Image processing & Machine Vision

Assignment – 01

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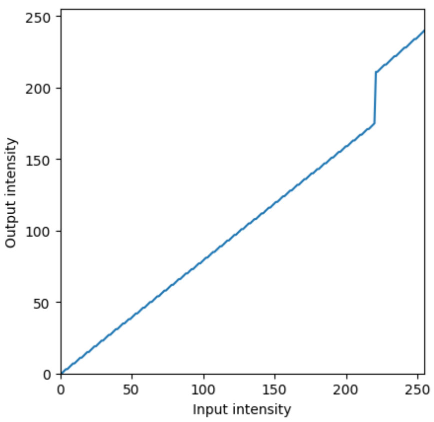
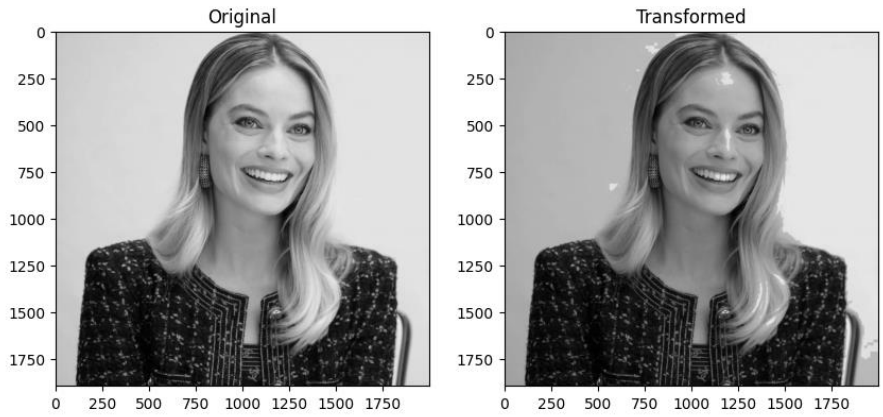
Git Hub Link: https://github.com/Sandeepa0/Image-Processing

Question 01

```python
c = np.array([(220, 175), (220, 210), (255, 240)])

t1 = np.linspace(0, c[0, 1], c[0, 0]+1).astype('uint8')
print(len(t1))
t2 = np.linspace(c[0, 1] + 1, c[1, 0]-c[0, 0], c[1, 0]-c[0, 0]).astype('uint8')
print(len(t2))
t3 = np.linspace(c[1, 1] + 1, 240, 255 - c[1, 0]).astype('uint8')
print(len(t3))

transform = np.concatenate((t1, t2, t3), axis=0).astype('uint8')
print(len(transform))

fig, ax = plt.subplots()
ax.plot(transform)
ax.set_xlabel(r'Input intensity')
ax.set_ylabel('Output intensity')
ax.set_xlim(0, 255)
ax.set_ylim(0, 255)
ax.set_aspect('equal')
plt.show()

img_orig = cv.imread('margot_golden_gray.jpg', cv.IMREAD_GRAYSCALE)
image_transformed = cv.LUT(img_orig, transform)

fig, ax = plt.subplots(1, 2, figsize=(10, 20))
ax[0].imshow(img_orig, cmap="gray")
ax[0].set_title("Original")
ax[1].imshow(image_transformed, cmap="gray")
ax[1].set_title("Transformed")
plt.show()
```



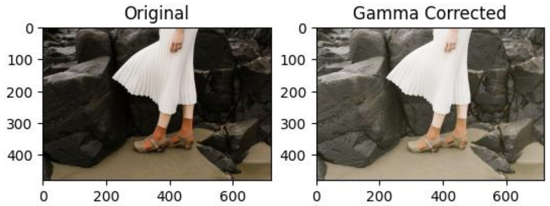


Intensity transformation plays a crucial role in adjusting the overall brightness, contrast, and other adjustment of the images. Also, intensity transformation is the fundamental process in image processing that can modify the pixel values. I attached the code and results.

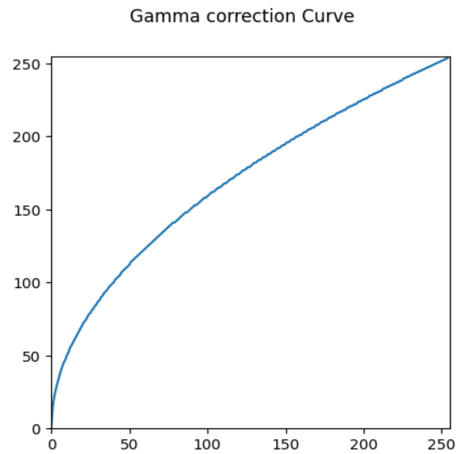
Question 02

a.

```python
img_orig = cv.imread('highlights_and_shadows.jpg', cv.IMREAD_COLOR)

gamma = .5

table = np.array(
    [(i/255.0)**(gamma)*255.0 for i in np.arange(0, 256)]).astype('uint8')

img_gamma = cv.LUT(img_orig, table)
img_orig = cv.cvtColor(img_orig, cv.COLOR_BGR2RGB)
img_gamma = cv.cvtColor(img_gamma, cv.COLOR_BGR2RGB)

f, axarr = plt.subplots(1, 2)
axarr[0].imshow(img_orig)
axarr[0].set_title('Original')
axarr[1].imshow(img_gamma)
axarr[1].set_title('Gamma Corrected')
```

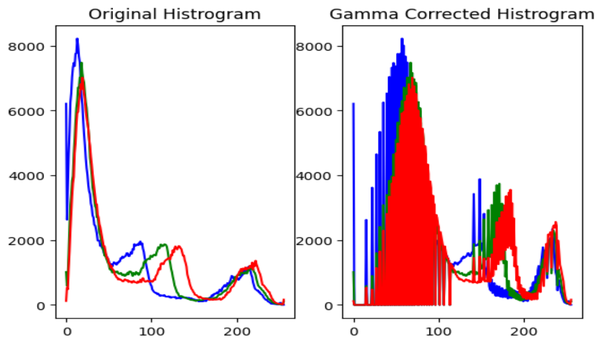



```python
img_orig = cv.imread('highlights_and_shadows.jpg', cv.IMREAD_COLOR)

gamma = .5

table = np.array(
    [(i/255.0)**(gamma)*255.0 for i in np.arange(0, 256)]).astype('uint8')

img_gamma = cv.LUT(img_orig, table)
img_orig = cv.cvtColor(img_orig, cv.COLOR_BGR2RGB)
img_gamma = cv.cvtColor(img_gamma, cv.COLOR_BGR2RGB)

fig, axarr = plt.subplots()
axarr.plot(table)
axarr.set_xlim(0, 255)
axarr.set_ylim(0, 255)
axarr.set_aspect('equal')

plt.suptitle("Gamma correction Value Curve")
plt.show()
```



b.

```python
gamma = .5

table = np.array(
    [(i/255.0)**(gamma)*255.0 for i in np.arange(0, 256)]).astype('uint8')

img_gamma = cv.LUT(img_orig, table)
img_orig = cv.cvtColor(img_orig, cv.COLOR_BGR2RGB)
img_gamma = cv.cvtColor(img_gamma, cv.COLOR_BGR2RGB)

f, axarr = plt.subplots(1, 2)
color = ('b', 'g', 'r')

for i, c in enumerate(color):
    hist_orig = cv.calcHist([img_orig], [i], None, [256], [0, 256])
    axarr[0].plot(hist_orig, color=c)
    axarr[0].set_title('Original Histrogram')
    hist_gamma = cv.calcHist([img_gamma], [i], None, [256], [0, 256])
    axarr[1].plot(hist_gamma, color=c)
    axarr[1].set_title('Gamma Corrected Histrogram')
```



Histograms show a visual representation of the distribution of pixel intensities in an image. Original Histogram color spaces reflect the pixel intensities in the L channel. Indicate how common each intensities level is within the image. After applying gamma correction alters the relationship between the input and output pixel intensities this one affected overall brightness and contrast.

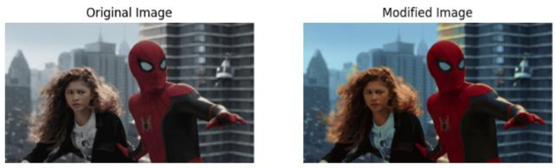
Question 03

a.

```python
def f(x, a, sigma):
    return np.minimum(x + a * 128 * np.exp(-(x - 128) ** 2 / (2 * sigma ** 2)), 255)

image = cv.imread("spider.png")
hsv_image = cv.cvtColor(image, cv.COLOR_BGR2HSV)

saturation_plane = hsv_image[:, :, 1]

a = 0.5
sigma = 70

modified_saturation = f(saturation_plane, a, sigma)

hsv_image[:, :, 1] = modified_saturation.astype(np.uint8)
modified_image = cv.cvtColor(hsv_image, cv.COLOR_HSV2BGR)
hue_plane, saturation_plane, value_plane = cv.split(cv.cvtColor(modified_image, cv.COLOR_BGR2HSV))

fig, ax = plt.subplots(1, 3, figsize=(10,5), sharey = True)

ax[0].imshow(hue_plane, cmap='gray')
ax[0].set_title('Hue Plane')
ax[0].axis('off')

ax[1].imshow(saturation_plane, cmap='gray')
ax[1].set_title('Saturation Plane')
ax[1].axis('off')

ax[2].imshow(value_plane, cmap='gray')
ax[2].set_title('Value Plane')
ax[2].axis('off')
```

b.

```python
def f(x, a, sigma):
    return np.minimum(x + a * 128 * np.exp(-(x - 128) ** 2 / (2 * sigma ** 2)), 255)

image = cv.imread("spider.png")

hsv_image = cv.cvtColor(image, cv.COLOR_BGR2HSV)
saturation_plane = hsv_image[:, :, 1]

a = 0.5
sigma = 70

modified_saturation = f(saturation_plane, a, sigma)

hsv_image[:, :, 1] = modified_saturation.astype(np.uint8)
modified_image = cv.cvtColor(hsv_image, cv.COLOR_HSV2BGR)

fig, ax = plt.subplots(1, 2, figsize=(10, 20))
ax[0].imshow(cv.cvtColor(image, cv.COLOR_BGR2RGB))
ax[0].set_title('Original Image')
ax[0].axis('off')
ax[1].imshow(cv.cvtColor(modified_image, cv.COLOR_BGR2RGB))
ax[1].set_title('Modified Image')
ax[1].axis('off')
plt.show()
```

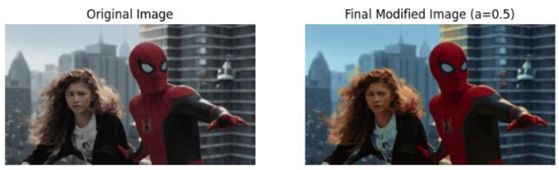


c.

```python
a = 0.2
sigma = 70

modified_saturation = f(saturation_plane, a, sigma)

hsv_image[:, :, 1] = modified_saturation.astype(np.uint8)
modified_image = cv.cvtColor(hsv_image, cv.COLOR_HSV2BGR)

fig, ax = plt.subplots(1, 2, figsize=(10, 20))
ax[0].imshow(cv.cvtColor(image, cv.COLOR_BGR2RGB))
ax[0].set_title('Original Image')
ax[0].axis('off')
ax[1].imshow(cv.cvtColor(modified_image, cv.COLOR_BGR2RGB))
ax[1].set_title(f'Modified Image (a={a})')
ax[1].axis('off')
plt.show()
```

d.

```python
hsv_image = cv.cvtColor(image, cv.COLOR_BGR2HSV)
hue_plane, saturation_plane, value_plane = cv.split(hsv_image)

a = 0.5
sigma = 70

modified_saturation = f(saturation_plane, a, sigma)

hsv_image[:, :, 1] = modified_saturation.astype(np.uint8)
modified_image = cv.merge([hue_plane, hsv_image[:, :, 1], value_plane])
final_modified_image = cv.cvtColor(modified_image, cv.COLOR_HSV2BGR)
```



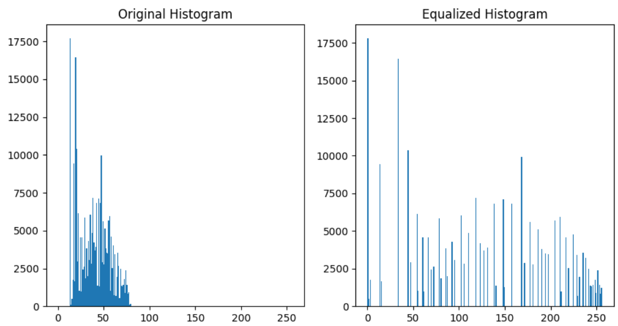
e.

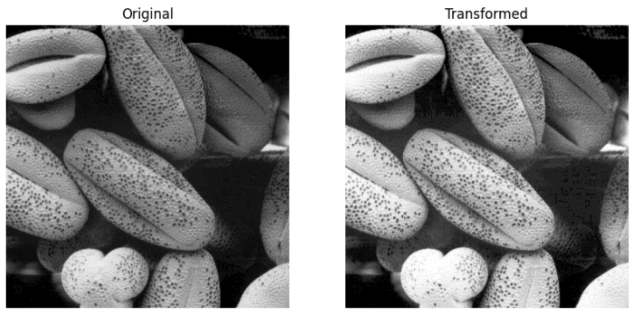
```python
def f(x, a, sigma):
    return np.minimum(x + a * 128 * np.exp(-(x - 128) ** 2 / (2 * sigma ** 2)), 255)

original_image = cv.imread("spider.png")

hsv_image = cv.cvtColor(original_image, cv.COLOR_BGR2HSV)

saturation_plane = hsv_image[:, :, 1]

vibrance_factor = 1.5
vibrance_enhanced_image = original_image.copy()
vibrance_enhanced_image[:, :, 1] = np.clip(vibrance_factor * saturation_plane, 0, 255)

a = 0.5
sigma = 70

modified_saturation = f(saturation_plane, a, sigma)
hsv_image[:, :, 1] = modified_saturation.astype(np.uint8)

intensity_transformed_image = cv.cvtColor(hsv_image, cv.COLOR_HSV2BGR)

fig, ax = plt.subplots(1, 3, figsize=(10,5), sharey = True)

ax[0].imshow(cv.cvtColor(original_image, cv.COLOR_BGR2RGB))
ax[0].set_title('Original Image')
ax[0].axis('off')

ax[1].imshow(cv.cvtColor(vibrance_enhanced_image, cv.COLOR_BGR2RGB))
ax[1].set_title('Vibrance Enhanced')
ax[1].axis('off')

ax[2].imshow(cv.cvtColor(intensity_transformed_image, cv.COLOR_BGR2RGB)),
ax[2].set_title('Intensity Transformed')
ax[2].axis('off')
plt.show()
```

Under this question we consider the image enhancement process after we increase the vibrance of an image by applying intensity transformation to the saturation, HUE, HSV planes. Considering these three planes we focus directed towards enhancing and bringing out more vivid colors. The intensity transformation involves a parameter ‘a’ is adjusted to achieve a pleasing vibrance enhancement.

Question 04

```python
import cv2 as cv
import matplotlib.pyplot as plt
import numpy as np

im = cv.imread('shells.tif', cv.IMREAD_GRAYSCALE)

im_equalized = cv.equalizeHist(im)

plt.figure(figsize=(10, 5))
plt.subplot(1, 2, 1)
plt.title('Original Histogram')
plt.hist(im.flatten(), bins=256, range=[0, 256])

plt.subplot(1, 2, 2)
plt.title('Equalized Histogram')
plt.hist(im_equalized.flatten(), bins=256, range=[0, 256])

fig, ax= plt.subplots(1,2, figsize=(10,20))
ax[0].imshow(im, cmap="gray")
ax[0].set_title('Original')
ax[0].axis('off')

ax[1].imshow(im_equalized, cmap="gray")
ax[1].set_title('Transformed')
ax[1].axis('off')
plt.show()
```

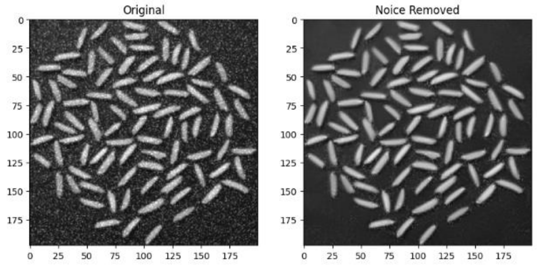




Question 05

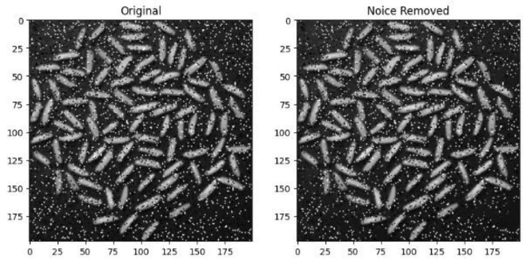
a.

```
image = cv.imread("rice_gaussian_noise.png")

dst = cv.fastNlMeansDenoisingColored(image, None, 20, 20, 7, 15)

fig, ax = plt.subplots(1, 2, figsize=(10, 20))
ax[0].imshow(image, cmap="gray")
ax[0].set_title("Original")
ax[1].imshow(dst, cmap="gray")
ax[1].set_title("Noice Removed")
plt.show()
```



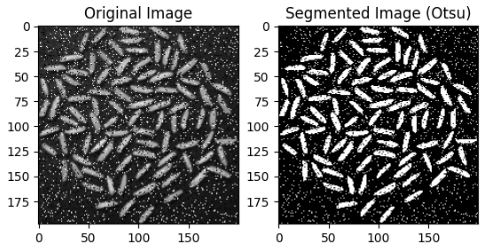
b.

```
dst = cv.fastNlMeansDenoisingColored(image, None, 20, 20, 7, 15)

fig, ax = plt.subplots(1, 2, figsize=(10, 20))
ax[0].imshow(image, cmap="gray")
ax[0].set_title("Original")
ax[1].imshow(dst, cmap="gray")
ax[1].set_title("Noice Removed")
plt.show()
```



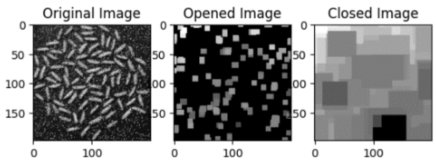
c.

```
import cv2 as cv
import matplotlib.pyplot as plt

image = cv.imread("rice_salt_pepper_noise.png", cv.IMREAD_GRAYSCALE)

_, binary_image = cv.threshold(image, 0, 255, cv.THRESH_BINARY + cv.THRESH_OTSU)

plt.subplot(121), plt.imshow(image, cmap='gray'), plt.title('Original Image')
plt.subplot(122), plt.imshow(binary_image, cmap='gray'), plt.title('Segmented Image (Otsu)')
plt.show()
```



d.

```
kernel_open = np.ones((5, 5), np.uint8)
image_opened = cv.morphologyEx(image, cv.MORPH_OPEN, kernel_open, iterations=2)

kernel_close = np.ones((5, 5), np.uint8)
image_closed = cv.morphologyEx(image_opened, cv.MORPH_CLOSE, kernel_close, iterations=10)
```



e.

```
im = cv.imread('rice_gaussian_noise.png', cv.IMREAD_GRAYSCALE)

denoised_im = cv.fastNlMeansDenoising(im, None, h=28, searchWindowSize=10)

_, segmented_image = cv.threshold(denoised_im, 0, 255, cv.THRESH_BINARY + cv.THRESH_OTSU)

kernel = cv.getStructuringElement(cv.MORPH_ELLIPSE, (5, 5))

closed_image = cv.morphologyEx(segmented_image, cv.MORPH_CLOSE, kernel)

opened_image = cv.morphologyEx(closed_image, cv.MORPH_OPEN, kernel)

num_labels, labels = cv.connectedComponents(opened_image)

num_rice_grains = num_labels - 1

print("Number of rice grains:", num_rice_grains)
```

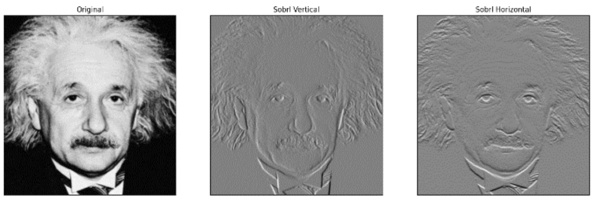
```
Number of rice grains: 68
```

Otsu’s method applied to segment the images, disfurnishing rice grains from the background. Morphological operations refine the segmentation by eliminating small artifacts and filling in gaps.

Question 06

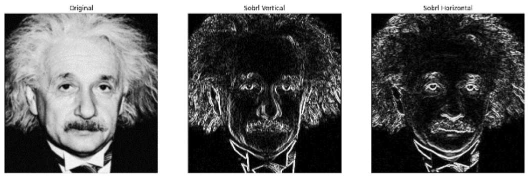
a.

```
kernal = np.ones((11,11),np.float32)/121
imgc =cv. filter2D(img,-1,kernal)

sobel_kernel_x = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]], dtype=np.float32)
sobel_kernel_y = np.array([[-1, -2, -1], [0, 0, 0], [1, 2, 1]], dtype=np.float32)

sobel_x = cv.filter2D(img, cv.CV_64F, sobel_kernel_x)
sobel_y = cv.filter2D(img, cv.CV_64F, sobel_kernel_y)


fig,axes = plt.subplots(1,3, sharex='all', sharey='all', figsize=(18,18))
axes[0].imshow(img, cmap='gray')
axes[0].set_title('Original')
axes[0].set_xticks([]), axes[0].set_yticks([])

axes[1].imshow(sobel_x, cmap='gray')
axes[1].set_title('Sobrl Vertical')
axes[1].set_xticks([]), axes[1].set_yticks([])

axes[2].imshow(sobel_y, cmap='gray')
axes[2].set_title('Sobrl Horizontal')
axes[2].set_xticks([]), axes[0].set_yticks([])
```



b.

```
sobel_kernel_x = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]], dtype=np.float32)
sobel_kernel_y = np.array([[-1, -2, -1], [0, 0, 0], [1, 2, 1]], dtype=np.float32)

sobel_x = cv.filter2D(image, cv.CV_64F, sobel_kernel_x)
sobel_y = cv.filter2D(image, cv.CV_64F, sobel_kernel_y)

sobel_x = cv.convertScaleAbs(sobel_x)
sobel_y = cv.convertScaleAbs(sobel_y)
```



c.

```
def sobel_filter(image):

    sobel_kernel_x = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]])
    sobel_kernel_y = np.array([[-1, -2, -1], [0, 0, 0], [1, 2, 1]])

    sobel_x = convolve2d(image, sobel_kernel_x)
    sobel_y = convolve2d(image, sobel_kernel_y)


    gradient_magnitude = np.sqrt(sobel_x**2 + sobel_y**2)
    sobel_x = np.abs(sobel_x).astype(np.uint8)
    sobel_y = np.abs(sobel_y).astype(np.uint8)
    gradient_magnitude = gradient_magnitude.astype(np.uint8)

    return sobel_x, sobel_y, gradient_magnitude

def convolve2d(image, kernel):
    height, width = image.shape
    k_height, k_width = kernel.shape

    pad_height = k_height // 2
    pad_width = k_width // 2
    padded_image = np.pad(image, ((pad_height, pad_height), (pad_width, pad_width)), mode='edge')

    result = np.zeros_like(image)
    for i in range(height):
        for j in range(width):
            result[i, j] = np.sum(padded_image[i:i+k_height, j:j+k_width] * kernel)

    return result

image = cv.imread('einstein.png', cv.IMREAD_GRAYSCALE)

if len(image.shape) > 2:
    image = cv.cvtColor(image, cv.COLOR_BGR2GRAY)

sobel_x, sobel_y, gradient_magnitude = sobel_filter(image)
```

Sobel filtering is a crucial technique in image processing that emphasizes intensity changes for edge detection. In the context of Figure 6, three approaches are employed. First, with the existing filter2D function, Sobel filtering may be completed efficiently and rapidly. Second, a custom Sobel filter implementation offers an interactive understanding of the underlying computations.

Question 07

a.

```python
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt

img = cv.imread('im01small.png')

scale = 4
rows = int(img.shape[0] * scale)
cols = int(img.shape[1] * scale)

zoomed = np.zeros((rows, cols, img.shape[2]), dtype=np.uint8)
for i in range(0, rows):
    for j in range(0, cols):
        zoomed[i, j] = img[int(i/scale), int(j/scale)]

fig, ax = plt.subplots(1, 2)
ax[0].imshow(cv.cvtColor(img, cv.COLOR_BGR2RGB))
ax[0].set_title('Original')
ax[1].imshow(cv.cvtColor(zoomed, cv.COLOR_BGR2RGB))
ax[1].set_title('Zoomed')
```

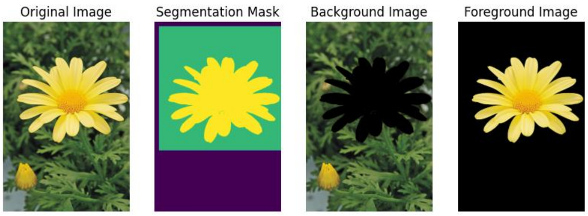
b.

```python
def bilinear_interpolation(image, scale):
    new_rows, new_cols = int(image.shape[0] * scale), int(image.shape[1] * scale)
    zoomed_image = np.zeros((new_rows, new_cols, 3), dtype=np.uint8)

    for i in range(new_rows):
        for j in range(new_cols):
            x, y = i / scale, j / scale
            x1, y1, x2, y2 = int(x), int(y), min(int(x) + 1, image.shape[0] - 1), min(int(y) + 1, image.shape[1] - 1)
            dx, dy = x - x1, y - y1
            zoomed_image[i, j] = (1 - dx) * (1 - dy) * image[x1, y1] + dx * (1 - dy) * image[x2, y1] + (1 - dx) * dy * image[x1, y2] + dx * dy * image[x2, y2

    return zoomed_image

im = cv.imread('im01small.png')
assert im is not None, "Image not found"

scale = 4
zoomed_image = bilinear_interpolation(im, scale)

fig, ax = plt.subplots(1, 2)
ax[0].imshow(cv.cvtColor(im, cv.COLOR_BGR2RGB))
ax[0].set_title('Original Image')
ax[1].imshow(cv.cvtColor(zoomed_image, cv.COLOR_BGR2RGB))
ax[1].set_title('Zoomed Image (Bilinear Interpolation)')
plt.show()
```

Question 08

a.

```python
image = cv.imread('daisy.jpg')

mask = np.zeros(image.shape[:2], np.uint8)
background = np.zeros((1,65), np.float64)

rect = (20, 20, 550, 550)

cv.grabCut(image, mask, rect, None, None, 5, cv.GC_INIT_WITH_RECT)

mask2 = np.where((mask == cv.GC_FGD) | (mask == cv.GC_PR_FGD), 1, 0).astype('uint8')

foreground = cv.bitwise_and(image, image, mask=mask2)
background = cv.bitwise_and(image, image, mask=1 - mask2)

segmentation_mask = np.where(mask2[:, :, np.newaxis] == 1, 255, 0).astype('uint8')

fig, ax = plt.subplots(1, 4, figsize=(10,10), sharey = True)

ax[0].imshow(image[:,:,::-1]),
ax[0].set_title('Original Image')
ax[0].axis('off')

ax[1].imshow(mask)
ax[1].set_title('Segmentation Mask')
ax[1].axis('off')

ax[2].imshow(background[:,:,::-1]),
ax[2].set_title('Background Image')
ax[2].axis('off')

ax[3].imshow(foreground[:,:,::-1])
ax[3].set_title('Foreground Image')
ax[3].axis('off')
```



b.

```python
image = cv.imread('daisy.jpg')

mask = np.zeros(image.shape[:2], np.uint8)
background = np.zeros((1,65), np.float64)

rect = (20, 20, 550, 550)

cv.grabCut(image, mask, rect, None, None, 5, cv.GC_INIT_WITH_RECT)

mask2 = np.where((mask == cv.GC_FGD) | (mask == cv.GC_PR_FGD), 1, 0).astype('uint8')

foreground = cv.bitwise_and(image, image, mask=mask2)
background = cv.bitwise_and(image, image, mask=1 - mask2)
segmentation_mask = np.where(mask2[:, :, np.newaxis] == 1, 255, 0).astype('uint8')

blurred_bg = cv.GaussianBlur(background, (31, 31), 0)
enhanced_img = cv.addWeighted(foreground, 1, blurred_bg, 0.8, 0)

fig, ax = plt.subplots(1, 2, figsize=(12,6), sharey = True)

ax[0].imshow(image[:,:,::-1])
ax[0].set_title('Original Image')
ax[0].axis('off')

ax[1].imshow(enhanced_img[:,:,::-1])
ax[1].set_title('Enhanced Image')
ax[1].axis('off')
```

c. The improved image's darker backdrop, which extends over the margin of the flower, is mostly the outcome of a Gaussian blur applied to the background. The image is first divided into foreground (flower) and background using Grab Cut. The background is then smoothed using a Gaussian blur with a (15, 15) kernel. The backdrop appears darker because of this smoothing effect, which averages pixel values. The final improved image is produced by combining the sharp foreground with the blurred backdrop. The degree of blurring and the ensuing darkness in the backdrop can be altered by varying certain parameters, such as the kernel size.