MP0

January 25, 2019

1 MP0 : Image Demosaicing

Welcome to CS 543! This assignment is a warm-up assignment to get you back up working from the winter break! We will try to provide you an iPython Notebook (like this) for all the future assignments! The notebook will provide you some further instructions(implementation related mainly), in addition to the ones provided on class webpage.

1.0.1 Import statements

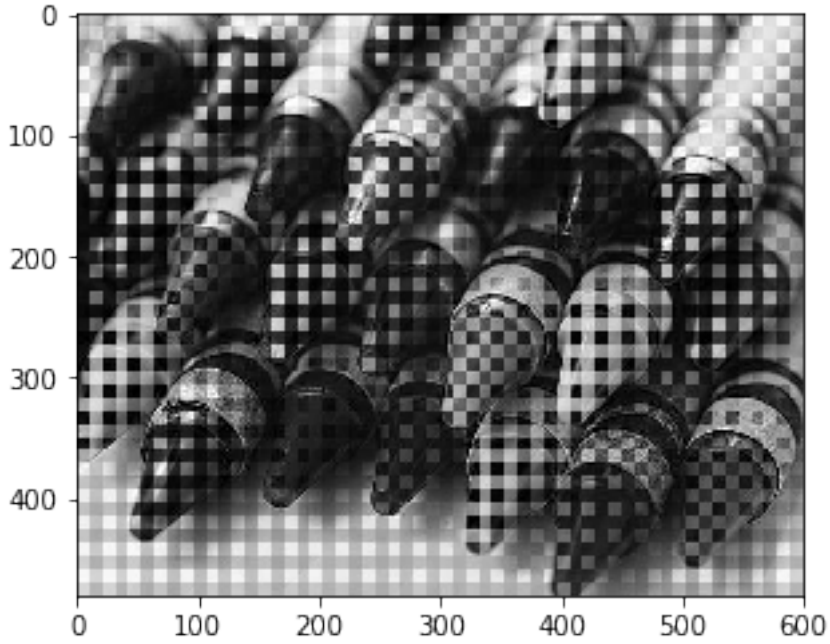
The following cell is only for import statements. You can use any of the 3 : cv2, matplotlib or skimage for image i/o and other functions. We will provide you the names of the relevant functions for each module. **{For convenience provided at the end of the class assignment webpage}**

```
In [88]: import numpy as np
         import cv2
         import matplotlib.image as mpimg
         import matplotlib.pyplot as plt
         import skimage
         import scipy
         import scipy.ndimage
         from scipy.signal import medfilt2d
         %matplotlib inline
```

1.0.2 Reading the Mosaic Image

```
In [89]: def read_image(IMG_NAME):
             bgr_img = cv2.imread('images/' + IMG_NAME, 1)
             b, g, r = cv2.split(bgr_img) # get b,g,r
             rgb_img = cv2.merge([r,g,b]) # switch to rgb
             return rgb_img

In [90]: IMG_DIR = 'images/'
         IMG_NAME = 'crayons.bmp'
         mosaic_img = read_image(IMG_NAME)
         # print(mosaic_img.shape)

In [91]: # For a sanity check, display your image here
         def display(img):
```

```
        imgplot = plt.imshow(img)
        # plt.xticks([]), plt.yticks([])
        plt.show()
        return

display(mosaic_img)
```



1.0.3 Linear Interpolation

```
In [92]: ### HINT : You might want to use filters

In [93]: ### HINT : To use filters you might want to write your kernels

In [94]: ### HINT : For writing your kernels you might want to see the RGB Pattern provided on

In [95]: ### HINT : To improve your kernels, you might want to use the squared difference
         ###        between your solution image and the original image

In [96]: def kernel_function_selection():
             kernel_green = np.array([[0, 0.25 ,0],
                                      [0.25,1.0, 0.25],
                                      [0,0.25,0]])
             kernel_red_blue = np.array([[0.25, 0.5, 0.25],
                                         [0.5, 1, 0.5],
                                         [0.25, 0.5, 0.25]])
             return kernel_green, kernel_red_blue
```

```
def get_solution_image(mosaic_img):
    '''
    This function should return the soln image.
    Feel free to write helper functions in the above cells
    as well as change the parameters of this function.
    '''
    mosaic_shape = np.shape(mosaic_img)
    soln_image = np.zeros((mosaic_shape[0], mosaic_shape[1], 3), dtype= 'uint8')

    # Initilize r,b,g
    r = np.zeros((mosaic_shape[0],mosaic_shape[1]))
    b = np.zeros((mosaic_shape[0],mosaic_shape[1]))
    g = np.zeros((mosaic_shape[0],mosaic_shape[1]))

    # Split and assign value into these three channels
    r[0::2, 0::2] = mosaic_img[:,:,0][0::2, 0::2]
    g[1::2, 0::2] = mosaic_img[:,:,1][1::2, 0::2]
    g[0::2, 1::2] = mosaic_img[:,:,1][0::2, 1::2]
    b[1::2, 1::2] = mosaic_img[:,:,2][1::2, 1::2]

    kernel_green, kernel_red_blue = kernel_function_selection()

    # convolve
    soln_image[:,:, 0] = scipy.ndimage.filters.convolve(r, kernel_red_blue, mode = 'mi
    soln_image[:,:, 1] = scipy.ndimage.filters.convolve(g, kernel_green, mode = 'mirro
    soln_image[:,:, 2] = scipy.ndimage.filters.convolve(b, kernel_red_blue, mode = 'mi

    return soln_image
```

In [97]:
```
def compute_errors(soln_image, original_image, save_error_map = False):
    '''
    Compute the Average and Maximum per-pixel error
    for the image.

    Also generate the map of pixel differences
    to visualize where the mistakes are made
    '''
    # error
    error = (soln_image - original_image)**2
    ssd = np.sum(error, axis = 2)
    max_err = np.max(ssd)
    pp_err = np.mean(ssd)
    map_display(ssd)
    if save_error_map == False:
        return pp_err, max_err
    if save_error_map == True:
        return pp_err, max_err, ssd
```

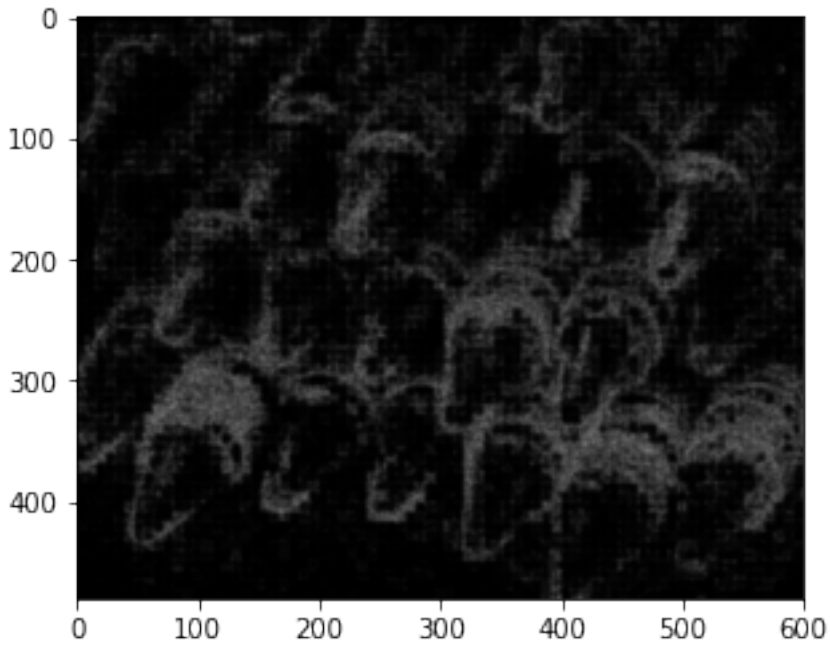
```
def map_display(img):
    plt.imshow(img, cmap = 'gray', interpolation = 'bicubic')
#     plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
    plt.show()
    return
```

We provide you with 3 images to test if your solution works. Once it works, you should generate the solution for test image provided to you.

In [98]:
```
mosaic_img = read_image('crayons.bmp')
soln_image = get_solution_image(mosaic_img)
original_image = read_image('crayons.jpg')
# For sanity check display your solution image here
# map_display(soln_image)
# display(original_image)
display(soln_image)
image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
cv2.imwrite('crayons_training_linear.png', image_to_write)
```

Out[98]: True

In [99]:
```
pp_err, max_err = compute_errors(soln_image, original_image)

print("The average per-pixel error for crayons is: "+str(pp_err))
print("The maximum per-pixel error for crayons is: "+str(max_err))
```

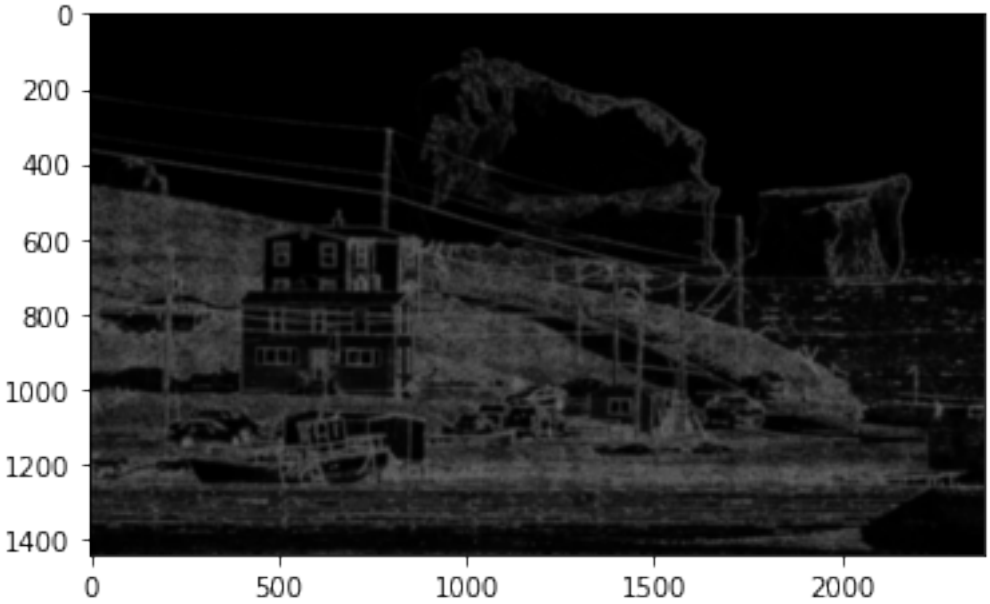



```
The average per-pixel error for crayons is: 47.86914236111111
The maximum per-pixel error for crayons is: 678
```

```
In [100]: mosaic_img = read_image('iceberg.bmp')
          soln_image = get_solution_image(mosaic_img)
          original_image = read_image('iceberg.jpg')
          # For sanity check display your solution image here
          # map_display(soln_image)
          display(soln_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('iceberg_training_linear.png', image_to_write)
```

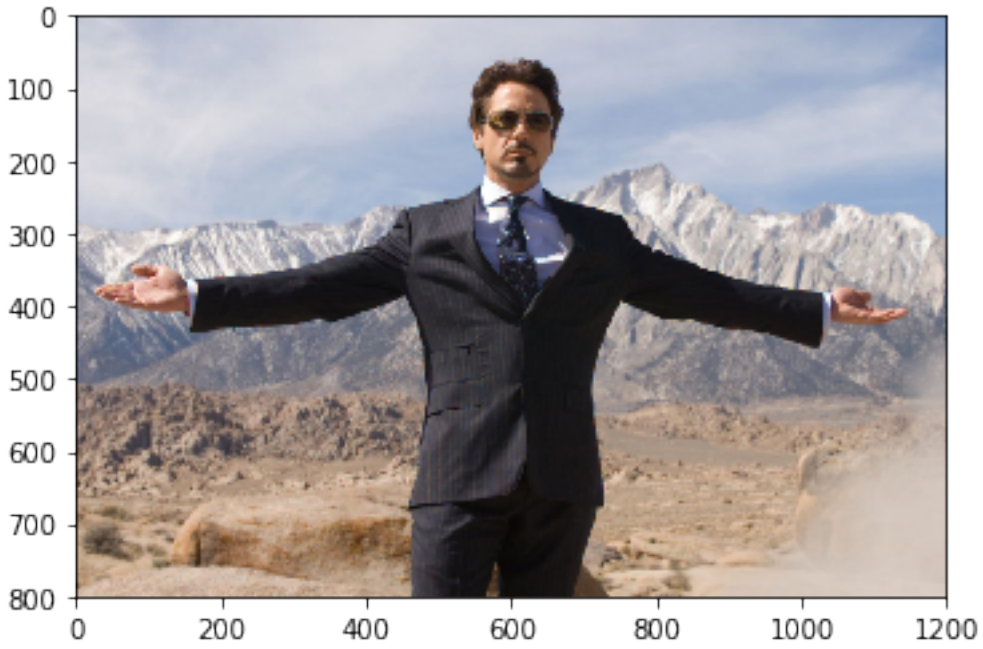
Out[100]: True

In [101]:
```
pp_err, max_err = compute_errors(soln_image, original_image)
print("The average per-pixel error for iceberg is: "+str(pp_err))
print("The maximum per-pixel error for iceberg is: "+str(max_err))
```



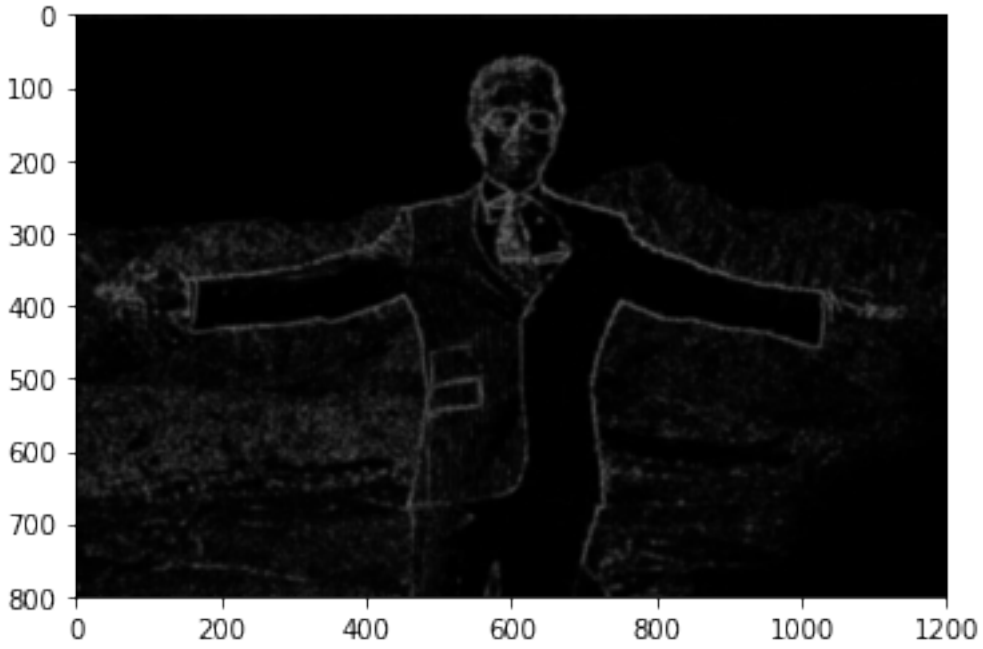
```
The average per-pixel error for iceberg is: 43.93339164101129
The maximum per-pixel error for iceberg is: 498
```

```
In [102]: mosaic_img = read_image('tony.bmp')
          soln_image = get_solution_image(mosaic_img)
          original_image = read_image('tony.jpg')
          # For sanity check display your solution image here
          # map_display(soln_image)
          display(soln_image)
          # display(original_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('tony_training_linear.png', image_to_write)
```




```
Out[102]: True
```

```
In [103]: pp_err, max_err = compute_errors(soln_image, original_image)
          print("The average per-pixel error for tony is: "+str(pp_err))
          print("The maximum per-pixel error for tony is: "+str(max_err))
```




```
The average per-pixel error for tony is: 14.996192708333334
The maximum per-pixel error for tony is: 482
```

```
In [104]: mosaic_img = read_image('hope.bmp')
          soln_image = get_solution_image(mosaic_img)
          # Generate your solution image here and show it
          # map_display(soln_image)
          display(soln_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('hope_linear.png', image_to_write)
```

Out[104]: True

1.0.4 Freeman's Method

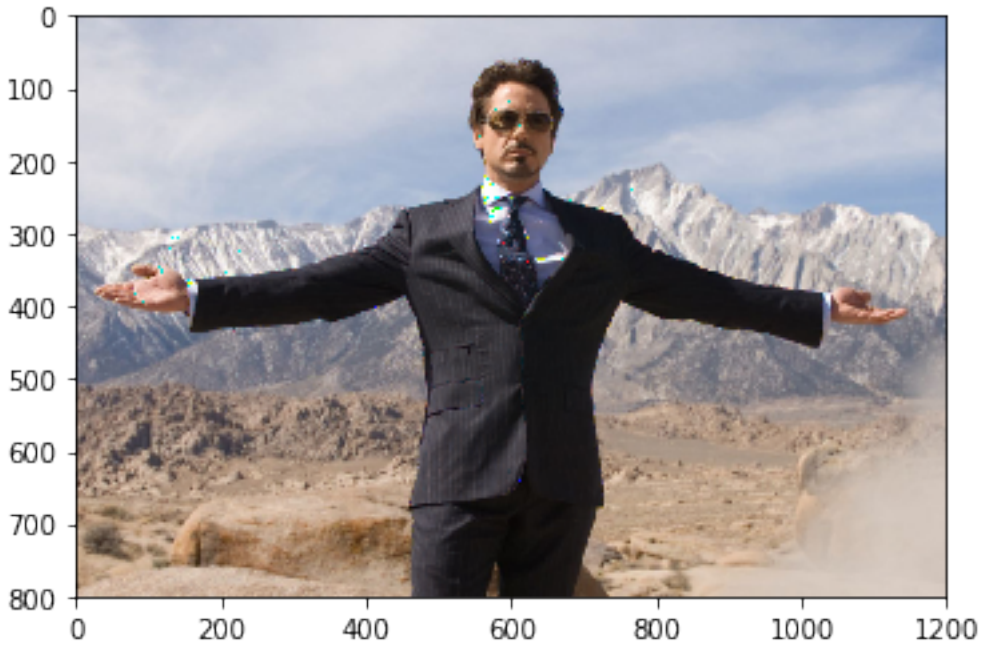
For details of the freeman's method refer to the class assignment webpage.

MAKE SURE YOU FINISH LINEAR INTERPOLATION BEFORE STARTING THIS PART!!!

```
In [105]: def get_freeman_solution_image(mosaic_img):
              '''
              This function should return the freeman soln image.
              Feel free to write helper functions in the above cells
              as well as change the parameters of this function.

              HINT : Use the above get_solution_image function.
              '''
              temp_image = get_solution_image(mosaic_img)
              r = temp_image[:,:,0]
              g = temp_image[:,:,1]
              b = temp_image[:,:,2]

              # Compute the differences
              r_g = r-g
              b_g = b-g

              # Median filtering
```

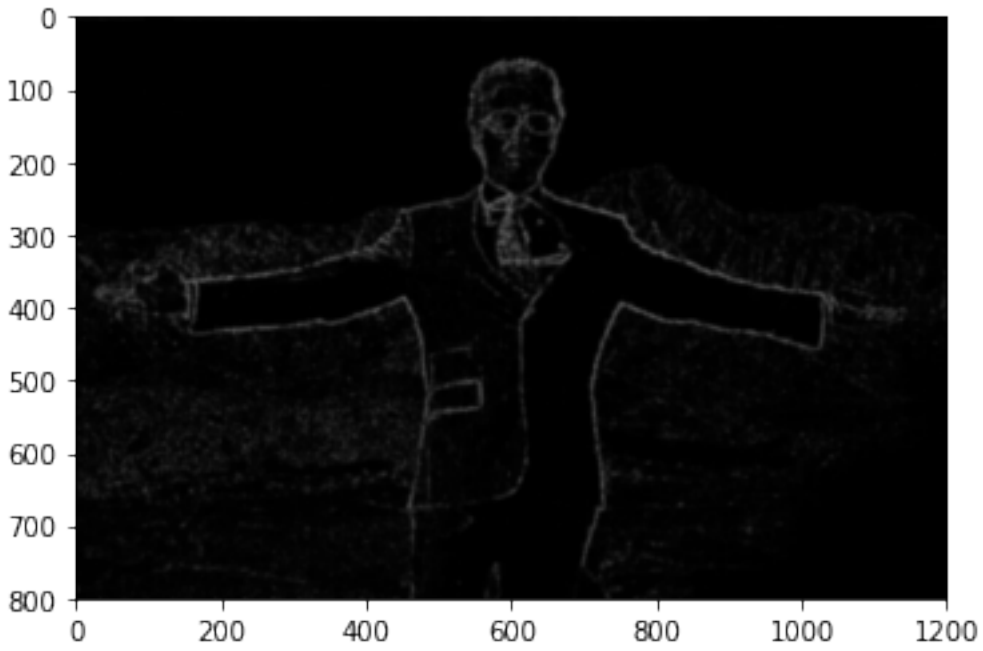
```
            new_r = medfilt2d(r_g)+g
            new_b = medfilt2d(b_g)+g

            # Stack new r,g,b together

            freeman_soln_image = temp_image
            freeman_soln_image[:,:,0] = new_r
            freeman_soln_image[:,:,2] = new_b
        #     freeman_soln_image = np.float64(freeman_soln_image / 255)
        #     freeman_soln_image = cv2.normalize(freeman_soln_image.astype('float'), None, 0
            return freeman_soln_image
```

In [106]:
```
mosaic_img = read_image('tony.bmp')
soln_image = get_freeman_solution_image(mosaic_img)
original_image = read_image('tony.jpg')
# For sanity check display your solution image here
# map_display(soln_image)
display(soln_image)
image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
cv2.imwrite('tnoy_training_freeman.png', image_to_write)
```



Out[106]: True

In [107]:
```
pp_err, max_err = compute_errors(soln_image, original_image)
print("The average per-pixel error for tony is: "+str(pp_err))
print("The maximum per-pixel error for tony is: "+str(max_err))
```



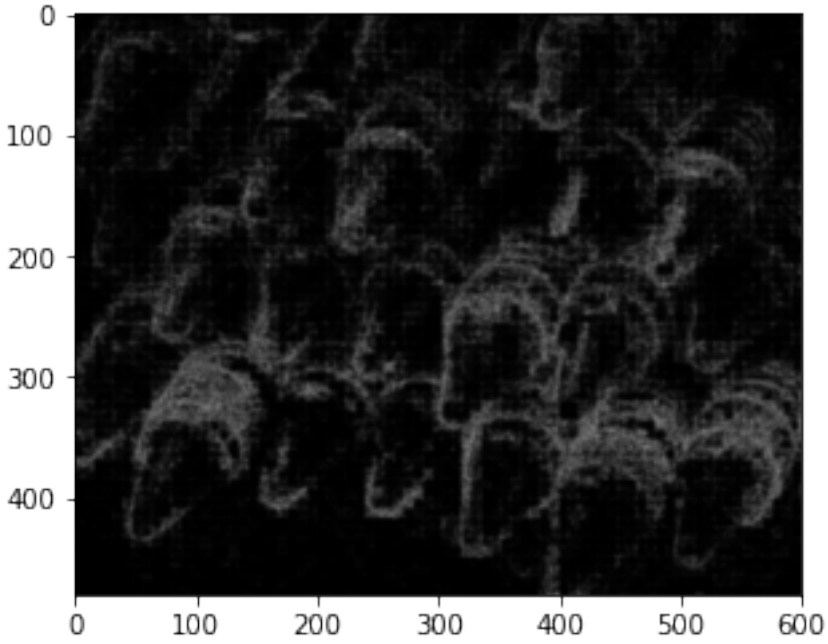

```
The average per-pixel error for tony is: 14.552795833333333
The maximum per-pixel error for tony is: 681
```

```
In [108]: ### Feel free to play around with other images for Freeman's method above ###
```

```
In [109]: mosaic_img = read_image('crayons.bmp')
          soln_image = get_freeman_solution_image(mosaic_img)
          original_image = read_image('crayons.jpg')
          # For sanity check display your solution image here
          # map_display(soln_image)
          display(soln_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('crayons_training_freeman.png', image_to_write)
```

Out[109]: True

In [110]:
```
pp_err, max_err = compute_errors(soln_image, original_image)
print("The average per-pixel error for tony is: "+str(pp_err))
print("The maximum per-pixel error for tony is: "+str(max_err))
```

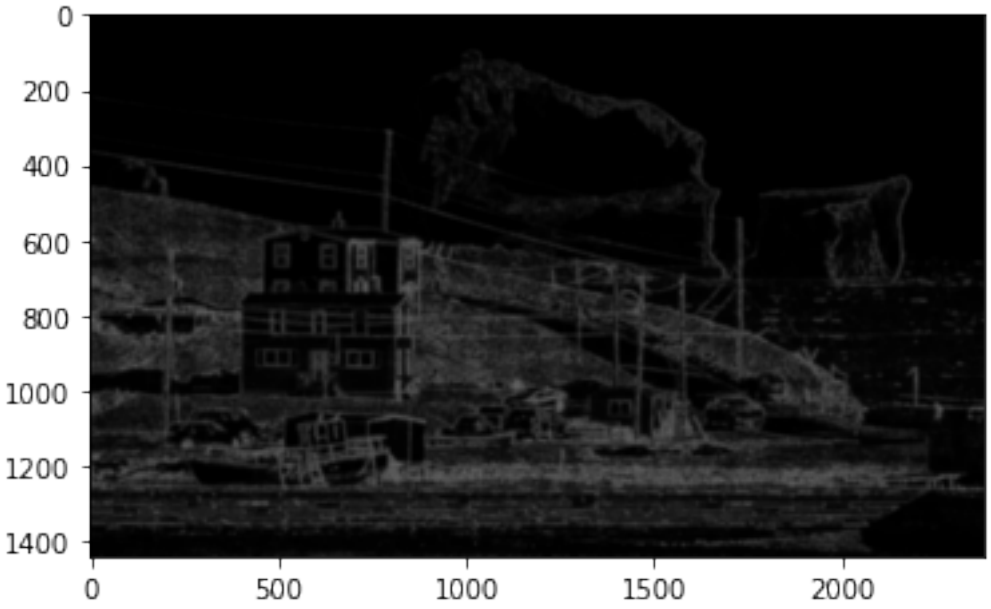


```
The average per-pixel error for tony is: 49.50285763888889
The maximum per-pixel error for tony is: 715
```

```
In [111]: mosaic_img = read_image('iceberg.bmp')
          soln_image = get_freeman_solution_image(mosaic_img)
          original_image = read_image('iceberg.jpg')
          # For sanity check display your solution image here
          # map_display(soln_image)
          display(soln_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('iceberg_training_freeman.png', image_to_write)
```


```
Out[111]: True
```

```
In [112]: pp_err, max_err = compute_errors(soln_image, original_image)
          print("The average per-pixel error for tony is: "+str(pp_err))
          print("The maximum per-pixel error for tony is: "+str(max_err))
```




```
The average per-pixel error for tony is: 45.97697779643624
The maximum per-pixel error for tony is: 718
```

```
In [113]: mosaic_img = read_image('hope.bmp')
          soln_image = get_freeman_solution_image(mosaic_img)
          # Generate your solution image here and show it
          display(soln_image)
          image_to_write = cv2.cvtColor(soln_image, cv2.COLOR_RGB2BGR)
          cv2.imwrite('Hope_freeman.png', image_to_write)
```

Out[113]: True

1.0.5 Mosaicing an Image

Now lets take a step backwards and mosaic an image.

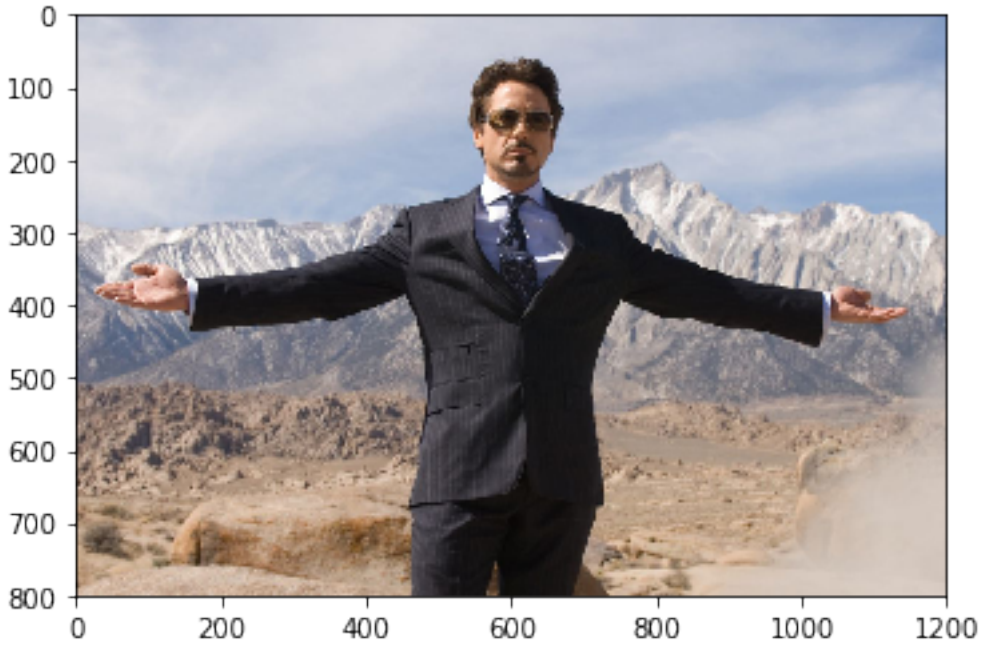
```
In [114]: def get_mosaic_image(original_image):
              '''
              Generate the mosaic image using the Bayer Pattern.
              '''
          #     height, width = original_image.shape[0], original_image.shape[1]
          # #     print(height, width)
          #     mosaic_img = np.zeros((height, width, 3), dtype= 'uint8')
          # #     mosaic_img[:,:,0][0::2, 0::2] = original_image[:,:,0][0::2, 0::2] # Red
          # #     mosaic_img[:,:,1][1::2, 0::2] = original_image[:,:,1][1::2, 0::2] # Green
          # #     mosaic_img[:,:,1][0::2, 1::2] = original_image[:,:,1][0::2, 1::2] # Green
          # #     mosaic_img[:,:,2][1::2, 1::2] = original_image[:,:,2][1::2, 1::2] # Blue
          #     height, width = original_image.shape[0], original_image.shape[1]
          #     print(height, width)
              mosaic_img = np.zeros((original_image.shape[0], original_image.shape[1],3), dtype
              mosaic_img[:,:,0][::2, ::2] = original_image[:,:,0][::2, ::2] # Red
              mosaic_img[:,:,1][1::2, 0::2] = original_image[:,:,1][1::2, ::2] # Green
              mosaic_img[:,:,1][::2, 1::2] = original_image[:,:,1][::2, 1::2] # Green
              mosaic_img[:,:,2][1::2, 1::2] = original_image[:,:,2][1::2, 1::2] # Blue
          #     b, g, r = cv2.split(original_image) # get b,g,r
```

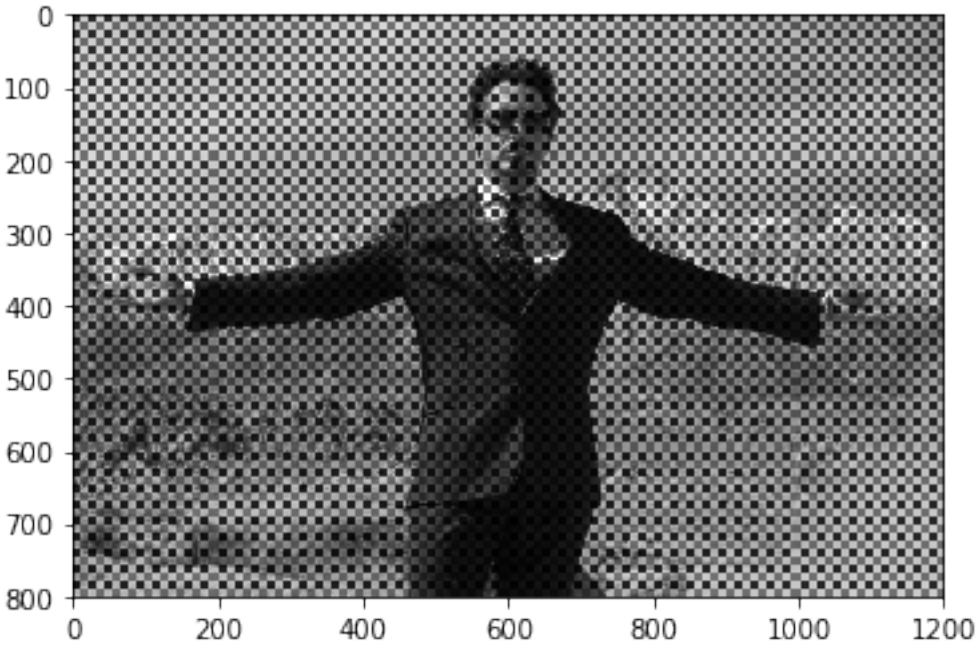
```
        #     mosaic_img = cv2.merge([r,g,b]) # switch to rgb
            return mosaic_img
```

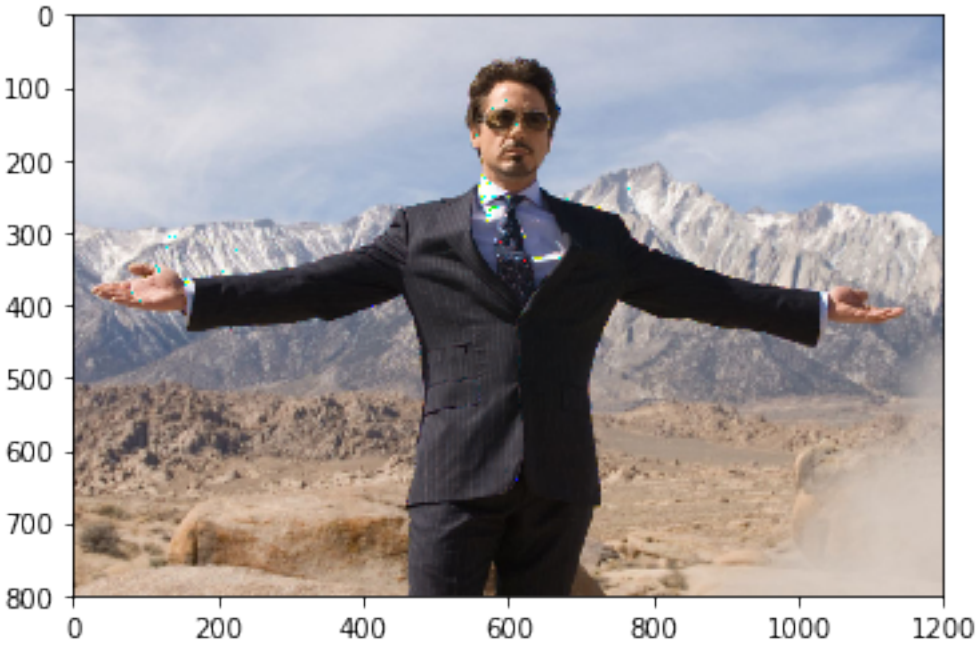
In [115]:
```
def rgb2gray(rgb):
    return np.dot(rgb[...,:3], [0.299, 0.587, 0.114])

# def grey_display(image):
#     img = mpimg.imread('image.png')
#     gray = rgb2gray(img)
#     plt.imshow(gray, cmap = plt.get_cmap('gray'))
#     plt.show()
```

In [116]:
```
### YOU CAN USE ANY OF THE PROVIDED IMAGES TO CHECK YOUR get_mosaic_function
```

In [117]:
```
orig_image = read_image('tony.jpg')
display(orig_image)
mosaic_image = get_mosaic_image(orig_image)
# display(mosaic_image)
# img = mpimg.imread('image.png')
gray = rgb2gray(mosaic_image)
plt.imshow(gray, cmap = plt.get_cmap('gray'))
plt.show()

soln_image = get_freeman_solution_image(mosaic_image)
display(soln_image)
```







Use any 3 images you find interesting and generate their mosaics as well as their demosaics. Try to find images that break your demosaicing function.

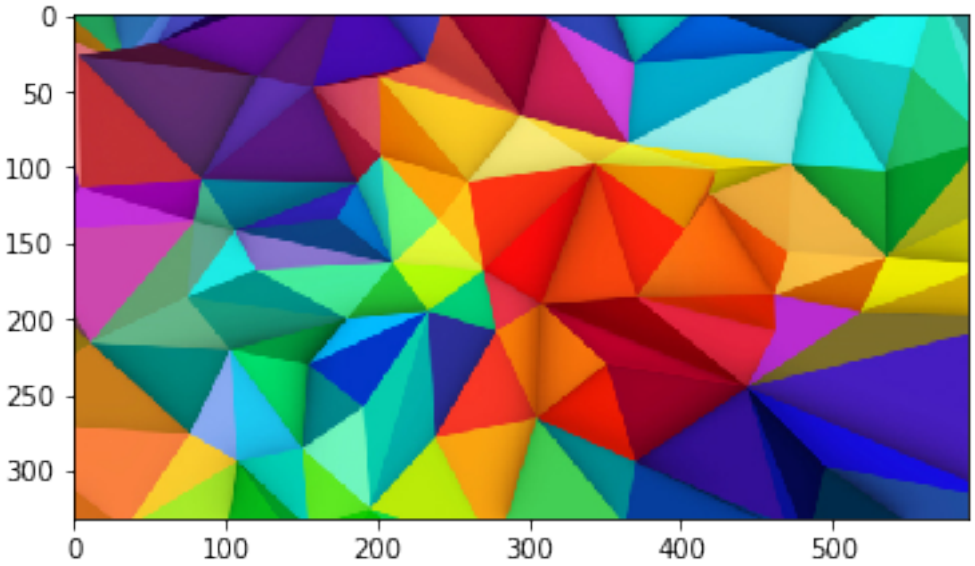
```
In [118]: # ### YOUR CODE HERE ###
          # # 1
```

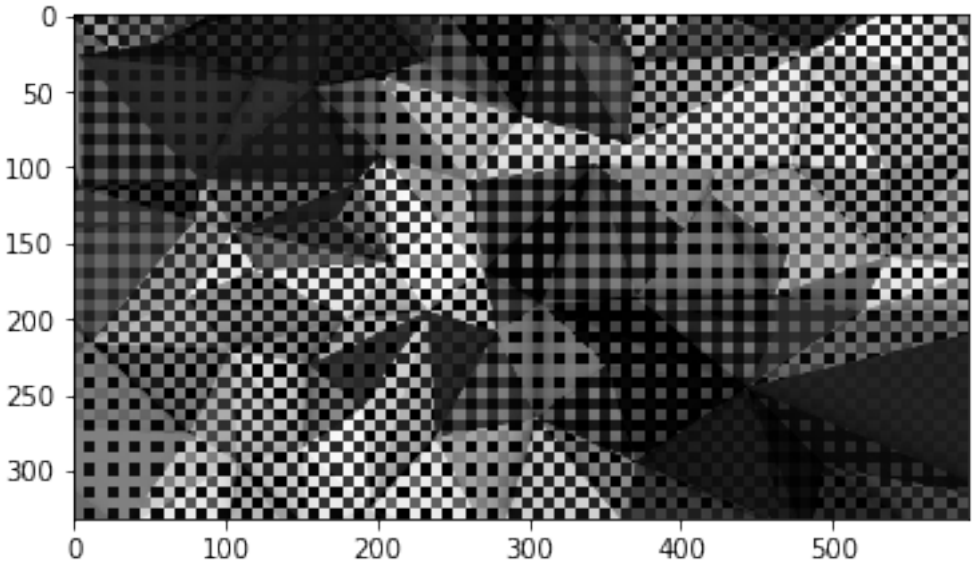
```
# origi_img1 = read_image('img1.jpg')
# mosaic_img1 = get_mosaic_image(origi_img1)
# # display(mosaic_img1)
# gray = rgb2gray(mosaic_img1)
# plt.imshow(gray, cmap = plt.get_cmap('gray'))
# plt.show()
# soln_img1 = get_freeman_solution_image(mosaic_img1)
# display(soln_img1)
# pp_err, max_err, ssd = compute_errors(soln_img1, origi_img1, True)
# print("The average per-pixel error for tony is: "+str(pp_err))
# print("The maximum per-pixel error for tony is: "+str(max_err))

# image_to_write = cv2.cvtColor(soln_img1, cv2.COLOR_RGB2BGR)
# cv2.imwrite('soln_img1.png', image_to_write)

# # image_to_write = cv2.cvtColor(ssd, cv2.COLOR_RGB2BGR)
# # cv2.imwrite('soln_img1_error.png', ssd)
```

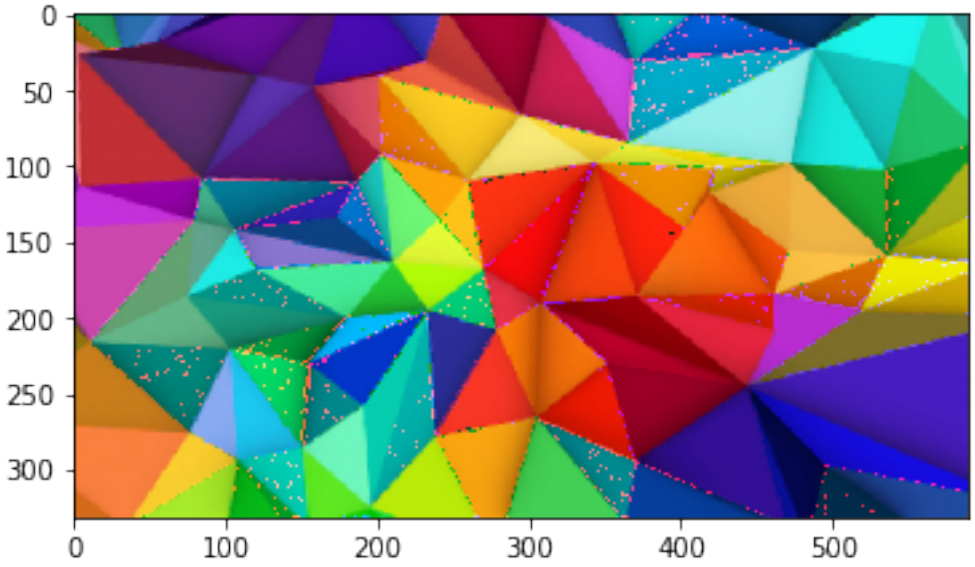
In [119]:
```
# # 2
# origi_img2 = read_image('img2.jpg')
# mosaic_img2 = get_mosaic_image(origi_img2)
# # display(mosaic_img2)
# gray = rgb2gray(mosaic_img2)
# plt.imshow(gray, cmap = plt.get_cmap('gray'))
# plt.show()
# soln_img2 = get_freeman_solution_image(mosaic_img2)
# display(soln_img2)

# pp_err, max_err, ssd = compute_errors(soln_img2, origi_img2, True)
# print("The average per-pixel error for tony is: "+str(pp_err))
# print("The maximum per-pixel error for tony is: "+str(max_err))
```

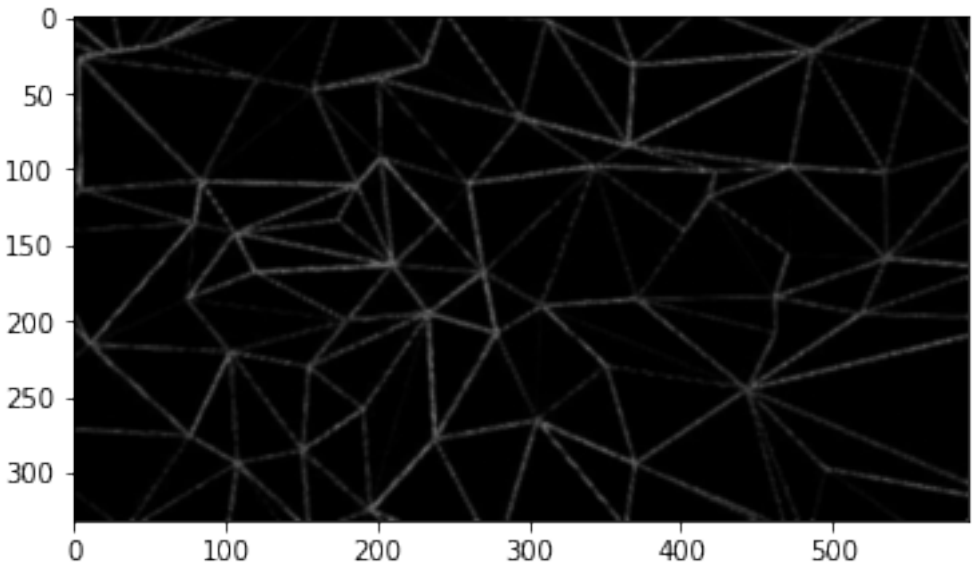
In [120]:
```
# # 3
# origi_img3 = read_image('img3.jpg')
# mosaic_img3 = get_mosaic_image(origi_img3)
# # display(mosaic_img3)
# gray = rgb2gray(mosaic_img3)
# plt.imshow(gray, cmap = plt.get_cmap('gray'))
# plt.show()
# soln_img3 = get_freeman_solution_image(mosaic_img3)
# display(soln_img3)



# pp_err, max_err, ssd = compute_errors(soln_img3, origi_img3, True)
# print("The average per-pixel error for tony is: "+str(pp_err))
# print("The maximum per-pixel error for tony is: "+str(max_err))

# image_to_write = cv2.cvtColor(soln_img3, cv2.COLOR_RGB2BGR)
# cv2.imwrite('soln_img3.png', image_to_write)
```

In [121]:
```
# 4
origi_img4 = read_image('img4.jpg')
mosaic_img4 = get_mosaic_image(origi_img4)
display(origi_img4)
gray = rgb2gray(mosaic_img4)
plt.imshow(gray, cmap = plt.get_cmap('gray'))
plt.show()
soln_img4 = get_freeman_solution_image(mosaic_img4)
display(soln_img4)


pp_err, max_err, ssd = compute_errors(soln_img4, origi_img4, True)
print("The average per-pixel error for tony is: "+str(pp_err))
print("The maximum per-pixel error for tony is: "+str(max_err))

image_to_write = cv2.cvtColor(soln_img4, cv2.COLOR_RGB2BGR)
cv2.imwrite('soln_img4.png', image_to_write)
```




0
50
100
150
200
250
300
0
100
200
300
400
500

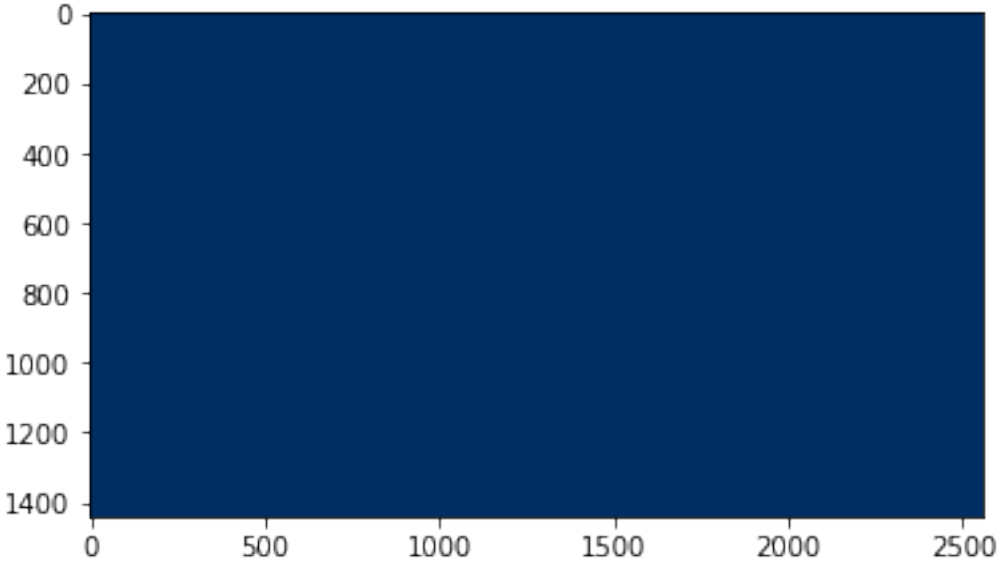

0
50
100
150
200
250
300
0
100
200
300
400
500

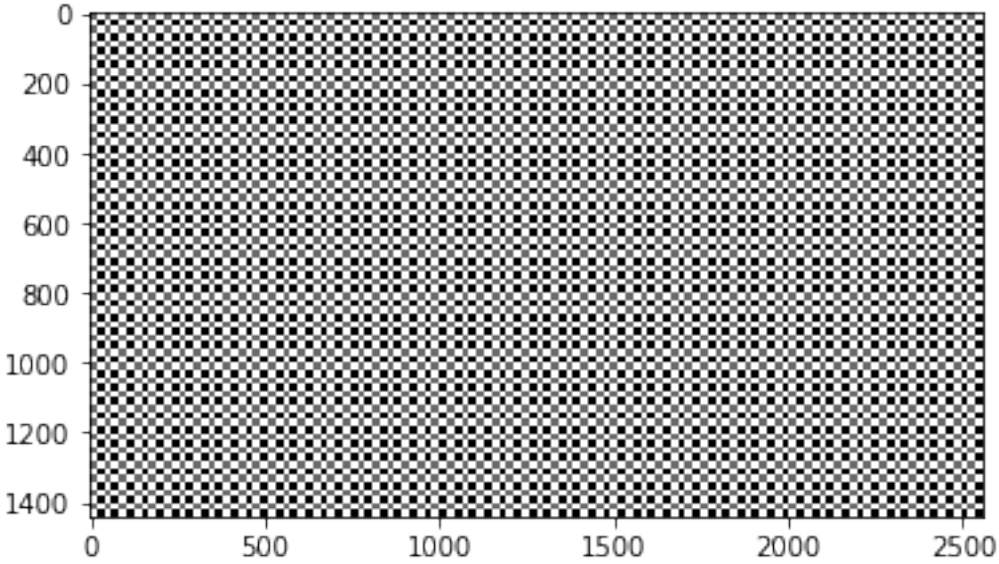


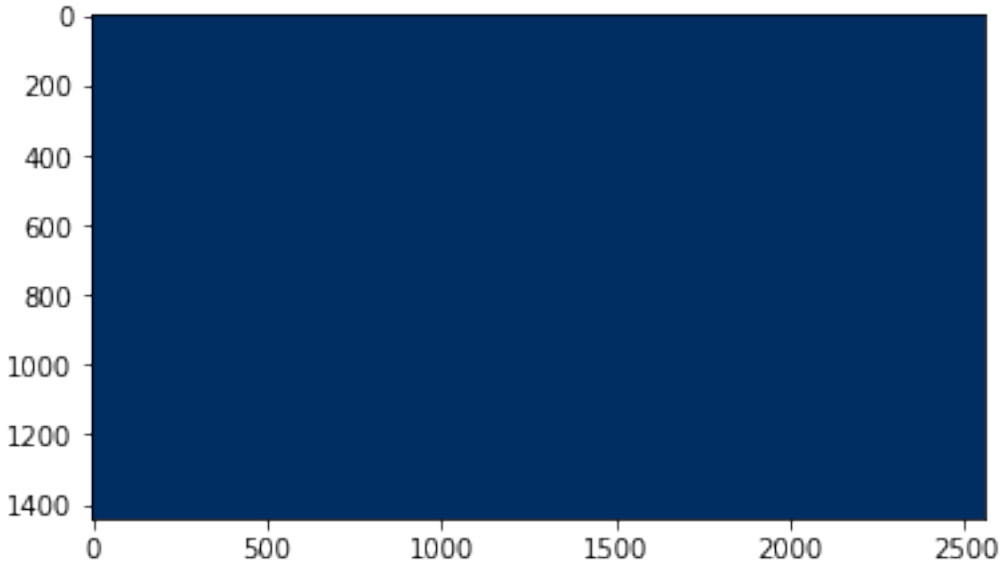

```
The average per-pixel error for tony is: 21.396390647335103
The maximum per-pixel error for tony is: 684
```

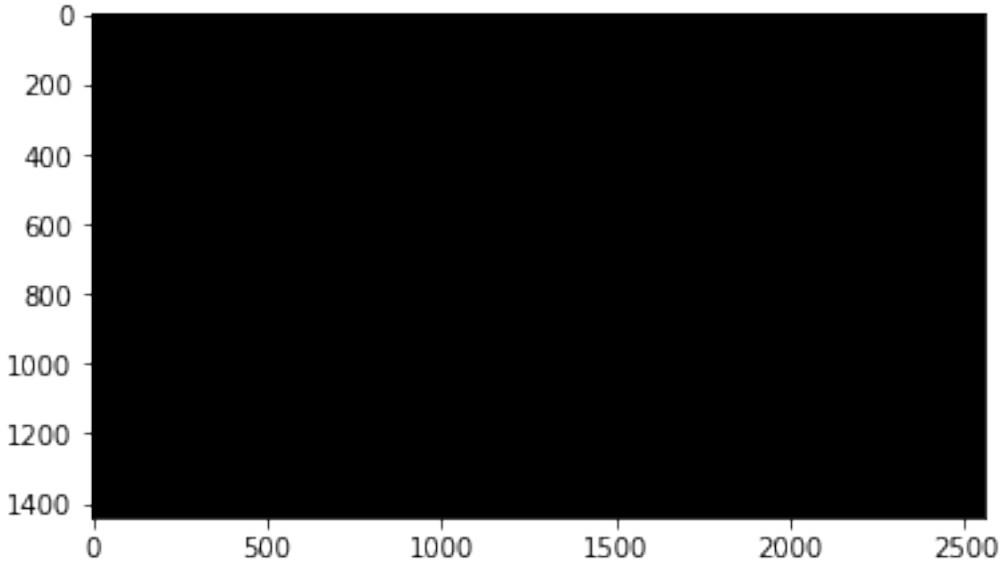
```
Out[121]: True
```

```
In [122]: # 5
          origi_img5 = read_image('img5.jpg')
          mosaic_img5 = get_mosaic_image(origi_img5)
          display(origi_img5)
          gray = rgb2gray(mosaic_img5)
          plt.imshow(gray, cmap = plt.get_cmap('gray'))
          plt.show()
          soln_img5 = get_freeman_solution_image(mosaic_img5)
          display(soln_img5)


          pp_err, max_err, ssd = compute_errors(soln_img5, origi_img5, True)
          print("The average per-pixel error for tony is: "+str(pp_err))
          print("The maximum per-pixel error for tony is: "+str(max_err))

          image_to_write = cv2.cvtColor(soln_img5, cv2.COLOR_RGB2BGR)
          cv2.imwrite('soln_img5.png', image_to_write)
```


0
200
400
600
800
1000
1200
1400
0
500
1000
1500
2000
2500


0
200
400
600
800
1000
1200
1400
0
500
1000
1500
2000
2500






```
The average per-pixel error for tony is: 0.0002300347222222222
The maximum per-pixel error for tony is: 212
```

```
Out[122]: True
```

1.0.6 Bonus Points

```
In [123]: ### YOUR CODE HERE ###
          ### YOU ARE ON YOUR OWN :) ####
```