379380702972412, 13.109219551821944
Epoch: 12 - Batch: 2/171 - - 1.6207799546918977e-08, 15.123725891113281
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WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile met
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WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_met
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Epoch: 50 - Batch: 132/171 - - 8.25972743570243e-15, 9.561500375331669
Epoch: 50 - Batch: 133/171 - - 9.929276803476049e-36, 10.039561600093222
Epoch: 50 - Batch: 134/171 - - 0.0, 10.062076347232226
Epoch: 50 - Batch: 135/171 - - 0.0, 8.747278930151566
Epoch: 50 - Batch: 136/171 - - 2.4630053998123535e-26, 7.148629101230427
Epoch: 50 - Batch: 137/171 - - 2.5766441203922666e-30, 9.913742226580085
Epoch: 50 - Batch: 138/171 - - 9.998287381174353e-24, 12.30389391316207
Epoch: 50 - Batch: 139/171 - - 2.6415883369601545e-12. 11.435509257645958
Epoch: 50 - Batch: 140/171 - - 8.54572545309379e-24, 8.030168591076214
Epoch: 50 - Batch: 141/171 - - 5.9704337827815035e-12, 9.438654622931733
Epoch: 50 - Batch: 142/171 - - 2.117088622466401e-12, 8.298122683191856
Epoch: 50 - Batch: 143/171 - - 2.8028091492160456e-06, 9.932010232818465
Epoch: 50 - Batch: 144/171 - - 1.6033398567150137e-14, 7.544106927079564
Epoch: 50 - Batch: 145/171 - - 6.71186602875284e-24, 11.489995111235613
Epoch: 50 - Batch: 146/171 - - 1.3950146259078145e-17, 9.312344901224208
Epoch: 50 - Batch: 147/171 - - 1.1954521746095988e-17, 8.197307730772483
Epoch: 50 - Batch: 148/171 - - 1.2904195940965923e-11, 10.297754314620237
Epoch: 50 - Batch: 149/171 - - 6.8311235197479e-17, 8.023050204474066
Epoch: 50 - Batch: 150/171 - - 1.5469699171419443e-19, 6.044776135765608
Epoch: 50 - Batch: 151/171 - - 1.9845268444277036e-28, 9.361334924709134
Epoch: 50 - Batch: 152/171 - - 6.758565895758985e-31, 7.579828370857972
Epoch: 50 - Batch: 153/171 - - 2.226577449252838e-22, 8.004057551274764
Epoch: 50 - Batch: 154/171 - - 6.438383458863642e-17, 11.456750538416145
Epoch: 50 - Batch: 155/171 - - 5.920473765943371e-17, 9.427861485132116
Epoch: 50 - Batch: 156/171 - - 1.7840363500737746e-24, 9.75614199708441
Epoch: 50 - Batch: 157/171 - - 2.9386107262829864e-14, 5.146634956000264
Epoch: 50 - Batch: 158/171 - - 0.0006621604552492499, 7.111854345975992
Epoch: 50 - Batch: 159/171 - - 4.248715637124312e-13, 8.637034408986421
Epoch: 50 - Batch: 160/171 - - 2.6534431359827434e-21, 12.221410483334337
```

```
Epoch: 50 - Batch: 161/171 - - 5.06964826302861e-29, 7.332688459536035

Epoch: 50 - Batch: 162/171 - - 2.9272939601274243e-18, 10.645198173477457

Epoch: 50 - Batch: 163/171 - - 1.6472714576935832e-13, 12.21815780835156

Epoch: 50 - Batch: 164/171 - - 2.0840835385608234e-16, 9.457781361974346

Epoch: 50 - Batch: 165/171 - - 7.87431741696241e-23, 7.354656598824056

Epoch: 50 - Batch: 166/171 - - 2.7534428152927813e-25, 8.022226672053034

Epoch: 50 - Batch: 168/171 - - 2.0884675958073544e-17, 9.508529890182492

Epoch: 50 - Batch: 168/171 - - 1.3494473094510795e-08, 8.449683444229029

Epoch: 50 - Batch: 169/171 - - 1.2634277060000986e-18, 8.204274550527476

Epoch: 50 - Batch: 170/171 - - 3.128608729033246e-15, 8.235164021658193

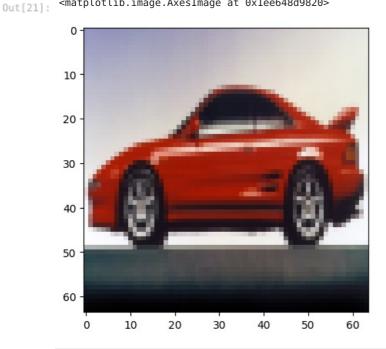
Epoch: 50 - Batch: 171/171 - - 1.86031410158558e-18, 9.199040210318344
```

In []: #Overall, this function trains the GAN model for the specified number of epochs, printing the loss values perio #and saving the generator model checkpoints every 10 epochs.

```
In [20]: # Here we load the weights from the saved file
    g_model.load_weights("generator_model_epoch_0.h5")
    g_model.load_weights("generator_model_epoch_10.h5")
    g_model.load_weights("generator_model_epoch_20.h5")
    g_model.load_weights("generator_model_epoch_30.h5")
    g_model.load_weights("generator_model_epoch_40.h5")
    # Compile the generator model
    g_model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
```

```
img_path = 'C:/Users/student/Desktop/dataset/Raw Data/low_res/13.png'
img = cv2.imread(img_path)
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
#This line converts the color space of the image from BGR (Blue-Green-Red) to RGB (Red-Green-Blue), which is th
#color space used in most image processing libraries, including Matplotlib.
img = img/255.#This line normalizes the pixel values of the image to the range [0, 1] by dividing each pixel values of the image array to float32.
print('The shape of the image is',img.shape)
#This line prints the shape of the image array, which represents its dimensions (height, width, and number of c
plt.imshow(img)#This line uses Matplotlib (plt.imshow) to display the image
```

The shape of the image is (64, 64, 3) <matplotlib.image.AxesImage at 0x1ee648d9820>



```
In []: in_img = np.expand_dims(img,axis=0)
    a = g_model.predict(in_img)
    a = np.squeeze(a,axis=0)
    plt.imshow(a)
    plt.axis('off')
    plt.savefig('C:/Users/student/Desktop/dataset/generated_HR_13', bbox_inches='tight', pad_inches=0) # Save the
    plt.close()
```

```
In [22]: #This line expands the dimensions of the input image array img along the first axis, effectively adding a batch
#This is necessary because the predict method of Keras models expects input data with batch dimensions.
in_img = np.expand_dims(img,axis=0)
a = g_model.predict(in_img)
#This line uses the generator model (g_model) to generate a HR image from the LR input image.
#The predict method returns the predicted HR image.
a = np.squeeze(a,axis=0)
#This line removes the batch dimension from the predicted HR image, making it a 3-dimensional array representing
plt.imshow(a)
plt.axis('off')
#This code uses Matplotlib to display the predicted HR image without axis ticks.
plt.savefig('C:/Users/student/Desktop/dataset/generated_HR_13', bbox_inches='tight', pad_inches=0)
#This line saves the displayed image as a file named 'generated_HR_13' in the specified directory.
#The parameters bbox_inches='tight' and pad_inches=0 ensure that the saved image has minimal padding around it.
plt.close()
```

#Overall, this code takes a low-resolution input image, generates a high-resolution image using the generator m #displays it using Matplotlib, saves it as a file, and then closes the figure. If you run this code, you should #generated HR image saved at the specified location.

1/1 [======] - 6s 6s/step

```
path = "C:/Users/student/Desktop/dataset/generated_HR_13.png"
sift(path)#here we apply sift algorithm to find the key points in the generated HR image
```

('Number of Keypoints in this image are', 225)



```
def calculate_psnr(original_img, processed_img, max_pixel_value):
    mse = np.mean((original_img - processed_img) ** 2)
    psnr = 10 * np.log10((max_pixel_value ** 2) / mse)
    return psnr

original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/13.png', cv2.IMREAD_GRAYSCALE)
processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_13.png", cv2.IMREAD_GRAYSCALE)
original_image = cv2.resize(original_image, (processed_image.shape[1], processed_image.shape[0]))
original_image = original_image.astype(np.float64)
processed_image = processed_image.astype(np.float64)
max_pixel_value = 255
psnr = calculate_psnr(original_image, processed_image, max_pixel_value)

print("The PSNR value between the original image and processed image is:", psnr, "dB")
```

```
The PSNR value between the original image and processed image is: 25.81173013572808 dB
In []: '''Here's a breakdown of the code:
        Definition of calculate psnr function:
        This function takes three arguments: original img, processed img, and max pixel value.
        It calculates the Mean Squared Error (MSE) between the original and processed images.
        Using the formula for PSNR, it computes the PSNR value in decibels (dB).
        It returns the PSNR value.
        Loading and preprocessing images:
        The original and processed images are loaded using OpenCV's cv2.imread function.
        Both images are converted to grayscale using the flag cv2.IMREAD GRAYSCALE.
        The size of the original image is resized to match the dimensions of the processed image using cv2.resize.
        Both images are converted to floating-point arrays (np.float64) to ensure accurate computation.
        Calculation of PSNR:
        The maximum pixel value (max_pixel_value) is set to 255 for 8-bit images.
        PSNR is calculated using the calculate_psnr function.
        Printing the PSNR value:
        The PSNR value is printed to the console.
```

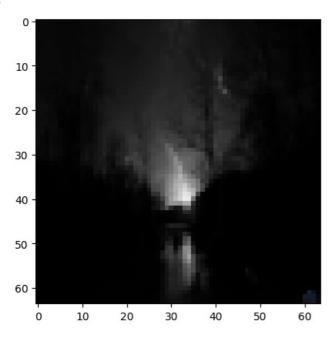
```
In [108... import numpy as np import cv2

def calculate_ssim(img1, img2):
    C1 = (0.01 * 255)**2
    C2 = (0.03 * 255)**2
    mu1 = np.mean(img1)
    mu2 = np.mean(img2)
    sigma1_sq = np.var(img1)
    sigma2_sq = np.var(img2)
    sigma12 = np.cov(img1.flatten(), img2.flatten())[0, 1]
    ssim_value = ((2 * mu1 * mu2 + C1) * (2 * sigma12 + C2)) / ((mu1**2 + mu2**2 + C1) * (sigma1_sq + sigma2_sq return ssim_value)
```

```
In [ ]:
         The provided code defines a function calculate ssim to compute the Structural Similarity Index (SSIM) between t
         Here's how the function works:
         Initialization of Constants (C1 and C2):
         C1 and C2 are constants used to stabilize the division with weak denominator. They are derived from the dynamic
         pixel values (255 for 8-bit images) and small constants (0.01 and 0.03), which are used to avoid instability wh
         or variance is close to zero.
         Calculation of Image Statistics:
         mul and mu2 represent the mean values of imgl and img2 respectively.
         sigma1_sq and sigma2_sq represent the variances of img1 and img2 respectively.
         sigmal2 represents the covariance between img1 and img2.
         Calculation of SSIM:
         The SSIM formula is applied using the computed statistics.
         The SSIM value is computed and returned.
         This function computes the SSIM value between two input images img1 and img2. It measures the structural simila
         the images, taking into account luminance, contrast, and structure.
         You can use this function to quantify the similarity between two images. Higher SSIM values indicate higher sim
         1 representing perfect similarity.
In [109... generated hr image = cv2.imread('C:/Users/student/Desktop/dataset/generated HR 13.png', cv2.IMREAD GRAYSCALE)
         ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/13.png', cv2.IMREAD_GRAY
         ground_truth_hr_image_resized = cv2.resize(ground_truth_hr_image, (generated_hr_image.shape[1], generated_hr_im
         ssim value = calculate ssim(generated hr image, ground truth hr image resized)
         print("SSIM between generated HR image and ground truth HR image:", ssim value)
         SSIM between generated HR image and ground truth HR image: 0.9856879080249447
 In [ ]: #This code snippet loads a generated high-resolution (HR) image and a ground truth high-resolution (HR) image,
         #ground truth image to match the dimensions of the generated image, and then calculates the Structural Similari
In [25]:
         import cv2
         import numpy as np
         img lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low res/13.png', cv2.IMREAD GRAYSCALE)
         img hr = cv2.imread('C:/Users/student/Desktop/dataset/generated HR 13.png', cv2.IMREAD GRAYSCALE)
         sift = cv2.SIFT create()
         keypoints_lr, descriptors_lr = sift.detectAndCompute(img_lr, None)
         keypoints hr, descriptors hr = sift.detectAndCompute(img hr, None)
         bf = cv2.BFMatcher()
         matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)
         good matches = []
         for m, n in matches:
             if m.distance < 0.75 * n.distance:</pre>
                 good matches.append(m)
         num matched keypoints = len(good matches)
         print("Number of keypoints matched:", num_matched_keypoints)
         Number of keypoints matched: 17
 In [ ]:
         '''This code snippet uses the SIFT (Scale-Invariant Feature Transform) algorithm to detect keypoints and comput
         for both a low-resolution (LR) image (img_lr) and a generated high-resolution (HR) image (img_hr). Then, it mat
         between the LR and HR images using a brute-force matcher (cv2.BFMatcher()).
         Let's break down the code:
         Loading Images:
         The LR image (img lr) and HR image (img hr) are loaded using OpenCV's cv2.imread function with the cv2.IMREAD G
         to load them in grayscale mode.
         SIFT Feature Detection and Description:
         A SIFT object is created using cv2.SIFT_create().
         SIFT keypoints and descriptors are computed for both the LR and HR images using the detectAndCompute method.
         Keypoint Matching:
         A brute-force matcher (bf) is created using cv2.BFMatcher().
         Keypoints and descriptors of the LR and HR images are matched using the knnMatch method with k=2 (to find the 2
         neighbors for each keypoint).
         Good matches are selected based on the ratio test, where only matches with a distance ratio less than 0.75 are
         Counting Matched Keypoints:
         The number of good matches is counted, and the result is printed.
         This code snippet provides a quantitative measure of how well corresponding features are matched between the LR
           The number of matched keypoints indicates the degree of similarity or alignment between the LR and HR images.
         Higher numbers of matched keypoints generally suggest better alignment.''
         #Load and plot the 14 th LR image
In [26]:
         img_path_14 = 'C:/Users/student/Desktop/dataset/Raw Data/low_res/14.png'
         img_14 = cv2.imread(img_path_14)
```

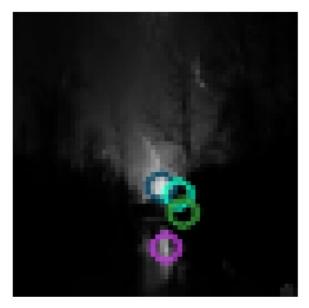
```
img_14 = cv2.cvtColor(img_14, cv2.COLOR_BGR2RGB)
img_14 = img_14/255.
img_14 = img_14.astype('float32')
print('The shape of the image is',img_14.shape)
plt.imshow(img_14)
```

The shape of the image is (64, 64, 3) Out[26]: <matplotlib.image.AxesImage at 0x1ee7f80cca0>

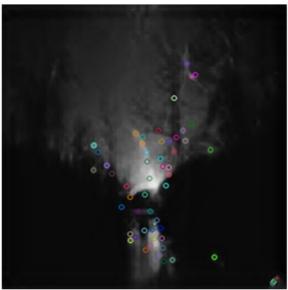


In [31]: sift(img_path_14)#apply SIFT to LR image

Out[31]: ('Number of Keypoints in this image are', 4)



Out[33]: ('Number of Keypoints in this image are', 65)



bf = cv2.BFMatcher()

good_matches = []
for m, n in matches:

matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)

print("Number of keypoints matched:", num_matched_keypoints)

```
In [34]: def calculate_psnr(original_img, processed_img, max_pixel_value):#calculate PSNR value
             mse = np.mean((original img - processed img) ** 2)
             psnr = 10 * np.log10((max pixel value ** 2) / mse)
             return psnr
         original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/14.png', cv2.IMREAD_GRAYSCALE)
         processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_14.png", cv2.IMREAD_GRAYSCALE)
         original_image = cv2.resize(original_image, (processed_image.shape[0]))
         original image = original image.astype(np.float64)
         processed_image = processed_image.astype(np.float64)
         max_pixel_value = 255
         psnr = calculate psnr(original image, processed image, max pixel value)
         print("The PSNR value between the original image and processed image is:", psnr, "dB")
         The PSNR value between the original image and processed image is: 27.385943270353103 dB
In [110... generated_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_14.png', cv2.IMREAD_GRAYSCALE)
         ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/14.png', cv2.IMREAD_GRAY
         ground_truth_hr_image_resized = cv2.resize(ground_truth_hr_image, (generated_hr_image.shape[1], generated_hr_im
         ssim_value = calculate_ssim(generated_hr_image, ground_truth_hr_image_resized)
         print("SSIM between generated HR image and ground truth HR image:", ssim value)
         SSIM between generated HR image and ground truth HR image: 0.8837812526794573
In [35]: import cv2
         import numpy as np
         img lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low res/14.png', cv2.IMREAD GRAYSCALE)
         img_hr = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_14.png', cv2.IMREAD_GRAYSCALE)
         sift = cv2.SIFT create()
         keypoints lr, descriptors lr = sift.detectAndCompute(img lr, None)
         keypoints\_hr, \ descriptors\_hr = sift.detectAndCompute(img\_hr, \ \textit{None})
```

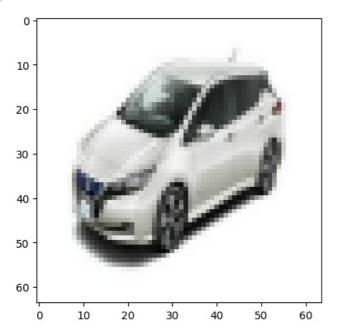
```
Number of keypoints matched: 3

In [36]: img_path_16 = 'C:/Users/student/Desktop/dataset/Raw Data/low_res/16.png'
    img_16 = cv2.imread(img_path_16)
    img_16 = cv2.cvtColor(img_16, cv2.COLOR_BGR2RGB)
    img_16 = img_16/255.
    img_16 = img_16.astype('float32')
    print('The shape of the image is',img_16.shape)
```

```
plt.imshow(img_16)
```

The shape of the image is (64, 64, 3) <matplotlib.image.AxesImage at 0x1ee4ce87790>

```
Out[36]:
```



```
In [39]: sift(img_path_16)
```

('Number of Keypoints in this image are', 31) Out[39]:



```
In [40]: in img 16 = np.expand dims(img <math>16,axis=0)
         c = g_model.predict(in_img_16)
c = np.squeeze(c,axis=0)
         plt.imshow(c)
         plt.axis('off')
         plt.savefig('C:/Users/student/Desktop/dataset/generated_HR_16', bbox_inches='tight', pad_inches=0) # Save the
         plt.close()
         1/1 [======] - 0s 15ms/step
```

```
In [41]: path_16 = "C:/Users/student/Desktop/dataset/generated_HR_16.png"
         sift(path 16)
```

('Number of Keypoints in this image are', 354) Out[41]:



```
def calculate_psnr(original_img, processed_img, max_pixel_value):
    mse = np.mean((original_img - processed_img) ** 2)
    psnr = 10 * np.log10((max_pixel_value ** 2) / mse)
    return psnr

original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/16.png', cv2.IMREAD_GRAYSCALE)
processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_16.png", cv2.IMREAD_GRAYSCALE)
original_image = cv2.resize(original_image, (processed_image.shape[1], processed_image.shape[0]))
original_image = original_image.astype(np.float64)
processed_image = processed_image.astype(np.float64)
max_pixel_value = 255
psnr = calculate_psnr(original_image, processed_image, max_pixel_value)

print("The PSNR value between the original image and processed image is:", psnr, "dB")
```

The PSNR value between the original image and processed image is: $24.58003036540086 \ dB$

In [111... generated_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_16.png', cv2.IMREAD_GRAYSCALE)
 ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/16.png', cv2.IMREAD_GRAY
 ground_truth_hr_image_resized = cv2.resize(ground_truth_hr_image, (generated_hr_image.shape[1], generated_hr_im
 ssim_value = calculate_ssim(generated_hr_image, ground_truth_hr_image_resized)
 print("SSIM between generated HR image and ground truth HR image:", ssim_value)

SSIM between generated HR image and ground truth HR image: 0.9863751842828165

```
import cv2
import numpy as np

img_lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low_res/16.png', cv2.IMREAD_GRAYSCALE)
img_hr = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_16.png', cv2.IMREAD_GRAYSCALE)
sift = cv2.SIFT_create()
keypoints_lr, descriptors_lr = sift.detectAndCompute(img_lr, None)
keypoints_hr, descriptors_hr = sift.detectAndCompute(img_hr, None)

bf = cv2.BFMatcher()
matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)

good_matches = []
for m, n in matches:
    if m.distance < 0.75 * n.distance:
        good_matches.append(m)

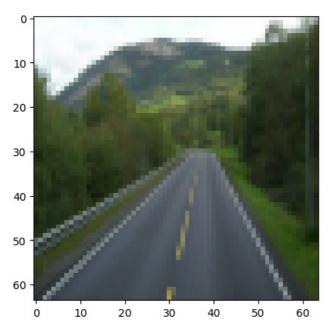
num_matched_keypoints = len(good_matches)
print("Number of keypoints matched:", num_matched_keypoints)</pre>
```

Number of keypoints matched: 23

```
In [45]: img_path_171 = 'C:/Users/student/Desktop/dataset/Raw Data/low_res/171.png'
img_171 = cv2.imread(img_path_171)
img_171 = cv2.cvtColor(img_171, cv2.COLOR_BGR2RGB)
```

```
img_171 = img_171/255.
img_171 = img_171.astype('float32')
print('The shape of the image is',img_171.shape)
plt.imshow(img_171)
```

The shape of the image is (64, 64, 3)<matplotlib.image.AxesImage at 0x1f13f254ca0> Out[45]:



```
In [48]:
         sift(img_path_171)
```

('Number of Keypoints in this image are', 14) Out[48]:

Out[50]:



```
In [49]: in_img_171 = np.expand_dims(img_171,axis=0)
         c = g_model.predict(in_img_171)
c = np.squeeze(c,axis=0)
         plt.imshow(c)
         plt.axis('off')
         plt.savefig('C:/Users/student/Desktop/dataset/generated_HR_171', bbox_inches='tight', pad_inches=0) # Save the
         plt.close()
         1/1 [======] - 0s 17ms/step
In [50]:
         path_171 = "C:/Users/student/Desktop/dataset/generated_HR_171.png"
         sift(path_171)
         ('Number of Keypoints in this image are', 240)
```



```
In [51]: def calculate_psnr(original_img, processed_img, max_pixel_value):
                                    mse = np.mean((original_img - processed_img) ** 2)
                                     psnr = 10 * np.log10((max_pixel_value ** 2) / mse)
                                     return psnr
                         original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/171.png', cv2.IMREAD_GRAYSCALE)
                          processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_171.png", cv2.IMREAD_GRAYSCALE)
                          original image = cv2.resize(original image, (processed image.shape[0]))
                         original_image = original_image.astype(np.float64)
                          processed_image = processed_image.astype(np.float64)
                          max pixel value = 255
                         psnr = calculate psnr(original image, processed image, max pixel value)
                          print("The PSNR value between the original image and processed image is:", psnr, "dB")
                         The PSNR value between the original image and processed image is: 26.04971422802578 dB
                         \label{eq:generated_hr_image} generated_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_171.png', cv2.IMREAD_GRAYSCALE)\\ ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw_Data/high_res/171.png', cv2.IMREAD_GRAWSCALE)\\ ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw_Data/high_res/171.png')\\ ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw_Data/high_res/171.png')\\ ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw_Data/high_res/171.png')\\ ground_truth_hr_image = cv2.imread('C:/Users/stu
In [113...
                          ground truth hr image resized = cv2.resize(ground truth hr image, (generated hr image.shape[1], generated hr im
```

ssim_value = calculate_ssim(generated_hr_image, ground_truth_hr_image_resized) print("SSIM between generated HR image and ground truth HR image:", ssim value)

SSIM between generated HR image and ground truth HR image: 0.9792410640644867

```
In [52]:
          import cv2
          import numpy as np
          img lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low res/171.png', cv2.IMREAD GRAYSCALE)
          img hr = cv2.imread('C:/Users/student/Desktop/dataset/generated HR 171.png', cv2.IMREAD GRAYSCALE)
          sift = cv2.SIFT create()
          keypoints_lr, descriptors_lr = sift.detectAndCompute(img_lr, None)
keypoints_hr, descriptors_hr = sift.detectAndCompute(img_hr, None)
          bf = cv2.BFMatcher()
          matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)
          good matches = []
          for m, n in matches:
               if m.distance < 0.75 * n.distance:</pre>
                   good matches.append(m)
          num matched keypoints = len(good matches)
          print("Number of keypoints matched:", num matched keypoints)
```

Number of keypoints matched: 13

```
img path 543 = 'C:/Users/student/Desktop/dataset/Raw Data/low res/543.png'
In [53]:
         img 543 = cv2.imread(img path 543)
         img_543 = cv2.cvtColor(img_543, cv2.COLOR_BGR2RGB)
         img_543 = img_543/255.
         img 543 = img 543.astype('float32')
```

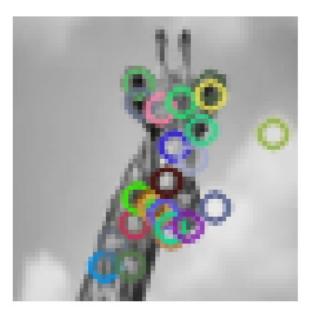
```
print('The shape of the image is',img_543.shape)
plt.imshow(img_543)
```

The shape of the image is (64, 64, 3) Out[53]: <matplotlib.image.AxesImage at 0xlee6d226f40>

> 10 -20 -30 -40 -50 -60 -0 10 20 30 40 50 60

```
In [56]: sift(img_path_543)
```

Out[56]: ('Number of Keypoints in this image are', 28)



```
In [58]: path_543 = "C:/Users/student/Desktop/dataset/generated_HR_543.png"
    sift(path_543)
```

 ${\tt Out[58]:}$ ('Number of Keypoints in this image are', 259)



```
In [59]: def calculate_psnr(original_img, processed_img, max_pixel_value):
    mse = np.mean((original_img - processed_img) ** 2)
    psnr = 10 * np.log10((max_pixel_value ** 2) / mse)
    return psnr

original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/543.png', cv2.IMREAD_GRAYSCALE)
processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_543.png", cv2.IMREAD_GRAYSCALE)
original_image = cv2.resize(original_image, (processed_image.shape[1], processed_image.shape[0]))
original_image = original_image.astype(np.float64)
processed_image = processed_image.astype(np.float64)
max_pixel_value = 255
psnr = calculate_psnr(original_image, processed_image, max_pixel_value)

print("The PSNR value between the original image and processed image is: ", psnr, "dB")

The PSNR value between the original image and processed image is: 25.517713288395726 dB
```

In [114__ generated_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_543.png', cv2.IMREAD_GRAYSCALE)
 ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/543.png', cv2.IMREAD_GRA'
 ground_truth_hr_image_resized = cv2.resize(ground_truth_hr_image, (generated_hr_image.shape[1], generated_hr_im
 ssim_value = calculate_ssim(generated_hr_image, ground_truth_hr_image_resized)
 print("SSIM between generated HR image and ground truth HR image:", ssim_value)

SSIM between generated HR image and ground truth HR image: 0.9674866184987523

Number of keypoints matched: 23

```
import cv2
import numpy as np

img_lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low_res/543.png', cv2.IMREAD_GRAYSCALE)

img_hr = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_543.png', cv2.IMREAD_GRAYSCALE)

sift = cv2.SIFT_create()
keypoints_lr, descriptors_lr = sift.detectAndCompute(img_lr, None)
keypoints_hr, descriptors_hr = sift.detectAndCompute(img_hr, None)

bf = cv2.BFMatcher()
matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)

good_matches = []
for m, n in matches:
    if m.distance < 0.75 * n.distance:
        good_matches.append(m)

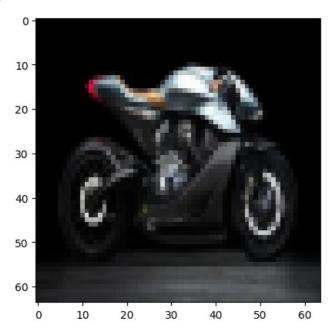
num_matched_keypoints = len(good_matches)
print("Number of keypoints matched:", num_matched_keypoints)</pre>
```

In [86]: img_path_10 = 'C:/Users/student/Desktop/dataset/Raw Data/low_res/10.png'
img_10 = cv2.imread(img_path_10)
img_10 = cv2.cvtColor(img_10, cv2.COLOR_BGR2RGB)

```
img_10 = img_10/255.
img_10 = img_10.astype('float32')
print('The shape of the image is',img_10.shape)
plt.imshow(img_10)
```

The shape of the image is (64, 64, 3)

Out[86]: <matplotlib.image.AxesImage at 0x1f1f3ec8190>



```
In [89]: sift(img_path_10)
```

Out[89]: ('Number of Keypoints in this image are', 38)



('Number of Keypoints in this image are', 322)

Out[91]:



```
In [92]: def calculate_psnr(original_img, processed_img, max_pixel_value):
              mse = np.mean((original_img - processed_img) ** 2)
              psnr = 10 * np.log10((max_pixel_value ** 2) / mse)
              return psnr
          original_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/10.png', cv2.IMREAD_GRAYSCALE)
          processed_image = cv2.imread("C:/Users/student/Desktop/dataset/generated_HR_10.png", cv2.IMREAD_GRAYSCALE)
          original image = cv2.resize(original image, (processed image.shape[0]))
          original_image = original_image.astype(np.float64)
          processed_image = processed_image.astype(np.float64)
          max_pixel_value = 255
          psnr = calculate psnr(original image, processed image, max pixel value)
          print("The PSNR value between the original image and processed image is:", psnr, "dB")
          The PSNR value between the original image and processed image is: 24.81837466346962 dB
         generated_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/generated_HR_10.png', cv2.IMREAD_GRAYSCALE)
ground_truth_hr_image = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/high_res/10.png', cv2.IMREAD_GRAY
In [115...
          ground_truth_hr_image_resized = cv2.resize(ground_truth_hr_image, (generated_hr_image.shape[1], generated_hr_im
```

ssim value = calculate ssim(generated hr image, ground truth hr image resized) print("SSIM between generated HR image and ground truth HR image:", ssim value)

SSIM between generated HR image and ground truth HR image: 0.9391832851854323

```
In [105...
          import cv2
          import numpy as np
          img lr = cv2.imread('C:/Users/student/Desktop/dataset/Raw Data/low res/10.png', cv2.IMREAD GRAYSCALE)
          img hr = cv2.imread('C:/Users/student/Desktop/dataset/generated HR 10.png', cv2.IMREAD GRAYSCALE)
          sift = cv2.SIFT create()
          keypoints_lr, descriptors_lr = sift.detectAndCompute(img_lr, None)
keypoints_hr, descriptors_hr = sift.detectAndCompute(img_hr, None)
          bf = cv2.BFMatcher()
          matches = bf.knnMatch(descriptors_lr, descriptors_hr, k=2)
          good matches = []
          for m, n in matches:
               if m.distance < 0.75 * n.distance:</pre>
                   good matches.append(m)
          num matched keypoints = len(good matches)
          print("Number of keypoints matched:", num matched keypoints)
```

Number of keypoints matched: 31

```
In [ ]:
In [ ]:
```