HW3_PA_Report

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1 Programming Assignment 3

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Import some prerequisites

[8]:
```
import cv2
import matplotlib.pyplot as plt
import numpy as np
import os
import time
```

Plotting cell

[9]:
```
def plotter(img_list, r, w, gray, wr, hr, fig_name = None):
    '''
    Plots images' list with its' caption and saves result image if you want.

    Parameters:
        img_list (list): The list of tuples of image and its' caption.
        r (int): The number of row(s).
        w (int): The number of colunm(s).
        gray (bool): The flag for plotting images in grayscale mode.
        wr (int): The width of one figure.
        hr (int): The height of one figure.
        fig_name (str): The name of the image of the plot. if not set this␣
↪parameter the plot doesn't save.
    '''

    plt.rcParams['figure.figsize'] = (wr, hr)
    for i in range(len(img_list)):
        plt.subplot(r, w, i + 1)
        if img_list[i][2] == 'img':
            if gray:
                plt.imshow(img_list[i][0], cmap = 'gray')
            else:
                plt.imshow(img_list[i][0])
            plt.xticks([])
            plt.yticks([])
```

```
        elif img_list[i][2] == 'hist':
            plt.bar(np.arange(len(img_list[i][0])), img_list[i][0], color = 'c')
        else:
            raise Exception("Only image or histogram. Use third parameter of␣
↪tuples in img_list and set it to img or hist.")
        plt.title(img_list[i][1])
    if fig_name is not None:
        plt.savefig(fig_name + '.png')
    plt.show()
```

2 PART 4

Implementing some helper functions

[10]:
```
### From HW2 with slight modifications

def compute_transition(image):
    '''
    Equalizes the histogram of the input image.

    Parameters:
        image (numpy.ndarray): The input image.

    Returns:
        numpy.ndarray: The result image that it's histogram be eqaulized.
    '''

    h = compute_histogram(image)

    ####### your code ########
    n_pixel = image.shape[0] * image.shape[1]
    transition = (h.cumsum().astype(np.float64) / n_pixel) * 255
    ##########################
    return transition
```

[11]:
```
### From HW2 with slight modifications
def compute_histogram(image):
    '''
    Computes histogram of the input image.

    Parameters:
        image (numpy.ndarray): The input image.

    Returns:
        numpy.ndarray: The numpy array of numbers in histogram.
    '''
```

```
    histogram = np.zeros((256), np.int)

    ####### your code ########
    image = image.astype(int)
    np.add.at(histogram, image, 1)
    #########################

    return histogram
```

2.1 Histogram Matching

I used two methods for hisogram matching:

1. Linear Interpolation: In this method, I used Linear Interpolation in NumPy to extract a relation between reference image transition and the reference image itself. Then I used that relation and applied it to the input image, so the result image's histogram is very similar to the ref image.

2. CDF Matching: this approach is the traditional approach explained at the class (the usual way). I computed EQ transition for both images and mapped the color intensity values of input image to new values according to ref image transition function.

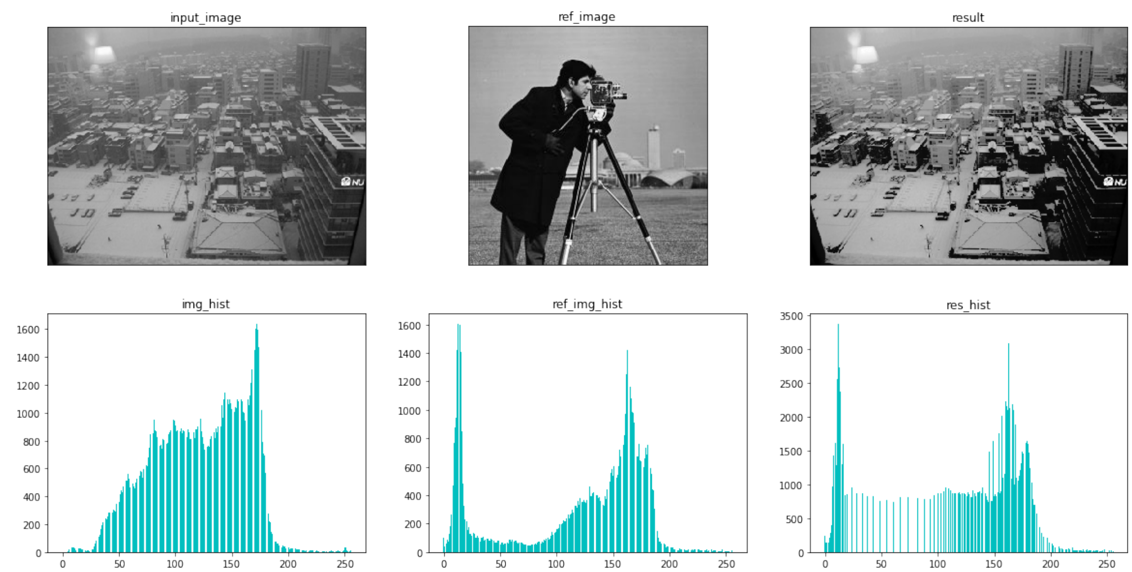
Note: There is a boolean variable *use_interp* in the beginning of the method to determine which method to use.

[12]:
```
def histogram_matching(img, ref_img):
    '''
    Matchs the histogram of the input image to the histogram of reference image.

    Parameters:
        img (numpy.ndarray): The input image.
        ref_img (numpy.ndarray): The reference image.

    Returns:
        numpy.ndarray: The result image.
    '''
    out_img = img.copy()

    ### For interpolation, set the following variable to true.
    use_interp = True

    if use_interp:

        input_transition = compute_transition(img)
        ref_transition = compute_transition(ref_img)
        ref_img_unique = np.unique(ref_img)

        final_transition = np.interp(input_transition, ref_transition,␣
 ↪ref_img_unique)
```

```
        out_img = final_transition[out_img]

    else:

        input_transition = compute_transition(img).astype(int)
        ref_transition = compute_transition(ref_img).astype(int)

        transition = np.array([np.where(input_transition[i] <= ref_transition)[0][0] for i in range(256)])

        out_img = transition[out_img]

    return out_img
```

Test of implementation:

```
[13]: img = cv2.imread(os.path.join('images', 'Q4.jpg'), cv2.IMREAD_GRAYSCALE)
ref_img = cv2.imread(os.path.join('images', 'Q4_ref.jpg'), cv2.IMREAD_GRAYSCALE)
output = histogram_matching(img,ref_img)
h_img = compute_histogram(img)
h_ref_img = compute_histogram(ref_img)
h_out = compute_histogram(output)
image_list = []
image_list.append([img, 'input_image', 'img'])
image_list.append([ref_img, 'ref_image', 'img'])
image_list.append([output, 'result', 'img'])
image_list.append([h_img, 'img_hist', 'hist'])
image_list.append([h_ref_img, 'ref_img_hist', 'hist'])
image_list.append([h_out, 'res_hist', 'hist'])
plotter(image_list, 2, 3, True, 20, 10, 'q4')
```



3 PART 5

Here is my gaussian helper function.

[14]:
```python
def gaussian(x, y, std):
    return (1 / (2 * np.pi * np.square(std))) * (np.exp(-(np.square(x) + np.
 ↪square(y)) / (2 * np.square(std))))
```

3.1 Gaussian Filter

In this method, I implemented the code for creation of a Gausiian Kernel without using prepared libraries.

First, I calculate the value which should be substracted from i and j values (indices of NumPy ndarray) to map them to Cartesian space indices (x and y coordinates). Then I calculate the gaussian function value for each element of the array using it's Cartesian coordinates.

[15]:
```python
def gaussian_filter(size, std):
    '''
    Creates the Guassian kernel with given size and std.

    Parameters:
        size (int): The size of the kernel. It must be odd.
        std (float): The standard deviation of the kernel.

    Returns:
        numpy.ndarray: The Guassina kernel.
    '''

    kernel = np.zeros((size,size), np.float)

    ####### your code ########
    zero_based_gap = np.floor(size / 2)

    for i in range(kernel.shape[0]):
        for j in range(kernel.shape[1]):
            x = i - zero_based_gap
            y = j - zero_based_gap
            kernel[i, j] = gaussian(x, y, std)


    ##########################
    return kernel
```

Using the OpenCV Gaussian Blur function to filter image

[16]:
```python
def opencv_filter(img):
    '''
    Applys the OpenCV's guassian blur function on input image.

    Parameters:
        img (numpy.ndarray): The input image.

    Returns:
        numpy.ndarray: The result image.
    '''

    ####### your code ########
    out = cv2.GaussianBlur(img, (3, 3), 0)
    ##########################

    return out
```

Test of implementation:

[17]:
```python
img = cv2.imread(os.path.join('images', 'img5.jpg'), cv2.IMREAD_GRAYSCALE)
size = 3
std = 1
t1 = time.time()
kernel = gaussian_filter(size, std)
out_y_imp = cv2.filter2D(img, -1, kernel)
t2 = time.time()
out_ocv_imp = opencv_filter(img)
t3 = time.time()
print('time for applying your guassian filter: %f s' % (t2 - t1))
print('time for applying OpenCV guassian filter: %f s' % (t3 - t2))
image_list = []
image_list.append([img, 'input_image', 'img'])
image_list.append([out_y_imp, 'result of your implementation', 'img'])
image_list.append([out_ocv_imp, 'result of OpenCV implementation', 'img'])
plotter(image_list, 1, 3, True, 20, 10, 'q5')
```

```
time for applying your guassian filter: 0.007573 s
time for applying OpenCV guassian filter: 0.004658 s
```

Result: **In terms of output image:** The size of the kernel in both examples was identical, and as we can see there is not much of a difference between the images outputed from two methods respectively.

In terms of computation time As can be seen above, the OpenCV GaussianBlur function takes less time to run and is more efficient in terms of computation time (and maybe resources).

4 CLAHE

Implementation for theory question 3: Using OpenCV CLAHE and comparing the results.

[29]:
```
def clahe(image, clip_limit):
    '''
    Applys the OpenCV's CLAHE on the input image.

    Parameters:
        image (numpy.ndarray): The input image.

    Returns:
        numpy.ndarray: The result image.
    '''

    out_image = image.copy()

    # First creating a OpenCV CLAHE object, with contrast limiting of 2 and␣
↪tiles size of (10, 10)
    clahe = cv2.createCLAHE(clipLimit=clip_limit, tileGridSize=(3,3))

    # Applying the CLAHE algorithm to the image using the CLAHE object
    out_image = clahe.apply(image)

    return out_image
```

Now using the above method for the sample photo provided in HW3 Theory Question no. 3

[38]:
```
image = np.array([
    [46, 51, 57, 59],
    [46, 52, 58, 60],
    [46, 52, 58, 60]
], dtype=np.uint8)

output_lim1 = clahe(image, 1.0)
print('With Clip limit of 1:\n', output_lim1)

output_lim2 = clahe(image, 2.0)
print('\nWith Clip limit of 2:\n', output_lim2)
```

```python
if(output_lim1.all() == output_lim2.all()):
    print('\nTwo outputs are identical!')
```

```
With Clip limit of 1:
 [[128 191 160 191]
 [128 255 192 255]
 [128 223 176 223]]

With Clip limit of 2:
 [[128 191 160 191]
 [128 255 192 255]
 [128 223 176 223]]

Two outputs are identical!
```

For reasoning, look for Question 3 subsection 3 in HW3_Theory.pdf file