Basics of Image Processing

Arafat Hasan

<opendoor.arafat@gmail.com>

December 17, 2019

https://github.com/arafat-hasan/oh-my-image-processing-course

Table of Contents

EXPERIMENT 1

Basic Operations on an Image

1.1 Objective

- Familiarize with IDE, environment.
- Read, write operations of an image.
- Basic image manipulation.
- Iterate over image pixels.
- Access image properties.
- Access pixel values and modify them.

Almost all the operations in this section is mainly related to `Numpy` rather than `OpenCV`. A good knowledge of `Numpy` is required to write better optimized code with `OpenCV`.

1.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
import os
```

2. Start main function and read image.

```
if __name__ == '__main__':

    path = '../../img/misc/house.tiff'

    if os.path.isfile(path):
        img = cv2.imread(path)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Show the image using OpenCV `imshow` method and write to disk a new image using `imwrite` method.

```
    cv2.imshow('Original', img)
    cv2.imwrite('NewHouseImage.png', img)
```

4. Access an arbitrary pixel and print it.

```
    arbitraryPixel = img[2, 3]
    print('An arbitrary Pixel: ', arbitraryPixel)
```

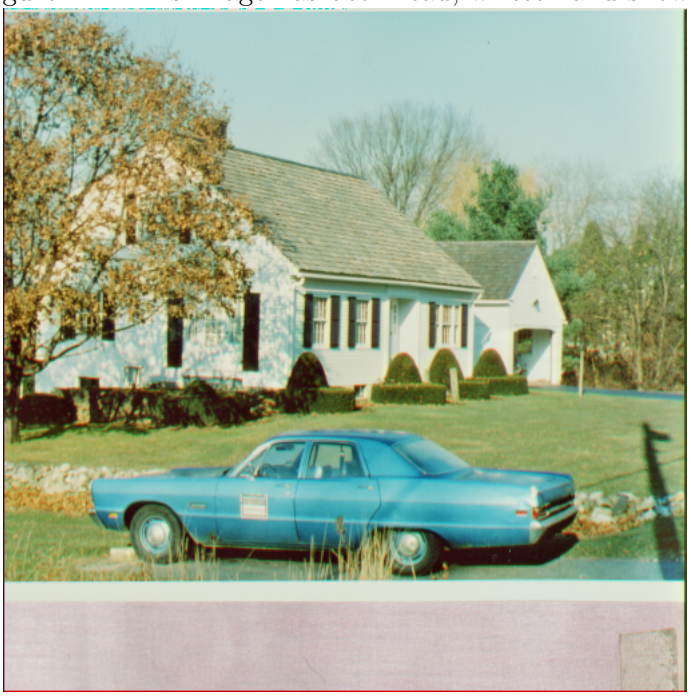
5. Get image dimension, height, width, channels and print them and exit window.

```
    dimensions = img.shape
    height = img.shape[0]
    width = img.shape[1]
    channels = img.shape[2]

    print('Image Dimension: ', dimensions)
    print('Image Height: ', height)
    print('Image Width: ', width)
    print('Total Number of pixels :', img.size)

    k = cv2.waitKey(0)
    cv2.destroyAllWindows()

    print("[INFO] All operations finished successfully...")
```

1.3 Input and Output

1.3.1 Image Output

Figure 1.1: This image has been read, written and shown.



1.3.2 Text Output

```
[INFO] Image has been read successfully...
An arbitrary Pixel:  [211 222 218]
Image Dimension:  (512, 512, 3)
Image Height:  512
Image Width:  512
Total Number of pixels : 786432
[INFO] All operations finished successfully...
```

EXPERIMENT 2

Addition of Two Images

2.1 Objective

- Take two same sized image as input.
- Produce a third image with same size of the input image which pixels are sum of two input images pixels.

Image addition equation is:

$$g(x, y) = f_1(x, y) + f_2(x, y) \tag{2.1}$$

Here $f_1(x, y)$ and $f_2(x, y)$ are two input images and $g(x, y)$ is output image.

2.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main function and read images

```
if __name__ == '__main__':
    path1 = '../../img/rectangle-1.png'
    path2 = '../../img/rectangle-2.png'

    if os.path.isfile(path1):
        img1 = cv2.imread(path1, cv2.IMREAD_GRAYSCALE)
        print("[INFO] First image has been read successfully...")
    else:
        print("[INFO] The file '" + path1 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path2):
        img2 = cv2.imread(path2, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Second image has been read successfully...")
    else:
        print("[INFO] The file '" + path2 + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size, if not then resize one of them. Image ratio may change. Better use same sized image.

```
    if img1.shape != img2.shape:
        print("Image sizes are not identical, resizing second image.")
        img2 = cv2.resize(img2, img1.shape[1], img1.shape[2])
```

4. Get image size and create a blank image as output.

```
    rows, cols = img1.shape
    output = np.zeros((rows, cols), dtype='uint8')
```

5. Iterate over the pixels and add individual pixel to get output.

```
    for row in range(rows):
        for col in range(cols):
            tmp = int(img1[row, col]) + int(img2[row, col])
            output[row, col] = max(0, min(tmp, 255))
```

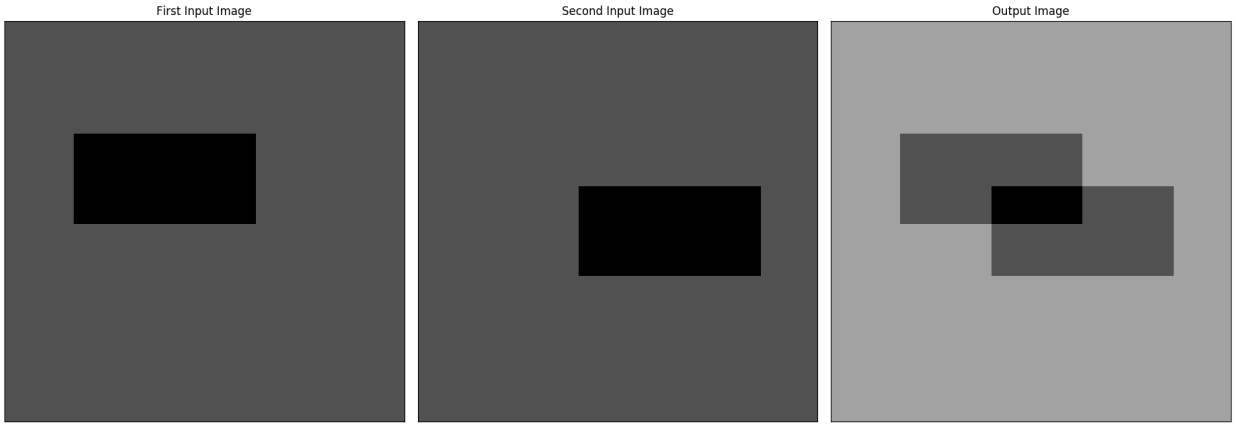
6. Plot two input images and an output image as addition result.

```
    titles = ['First Input Image', 'Second Input Image', 'Output Image']
    imgarr = [img1, img2, output]
    for i in range(3):
        plt.subplot(1, 3, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

2.3 Input and Output

2.3.1 Image Output

Figure 2.1: Addition of two images.



2.3.2 Text Output

```
[INFO] First image has been read successfully...
[INFO] Second image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 3

Multiplication of Two Images

3.1 Objective

Take two input image and multiply them and generate new output image. The multiplication of two images is performed in the obvious way in a single pass using the formula:

$$Q(i,j) = P_1(i,j) \times P_2(i,j) \tag{3.1}$$

3.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main code section and read images.

```
if __name__ == '__main__':
    path1 = '../../img/circle-1.png'
    path2 = '../../img/circle-2.png'

    if os.path.isfile(path1):
        img1 = cv2.imread(path1, cv2.IMREAD_GRAYSCALE)
        print("[INFO] First image has been read successfully...")
    else:
        print("[INFO] The file '" + path1 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path2):
        img2 = cv2.imread(path2, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Second image has been read successfully...")
    else:
        print("[INFO] The file '" + path2 + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size.

```
    if img1.shape != img2.shape:
        print("[INFO] Image sizes are not identical, resizing second image.")
        img2 = cv2.resize(img2, img1.shape[1], img1.shape[2])
```

4. Ceate a blank output image and convert input images form *uint*8 to *float* to encounter overflow problem with *uint*8.

```
    rows, cols = img1.shape
    output = np.zeros((rows, cols), dtype='float')
    img1 = img1.astype(float)
    img2 = img2.astype(float)
```

5. Iterate over every pixel and multiply input image's pixel to get output pixels.

```
    for row in range(rows):
        for col in range(cols):
            tmp = img1[row, col] * img2[row, col]
            output[row, col] = max(0, min(tmp, 255))
```

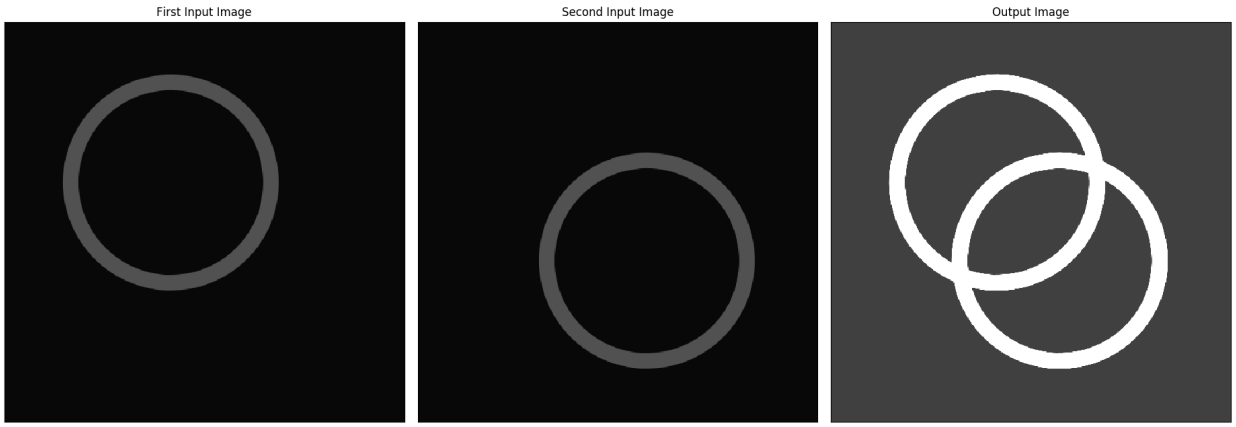
6. Plot two input images and result image's using *matplotlib*.

```
    titles = ['First Input Image', 'Second Input Image', 'Output Image']
    imgarr = [img1, img2, output]
    for i in range(3):
        plt.subplot(1, 3, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

3.3 Input and Output

3.3.1 Image Output

Figure 3.1: Multiplication of two images.



3.3.2 Text Output

```
[INFO] First image has been read successfully...
[INFO] Second image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 4

Division of Two Images

4.1 Objective

Take two input image and divide one by another and generate new output image. The division of two images is performed in the obvious way in a single pass using the formula:

$$Q(i,j) = P_1(i,j) \div P_2(i,j) \tag{4.1}$$

4.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import math
import os
import sys
```

2. Start main code section and read images.

```
if __name__ == '__main__':
    path1 = '../../img/rectangle-div-1.png'
    path2 = '../../img/rectangle-div-2.png'

    if os.path.isfile(path1):
        img1 = cv2.imread(path1, cv2.IMREAD_GRAYSCALE)
        print("[INFO] First image has been read successfully...")
    else:
        print("[INFO] The file '" + path1 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path2):
        img2 = cv2.imread(path2, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Second image has been read successfully...")
    else:
        print("[INFO] The file '" + path2 + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size.

```
    if img1.shape != img2.shape:
        print("Image sizes are not identical, resizing second image.")
        img2 = cv2.resize(img2, img1.shape[1], img1.shape[2])
```

4. Ceate a blank output image and convert input images form *uint*8 to *float* to encounter overflow problem with *uint*8.

```
    rows, cols = img1.shape
    output = np.zeros((rows, cols), dtype='float')
    img1 = img1.astype(float)
    img2 = img2.astype(float)
```

5. Iterate over every pixel and divide input image's pixels to get output pixels.

```
    for row in range(rows):
        for col in range(cols):
            if img2[row, col] != 0:
                tmp = math.ceil(img1[row, col] / img2[row, col])
            else:  # division by zero wiil generate a huge number, here 255 is
    that huge
                tmp = 255
            output[row, col] = max(0, min(tmp, 255))
```

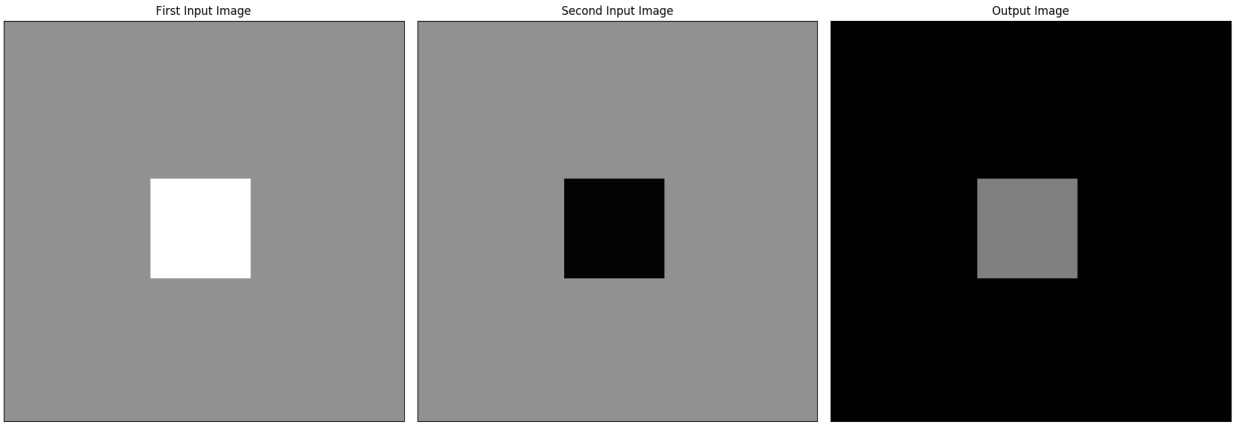
6. Plot two input images and result image's using *matplotlib*.

```
    titles = ['First Input Image', 'Second Input Image', 'Output Image']
    imgarr = [img1, img2, output]
    for i in range(3):
        plt.subplot(1, 3, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

4.3 Input and Output

4.3.1 Image Output

Figure 4.1: Division of two images.



4.3.2 Text Output

```
[INFO] First image has been read successfully...
[INFO] Second image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 5

Brightness Increasing and Calculation

5.1 Objective

Brightness is one of the most significant pixel characteristics. It is involved in many image-editing algorithms such as contrast or shadow/highlight.

- Brightness calculation
- Increase brightness of an image

Brightness calculation formula is:

$$B = \frac{\sum_{M,\ N} I(m,n)}{M \times N} \tag{5.1}$$

In this equation, M and N are the number of rows and columns in the input images. To increase/decrease brightness level of the image, simply add/subtract a constant positive value to each and every image pixel.

$$Image_{new}(m,n) = Image_{old}(m,n) \pm BrightnessConstant \tag{5.2}$$

5.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/lennaGray.png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create a blank image and set a brightness constant.

```
    rows, cols = img.shape
    output = np.zeros((rows, cols), dtype='float')
    img = img.astype(float)  # To get rid of from overflow
    brightnessConstant = 70
```

4. Iterate over all pixels and decrease intensity of each pixel and bond the pixels in range $[0, 255]$.

```
    for row in range(rows):
        for col in range(cols):
            tmp = img[row, col] - brightnessConstant
            output[row, col] = max(0, min(tmp, 255))
```

5. A more pythonic way to do the previous step is written here as comment. No need to iterate over pixels, python and numpy do the stuffs for us.

```
    # This is more pythonic way for changing  brightness
    # output = img - brightnessConstant  # No need to iterate over every pixel
    # lowerbound, upperbound = 0, 255
    # np.clip(output, lowerbound, upperbound, out=output)  # Numpy do the
    bounding
```

6. Print original calculated brightness and changed brightness.

```
    print('Original Brightness: ', np.mean(img))
    print('Changed Brightness: ', np.mean(output))
```

7. Plot main input image and brightness changed image.

```
    titles = ['Original Brightness', 'Changed Brightness']
    imgarr = [img, output]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin = 0, vmax = 255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

5.3 Input and Output

5.3.1 Image Output

Figure 5.1: Change in brightness on Lenna's image.

5.3.2 Text Output

```
[INFO] Image has been read successfully...
Original Brightness:  123.54518127441406
Changed Brightness:  57.06407165527344
[INFO] All operations finished successfully...
```

EXPERIMENT 6

Image Contrast Changing and Calculation

6.1 Objective

Contrast is the difference in luminance or color that makes an object (or its representation in an image or display) distinguishable. Contrast can be simply explained as the difference between maximum and minimum pixel intensity in an image.

Objective of this experiment is to:

- Increase the contrast of an image.
- Calculate contrast of an image.

Contrast calculation formula:

$$Contrast = Maximum\ pixel\ intensity - Minimum\ pixel\ intensity \tag{6.1}$$

6.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/misc/7.1.01.tiff'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create a blank image and set a contrast constant.

```
    rows, cols = img.shape
    output = np.zeros((rows, cols), dtype='float')
    img = img.astype(float)  # To get rid of from overflow
    contrastConstant = 1.7
```

4. Iterate over all pixels and multiply the constant with each pixel and bond the pixels in range $[0, 255]$.

```
    for row in range(rows):
        for col in range(cols):
            tmp = img[row, col] * contrastConstant
            output[row, col] = max(0, min(tmp, 255))
```

5. A more pythonic way to do the previous step is written here as comment. No need to iterate over pixels, python and numpy do the stuffs for us.

```
    # This is more pythonic way for changing  brightness
    # output = img * contrastConstant  # No need to iterate over every pixel
    # lowerbound, upperbound = 0, 255
    # np.clip(output, lowerbound, upperbound, out=output)  # Numpy do the
    bounding
```

6. Print original calculated contrast and changed contrast.

```
    print('Original Contrast: ', np.amax(img) - np.amin(img))
    print('Increased Contrast: ', np.amax(output) - np.amin(output))
```

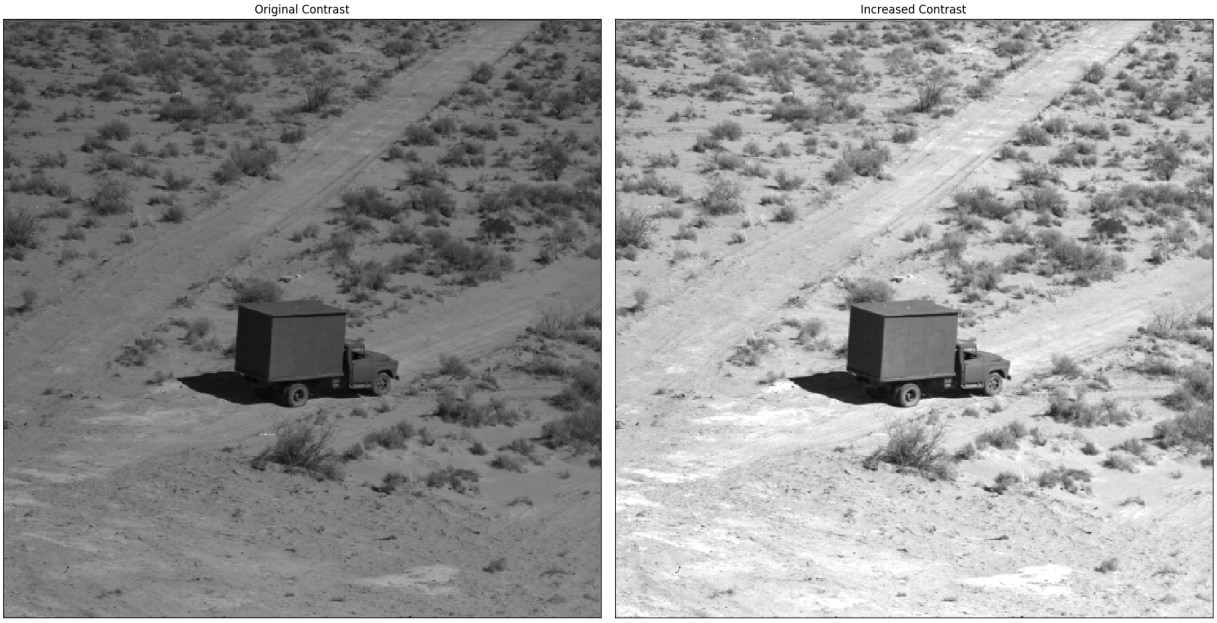
7. Plot main input image and contrast changed image.

```
    titles = ['Original Contrast', 'Increased Contrast']
    imgarr = [img, output]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

6.3 Input and Output

6.3.1 Image Output

Figure 6.1: Change in contrast on a desert image.



6.3.2 Text Output

```
[INFO] Image has been read successfully...
Original Contrast:  247.0
Increased Contrast:  249.9
[INFO] All operations finished successfully...
```

EXPERIMENT 7

Reading and Writing of Color Image

7.1 Objective

- Familiarize with IDE, environment.
- Read, write operations of an image.
- Basic image manipulation.
- Iterate over image pixels.
- Access image properties.
- Access pixel values and modify them.

Almost all the operations in this section is mainly related to `Numpy` rather than `OpenCV`. A good knowledge of `Numpy` is required to write better optimized code with `OpenCV`.

7.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
import os
```

2. Start main function and read image.

```
if __name__ == '__main__':

    path = '../../img/misc/house.tiff'

    if os.path.isfile(path):
        img = cv2.imread(path)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Show the image using OpenCV `imshow` method and write to disk a new image using `imwrite` method.

```
    cv2.imshow('Original', img)
    cv2.imwrite('NewHouseImage.png', img)
```

4. Access an arbitrary pixel and print it.

```
    arbitraryPixel = img[2, 3]
    print('An arbitrary Pixel: ', arbitraryPixel)
```

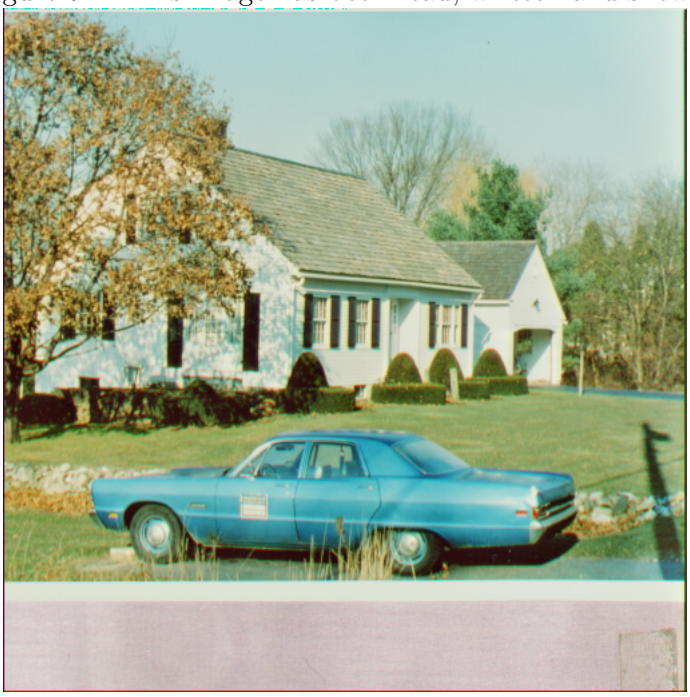
5. Get image dimension, height, width, channels and print them and exit window.

```
    dimensions = img.shape
    height = img.shape[0]
    width = img.shape[1]
    channels = img.shape[2]

    print('Image Dimension: ', dimensions)
    print('Image Height: ', height)
    print('Image Width: ', width)
    print('Total Number of pixels :', img.size)

    k = cv2.waitKey(0)
    cv2.destroyAllWindows()

    print("[INFO] All operations finished successfully...")
```

7.3 Input and Output

7.3.1 Image Output

Figure 7.1: This image has been read, written and shown.



7.3.2 Text Output

```
[INFO] Image has been read successfully...
An arbitrary Pixel:  [211 222 218]
Image Dimension:  (512, 512, 3)
Image Height:  512
Image Width:  512
Total Number of pixels : 786432
[INFO] All operations finished successfully...
```

EXPERIMENT 8

Grayscale and Binary Conversion

8.1 Objective

An RGB image can be viewed as three different images(a red scale image, a green scale image and a blue scale image) stacked on top of each other, and when fed into the red, green and blue inputs of a color monitor, it produces a color image on the screen.

An RGB image is sometimes referred to as a true color image as the precision with which a real-life image can be replicated has led to the nickname *true color image*.

8.1.1 Grayscale Conversion

There are two methods to convert an color image into a grayscale image. Both has their own merits and demerits. The methods are:

- Average method
- Weighted method or luminosity method

Average method

Average method is the most simple one. You just have to take the average of three colors. Since its an RGB image, so it means that you have add r with g with b and then divide it by 3 to get your desired grayscale image.

Its done in this way.

$$Grayscale = (R + G + B/3) \tag{8.1}$$

Weighted method or luminosity method

Since red color has more wavelength of all the three colors, and green is the color that has not only less wavelength then red color but also green is the color that gives more soothing effect to the eyes.

It means that we have to decrease the contribution of red color, and increase the contribution of the green color, and put blue color contribution in between these two.

So the new equation that form is:

$$New\ grayscale\ image = ((0.299 * R) + (0.587 * G) + (0.144 * B)). \tag{8.2}$$

According to this equation, Red has contribute 30%, Green has contributed 59% which is greater in all three colors and Blue has contributed 11%.

8.1.2 Binary Conversion

To convert RGB image to Binary image, we have to the RGB image into Grayscale image first. Then we set threshold value. Then we use this equation :

$$y = \begin{cases} 1, & \text{if } y \geq threshhold \\ 0, & \text{otherwise} \end{cases} \tag{8.3}$$

8.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import math
import numpy as np
import matplotlib.pyplot as plt
import os
```

2. Start main code section and read image.

```
if __name__ == '__main__':

    path = '../../img/misc/4.1.08.tiff'

    if os.path.isfile(path):
        img = cv2.imread(path)
        img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create two grayscale and a binary dump image of that size. Set thresh value.

```
    rows, cols, ch = img.shape
    img = img.astype('float')
    imgGraygen = np.zeros((rows, cols), dtype='uint8')
    imgGrayweighted = np.zeros((rows, cols), dtype='uint8')
    imgBinary = np.zeros((rows, cols), dtype='bool_')
    thresh = 170
```

4. Iterate over pixels and calculate average, weighted average and get binary intensity based on range.

```
    for row in range(rows):
        for col in range(cols):
            pixel = img[row, col]
            avggen = int(math.ceil(pixel[0] + pixel[1] + pixel[2]) / 3)
            avgweighted = int(
                math.ceil(pixel[0] * 0.299 + pixel[1] * 0.587 +
                          pixel[2] * 0.144))
            imgGraygen[row, col] = max(0, min(avggen, 255))
            imgGrayweighted[row, col] = max(0, min(avgweighted, 255))
            imgBinary[row, col] = False if avgweighted > thresh else True
```

5. Convert to binary image using OpenCV library, given as comment.

```
    # =======================================================
    # IMPLEMENTATION USING OPENCV LIBRARY
    # =======================================================
    # (thresh, imgBinary) = cv2.threshold(imgGrayweighted, 128, 255, cv2.
    THRESH_BINARY | cv2.THRESH_OTSU)
```

6. Show main image, grayscale images and binary image using `matplotlib.pyplot`.

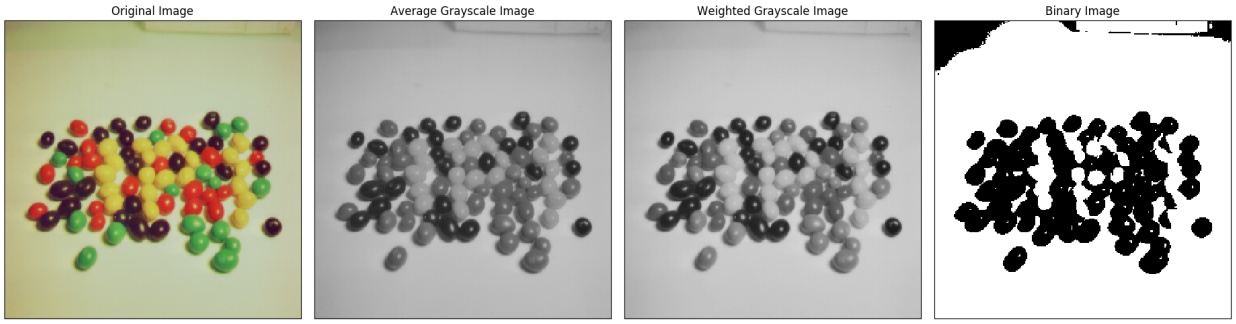
```
    titles = [
        'Original Image', 'Average Grayscale Image', 'Weighted Grayscale Image',
        'Binary Image'
    ]
    imgarr = [img, imgGraygen, imgGrayweighted, imgBinary]

    plt.subplot(1, 4, 1)
```

```
    plt.imshow(np.uint8(imgarr[0]))
    plt.title(titles[0])
    plt.xticks([])
    plt.yticks([])

    plt.subplot(1, 4, 2)
    plt.imshow(imgarr[1], cmap='gray', vmin=0, vmax=255)
    plt.title(titles[1])
    plt.xticks([])
    plt.yticks([])

    plt.subplot(1, 4, 3)
    plt.imshow(imgarr[2], cmap='gray', vmin=0, vmax=255)
    plt.title(titles[2])
    plt.xticks([])
    plt.yticks([])

    plt.subplot(1, 4, 4)
    plt.imshow(imgarr[3], cmap='binary')
    plt.title(titles[3])
    plt.xticks([])
    plt.yticks([])
    plt.show()

    print("[INFO] All operations finished successfully...")
```

8.3 Input and Output

8.3.1 Image Output

Figure 8.1: RGB to grayscale and binary conversion.



8.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 9

Negative Transformation

9.1 Objective

Black and white image inversion refers to an image processing technique where light areas are mapped to dark, and dark areas are mapped to light. In other words, after image inversion black becomes white and white becomes black. An inverted black and white image can be thought of as a digital negative of the original image.

This is particularly useful for enhancing white or gray details embedded in dark regions of an image.

$$I_{inverted}(x, y) = 255 - I(x, y) \tag{9.1}$$

9.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/pollen-image-plants.jpg'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create a blank image identical in size with input image.

```
    rows, cols = img.shape
    output = np.zeros((rows, cols), dtype='uint8')
```

4. Iterate over every pixel and apply the negation equation to determine output pixel.

```
    for row in range(rows):
        for col in range(cols):
            output[row, col] = 255 - img[row, col]
```

5. Plot input image and result output image using *matplotlib*.

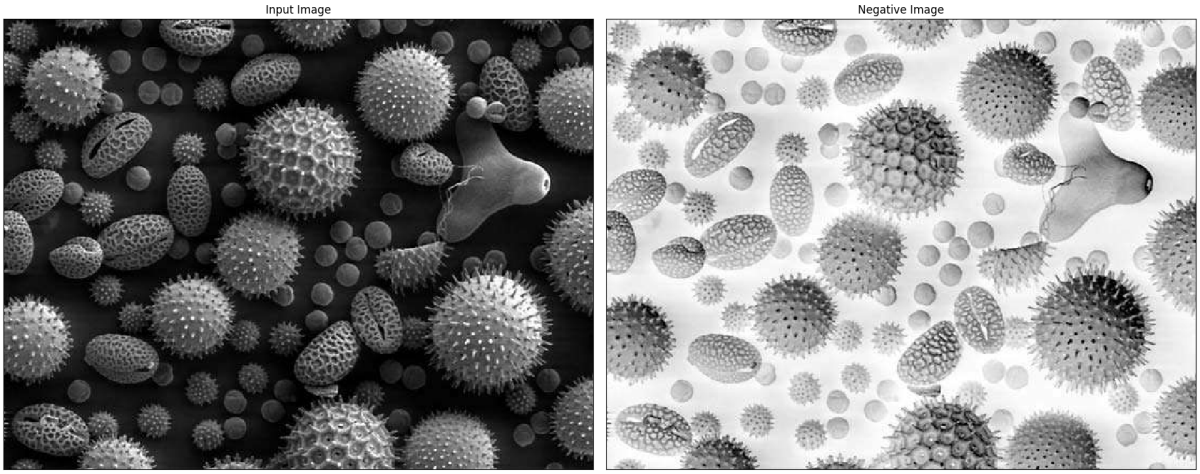
```
    titles = ['Input Image', 'Negative Image']
    imgarr = [img, output]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])
```

```
9
10      plt.show()
11
12      print("[INFO] All operations finished successfully...")
```

9.3 Input and Output

9.3.1 Image Output

Figure 9.1: Negative Transformation over pollen image to enhance details.



9.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 10

Alpha Blending

10.1 Objective

Alpha blending is the process of overlaying a **foreground** image with transparency over a **background** image. The transparency is often the fourth channel of an image (e.g. in a transparent PNG), but it can also be a separate image. This transparency mask is often called the **alpha mask** or the **alpha matte**.

The math behind alpha blending is straight forward. At **every pixel** of the image, we need to combine the foreground image color (F) and the background image color (B) using the alpha mask (α).

$$I = \alpha F + (1 - \alpha)B \tag{10.1}$$

From the equation above, you can make the following observations.

- When $\alpha = 0$, the output pixel color is the background.
- When $\alpha = 1$, the output pixel color is simply the foreground.
- When $0 < \alpha < 1$ the output pixel color is a mix of the background and the foreground. For realistic blending, the boundary of the alpha mask usually has pixels that are between 0 and 1.

10.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main code section and read images.

```
if __name__ == '__main__':
    path1 = '../../img/chair-1.png'
    path2 = '../../img/dog-main-1.png'
    path3 = '../../img/dog-alpha-1.png'

    if os.path.isfile(path1):
        background = cv2.imread(path1, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Background image has been read sucessfully...")
    else:
        print("[INFO] The file '" + path1 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path2):
        foreground = cv2.imread(path2, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Foreground image has been read sucessfully...")
    else:
        print("[INFO] The file '" + path2 + "' does not exist.")
        sys.exit(0)

```

```
    if os.path.isfile(path3):
        alphaMask = cv2.imread(path3, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Alpha Mask image has been read sucessfully...")
    else:
        print("[INFO] The file '" + path3 + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size.

```
    if foreground.shape != background.shape or background.shape != alphaMask.
    shape:
        print(
            "[INFO] Image sizes are not identical, resizing possible but not
    recommended."
        )
        print("[INFO] Aborting program...")
        sys.exit(0)
```

4. Make a copy of alpha mask image to later use, main one will be normalized to keep intensity between 0 and 1. And create a blank output image.

```
    alphaCpy = alphaMask
    rows, cols = background.shape
    output = np.zeros((rows, cols), dtype='float')
```

5. Convert images form *uint*8 to *float*. And normalize the alpha mask to keep intensity between 0 and 1.

```
    foreground = foreground.astype(float)
    background = background.astype(float)
    alphaMask = alphaMask.astype(float) / 255
```

6. Iterate over every pixel and create new pixels based on the equation.

```
    print("[INFO] Blending on progress...")
    for row in range(rows):
        for col in range(cols):
            tmp = alphaMask[row, col] * foreground[row, col] + \
                    (1 - alphaMask[row, col]) * background[row, col]
            output[row, col] = max(0, min(tmp, 255))
    print("[INFO] Done...")
```

7. Plot background image, foreground image, alpha mask image and the output result image.

```
    titles = [
        'Background Image', 'Foreground Image', 'Alpha Mask', 'Output Image'
    ]
    imgarr = [background, foreground, alphaCpy, output]
    for i in range(4):
        plt.subplot(2, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

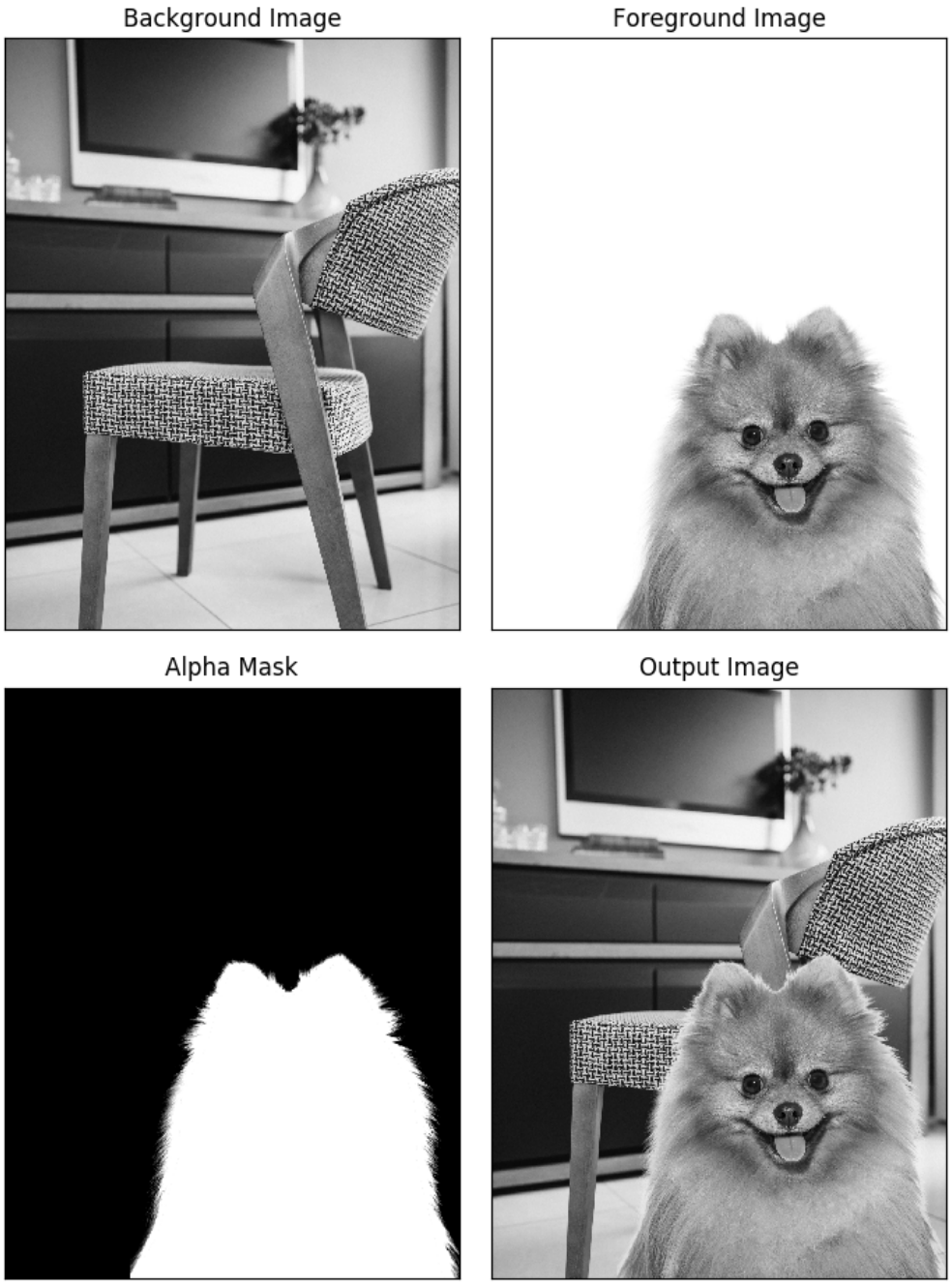
10.3 Input and Output

10.3.1 Text Output

```
[INFO] Background image has been read sucessfully...
[INFO] Foreground image has been read sucessfully...
[INFO] Alpha Mask image has been read sucessfully...
[INFO] Blending on progress...
[INFO] Done...
[INFO] All operations finished successfully...
```

10.3.2 Image Output

Figure 10.1: Use of alpha mask to overlap an foreground image over another background image.



EXPERIMENT 11

Log Transformation

11.1 Objective

The log transformations can be defined by this formula

$$s = c\ log(r + 1) \tag{11.1}$$

Where s and r are the pixel values of the output and the input image and c is a constant. The value 1 is added to each of the pixel value of the input image because if there is a pixel intensity of 0 in the image, then $log(0)$ is equal to infinity. So 1 is added, to make the minimum value at least 1.

During log transformation, the dark pixels in an image are expanded as compare to the higher pixel values. The higher pixel values are kind of compressed in log transformation. This result in following image enhancement.

The value of c in the log transform adjust the kind of enhancement you are looking for.

11.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/misc/7.2.01.tiff'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create a blank image identical in size with input image.

```
    rows, cols = img.shape
    output = np.zeros((rows, cols), dtype='uint8')
```

4. Iterate over every pixel and apply the negation equation to determine output pixel.

```
    c = 25
    for row in range(rows):
        for col in range(cols):
            output[row, col] = c * np.log(img[row, col] + 1)
```

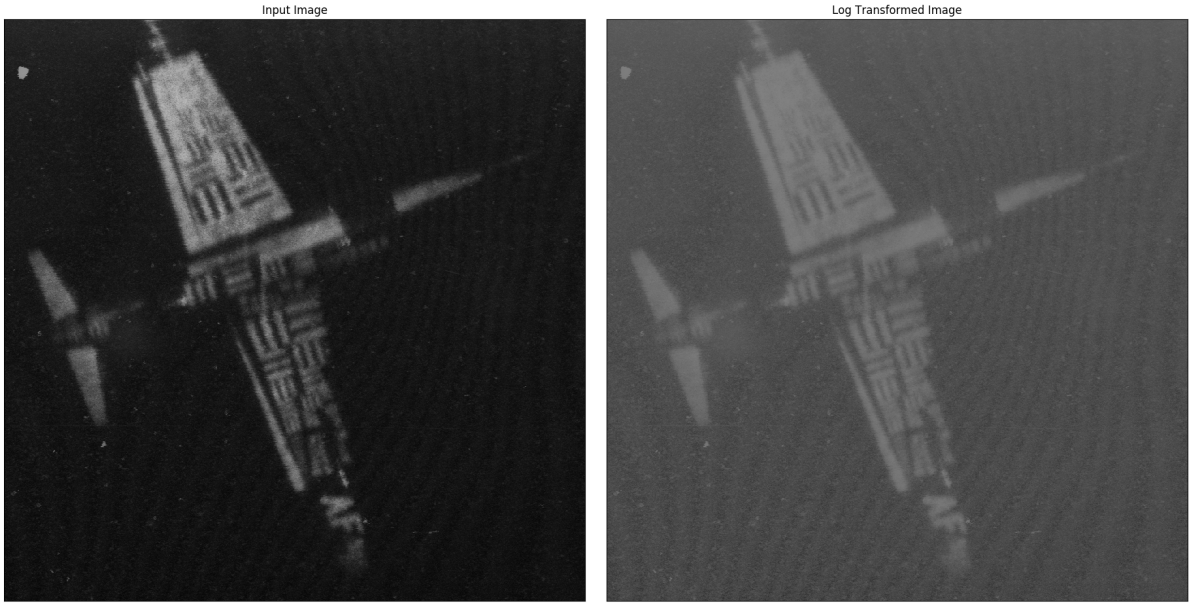
5. Plot input image and result output image using *matplotlib*.

```
    titles = ['Input Image', 'Log Transformed Image']
    imgarr = [img, output]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

11.3 Input and Output

11.3.1 Image Output

Figure 11.1: Log transformation over an aircraft image.



11.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 12

Intensity Level Slicing

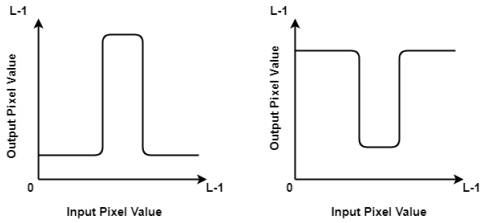
12.1 Objective

Intensity level slicing means highlighting a specific range of intensities in an image. In other words, we segment certain gray level regions from the rest of the image.

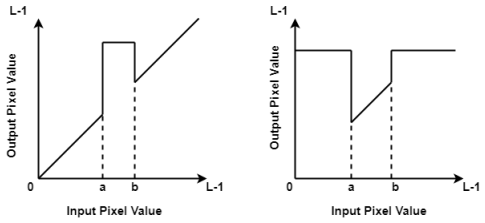
Suppose in an image, your region of interest always take value between say 80 to 150. So, intensity level slicing highlights this range and now instead of looking at the whole image, one can now focus on the highlighted region of interest.

Since, one can think of it as piecewise linear transformation function so this can be implemented in several ways. Here, we will discuss the two basic type of slicing that is more often used.

1. In the first type, we display the desired range of intensities in white and suppress all other intensities to black or vice versa. This results in a binary image. The transformation function for both the cases is shown below.



2. In the second type, we brighten or darken the desired range of intensities(a to b as shown below) and leave other intensities unchanged or vice versa. The transformation function for both the cases, first where the desired range is changed and second where it is unchanged, is shown below.



12.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
1 import cv2
2 import numpy as np
3 from matplotlib import pyplot as plt
4 import os
5 import sys
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/cameraman.tif'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get input image size and create two blank image identical in size with input image.

```
    rows, cols = img.shape
    outputWithBack = np.zeros((rows, cols), dtype='uint8')
    outputWithoutBack = np.zeros((rows, cols), dtype='uint8')
```

4. Iterate over every pixel and slice intensity.

```
    min_range = 5
    max_range = 55
    for row in range(rows):
        for col in range(cols):
            if img[row, col] > min_range and img[row, col] < max_range:
                outputWithBack[row, col] = 255
                outputWithoutBack[row, col] = 255
            else:
                outputWithBack[row, col] = img[row, col]
                outputWithoutBack[row, col] = 0
```

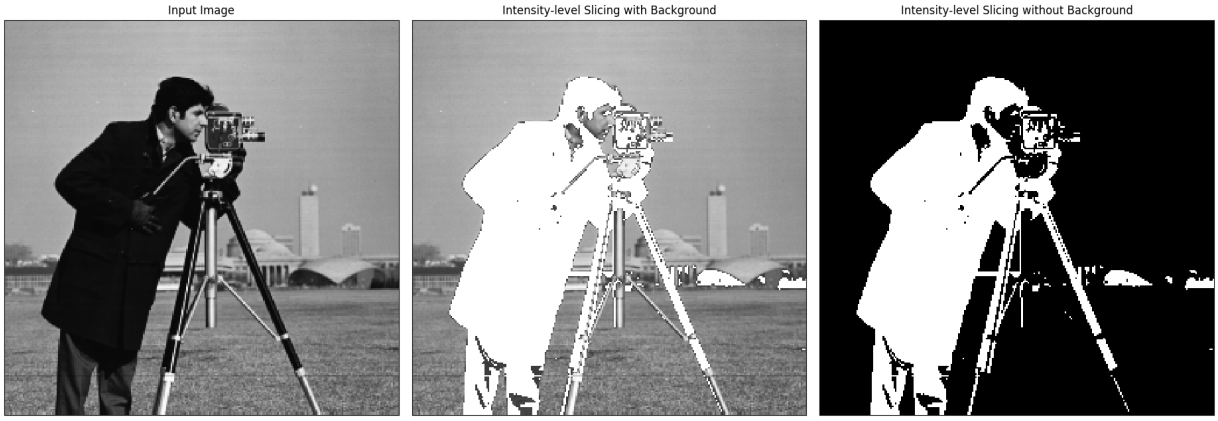
5. Plot input image and resulted with background and without background images using *matplotlib*.

```
    titles = [
        'Input Image', 'Intensity-level Slicing with Background',
        'Intensity-level Slicing without Background'
    ]
    imgarr = [img, outputWithBack, outputWithoutBack]
    for i in range(3):
        plt.subplot(1, 3, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

12.3 Input and Output

12.3.1 Image Output

Figure 12.1: Slice intensity of a cameraman image.



12.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 13

Bit Plane Slicing

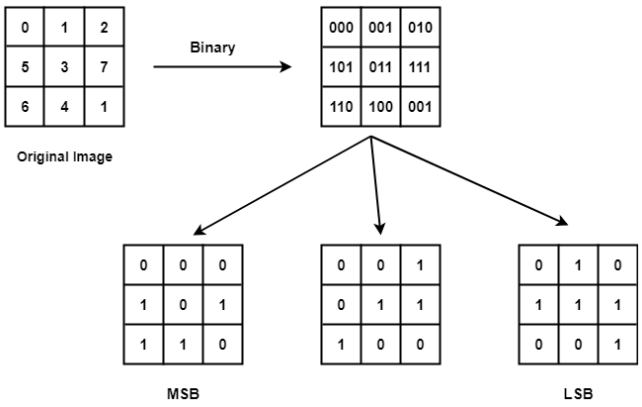
13.1 Objective

For an 8-bit image, a pixel value of 0 is represented as 00000000 in binary form and 255 is encoded as 11111111. Here, the leftmost bit is known as the most significant bit (MSB) as it contributes the maximum. e.g. if MSB of 11111111 is changed to 0 (i.e. 01111111), then the value changes from 255 to 127. Similarly, rightmost bit is known as Least significant bit (LSB).

In Bit-plane slicing, we divide the image into bit planes. This is done by first converting the pixel values in the binary form and then dividing it into bit planes.

For simplicity let's take a 3×3, 3-bit image as shown below. We know that the pixel values for 3-bit can take values between 0 to 7.

Figure 13.1: Bit Plane Slicing



13.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main code section and read image.

```
if __name__ == '__main__':
    path = '../../img/coins.jpg'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Create bit planes bitwise operation and append them in a list.

```
    out = []
    for k in range(0, 8):
        # create an image for each k bit plane
        plane = np.full((img.shape[0], img.shape[1]), 2**k, np.uint8)
        # execute bitwise and operation
        res = cv2.bitwise_and(plane, img)
        # multiply ones (bit plane sliced) with 255 just for better visualization
        x = res * 255
        # append to the output list
        out.append(x)
```

4. Arrange the list of images of planes to show perfectly.

```
    finalv = cv2.hconcat([out[3], out[2], out[1], out[0]])
    finalr = cv2.hconcat([out[7], out[6], out[5], out[4]])
    # Vertically concatenate
    final = cv2.vconcat([finalr, finalv])
```

5. Show the image planes.

```
    cv2.imshow('Bit Plane Slicing', final)
    cv2.waitKey(0)

    print("[INFO] All operations finished successfully...")
```

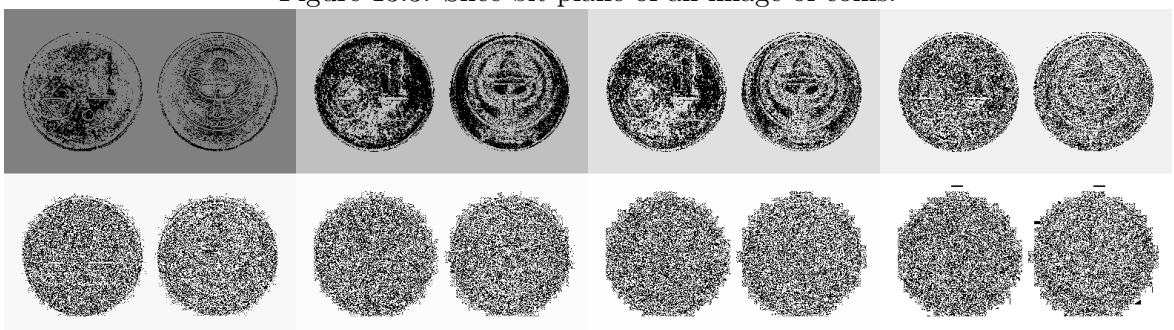
13.3 Input and Output

13.3.1 Image Input

Figure 13.2: Image of coins as input.

13.3.2 Image Output

Figure 13.3: Slice bit plane of an image of coins.



13.3.3 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations finished successfully...
```

EXPERIMENT 14

Average Filtering

14.1 Objective

The main objective of this experiment is to filter the images with average filtering. It helps in removing noise, blurring images etc.

Average filter:

- Replacing the value of every pixel in an image by the average of the intensity levels in the neighborhood defined by the filter mask.
- An important application of spatial averaging is to blur an image for image for the purpose of getting a gross representation of objects of interest , such that the intensity of smaller objects blends with the background and larger objects become “blob like” and easy to detect.
- The size of the mask establishes the relative size of the objects that will be blended with the background.

14.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
from skimage.exposure import rescale_intensity
import os
import sys
```

2. Define custom written convolution function which takes an image an kernel and apply the kernel over the image.

```
def convolve(image, kernel):
    (iH, iW) = image.shape[:2]
    (kH, kW) = kernel.shape[:2]

    pad = (kW - 1) // 2
    image = cv2.copyMakeBorder(image, pad, pad, pad, pad, cv2.BORDER_REPLICATE)
    output = np.zeros((iH, iW), dtype="float32")

    for y in np.arange(pad, iH + pad):
        for x in np.arange(pad, iW + pad):
            roi = image[y - pad:y + pad + 1, x - pad:x + pad + 1]
            k = (roi * kernel).sum()
            output[y - pad, x - pad] = k

    output = rescale_intensity(output, in_range=(0, 255))
    output = (output * 255).astype("uint8")

    return output
```

3. Start the driver program and read input image.

```
if __name__ == '__main__':
    path = '../../img/lennaNoisy.png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

4. Create average kernel and send it to `convolve` function with input image.

```
    averageKernel = np.ones((3, 3), np.float32) / 9

    print("[INFO] Applying average kernel...")
    convoleOutput = convolve(img, averageKernel)
```

5. Plot input image and result image using `matplotlib`.

```
    titles = ['Input Image', 'After Applying Average Filter']
    imgarr = [img, convoleOutput]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

14.3 Input and Output

14.3.1 Image Output

Figure 14.1: Apply of average filtering on Lenna's noisy image.

14.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Applying average kernel...
[INFO] All operations finished successfully...
```

EXPERIMENT 15

Gaussian Filter

15.1 Objective

A Gaussian filter is a linear filter. It's usually used to blur the image or to reduce noise. If you use two of them and subtract, you can use them for *unsharp masking* (edge detection). The Gaussian filter alone will blur edges and reduce contrast.

Gaussian filter:

- Gaussian filter is a filter whose impulse response is a Gaussian function.
- Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time.

15.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
from skimage.exposure import rescale_intensity
import os
import sys
```

2. Define custom written convolution function which takes an image an kernel and apply the kernel over the image.

```
def convolve(image, kernel):
    (iH, iW) = image.shape[:2]
    (kH, kW) = kernel.shape[:2]

    pad = (kW - 1) // 2
    image = cv2.copyMakeBorder(image, pad, pad, pad, pad, cv2.BORDER_REPLICATE)
    output = np.zeros((iH, iW), dtype="float32")

    for y in np.arange(pad, iH + pad):
        for x in np.arange(pad, iW + pad):
            roi = image[y - pad:y + pad + 1, x - pad:x + pad + 1]
            k = (roi * kernel).sum()
            output[y - pad, x - pad] = k

    output = rescale_intensity(output, in_range=(0, 255))
    output = (output * 255).astype("uint8")

    return output
```

3. Start the driver program and read input image.

```
if __name__ == '__main__':
    path = '../../img/lennaGaussianNoisy.png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
```

```
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

4. Create a Gaussian kernel and send it to `convolve()` function with input image.

```
    gaussianKernel = np.array(
        ([1, 4, 6, 4, 1], [4, 16, 24, 16, 4], [6, 24, 36, 24, 6],
         [4, 16, 24, 16, 4], [1, 4, 6, 4, 1]), np.float32) / 256

    print("[INFO] Applying Gaussian kernel...")
    convoleOutput = convolve(img, gaussianKernel)
```

5. Plot input image and result image using `matplotlib`.

```
    titles = ['Input Image', 'After Applying Gaussian Filter']
    imgarr = [img, convoleOutput]
    for i in range(2):
        plt.subplot(1, 2, i + 1)
        plt.imshow(imgarr[i], cmap='gray', vmin=0, vmax=255)
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

15.3 Input and Output

15.3.1 Image Output

Figure 15.1: Apply of Gaussian filtering on Lenna's noisy image.

15.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Applying Gaussian kernel...
[INFO] All operations finished successfully...
```

EXPERIMENT 16

Minimum, Maximum and Median Filter

16.1 Objective

Minimum, Maximum and Median filter are used to reduce noise on an image. Median filtering is excellent at reducing salt and pepper noise. Minimum filter can be used to reduce white spot form image and maximum filter can be used to reduce black spot from an image.

- Considering the minimum value of a region of interest is called minimum filtering.
- Considering the maximum value of a region of interest is called maximum filtering.
- Considering the Median value of a region of interest is called median filtering.

16.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
import matplotlib.pyplot as plt
from skimage.exposure import rescale_intensity
import os
import sys
```

2. Start main code section and read images.

```
if __name__ == '__main__':
    path1 = '../../img/lennaSaltPepperNoisy.png'
    path2 = '../../img/bone-with-white-spot.jpg'
    path3 = '../../img/bone-with-black-spot.jpg'

    if os.path.isfile(path1):
        img1 = cv2.imread(path1, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path1 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path2):
        img2 = cv2.imread(path2, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path2 + "' does not exist.")
        sys.exit(0)

    if os.path.isfile(path3):
        img3 = cv2.imread(path3, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path3 + "' does not exist.")
        sys.exit(0)
```

3. Resize the three images of same size to make the iteration over the images easy.

```
    # Making each image of same size
    img1 = cv2.resize(img1, (512, 512))
    img2 = cv2.resize(img2, (512, 512))
    img3 = cv2.resize(img3, (512, 512))
```

4. Create a clone of each image, the clones will be used to plot the images later. As the main images will be padded, and the shape will be changed.

```
    # Keeping a clone of each image without padding, to use later
    img1Cpy = img1.copy()
    img2Cpy = img2.copy()
    img3Cpy = img3.copy()
```

5. Get image size and declare the filter size.

```
    (iH, iW) = img1.shape[:2]
    kW = 3 # Filter size
    pad = (kW - 1) // 2
```

6. Create padding around the images using `cv2.copyMakeBorder`.

```
    img1 = cv2.copyMakeBorder(img1, pad, pad, pad, pad, cv2.BORDER_REPLICATE)
    img2 = cv2.copyMakeBorder(img2, pad, pad, pad, pad, cv2.BORDER_REPLICATE)
    img3 = cv2.copyMakeBorder(img3, pad, pad, pad, pad, cv2.BORDER_REPLICATE)
```

7. Create blank images to carry output.

```
    outputMedian = np.zeros((iH, iW), dtype="float32")
    outputMin = np.zeros((iH, iW), dtype="float32")
    outputMax = np.zeros((iH, iW), dtype="float32")
```

8. Iterate over images, as all the images are of same size, we are iterating over same range and working with all the images.

```
    print("[INFO] Applying various filters...")
    print("[INFO] This may take a while...")
    for y in np.arange(pad, iH + pad):
            for x in np.arange(pad, iW + pad):
                    roiMedian = img1[y - pad:y + pad + 1, x - pad:x + pad + 1]
                    roiMin = img2[y - pad:y + pad + 1, x - pad:x + pad + 1]
                    roiMax = img3[y - pad:y + pad + 1, x - pad:x + pad + 1]

                    outputMedian[y - pad, x - pad] = np.median(roiMedian)
                    outputMin[y - pad, x - pad] = np.amin(roiMin)
                    outputMax[y - pad, x - pad] = np.amax(roiMax)
    print("[INFO] Filter applying completed...")
```

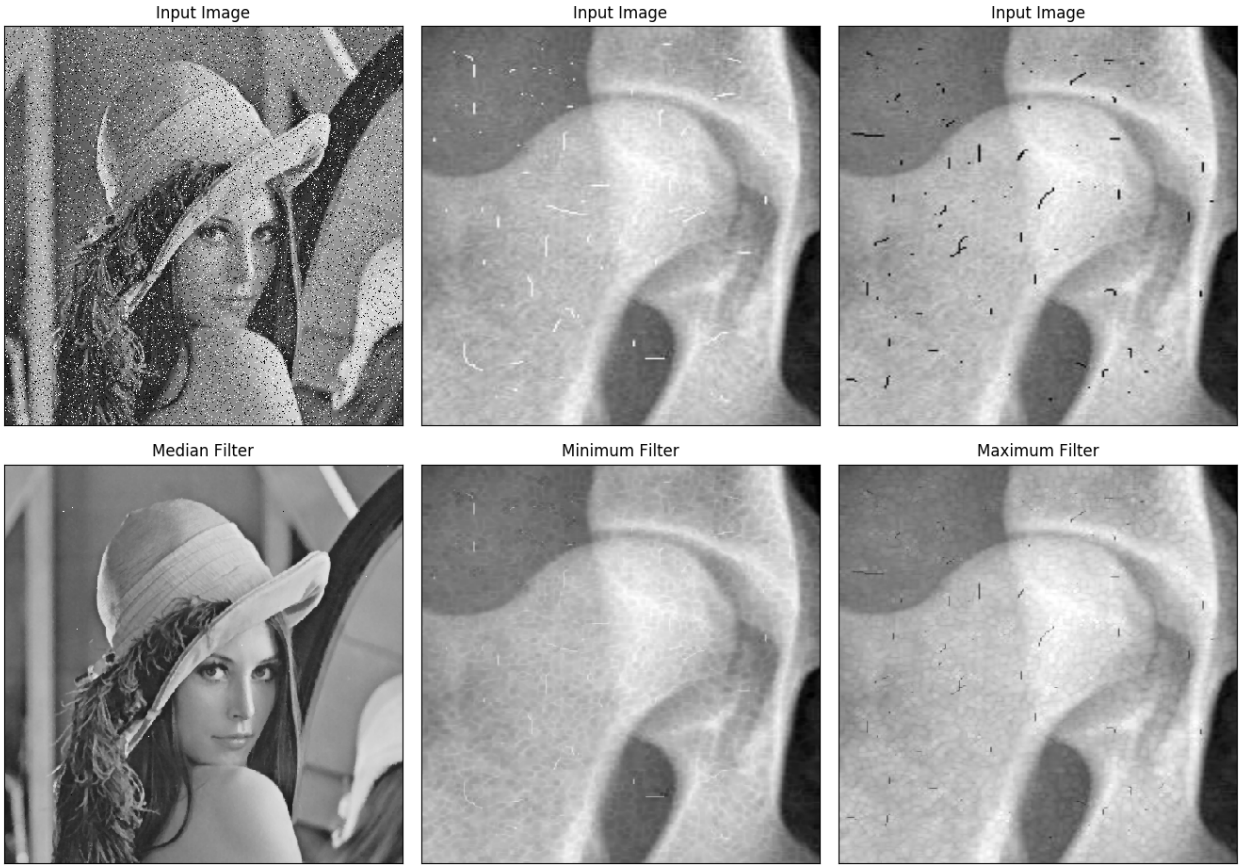
9. Plot all the images, input image plotted on upper side and output image plotted on bottom side.

```
    titles = ['Input Image', 'Input Image', 'Input Image', 'Median Filter', '
    Minimum Filter', 'Maximum Filter']
    imgarr = [img1Cpy, img2Cpy, img3Cpy, outputMedian, outputMin, outputMax]

    for i in range(6):
        plt.subplot(2, 3,i+1)
        plt.imshow(imgarr[i], cmap = 'gray', vmin = 0, vmax = 255)
        plt.title(titles[i])
        plt.xticks ([])
        plt.yticks ([])

    plt.show ()

    print("[INFO] All operations completed successfully...")
```

16.3 Input and Output

16.3.1 Image Output

Figure 16.1: Median, minimum and maximum filtering (Input image at upside, output at downside).



16.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Image has been read successfully...
[INFO] Image has been read successfully...
[INFO] Applying various filters...
[INFO] This may take a while...
[INFO] Filter applying completed...
[INFO] All operations completed successfully...
```

EXPERIMENT 17

Calculate MSE, SNR and PSNR

17.1 Objective

The main objective of this experiment is to calculate MSE, SNR, PSNR of an image. The mean-square error (MSE) and the peak signal-to-noise ratio (PSNR) are used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error.

To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,\ N} [I_1(m,n) - I_2(m,n)]^2}{M \times N} \tag{17.1}$$

In the previous equation, M and N are the number of rows and columns in the input images. Then the block computes the PSNR using the following equation:

$$PSNR = 10 \times \log_{10}\left(\frac{R^2}{MSE}\right) \tag{17.2}$$

In the previous equation, R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255, etc.

Signal-to-noise ratio (SNR) or peak signal-to-noise ratio (PSNR) are directly related quantities, in an inverse logarithmic scale (the higher the better), with respect to the data energy (SNR):

$$SNR = 10 \times \log_{10}\left(\frac{\frac{1}{M \times N}\sum_{M,\ N} I(m,n)^2}{MSE}\right) \tag{17.3}$$

17.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import random
import math
import numpy as np
import matplotlib.pyplot as plt
from skimage.util import random_noise
import os
import sys
```

2. Define custom written function to calculate MSE, PSNR and SNR according to the equations.

```
def fun(img):
    height, width = img.shape
    MSE_gauss = 0
    MSE_median = 0
    r = 0
```

```
    R = 0

    for i in range(0, height):
        for j in range(0, width):
            p = img[i, j]
            R = max(R, p)
            # r = r + p
            r = r + p * p
            p1 = randomNoisy[i, j]
            p2 = saltPepperNoisy[i, j]
            p3 = gausianBlur[i, j]
            p4 = medianBlur[i, j]

            MSE_gauss = MSE_gauss + (p1 - p3) * (p1 - p3)
            MSE_median = MSE_median + (p2 - p4) * (p2 - p4)

    MSE_gauss = MSE_gauss / (height * width)
    MSE_median = MSE_median / (height * width)

    PSNR_gauss = 10 * math.log10((R * R) / MSE_gauss)
    PSNR_median = 10 * math.log10((R * R) / MSE_median)

    r = r // (height * width)

    # SNR_gauss = 10 * math.log10( (r*r) / MSE_gauss )
    # SNR_median = 10 * math.log10( (r*r) / MSE_median )
    SNR_gauss = 10 * math.log10(r / MSE_gauss)
    SNR_median = 10 * math.log10(r / MSE_median)
    print('Gaussian MSE: ', MSE_gauss, '\tMedian MSE: ', MSE_median)
    print('Gaussian SNR: ', SNR_gauss, '\tMedian SNR: ', SNR_median)
    print('Gaussian PSNR: ', PSNR_gauss, '\tMedian PSNR: ', PSNR_median)
```

3. Define a function for applying salt and pepper noise.

```
def saltPepperNoise(image, prob):
    # Thanks to ppk28
    # https://stackoverflow.com/a/27342545/7829174
    '''
    Add salt and pepper noise to image
    prob: Probability of the noise
    '''
    output = np.zeros(image.shape, np.uint8)  #uint8 - unsigned 8 bit integer

    thres = 1 - prob
    for i in range(image.shape[0]):
        for j in range(image.shape[1]):
            rdn = random.random(
            )  # generates a random number between (0.0 to 1.0)
            if rdn < prob:
                output[i][j] = 0
            elif rdn > thres:
                output[i][j] = 255
            else:
                output[i][j] = image[i][j]
    return output
```

4. Start driver program and read image.

```
if __name__ == '__main__':

    path = '../../img/lennaGray.png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
```

```
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

5. Apply various noise and kernels and make different images.

```
    randomNoisy = random_noise(img, mode='gaussian', seed=None, clip=True)
    saltPepperNoisy = saltPepperNoise(img, 0.05)
    gausianBlur = cv2.GaussianBlur(randomNoisy, (5, 5), 0)
    medianBlur = cv2.medianBlur(saltPepperNoisy, 5)
```

6. Convert images to `float`.

```
    img = img.astype(float)
    randomNoisy = randomNoisy.astype(float)
    saltPepperNoisy = saltPepperNoisy.astype(float)
    gausianBlur = gausianBlur.astype(float)
    medianBlur = medianBlur.astype(float)
```

7. Call `fun()` function to calculate MSE, PSNR and SNR and print.

```
    fun(img)
```

8. Plot various filter applied created images using `matplotlib`.

```
    imgArr = [randomNoisy, saltPepperNoisy, gausianBlur, medianBlur]
    title = [
        'Gaussian Noisy', 'Salt Pepper Noisy', 'Gaussian Blur', 'Median Blur'
    ]

    for i in range(len(imgArr)):
        plt.subplot(2, 2, i + 1)
        plt.imshow(imgArr[i], cmap='gray')
        plt.title(title[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations finished successfully...")
```

17.3 Input and Output

17.3.1 Image Output

Figure 17.1: Applying MSE, PSNR and SNR on various noisy and restored images.

17.3.2 Text Output

```
[INFO] Image has been read successfully...
Gaussian MSE:  0.00831215811499492  Median MSE:  1860.567268371582
Gaussian SNR:  63.24637556994362  Median SNR:  9.747059763742197
Gaussian PSNR:  68.58618372893046  Median PSNR:  15.08686792272904
[INFO] All operations finished successfully...
```

EXPERIMENT 18

Use of Weber's Ratio

18.1 Objective

Weber's law states that, as the ratio between the magnitudes of two stimuli increases, the more easily the difference between the two stimuli will be perceived.

Psycho-visual researchers early on found that the eye-brain response to a uniform step in intensity is not the same over the full range of human perception. In fact, they found that the just-noticeable percent is nearly constant over a wide range. This is known now as Weber's law. Writing I for the incident intensity (or luminance) and ΔI for the just-noticeable change, we have $\frac{\Delta I}{I} \approx constant$, with the constant value in the range $[0.01, 0.03]$, and this value holds constant for at least three decades in $logI$. We note that Weber's law says we are more sensitive to light intensity changes in low light levels than in strong ones.

The main objective of this experiment is to calculate Weber's ratio: $\frac{\Delta I_c}{I}$ and to detect on which limit of ratio we can separate the object from background.

- Calculate maximum Weber's ratio of an given image.
- Mark the pixels which have bigger brightness change than given Weber's constant.
- ΔI_c is the change in the object brightness required to just distinguish the object from the background

18.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import os
import numpy as np
import matplotlib.pyplot as plt
```

2. Start main code secton and read image.

```
if __name__ == '__main__':
    path = '../../img/weber-ratio.png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Get original image shape and duplicate the main image to show later with edges.

```
    rows, cols = img.shape
    output = cv2.cvtColor(img, cv2.COLOR_GRAY2RGB)
```

4. Set weber constant and iterate over every pixel and calculate weber ratio with their 8 neighbor pixels. If the ratio cross the constant set, then mark that pixel on the output image by setting the pixel of green to 255.

```
    weberConstant = 0.02
    weberMax = -999999.0
    print("[INFO] Operation on progress...")
    for row in range(rows):
        for col in range(cols):
            pix = img[row, col]
            for x, y in [(0, 1), (1, 1), (1, 0), (1, -1), (0, -1), (-1, -1),
                         (-1, 0), (-1, 1)]:  # move all eight directions
                tmpX = row + x
                tmpY = col + y
                # Handle if out of array
                if (tmpX < 0 or tmpY < 0 or tmpX >= rows or tmpY >= cols):
                    continue

                tmpPix = img[tmpX, tmpY]
                brightnessDiff = abs(int(pix) - int(tmpPix))

                # weberRatioTmp is weber ratio of current working pixel
                if (pix == 0):
                    weberRatioTmp = (brightnessDiff) / (pix + 1)
                else:
                    weberRatioTmp = brightnessDiff / pix
                weberMax = max(weberMax, weberRatioTmp)

                # Set GREEN channel to maximum to detect edges if it cross
    weberConstant
                if (weberRatioTmp > weberConstant):
                    output[row, col, 1] = 255
```

5. Print maximum Weber's ratio of the image.

```
    print("Maximum Weber's ratio: ", weberMax)
```

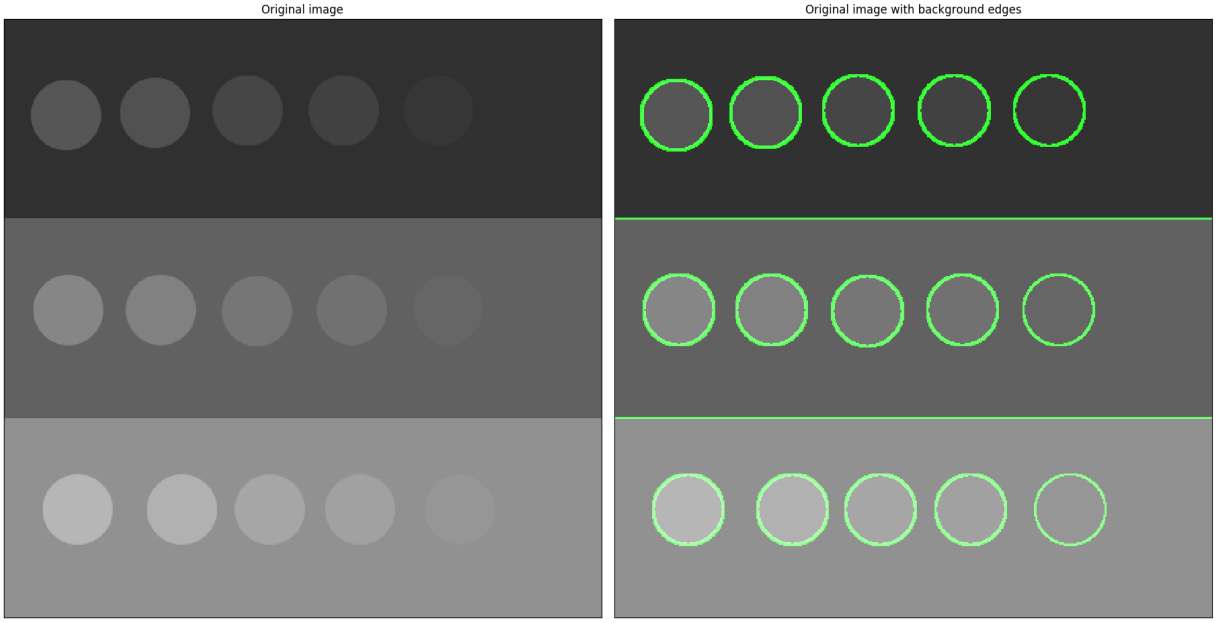
6. Plot both, original and created RGB image with green lines as edges.

```
    titles = ['Original image', 'Original image with background edges']
    plt.subplot(1, 2, 1)
    plt.imshow(img, cmap='gray', vmin=0, vmax=255)
    plt.title(titles[0])
    plt.xticks([])
    plt.yticks([])
    plt.subplot(1, 2, 2)
    plt.imshow(output)
    plt.title(titles[1])
    plt.xticks([])
    plt.yticks([])
    plt.show()

    print("[INFO] All operations finished successfully...")
```

18.3 Input and Output

18.3.1 Image Output

Figure 18.1: Use of Weber's ratio to detect background edges.



18.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Operation on progress...
Maximum Weber's ratio:  0.9795918367346939
[INFO] All operations finished successfully...
```

EXPERIMENT 19

Canny, Sobel and Prewitt

19.1 Objective

There are many different edge detection methods out there and the objective of this experiment is to compare them with each other.

We will be comparing the following methods:

- Sobel edge detector
- Prewitt edge detector
- Canny edge detector

We won't use respective CV2 methods for edge detection rather a custom written convolution function will be used. It may slow down the process but will be helpful to understand the convolution process and the kernels.

19.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
import matplotlib.pyplot as plt
from skimage.exposure import rescale_intensity
import os
import sys
```

2. Define custom written convolution function which takes an image an kernel and apply the kernel over the image.

```
def convolve(image, kernel):
  (iH, iW) = image.shape[:2]
  (kH, kW) = kernel.shape[:2]

  pad = (kW - 1) // 2
  image = cv2.copyMakeBorder(image, pad, pad, pad, pad,
    cv2.BORDER_REPLICATE)
  output = np.zeros((iH, iW), dtype="float32")

  for y in np.arange(pad, iH + pad):
    for x in np.arange(pad, iW + pad):
      roi = image[y - pad:y + pad + 1, x - pad:x + pad + 1]
      k = (roi * kernel).sum()
      output[y - pad, x - pad] = k

  output = rescale_intensity(output, in_range=(0, 255))
  output = (output * 255).astype("uint8")

  return output
```

3. Start the driver program and read input image.

```
if __name__ == '__main__':
    path = '../../img/Valve_original_(1).png'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

4. Create a Gaussian filtered image on which Sobel and Prewitt will be applied later. Edges using Canny detected.

```
    imgGaussian = cv2.GaussianBlur(img, (3, 3), 0)
    print("[INFO] Gaussian operator applied...")
    imgCanny = cv2.Canny(img,100,200)
    print("[INFO] Canny operator applied...")
```

5. Create Sobel kernels and apply them on the Gaussian filtered image.

```
    horizontalSobel = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]])
    verticalSobel = np.array([[-1, -2, -1], [0, 0, 0], [1, 2, 1]])
    # imgSobelX = cv2.Sobel(imgGaussian,cv2.CV_8U,1,0,ksize=3)
    # imgSobelY = cv2.Sobel(imgGaussian,cv2.CV_8U,0,1,ksize=3)
    imgSobelX = convolve(imgGaussian, horizontalSobel)
    imgSobelY = convolve(imgGaussian, verticalSobel)
    imgSobel = imgSobelX + imgSobelY
    print("[INFO] Sobel operator applied...")
```

6. Create Prewitt kernels and apply them on the Gaussian filtered image.

```
    prewittKernelX = np.array([[1,1,1],[0,0,0],[-1,-1,-1]])
    prewittKernelY = np.array([[-1,0,1],[-1,0,1],[-1,0,1]])
    # imgPrewittX = cv2.filter2D(imgGaussian, -1, prewittKernelX)
    # imgPrewittY = cv2.filter2D(imgGaussian, -1, prewittKernelY)
    imgPrewittX = convolve(imgGaussian, prewittKernelX)
    imgPrewittY = convolve(imgGaussian, prewittKernelY)
    imgPrewitt = imgPrewittX + imgPrewittY
    print("[INFO] Prewitt operator applied...")
```

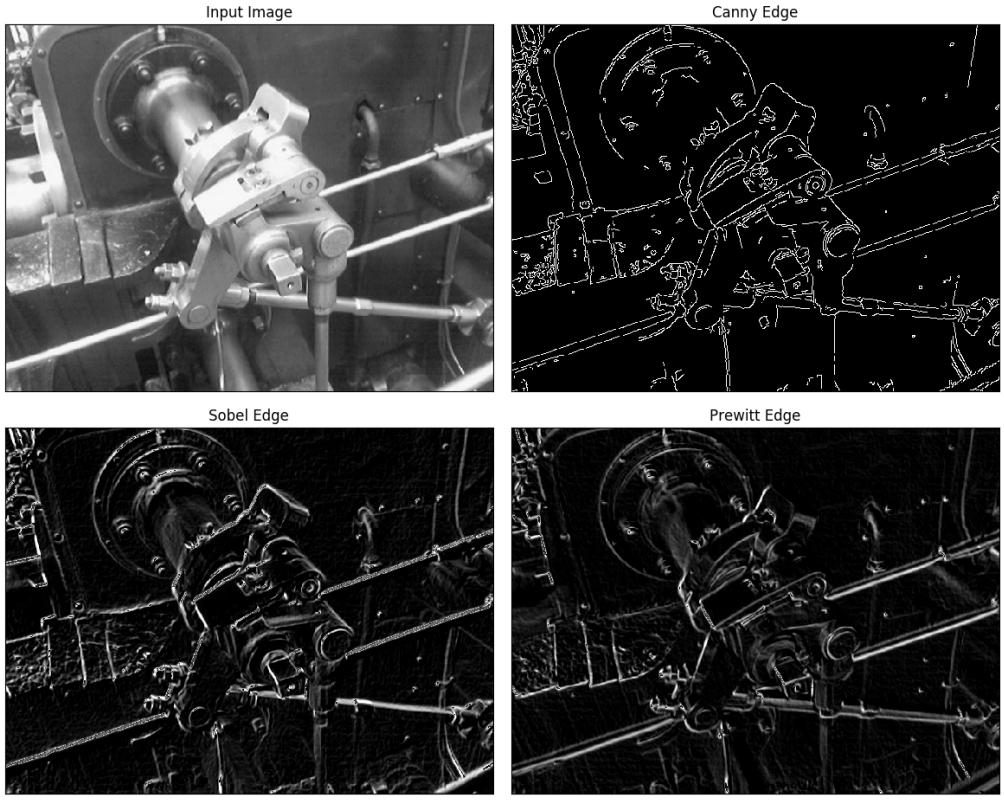
7. Plot input image and result images using `matplotlib`.

```
    titles = ['Input Image', 'Canny Edge', 'Sobel Edge','Prewitt Edge']
    imgarr = [img, imgCanny, imgSobel, imgPrewitt]

    plt.figure(figsize=(20,20))
    for i in range(4):
        plt.subplot(2,2,i+1)
        plt.imshow(imgarr[i], cmap='gray', vmin =0, vmax =255)
        plt.title(titles[i])
        plt.xticks ([])
        plt.yticks ([])

    plt.show ()

    print("[INFO] All operations completed successfully...")
```

19.3 Input and Output

19.3.1 Image Output

Figure 19.1: Apply of various edge detection operator.



19.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Gaussian operator applied...
[INFO] Canny operator applied...
[INFO] Sobel operator applied...
[INFO] Prewitt operator applied...
[INFO] All operations completed successfully...
```

EXPERIMENT 20

Line Detection

20.1 Objective

Line detection is an algorithm that takes a collection of n edge points and finds all the lines on which these edge points lie. In a convolution based technique, the line detector operator consists of a convolution masks tuned to detect the presence of lines of a particular width n and a orientation. Here are the four convolution masks to detect horizontal, vertical, oblique (+45 degrees), and oblique (-45 degrees) lines in an image.

1. Horizontal mask(R_1)
$$\begin{bmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{bmatrix}$$
2. Vertical (R_3)
$$\begin{bmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{bmatrix}$$
3. Oblique (+45 degrees)(R_2)
$$\begin{bmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{bmatrix}$$
4. Oblique (-45 degrees)(R_4)
$$\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

In practice, masks are run over the image and the responses are combined given by the following equation:

$$R(x, y) = max(|R_1(x, y)|, |R_2(x, y)|, |R_3(x, y)|, |R_4(x, y)|) \tag{20.1}$$

If $R(x, y) > T$, then discontinuity.

20.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
from skimage.exposure import rescale_intensity
import os
import sys
```

2. Define custom convolution method to run the filters over.

```
def convolve(image, kernel):
  (iH, iW) = image.shape[:2]
  (kH, kW) = kernel.shape[:2]

  pad = (kW - 1) // 2
  image = cv2.copyMakeBorder(image, pad, pad, pad, pad,
    cv2.BORDER_REPLICATE)
  output = np.zeros((iH, iW), dtype="float32")

  for y in np.arange(pad, iH + pad):
    for x in np.arange(pad, iW + pad):
      roi = image[y - pad:y + pad + 1, x - pad:x + pad + 1]
      k = (roi * kernel).sum()
      output[y - pad, x - pad] = k

  output = rescale_intensity(output, in_range=(0, 255))
  output = (output * 255).astype("uint8")

  return output
```

3. Start main function and read images.

```
if __name__ == '__main__':

    path = '../../img/Testbuilding.png'

    if os.path.isfile(path):
        image = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

4. Creating horizontal, vertical and oblique masks.

```
    horizontalMask = np.array((
            [-1, -1, -1],
            [2, 2, 2],
            [-1, -1, -1]), dtype="int")

    verticalMask = np.array((
            [-1, 2, -1],
            [-1, 2, -1],
            [-1, 2, -1]), dtype="int")

    oblique45P = np.array((
            [-1, -1, 2],
            [-1, 2, -1],
            [2, -1, -1]), dtype="int")

    oblique45N = np.array((
            [2, -1, -1],
            [-1, 2, -1],
            [-1, -1, 2]), dtype="int")
```

5. Construct a kernel bank, a list of kernels we are going to apply using custom `convole` function.

```
    # construct the kernel bank, a list of kernels we're going
    # to apply using custom `convole` function
    kernelBank = (
            ("Horizontal Mask", horizontalMask),
            ("Vertical Mask", verticalMask),
            ("Oblique +45 Degree", oblique45P),
            ("Oblique -45 Degree", oblique45N)
    )
```

6. Loop over the kernels and apply them.

```
    # loop over the kernels
    convoleOutput = []
    titles = []
    for (kernelName, kernel) in kernelBank:
        print("[INFO] Applying {} kernel...".format(kernelName))
        convoleOutput.append(convolve(image, kernel))
        titles.append(kernelName)
```

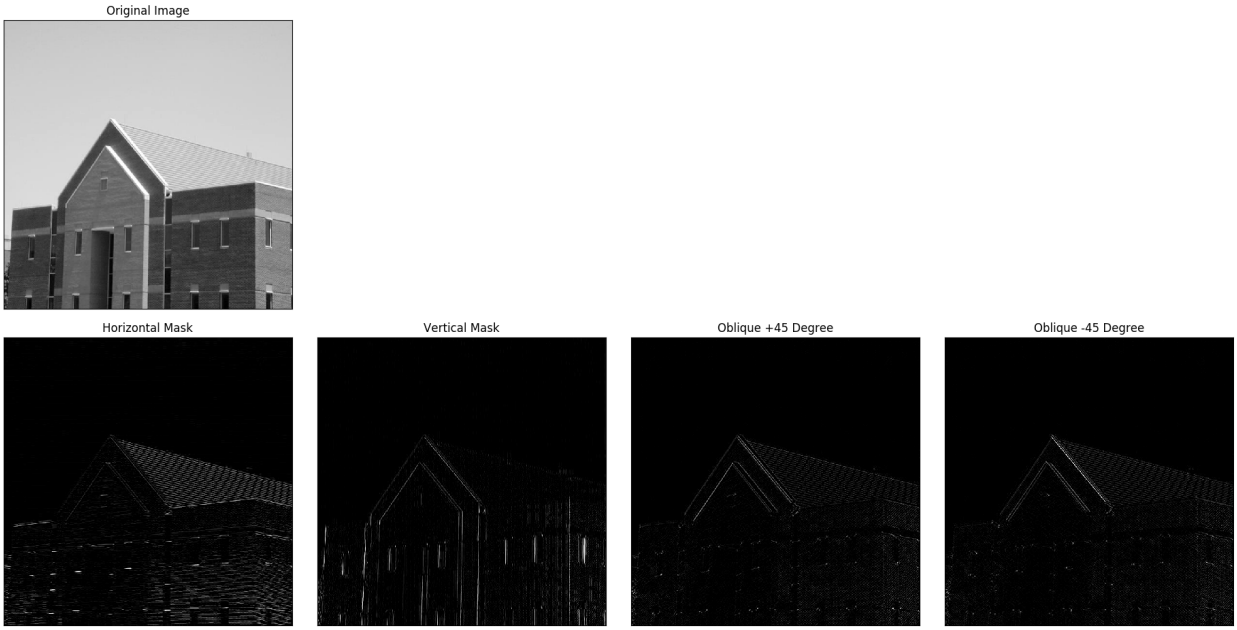
7. Plot the input image and the output images.

```
    plt.subplot(2, 4, 1)
    plt.imshow(image, cmap='gray', vmin = 0, vmax = 255)
    plt.title("Original Image")
    plt.xticks([]),plt.yticks([])

    for i in np.arange(4, 8):
        plt.subplot(2, 4, i+1)
        plt.imshow(convoleOutput[i-4], cmap='gray', vmin = 0, vmax = 255)
        plt.title(titles[i-4])
        plt.xticks([]),plt.yticks([])

    plt.show()

    print("[INFO] All operations completed successfully...")
```

20.3 Input and Output

20.3.1 Image Output

Figure 20.1: Line detection of an images.



20.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] Applying Horizontal Mask kernel...
[INFO] Applying Vertical Mask kernel...
[INFO] Applying Oblique +45 Degree kernel...
```

```
[INFO] Applying Oblique -45 Degree kernel...
[INFO] All operations completed successfully...
```

EXPERIMENT 21

Morphological Transformations

21.1 Objective

- Take two same sized image as input.
- Produce a third image with same size of the input image which pixels are sum of two input images pixels.

Image morphological-transformations equation is $g(x, y) = f_1(x, y) + f_2(x, y)$. Here $f_1(x, y)$ and $f_2(x, y)$ are two input images and $g(x, y)$ is output image.

21.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import os
import sys
```

2. Start main function and read images

```
if __name__ == '__main__':

    path = '../../img/finger-print.jpg'

    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print ("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size.

```
    ret, thresh = cv2.threshold(img,127,255,cv2.THRESH_BINARY)
    kernel = np.ones((3,3),np.uint8)
    erosion = cv2.erode(thresh,kernel,iterations = 1)
    dilation = cv2.dilate(erosion,kernel,iterations = 1)
    opening = cv2.morphologyEx(thresh, cv2.MORPH_OPEN, kernel)
    closing = cv2.morphologyEx(opening, cv2.MORPH_CLOSE, kernel)
```

4. Plot two input images and an output image as morphological-transformations result.

```
    titles = ['Main Image', 'Erosion on Main Image', 'Dilation on Erosion', '
    Opening on Main Image', 'Closing on Opening']
    imgArr = [thresh, erosion, dilation, opening, closing]

    for i in range(5):
        plt.subplot(1, 5, i+1)
        plt.imshow(imgArr[i], cmap='gray', vmin = 0, vmax = 255)
        plt.title(titles[i])
        plt.xticks([]),plt.yticks([])

```

```
10      plt.show()
11
12      print("[INFO] All operations completed successfully...")
```

21.3 Input and Output

21.3.1 Image Output

Figure 21.1: Various morphological transformations on a finger print image.

21.3.2 Text Output

```
1 [INFO] Image has been read successfully...
2 [INFO] All operations completed successfully...
```

EXPERIMENT 22

Ringing Artifacts

22.1 Objective

- Take two same sized image as input.
- Produce a third image with same size of the input image which pixels are sum of two input images pixels.

Image ringing-artifacts equation is $g(x, y) = f_1(x, y) + f_2(x, y)$. Here $f_1(x, y)$ and $f_2(x, y)$ are two input images and $g(x, y)$ is output image.

22.2 Procedure

1. Import python libraries for image processing and other stuffs.

```
import numpy as np
import cv2
from matplotlib import pyplot as plt
import os
```

2. Start main function and read images.

```
if __name__ == '__main__':

    path = '../../img/aerials/2.2.02.tiff'
    if os.path.isfile(path):
        img = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
        print("[INFO] Image has been read successfully...")
    else:
        print("[INFO] The file '" + path + "' does not exist.")
        sys.exit(0)
```

3. Check whether input images are in identical size.

```
    mask = np.zeros((rows, cols, 2), np.uint8)

    outputImgArr = [img, magnitudeSpectrum]
    maskSize = [5, 15, 25, 35, 50, 80]
```

4. Get image size and create a blank image as output.

```
    dft = cv2.dft(np.float32(img), flags=cv2.DFT_COMPLEX_OUTPUT)
    dft_shift = np.fft.fftshift(dft)
    magnitudeSpectrum = 20 * np.log(
        cv2.magnitude(dft_shift[:, :, 0], dft_shift[:, :, 1]))
```

5. Iterate over the pixels and add individual pixel to output.

```
    rows, cols = img.shape
    crow, ccol = int(rows / 2), int(cols / 2)
    # create a mask first, center square is 1, remaining all zeros
    mask = np.zeros((rows, cols, 2), np.uint8)
```

6. Plot two input images and an output image as ringing-artifacts result.

```
    outputImgArr = [img, magnitudeSpectrum]
    maskSize = [5, 15, 25, 35, 50, 80]
    titles = ['Input Image', "Magnitude Spectrum"
             ] + ['Mask Size: ' + str(i) for i in maskSize]
```

7. Plot two input images and an output image as ringing-artifacts result.

```
    for n in maskSize:
        mask[crow - n:crow + n, ccol - n:ccol + n] = 1
        # apply mask and inverse DFT
        fshift = dft_shift * mask
        f_ishift = np.fft.ifftshift(fshift)
        imgTmp = cv2.idft(f_ishift)
        outputImgArr.append(cv2.magnitude(imgTmp[:, :, 0], imgTmp[:, :, 1]))
```

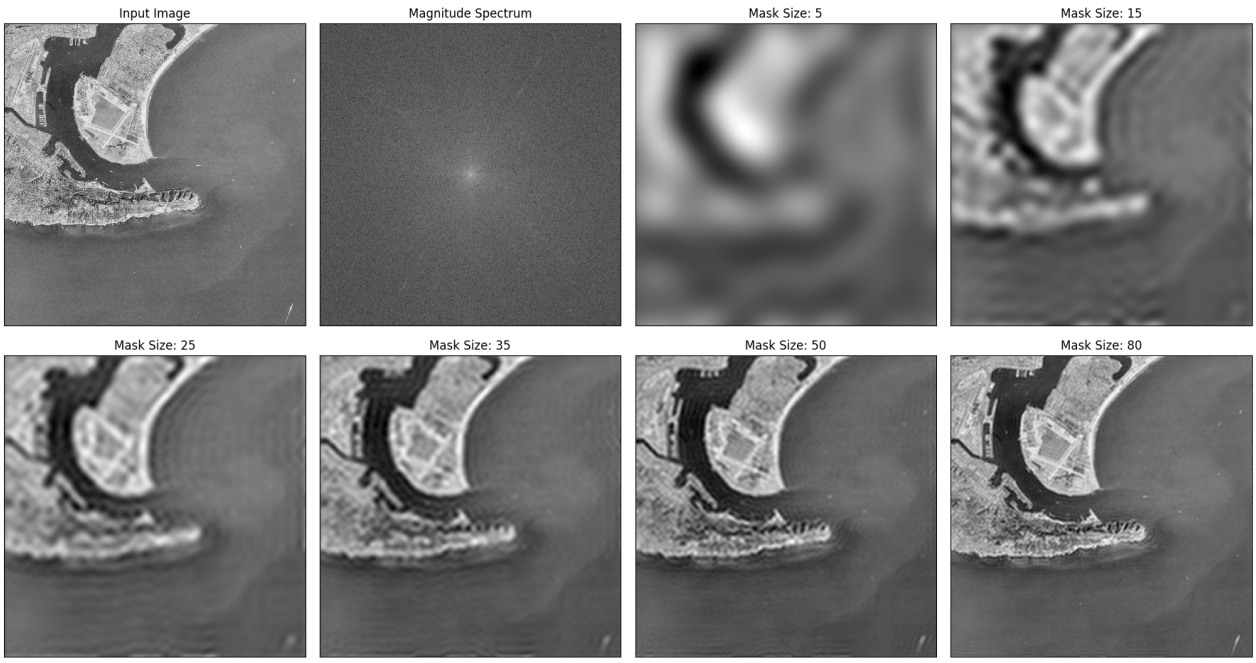
8. Plot two input images and an output image as ringing-artifacts result.

```
        outputImgArr.append(cv2.magnitude(imgTmp[:, :, 0], imgTmp[:, :, 1]))

    for i in range(len(outputImgArr)):
        plt.subplot(2, 4, i + 1)
        plt.imshow(outputImgArr[i], cmap='gray')
        plt.title(titles[i])
        plt.xticks([])
        plt.yticks([])

    plt.show()

    print("[INFO] All operations completed successfully...")
```

22.3 Input and Output

22.3.1 Image Output

Figure 22.1: Showing ringing artifact on an aerial image.



22.3.2 Text Output

```
[INFO] Image has been read successfully...
[INFO] All operations completed successfully...
```