

Grey and 3 channel separation

April 28, 2019

Grey and 3 channel separation

```
In [4]: import cv2
import numpy as np
import matplotlib.pyplot as plt

In [5]: image = cv2.imread("flower.jpeg", cv2.IMREAD_COLOR)

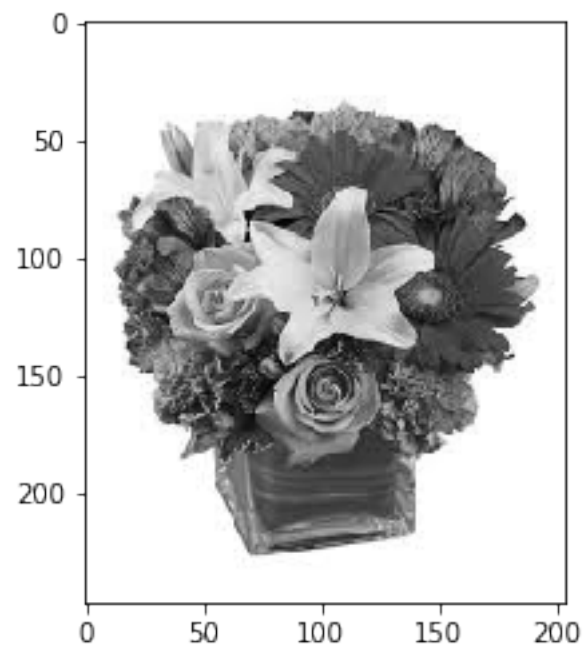
In [6]: image[:, :, 0], image[:, :, 2] = np.array(image[:, :, 2]), np.array(image[:, :, 0])

In [8]: shape = image.shape
gray_image = np.zeros(shape[:2])

In [10]: for i in range(shape[0]):
for j in range(shape[1]):
    red = image[i][j][0]
    green = image[i][j][1]
    blue = image[i][j][2]
    gray_image[i][j] = 0.3 * red + 0.59 * green + 0.11 * blue

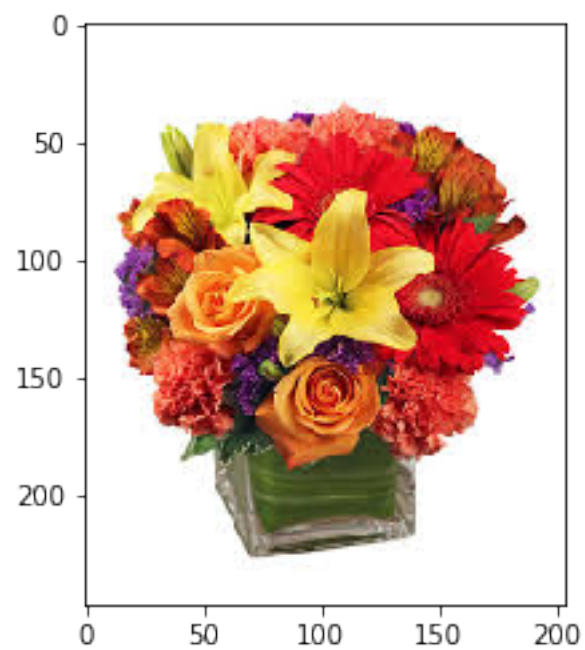
In [11]: plt.imshow(gray_image, cmap='gray')

Out[11]: <matplotlib.image.AxesImage at 0x12a8e3e48>
```



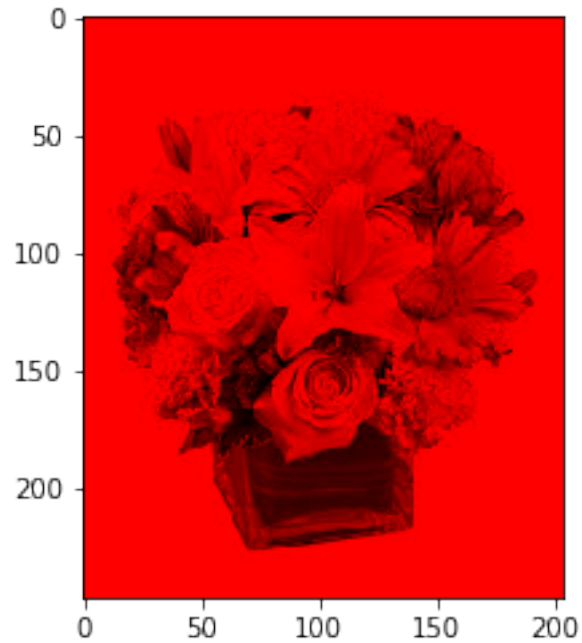
```
In [12]: plt.imshow(image)
```

```
Out[12]: <matplotlib.image.AxesImage at 0x12ab10588>
```



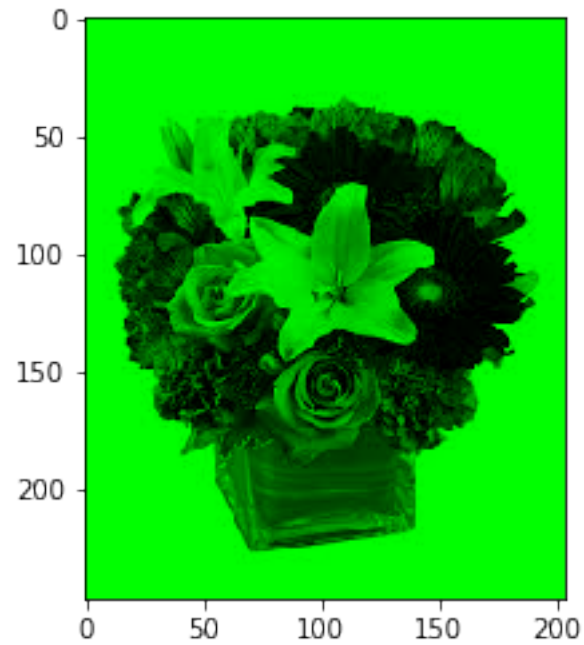
```
In [14]: red_channel = np.array(image)
         red_channel[:, :, 1:3] = 0
         plt.imshow(red_channel)
```

```
Out[14]: <matplotlib.image.AxesImage at 0x12aae2b70>
```



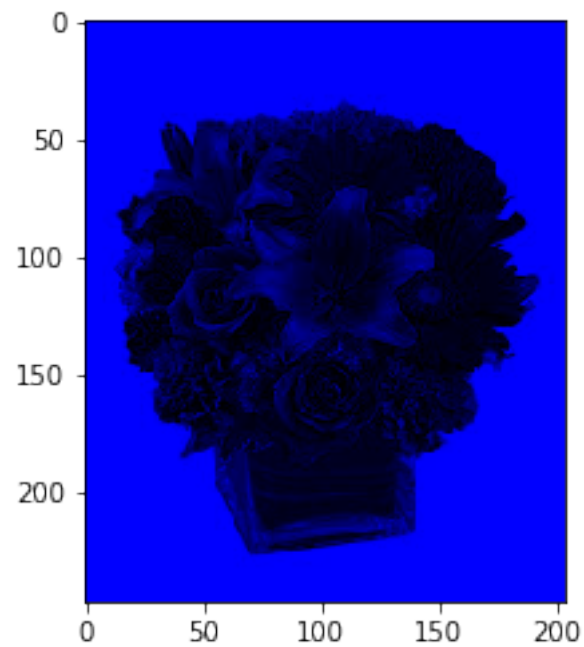
```
In [16]: green_channel = np.array(image)
         green_channel[:, :, 0] = 0
         green_channel[:, :, 2] = 0
         plt.imshow(green_channel)
```

```
Out[16]: <matplotlib.image.AxesImage at 0x12a9992e8>
```



```
In [17]: blue_channel = np.array(image)
         blue_channel[:, :, 0:2] = 0
         plt.imshow(blue_channel)
```

```
Out[17]: <matplotlib.image.AxesImage at 0x12ad253c8>
```



```
In [ ]:
```

Distance Measure

April 28, 2019

```
In [1]: import numpy as np
import cv2
import matplotlib.pyplot as plt
```

```
In [2]: img = cv2.imread('Echoes1.jpg')
img = np.array(img)
img[:, :, 0], img[:, :, 2] = img[:, :, 2], img[:, :, 0].copy()
plt.imshow(img)
```

```
Out[2]: <matplotlib.image.AxesImage at 0x1298e2c88>
```



```
In [6]: print(img[0][0])
```

```
[88 77 57]
```

```
In [1]: class Pixel():
```

```
    def __init__(self,x,y):  
        self.x = x  
        self.y = y
```

```
In [3]: np.power(2,3)
```

```
Out[3]: 8
```

```
In [4]: def euclid(p1,p2):  
    dis = np.sqrt(np.power((p1.x-p2.x),2)+np.power((p1.y-p2.y),2))  
    return dis
```

```
In [5]: def city_block(p1,p2):  
    return np.absolute(p1.x-p2.x)+np.absolute(p1.y-p2.y)
```

```
In [6]: def chessboard(p1,p2):  
    return max(np.absolute(p1.x-p2.x),np.absolute(p1.y-p2.y))
```

```
In [8]: p1 = Pixel(2,10)  
        p2 = Pixel(8,6)
```

```
In [9]: print(euclid(p1,p2))
```

```
7.211102550927978
```

```
In [10]: print(city_block(p1,p2))
```

```
10
```

```
In [11]: print(chessboard(p1,p2))
```

```
6
```

```
In [ ]:
```

steganography

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```
In [1]: # STEGANOGRAPHY.py
import numpy as np
import cv2
import matplotlib.pyplot as plt
```

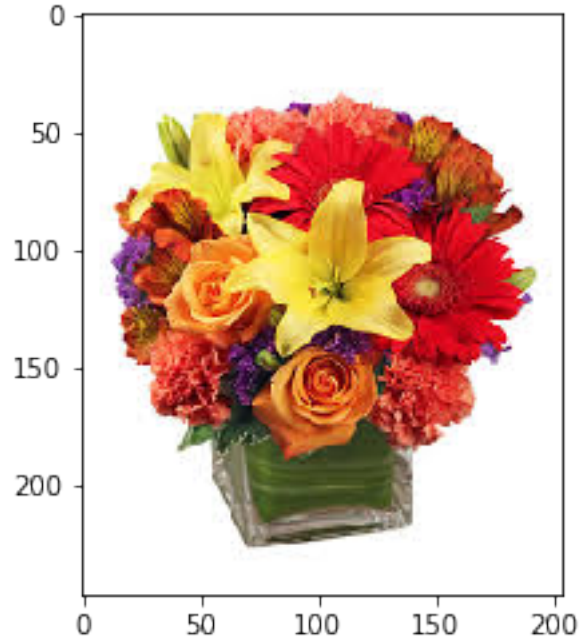
```
In [3]: img = cv2.imread('Echoes1.jpg')
img = np.array(img)
img[:, :, 0], img[:, :, 2] = img[:, :, 2], img[:, :, 0].copy()
plt.imshow(img)
```

```
Out[3]: <matplotlib.image.AxesImage at 0x11eff2048>
```



```
In [4]: img2 = cv2.imread('flower.jpeg')
img2 = np.array(img2)
img2[:, :, 0], img2[:, :, 2] = img2[:, :, 2], img2[:, :, 0].copy()
plt.imshow(img2)
```


Out[4]: <matplotlib.image.AxesImage at 0x129c99ef0>



```
In [5]: print(img.shape)
        print(img2.shape)
```

```
(3000, 4000, 3)
(247, 204, 3)
```

```
In [6]: # function for steganography
        def steganography(img, img2):
            for k in range(3):
                for i in range(img2.shape[0]):
                    col = 0
                    for j in range(img2.shape[1]):
                        c = 0
                        while c != 8:
                            if img[i][col][k] % 2:
                                img[i][col][k] -= 1
                            img[i][col][k] += img2[i][j][k] % 2
                            img2[i][j][k] //= 2
                            col = col + 1
                            c = c + 1
            return img

In [7]: steg = img.copy()
        to_hide = img2.copy()
        steg = steganography(steg, to_hide)
```

```
In [8]: plt.imshow(steg)
```

```
steg2 = steg.copy()
steg2[:, :, 0], steg2[:, :, 2] = steg2[:, :, 2], steg2[:, :, 0].copy()
cv2.imwrite('STEGANOGRAPHY.png', steg2, [0]) # for preserving quality
```

```
Out[8]: True
```



```
In [9]: # function for extracting image
```

```
def extraction(steg, shape):
    ext = np.zeros(shape, dtype = int)
    for k in range(3):
        for i in range(shape[0]):
            for j in range(shape[1] * 8):
                if j % 8 == 0:
                    pro = 1
                else:
                    pro *= 2
                ext[i][j // 8][k] += steg[i][j][k] % 2 * pro
    return ext
```

```
In [10]: steg_img = cv2.imread('STEGANOGRAPHY.png', cv2.IMREAD_COLOR)
steg_img = np.array(steg_img)
steg_img[:, :, 0], steg_img[:, :, 2] = steg_img[:, :, 2], steg_img[:, :, 0].copy()
plt.imshow(steg_img)
```

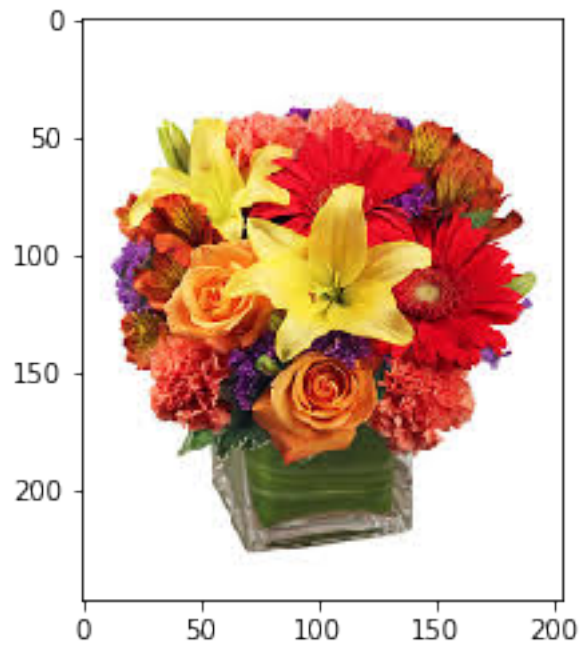
```
Out[10]: <matplotlib.image.AxesImage at 0x12edb4c88>
```



```
In [11]: # Extracting from steganographic image
         extract = extraction(steg_img, img2.shape)
```

```
In [12]: plt.imshow(extract)
```

```
Out[12]: <matplotlib.image.AxesImage at 0x13614ba90>
```



```
In [ ]:
```

Connectivity

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```
In [18]: class pixel:
```

```
    def __init__(self,x,y):
        self.x = x
        self.y = y
```

```
In [23]: def four_way_check(p1,p2):
```

```
    x1,y1 = p1.x,p1.y
    x2,y2 = p2.x,p2.y

    if x2==x1:
        if y2-1==y1:
            return True
        elif y2+1==y2:
            return True
    elif y2==y1:
        if x2-1==x1:
            return True
        elif x2+1==x1:
            return True
    else:
        return False
```

```
In [29]: def four_way(p1):
```

```
    x1,y1 = p1.x,p1.y
    neig_four = [(x1-1,y1),(x1+1,y1),(x1,y1-1),(x1,y1+1)]

    return neig_four
```

```
In [31]: def d_way(p1):
```

```
    x1,y1 = p1.x,p1.y
    neig_d = [(x1-1,y1-1),(x1-1,y1+1),(x1+1,y1-1),(x1+1,y1+1)]
    return neig_d
```

```
In [33]: def eight_way(p1):
```

```
    x1,y1 = p1.x,p1.y
```

```

        eight = [(x1-1,y1-1),(x1-1,y1),(x1-1,y1+1),(x1,y1-1),(x1,y1+1),(x1+1,y1-1),(x1+1,y1+1)]
        return eight

```

```

In [38]: print(four_way(p2))

```

```

[(0, 0), (2, 0), (1, -1), (1, 1)]

```

```

In [39]: print(d_way(p2))

```

```

[(0, -1), (0, 1), (2, -1), (2, 1)]

```

```

In [40]: print(eight_way(p2))

```

```

[(0, -1), (0, 0), (0, 1), (1, -1), (1, 1), (2, -1), (2, 0), (2, 1)]

```

```

In [21]: p1 = pixel(0,0)
        p2 = pixel(1,0)

```

```

        print(four_way(p1))

```

```

True

```

```

In [7]: p3 = pixel(1,1)
        print(four_way(p1,p3))

```

```

False

```

```

In [24]: def d_way_check(p1,p2):

```

```

    x1,y1 = p1.x,p1.y
    x2,y2 = p2.x,p2.y

    if x2-1==x1 and y2-1==y1:
        return True
    elif x2-1==x1 and y2+1==y1:
        return True
    elif x2+1==x1 and y2-1==y1:
        return True
    elif x2+1==x1 and y2+1==y1:
        return True
    else:
        return False

```

```

In [9]: d_way(p1,p2)

```

```
Out[9]: False
```

```
In [10]: d_way(p1,p3)
```

```
Out[10]: True
```

```
In [25]: def eight_way_check(p1,p2):
```

```
    x1,y1 = p1.x,p1.y
```

```
    x2,y2 = p2.x,p2.y
```

```
    eight = [(x1-1,y1-1),(x1-1,y1),(x1-1,y1+1),(x1,y1-1),(x1,y1+1),(x1+1,y1-1),(x1+1,y1+1)]
```

```
    if (x2,y2) in eight:
```

```
        return True
```

```
    else:
```

```
        return False
```

```
In [12]: eight_way(p1,p2)
```

```
Out[12]: True
```

```
In [13]: p4 = pixel(2,3)
```

```
In [14]: eight_way(p1,p4)
```

```
Out[14]: False
```

```
In [26]: def m_way_check(p1,p2):
```

```
    x1,y1 = p1.x,p1.y
```

```
    x2,y2 = p2.x,p2.y
```

```
    eight = [(x1-1,y1-1),(x1-1,y1),(x1-1,y1+1),(x1,y1-1),(x1,y1+1),(x1+1,y1-1),(x1+1,y1+1)]
```

```
    if (x2,y2) in eight:
```

```
        return True
```

```
    else:
```

```
        return False
```

```
In [16]: m_way(p1,p2)
```

```
Out[16]: True
```

```
In [17]: m_way(p1,p4)
```

```
Out[17]: False
```

```
In [ ]:
```

Connected Components

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```
In [2]: import cv2
import numpy as np
import matplotlib.pyplot as plt

In [3]: shp = (25,25)
img = np.floor(np.random.random(shp) + 0.5)

In [4]: def four_way(out, i, j, color, label):

    if i < 0 or i >= shp[0]:
        return
    if j < 0 or j >= shp[1]:
        return
    if vis[i][j] or img[i][j]==1:
        return

    vis[i][j] = True
    out[i][j] = color
    labels[i][j] = label
    four_way(out, i - 1, j, color, label)
    four_way(out, i + 1, j, color, label)
    four_way(out, i, j - 1, color, label)
    four_way(out, i, j + 1, color, label)

In [5]: def eight_way(out, i, j, color, label):
    if i < 0 or i >= shp[0]:
        return
    if j < 0 or j >= shp[1]:
        return
    if vis[i][j] or img[i][j] == 1:
        return

    vis[i][j] = True
    out[i][j] = color
    labels[i][j] = label

    eight_way(out, i - 1, j, color, label)
    eight_way(out, i + 1, j, color, label)
```



```

eight_way(out, i, j - 1, color,label)
eight_way(out, i, j + 1, color,label)
eight_way(out, i - 1, j - 1, color,label)
eight_way(out, i - 1, j + 1, color,label)
eight_way(out, i + 1, j - 1, color,label)
eight_way(out, i + 1, j + 1, color,label)

```

In [6]: `def m_conn(x1,y1,x2,y2):`

```

four_way_n_p1 = {}
four_way_n_p1[(x1-1,y1-1)] = img[x1-1][y1-1]
four_way_n_p1[(x1-1,y1)] = img[x1-1][y1]
four_way_n_p1[(x1,y1-1)] = img[x1][y1-1]
four_way_n_p1[(x1,y1)] = img[x1][y1]

n_p2 = [(x2-1,y2-1),(x2-1,y2),(x2,y2-1),(x2,y2)]

for cord in n_p2:
    if cord in four_way_n_p1.keys():
        if img[cord[0]][cord[1]] == 1:
            return False

return True

```

In [7]: `def m_way(out, i, j, color,label):`

```

if i<0 or i>= shp[0]:
    return
if j<0 or j>= shp[1]:
    return
if vis[i][j] or img[i][j] == 1:
    return

vis[i][j] = True
out[i][j] = color
labels[i][j] = label

m_way(out, i - 1, j, color,label)
m_way(out, i + 1, j, color,label)
m_way(out, i, j - 1, color,label)
m_way(out, i, j + 1, color,label)

if m_conn(i,j,i-1,j-1):
    m_way(out, i - 1, j - 1, color,label)
elif m_conn(i,j,i-1,j+1):
    m_way(out, i - 1, j + 1, color,label)
elif m_conn(i,j,i+1,j-1):
    m_way(out, i + 1, j - 1, color,label)
elif m_conn(i,j,i+1,j+1):
    m_way(out, i + 1, j + 1, color,label)

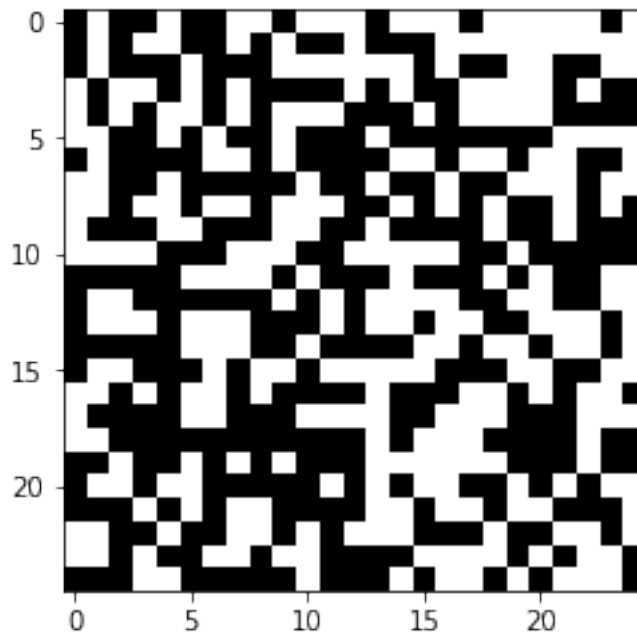
```

```
In [8]: def plot(out):
        fig, ax = plt.subplots(figsize=(20,10))

        ax.imshow(out)
        for i in range(shp[0]):
            for j in range(shp[1]):
                c = labels[j][i]
                ax.text(i, j, str(c), va='center', ha='center')
```

```
In [9]: fig = plt.figure(100)
        fig.canvas.set_window_title('Main')
        plt.imshow(img, cmap="Greys")
```

```
Out[9]: <matplotlib.image.AxesImage at 0x1254fed30>
```



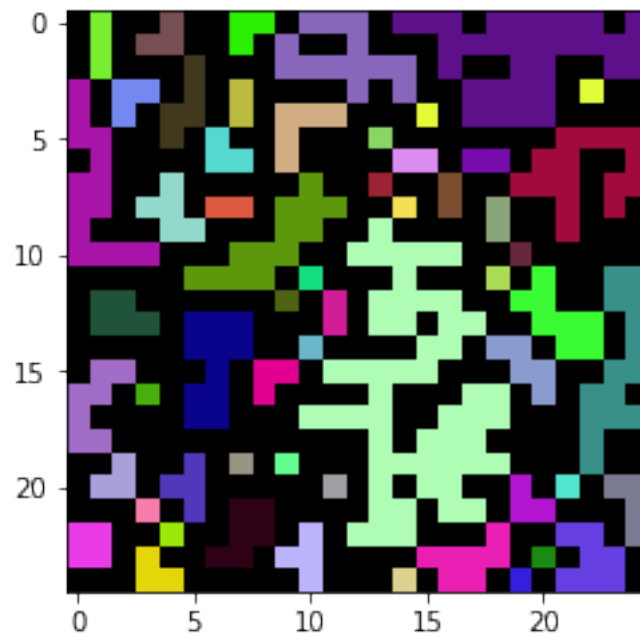
```
In [10]: vis = np.zeros(shp,dtype=bool)
        out = np.zeros(shp + (3, ), dtype=int)
        labels = np.zeros(shp,dtype=int)
        label=1
        for i in range(shp[0]):
            for j in range(shp[1]):
                if vis[i][j] or img[i][j]==1:
                    continue

                color = np.random.randint(0, 255, 3)
                four_way(out, i, j, color,label)
```

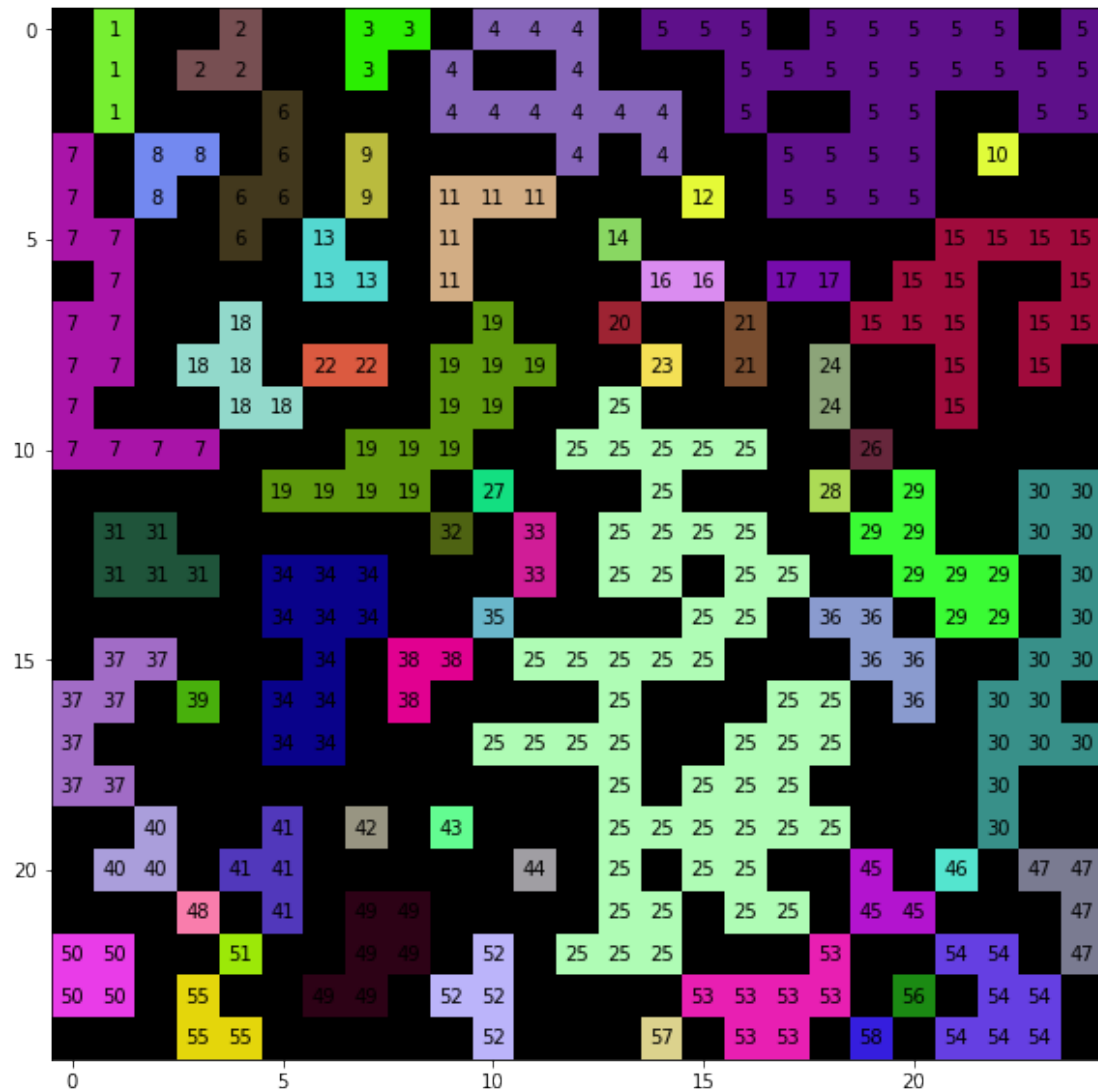
```
label+=1
```

```
fig = plt.figure(200)  
fig.canvas.set_window_title('4-Way')  
plt.imshow(out)
```

```
Out[10]: <matplotlib.image.AxesImage at 0x12566d748>
```



```
In [11]: plot(out)
```



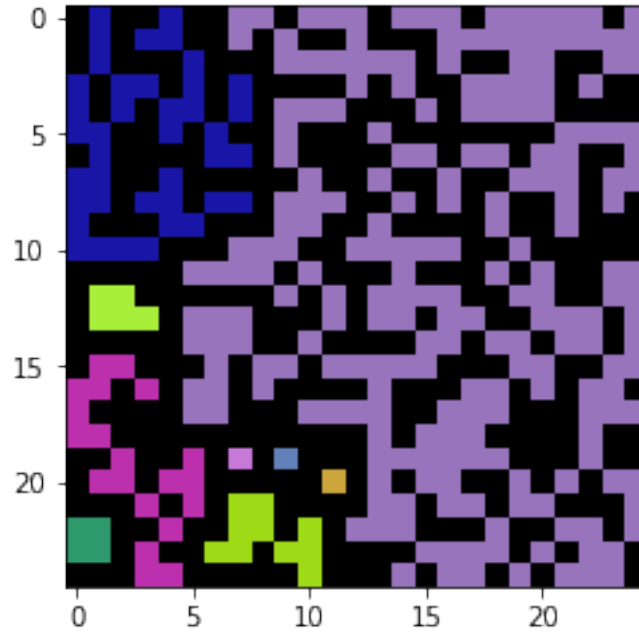
```
In [12]: vis = np.zeros(shp, dtype=bool)
out = np.zeros(shp + (3, ), dtype=int)
label=1
for i in range(shp[0]):
    for j in range(shp[1]):

        if vis[i][j] or img[i][j]==1:
            continue
        color = np.random.randint(0,255,3)
        eight_way(out, i, j, color,label)
        label+=1

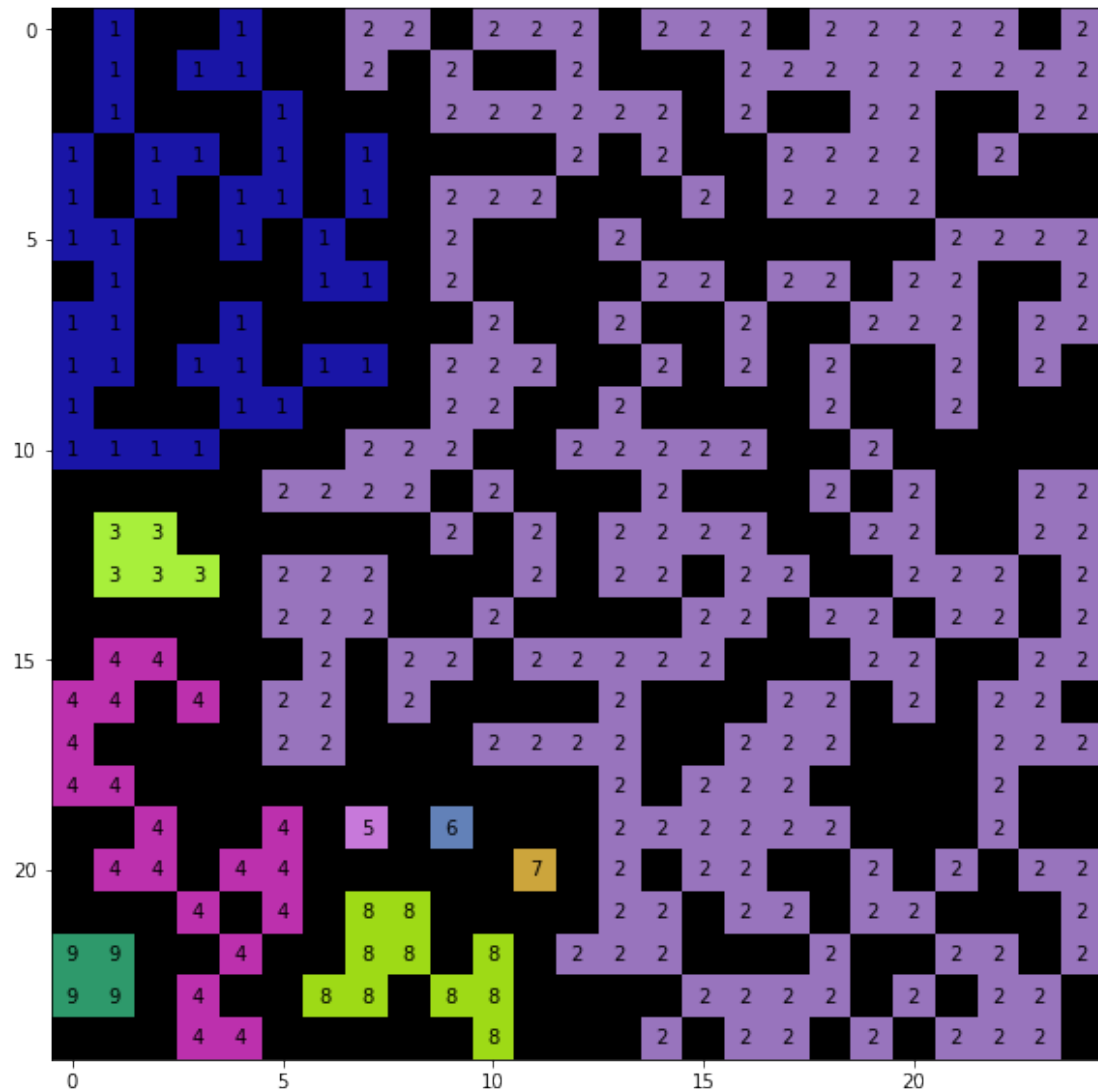
fig = plt.figure(300)
```

```
fig.canvas.set_window_title('8-Way')  
plt.imshow(out)
```

Out[12]: <matplotlib.image.AxesImage at 0x125f7dd30>



In [13]: plot(out)

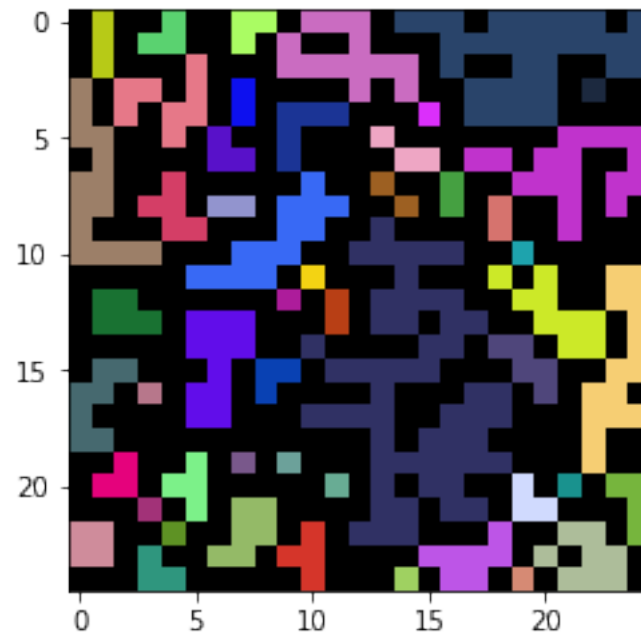


```
In [14]: vis = np.zeros(shp, dtype=bool)
out = np.zeros(shp + (3, ), dtype=int)
label=1
for i in range(shp[0]):
    for j in range(shp[1]):
        if vis[i][j] or img[i][j]==1:
            continue

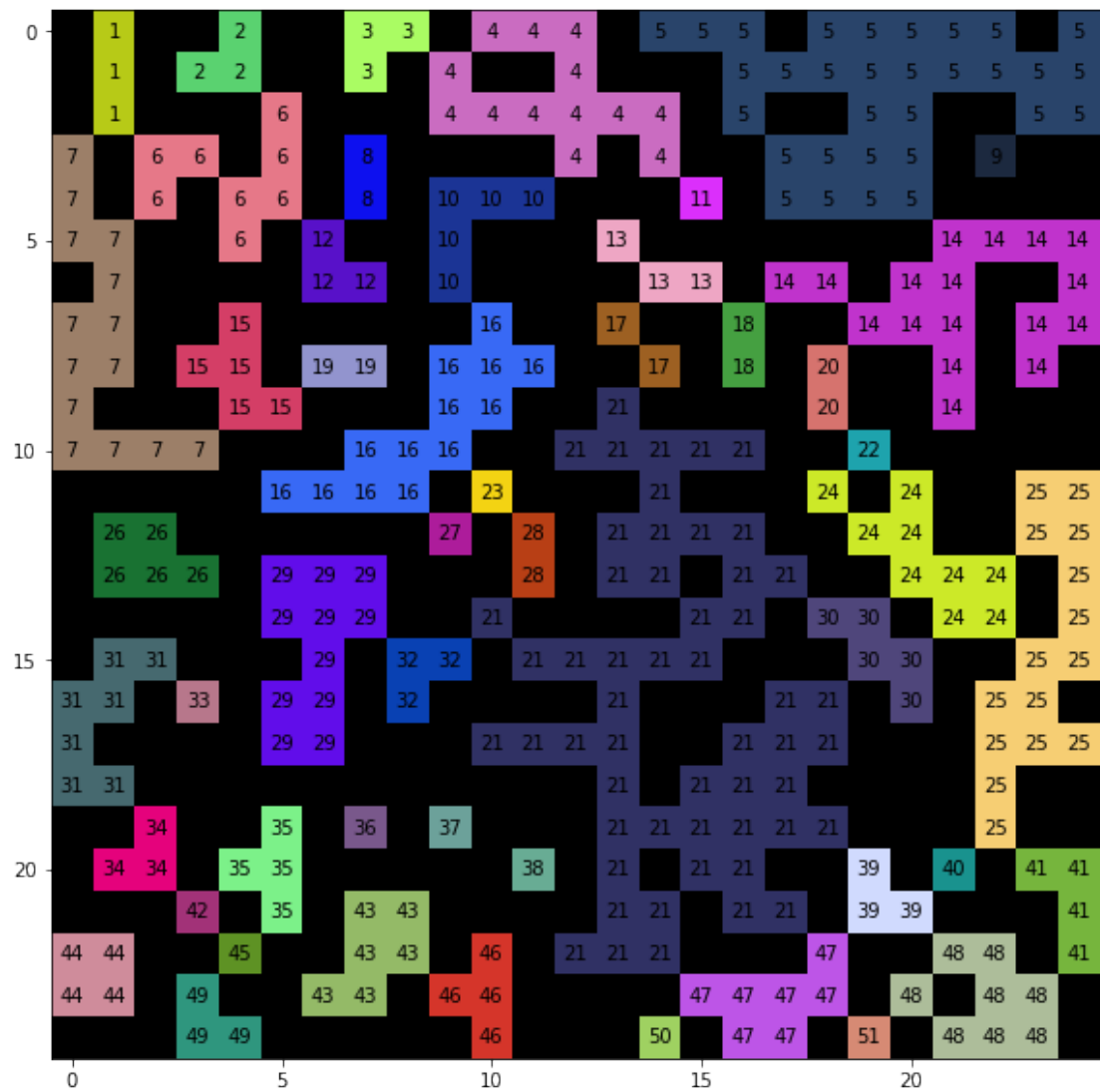
        color = np.random.randint(0, 255, 3)
        m_way(out, i, j, color,label)
        label+=1

fig = plt.figure(400)
```

```
fig.canvas.set_window_title('m-Way')  
plt.imshow(out)  
plt.show()
```



```
In [15]: plot(out)
```



In []:

Component Labelling

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```
In [1]: import cv2
import numpy as np
import matplotlib.pyplot as plt

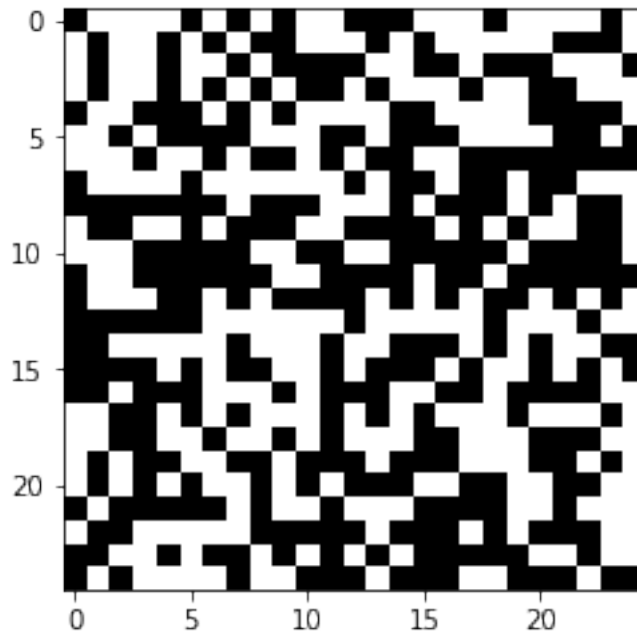
In [2]: shp = (25,25)
img = np.floor(np.random.random(shp) + 0.5)

In [3]: def plot(out):
    fig, ax = plt.subplots(figsize=(20,10))

    ax.imshow(out)
    for i in range(shp[0]):
        for j in range(shp[1]):
            c = out[j,i]
            ax.text(i, j, str(c), va='center', ha='center')

In [4]: fig = plt.figure(100)
fig.canvas.set_window_title('Main')
plt.imshow(img, cmap="Greys")

Out[4]: <matplotlib.image.AxesImage at 0x1195c2828>
```



```
In [5]: def first_pass(img):
```

```
    label=1
```

```
    for i in range(shp[0]):
        for j in range(shp[1]):
            if img[i][j]==1:
                continue
            if i==0 and j==0:
                out[i][j] = label
                if label not in parents:
                    parents[label]=label
                label+=1
            elif i==0:
                if out[i][j-1]==0:
                    out[i][j] = label
                    if label not in parents:
                        parents[label]=label
                    label+=1
                else:
                    out[i][j] = out[i][j-1]
            elif j==0:
                if out[i-1][j-1]==0:
                    out[i][j] = label
```

```

        if label not in parents:
            parents[label]=label
            label+=1
    else:
        out[i][j] = out[i-1][j]
else:
    if out[i-1][j]==0 and out[i][j-1]==0:
        out[i][j] = label
        if label not in parents:
            parents[label]=label
            label+=1
    elif out[i-1][j]==0:
        out[i][j] = out[i][j-1]
    elif out[i][j-1]==0:
        out[i][j] = out[i-1][j]
    else:
        out[i][j] = min(out[i-1][j],out[i][j-1])
        parent1 = parents[out[i-1][j]]
        current1 = out[i-1][j]
        while parent1!=current1:
            current1 = parent1
            parent1=parents[current1]

        parent2 = parents[out[i][j-1]]
        current2 = out[i][j-1]
        while parent2!=current2:
            current2 = parent2
            parent2=parents[current2]

        parents[out[i-1][j]] = min(parent1,parent2)
        parents[out[i][j-1]] = min(parent1,parent2)

```

In [6]: def second_pass(out):

```

    for i in range(shp[0]):
        for j in range(shp[1]):
            if out[i][j]==0:
                continue
            else:
                if parents[out[i][j]]==out[i][j]:
                    continue
                else:
                    parent = parents[out[i][j]]
                    current = out[i][j]
                    while parent!=current:
                        current = parent
                        parent=parents[current]
                    parents[out[i][j]] = parent

```

```
out[i][j] = parent
```

```
In [7]: def replace(out):
```

```
    for i in range(shp[0]):
        for j in range(shp[1]):
            if out[i][j]==0:
                continue
            out[i][j] = final_components[out[i][j]]
```

```
In [8]: def final_list_gen(parents):
```

```
    for key,value in parents.items():
        if key==value:
            final_list.append(key)
        else:
            continue
```

```
In [9]: def final_components_gen(final_list):
```

```
    for i in range(1,len(final_list)+1):
        final_components[final_list[i-1]] = i
```

```
In [10]: parents = {
```

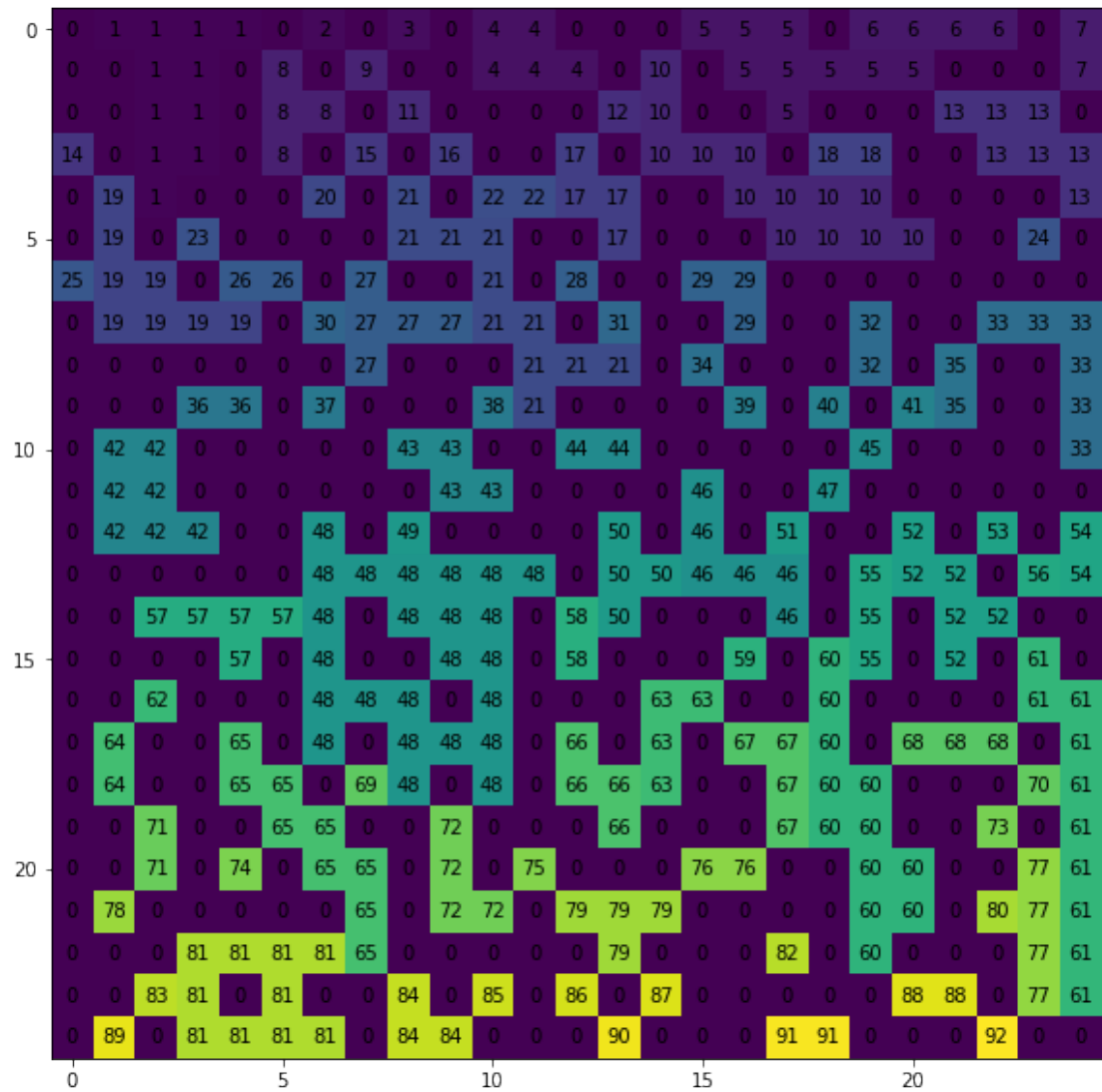
```
    1:1
```

```
}
```

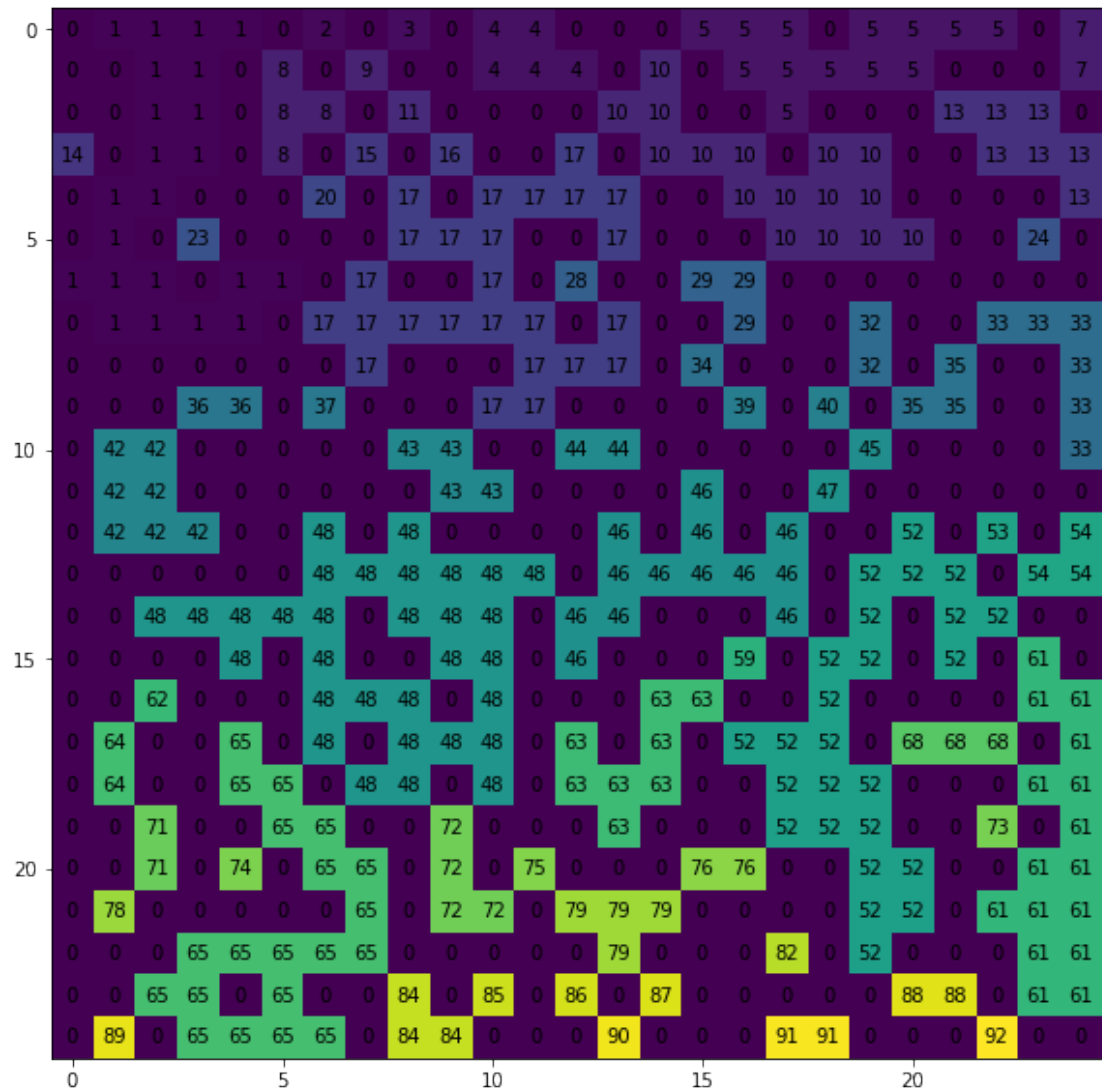
```
    out = np.zeros(shp,dtype=int)
```

```
In [11]: first_pass(img)
```

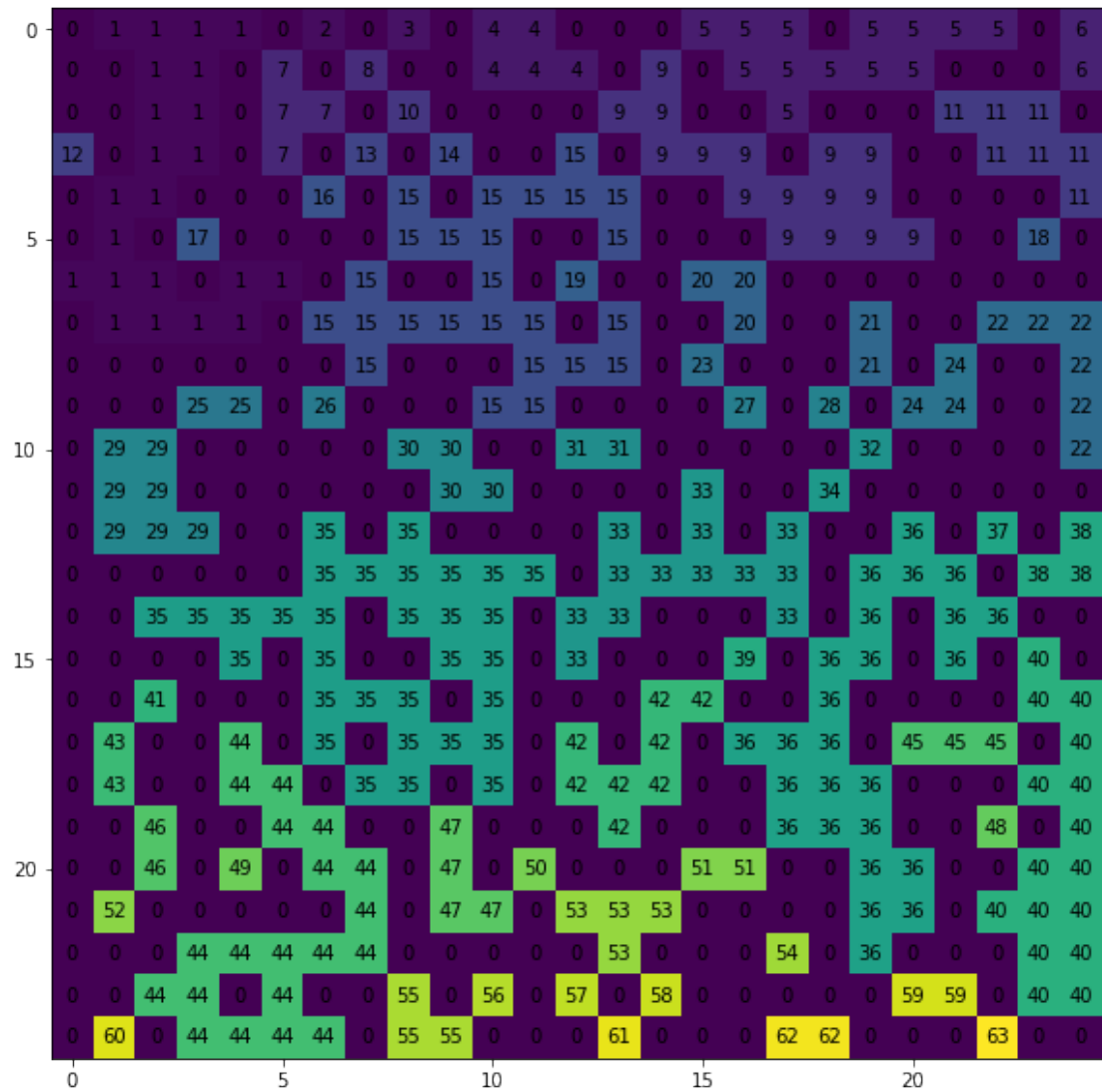
```
    plot(out)
```



```
In [12]: second_pass(out)
         plot(out)
```



```
In [13]: final_list = []
         final_list_gen(parents)
         final_components = {}
         final_components_gen(final_list)
         replace(out)
         plot(out)
```



In [14]: parents

Out[14]: {1: 1,
2: 2,
3: 3,
4: 4,
5: 5,
6: 5,
7: 7,
8: 8,
9: 9,
10: 10,
11: 11,

12: 10,
13: 13,
14: 14,
15: 15,
16: 16,
17: 17,
18: 10,
19: 1,
20: 20,
21: 17,
22: 17,
23: 23,
24: 24,
25: 1,
26: 1,
27: 17,
28: 28,
29: 29,
30: 17,
31: 17,
32: 32,
33: 33,
34: 34,
35: 35,
36: 36,
37: 37,
38: 17,
39: 39,
40: 40,
41: 35,
42: 42,
43: 43,
44: 44,
45: 45,
46: 46,
47: 47,
48: 48,
49: 48,
50: 46,
51: 46,
52: 52,
53: 53,
54: 54,
55: 52,
56: 54,
57: 48,
58: 46,
59: 59,


```
60: 52,  
61: 61,  
62: 62,  
63: 63,  
64: 64,  
65: 65,  
66: 63,  
67: 52,  
68: 68,  
69: 48,  
70: 61,  
71: 71,  
72: 72,  
73: 73,  
74: 74,  
75: 75,  
76: 76,  
77: 61,  
78: 78,  
79: 79,  
80: 61,  
81: 65,  
82: 82,  
83: 65,  
84: 84,  
85: 85,  
86: 86,  
87: 87,  
88: 88,  
89: 89,  
90: 90,  
91: 91,  
92: 92}
```

```
In [15]: final_components
```

```
Out[15]: {1: 1,  
2: 2,  
3: 3,  
4: 4,  
5: 5,  
7: 6,  
8: 7,  
9: 8,  
10: 9,  
11: 10,  
13: 11,  
14: 12,
```

15: 13,
16: 14,
17: 15,
20: 16,
23: 17,
24: 18,
28: 19,
29: 20,
32: 21,
33: 22,
34: 23,
35: 24,
36: 25,
37: 26,
39: 27,
40: 28,
42: 29,
43: 30,
44: 31,
45: 32,
46: 33,
47: 34,
48: 35,
52: 36,
53: 37,
54: 38,
59: 39,
61: 40,
62: 41,
63: 42,
64: 43,
65: 44,
68: 45,
71: 46,
72: 47,
73: 48,
74: 49,
75: 50,
76: 51,
78: 52,
79: 53,
82: 54,
84: 55,
85: 56,
86: 57,
87: 58,
88: 59,
89: 60,

```
90: 61,  
91: 62,  
92: 63}
```

```
In [16]: print("Number of components:", len(final_components.keys()))
```

```
Number of components: 63
```

```
In [17]: size = {}
```

```
def find_size(out):  
    for i in range(shp[0]):  
        for j in range(shp[1]):  
            if out[i][j]==0:  
                continue  
            value = out[i][j]  
            if value not in size.keys():  
                size[value] = 1  
            else:  
                size[value]+=1
```

```
In [18]: find_size(out)  
size
```

```
Out[18]: {1: 22,  
2: 1,  
3: 1,  
4: 5,  
5: 13,  
6: 2,  
7: 4,  
8: 1,  
9: 16,  
10: 1,  
11: 7,  
12: 1,  
13: 1,  
14: 1,  
15: 25,  
16: 1,  
17: 1,  
18: 1,  
19: 1,  
20: 3,  
21: 2,  
22: 6,  
23: 1,  
24: 3,
```

```
25: 2,  
26: 1,  
27: 1,  
28: 1,  
29: 7,  
30: 4,  
31: 2,  
32: 1,  
33: 13,  
34: 1,  
35: 31,  
36: 25,  
37: 1,  
38: 3,  
39: 1,  
40: 16,  
41: 1,  
42: 8,  
43: 2,  
44: 20,  
45: 3,  
46: 2,  
47: 4,  
48: 1,  
49: 1,  
50: 1,  
51: 2,  
52: 1,  
53: 4,  
54: 1,  
55: 3,  
56: 1,  
57: 1,  
58: 1,  
59: 2,  
60: 1,  
61: 1,  
62: 2,  
63: 1}
```

```
In [ ]:
```

Zoom

April 28, 2019

```
In [1]: import cv2
import numpy as np

In [2]: img=cv2.imread('landscape.jpg',1)
out=np.zeros((img.shape[0]*2,img.shape[1]*2,img.shape[2]))
out2=np.zeros((img.shape[0]*2,img.shape[1]*2,img.shape[2]))

In [4]: shp=img.shape
shp

Out[4]: (290, 590, 3)

In [8]: img[4]

Out[8]: 200

In [9]: for i in range(shp[0]):
out[2*i,:shp[1]]=np.copy(img[i,:])

In [ ]:

In [ ]: for i in range(shp[0]):
out[2*i,:shp[1]]=np.copy(img[i,:])

for j in range(shp[1]):
out2[:,2*j]=np.copy(out[:,j])

out=np.copy(out2)

for i in range(img.shape[0]-1):
out[2*i+1,:]=out[2*i,:]/2+out[2*i+2,:]/2

for j in range(img.shape[1]-1):
out[:,2*j+1]=out[:,2*j]/2+out[:,2*j+2]/2

out[-1,:]=out[-2,:]
out[:,-1]=out[:,-2]

out=np.array(out, dtype = np.uint8)
```

```
cv2.imshow('image', img)
cv2.imshow('zoomed', out)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Shrink

April 28, 2019

```
In [ ]: import cv2
import numpy as np

img=cv2.imread('cat.jpeg',0)
out=np.copy(img)

i=1

while i<out.shape[0]:
    out=np.delete(out,(i),axis=0)
    i=i+1
j=1

while j<out.shape[1]:
    out=np.delete(out,(j),axis=1)
    j=j+1

out=np.array(out, dtype = np.uint8)
print(img.shape)
print(out.shape)
cv2.imshow('image', img)
cv2.imshow('shrunked', out)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

```
In [ ]:
```

Contrast

April 28, 2019

```
In [ ]: import cv2
import numpy as np

img=cv2.imread('flower1.jpg',0)
int_min=np.amin(img)
int_max=np.amax(img)
x1=int_min
y1=0
x2=int_max
y2=255
m=float(y2-y1)/float(x2-x1)
out=img*m
out=out-(x1*m)

out=np.array(out, dtype = np.uint8)
print(img)
print(out)
cv2.imshow('image', img)
cv2.imshow('contrast expanded', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

[[126 126 126 ... 128 128 128]
 [126 126 126 ... 128 128 128]
 [126 126 127 ... 128 129 129]
 ...
 [135 135 134 ... 114 114 113]
 [133 134 133 ... 114 113 113]
 [134 136 134 ... 114 113 113]]
[[122 122 122 ... 124 124 124]
 [122 122 122 ... 124 124 124]
 [122 122 123 ... 124 125 125]
 ...
 [131 131 130 ... 110 110 108]
 [129 130 129 ... 110 108 108]
 [130 132 130 ... 110 108 108]]
```

```
In [ ]:
```


Invert

April 28, 2019

```
In [2]: import cv2
import numpy as np

def invertor(value):
    return 255-value

img=cv2.imread('cat.jpeg',0)
out=np.zeros(img.shape)
for i in range(img.shape[0]):
    for j in range(img.shape[1]):
        out[i,j]=invertor(img[i,j])

out=np.array(out, dtype = np.uint8)

cv2.imshow('image', img)
cv2.imshow('inverted', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

In [ ]:
```

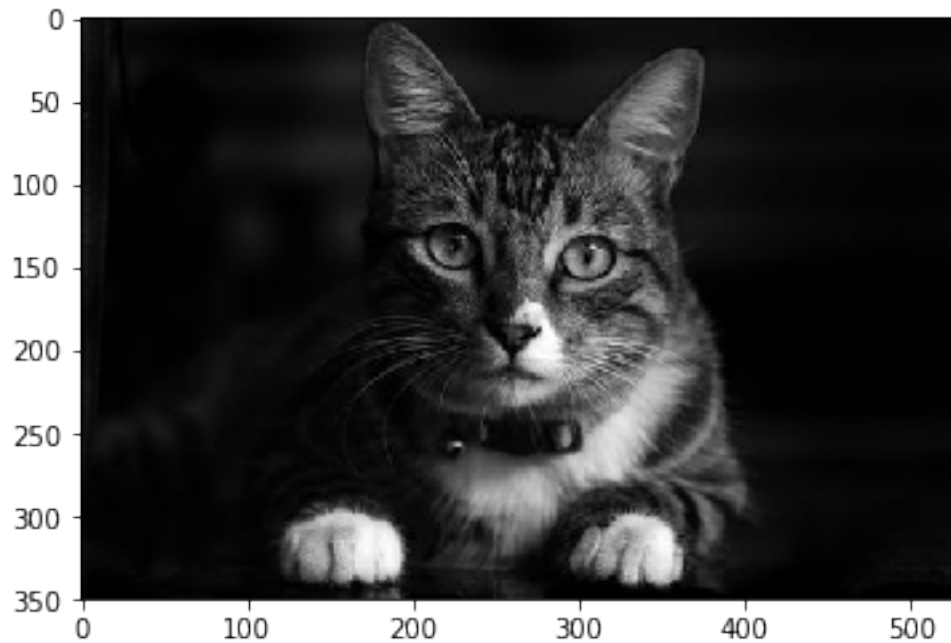
Low pass filter

April 28, 2019

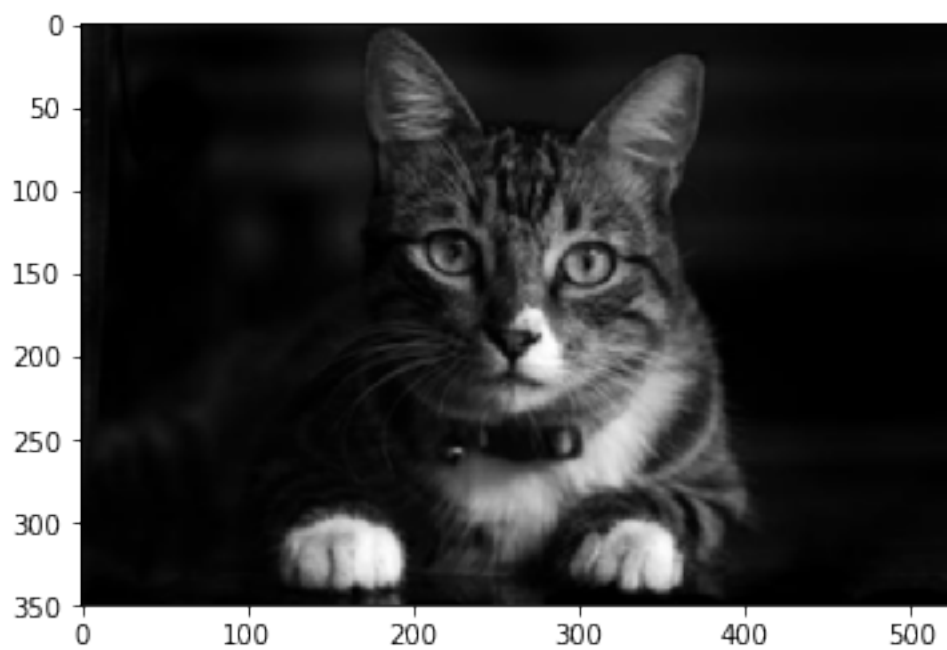
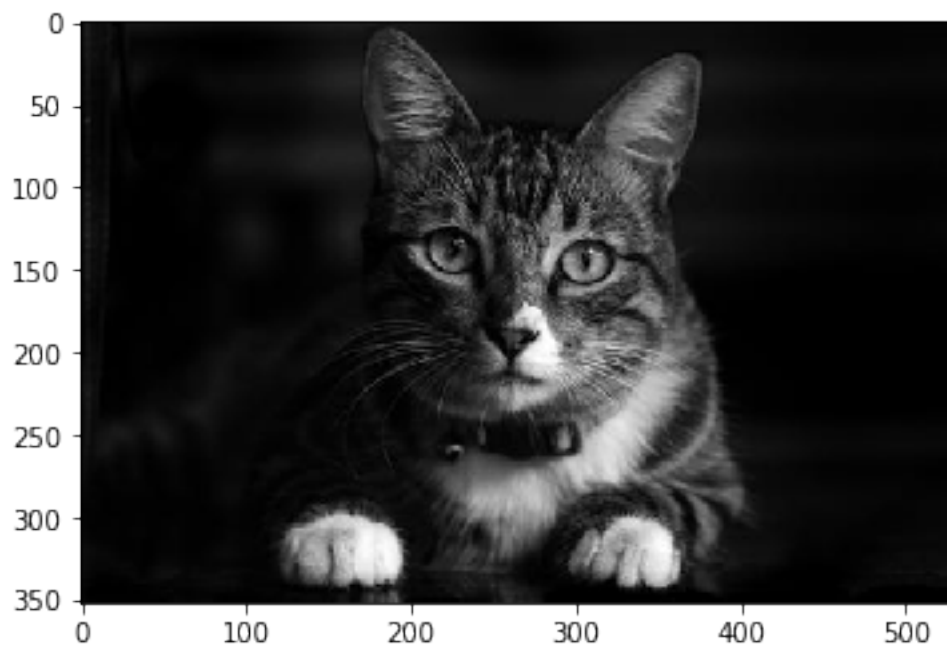
```
In [1]: import cv2
import numpy as np
import matplotlib.pyplot as plt

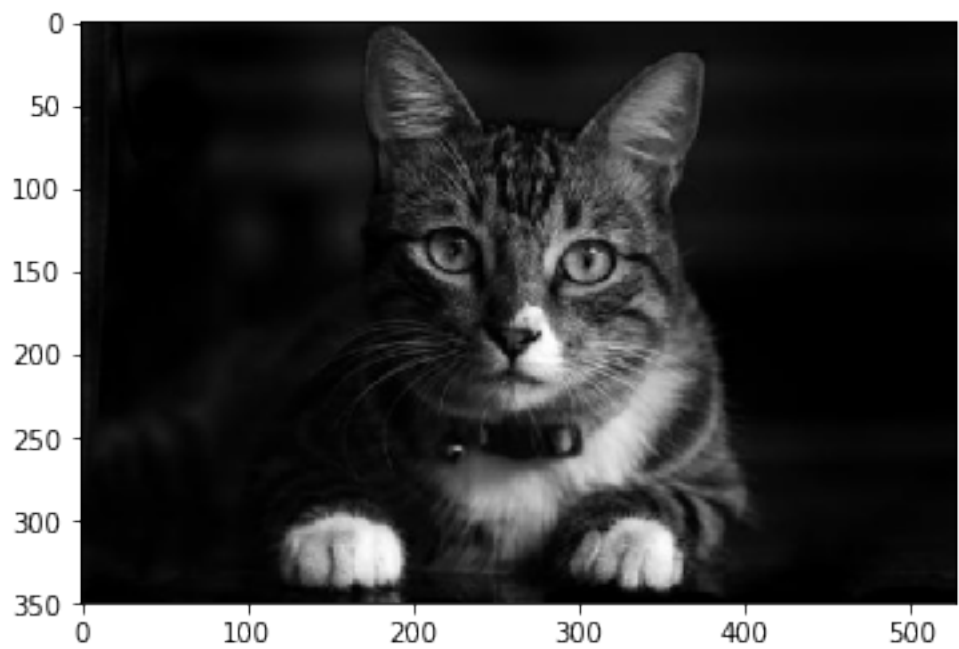
In [2]: def pad(img,shp):
    p=np.zeros((shp[0]+2,shp[1]+2))
    p[1:-1,1:-1]=np.copy(img)
    p[0,1:-1],p[-1,1:-1]=img[0],img[-1]
    p[1:-1,0],p[1:-1,-1]=img[:,0],img[:,-1]
    p[0,0],p[0,-1]=img[0,0],img[0,-1]
    p[-1,0],p[-1,-1]=img[-1,0],img[-1,-1]
    return p

In [22]: img=cv2.imread('cat.jpeg',0)
shp=img.shape
shpm=(3,3)
mask=np.full(shpm,1/9)
mask2=np.array([[0,1/8,0],[1/8,1/2,1/8],[0,1/8,0]])
p=pad(img,shp)
out=np.zeros((shp))
out2 = np.zeros((shp))
plt.imshow(img,cmap='gray')
plt.show()
```



```
In [26]: for i in range(shp[0]):
          for j in range(shp[1]):
              out[i,j]=np.floor(np.multiply(p[i:i+shpm[0],j:j+shpm[1]],mask).sum())
              out2[i,j]=np.floor(np.multiply(p[i:i+shpm[0],j:j+shpm[1]],mask2).sum())
          out=out.astype(int)
          out=np.array(out, dtype = np.uint8)
          out2=out2.astype(int)
          out2=np.array(out2,dtype = np.uint8)
          plt.imshow(p,cmap='gray')
          plt.show()
          plt.imshow(out,'gray')
          plt.show()
          plt.imshow(out2,'gray')
          plt.show()
```





In []:

Masking

April 28, 2019

```
In [2]: import cv2
import numpy as np
import matplotlib.pyplot as plt

def pad(img, shp):
    p=np.zeros((shp[0]+2,shp[1]+2))
    p[1:-1,1:-1]=np.copy(img)
    p[0,1:-1],p[-1,1:-1]=img[0],img[-1]
    p[1:-1,0],p[1:-1,-1]=img[:,0],img[:,-1]
    p[0,0],p[0,-1]=img[0,0],img[0,-1]
    p[-1,0],p[-1,-1]=img[-1,0],img[-1,-1]
    return p

shp=(25,25)
img = np.floor(np.random.random(shp)*255)

shpm=(3,3)
mask=np.full(shpm,1)
p=pad(img,shp)
out=np.zeros((shp))

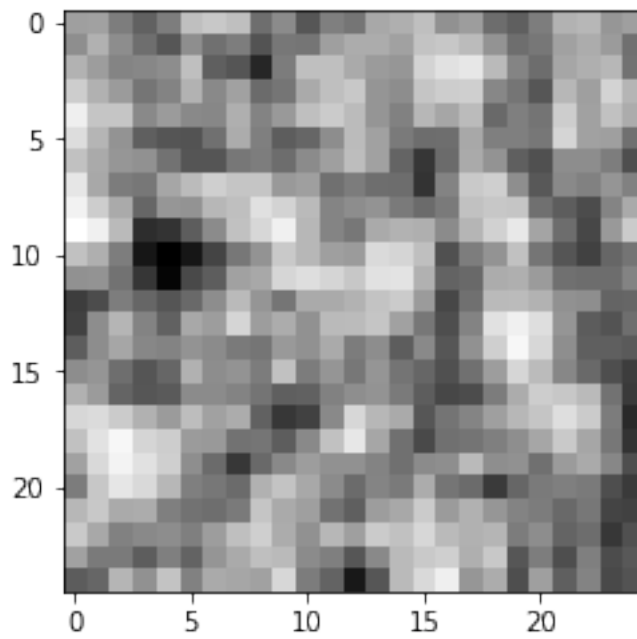
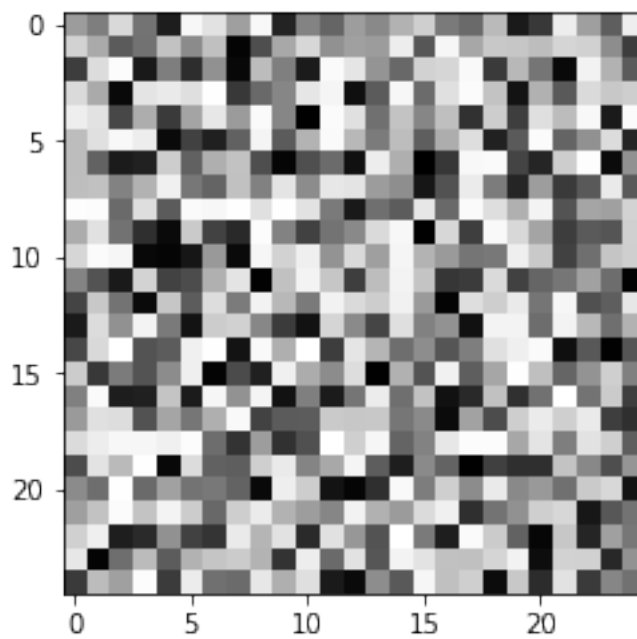
for i in range(shp[0]):
    for j in range(shp[1]):
        temp=np.multiply(p[i:i+shpm[0],j:j+shpm[1]],mask)
        temp2=temp.sum()
        out[i,j]=temp2

out=out/9
out=out.astype(int)
fig = plt.figure(100)
fig.canvas.set_window_title('Original image')
plt.imshow(img, cmap="Greys")

fig = plt.figure(200)
fig.canvas.set_window_title('Masked')
```

```
plt.imshow(out, cmap="Greys")
```

```
plt.show()
```



```
In [3]:
```

```
Out[3]: '3.4.4'
```

```
In [ ]:
```


Gaussian Filter

April 28, 2019

```
In [ ]: import numpy as np
import cv2
from matplotlib import pyplot as plt

In [ ]: def pad(img,shp,l):
    p=np.zeros((shp[0]+2*l,shp[1]+2*l))
    p[l:-l,l:-l]=np.copy(img)
    for j in range(l):
        p[l:-l,j]=p[l:-l,l]
        p[l:-l,-j-1]=p[l:-l,-l-1]

    for i in range(l):
        p[i]=p[l]
        p[-i-1]=p[-l-1]

    return p

In [ ]: def gauss(Z,var):
    N=int(Z/2)
    fil=np.zeros((Z,Z))
    for x in range(1,N+1):    #for non zero
        for y in range(x,N+1):
            ex=np.exp(-float(x*x+y*y)/(2*var))
            print(ex)
            fil[N-x,N-y]=ex
            fil[N+x,N-y]=ex
            fil[N-x,N+y]=ex
            fil[N+x,N+y]=ex
            if x!=y:
                fil[N-y,N-x]=ex
                fil[N+y,N-x]=ex
                fil[N-y,N+x]=ex
                fil[N+y,N+x]=ex
    for x in range(1,N+1):    #for zero elements
        ex=np.exp(-float(x*x)/(2*var))
        fil[N-x,N]=ex
        fil[N+x,N]=ex
        fil[N,N-x]=ex
```

```

        fil[N,N+x]=ex
    fil[N,N]=1
    print(fil)
    c=float(1)/float(fil[Z-1,Z-1])
    print(c)
    fil=np.round(fil*c).astype(int)
    return fil

In [ ]: N=int(input("Enter size of Gaussian Filter (odd number only): "))
var=int(input("Enter the variance of Gaussian Filter: "))
fil=gauss(N,var)
print(fil)
coeff=np.sum(fil)
print(coeff)
img=cv2.imread('cat.jpeg',0)
shp=img.shape
shpm=(N,N)
mask=fil
p=pad(img,shp,shpm[1])

out=np.zeros((shp))

for i in range(shp[0]):
    for j in range(shp[1]):
        temp=np.multiply(p[i:i+shpm[0],j:j+shpm[1]],mask)
        temp2=temp.sum()
        out[i,j]=np.floor(temp2)

out=out/coeff

out=np.array(out, dtype = np.uint8)

cv2.imshow('image', img)
cv2.imshow('masked', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

```

In []:

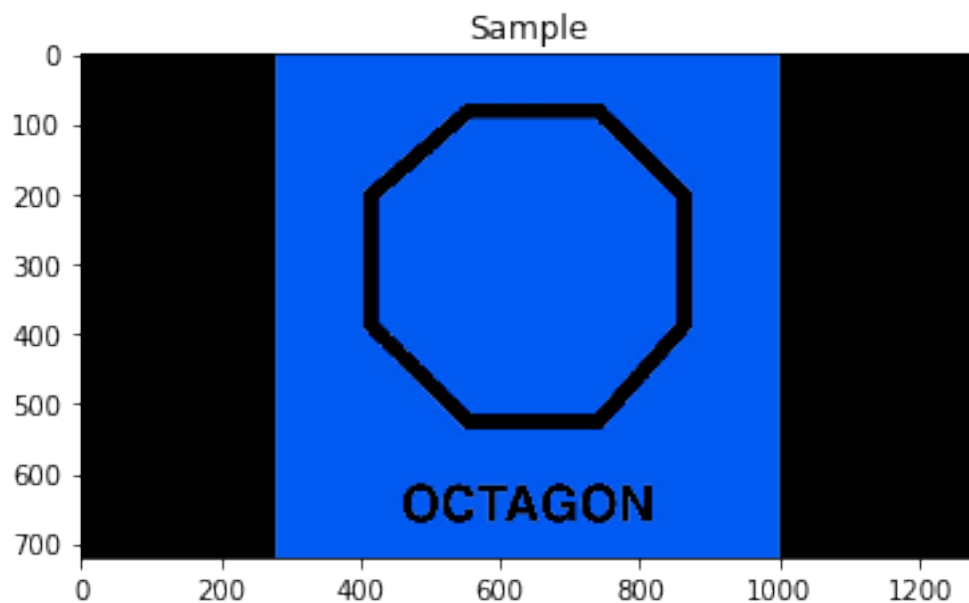
Edge Detection

April 28, 2019

0.0.1 Edge Detection

```
In [1]: import cv2
import numpy as np
from matplotlib import pyplot as plt
```

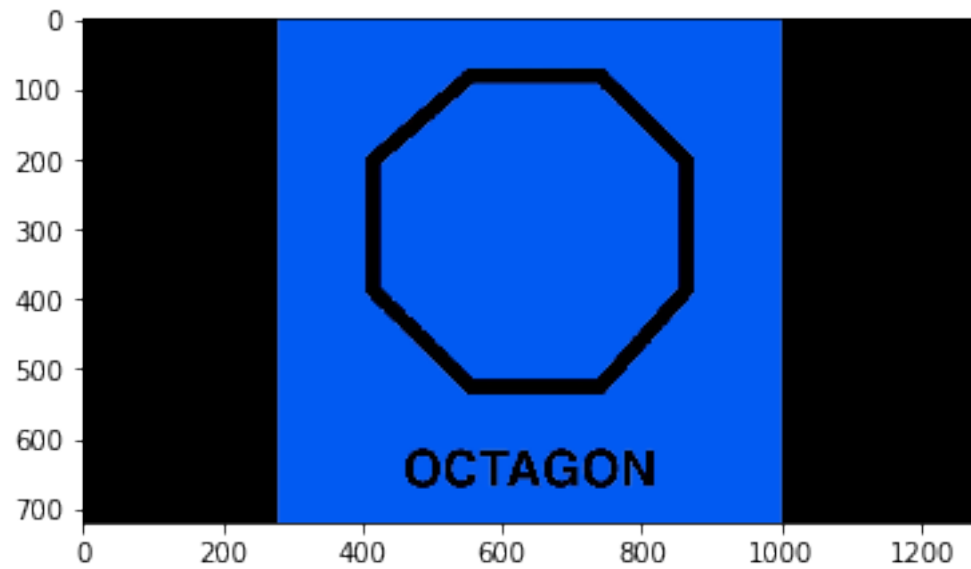
```
In [2]: img = cv2.imread('sample5.jpg')
plt.imshow(img)
plt.title('Sample')
plt.show()
```



```
In [3]: blur = cv2.fastNlMeansDenoisingColored(img, None, 10, 10, 7, 21)
```

```
In [4]: plt.imshow(blur, cmap='gray')
```

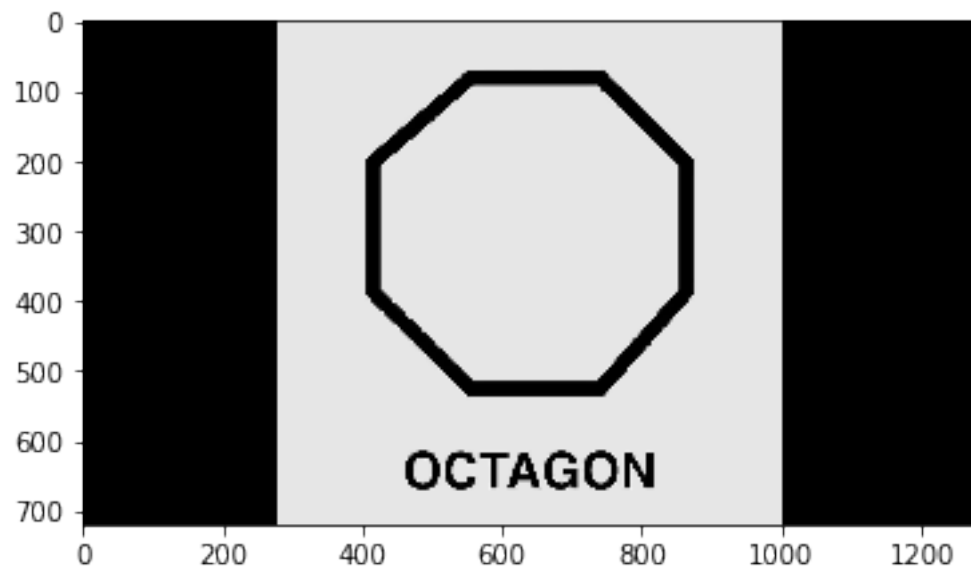
```
Out[4]: <matplotlib.image.AxesImage at 0x11a1daf28>
```



```
In [5]: gray = cv2.cvtColor(blur, cv2.COLOR_BGR2GRAY)
```

```
In [6]: plt.imshow(gray, cmap='gray')
```

```
Out[6]: <matplotlib.image.AxesImage at 0x1bf20e80>
```



```
In [7]: print(gray.shape)
```

(720, 1280)

```
In [8]: def pad(img,shp):
        p=np.zeros((shp[0]+2,shp[1]+2))
        p[1:-1,1:-1]=np.copy(img)
        p[0,1:-1],p[-1,1:-1]=img[0],img[-1]
        p[1:-1,0],p[1:-1,-1]=img[:,0],img[:,-1]
        p[0,0],p[0,-1]=img[0,0],img[0,-1]
        p[-1,0],p[-1,-1]=img[-1,0],img[-1,-1]
        return p

In [9]: def sobel_filter(img):
        sabel_x = np.array([[ -1,0,1],[ -2,0,2],[ -1,0,1]])
        sabel_y = np.array([[ -1,-2,-1],[ 0,0,0],[ 1,2,1]])
        shp = img.shape
        shpm=(3,3)
        padded_img=pad(img,shp)
        grad_matrix=np.zeros(shp)
        out=np.zeros(shp)
        exp = np.zeros(shp)
        for i in range(shp[0]):
            for j in range(shp[1]):
                g_x=np.multiply(padded_img[i:i+shpm[0],j:j+shpm[1]],sabel_x).sum()
                g_y=np.multiply(padded_img[i:i+shpm[0],j:j+shpm[1]],sabel_y).sum()
                if g_y!=0 or g_x!=0:
                    if g_x==0:
                        rad=np.arctan2(g_y,g_x)
                    else:
                        rad=np.arctan2(g_y,g_x)
                    deg=rad*(180/np.pi)
                    rad_rev = deg*(np.pi/180)
                    #print(rad*(180/np.pi),end=" ")
                    #print(rad_rev)
                    grad_matrix[i][j]=deg
                    if grad_matrix[i][j]<0:
                        exp[i][j] = grad_matrix[i][j]
                    out[i][j] = np.sqrt(np.square(g_x)+np.square(g_y))
                else:
                    out[i,j]=255
                    grad_matrix[i][j]=255
        out=np.array(out, dtype = np.uint8)
        grad_matrix=np.array(grad_matrix,dtype= np.uint8)

        return out,grad_matrix,exp

In [10]: def prewitt_filter(img):
        prewitt_x = np.array([[ -1,0,1],[ -1,0,1],[ -1,0,1]])
```

```

prewitt_y = np.array([[1,1,1],[0,0,0],[-1,-1,-1]])
shp = img.shape
shpm=(3,3)
padded_img=pad(img,shp)
grad_matrix=np.zeros(shp)
out=np.zeros(shp)
exp = np.zeros(shp)
for i in range(shp[0]):
    for j in range(shp[1]):
        g_x=np.multiply(padded_img[i:i+shpm[0],j:j+shpm[1]],prewitt_x).sum()
        g_y=np.multiply(padded_img[i:i+shpm[0],j:j+shpm[1]],prewitt_y).sum()
        if g_y!=0 or g_x!=0:
            if g_x==0:
                rad=np.arctan2(g_y,g_x)
            else:
                rad=np.arctan2(g_y,g_x)
            deg=rad*(180/np.pi)
            rad_rev = deg*(np.pi/180)
            #print(rad*(180/np.pi),end=" ")
            #print(rad_rev)
            grad_matrix[i][j]=deg
            if grad_matrix[i][j]<0:
                exp[i][j] = grad_matrix[i][j]
                print(exp[i][j])
            out[i][j] = np.sqrt(np.square(g_x)+np.square(g_y))
        else:
            out[i,j]=255
            grad_matrix[i][j]=255
out=np.array(out, dtype = np.uint8)

return out,grad_matrix,exp

```

In [11]: output, grad_matrix,exp = sobel_filter(gray)

In []:

In [12]: plt.imshow(exp,cmap='gray')

Out[12]: <matplotlib.image.AxesImage at 0x11c227dd8>

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

-90.0
-90.0
-90.0
-90.0
-90.0
-90.0
-90.0
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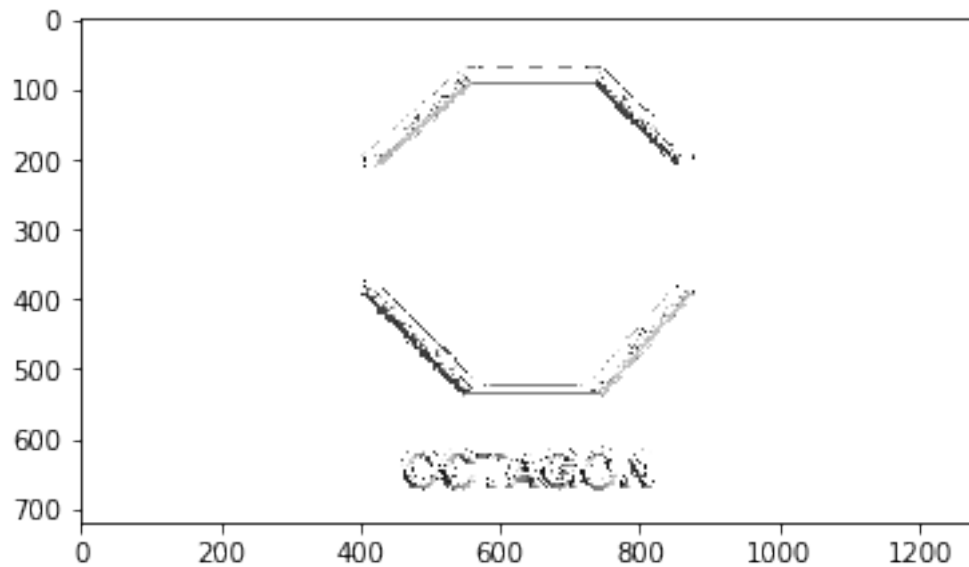
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```
In [14]: plt.imshow(exp2,cmap='gray')
```

```
Out[14]: <matplotlib.image.AxesImage at 0x11e0be828>
```



```
In [15]: output
```

```
Out[15]: array([[255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                ...,
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255]], dtype=uint8)
```

```
In [16]: output2
```

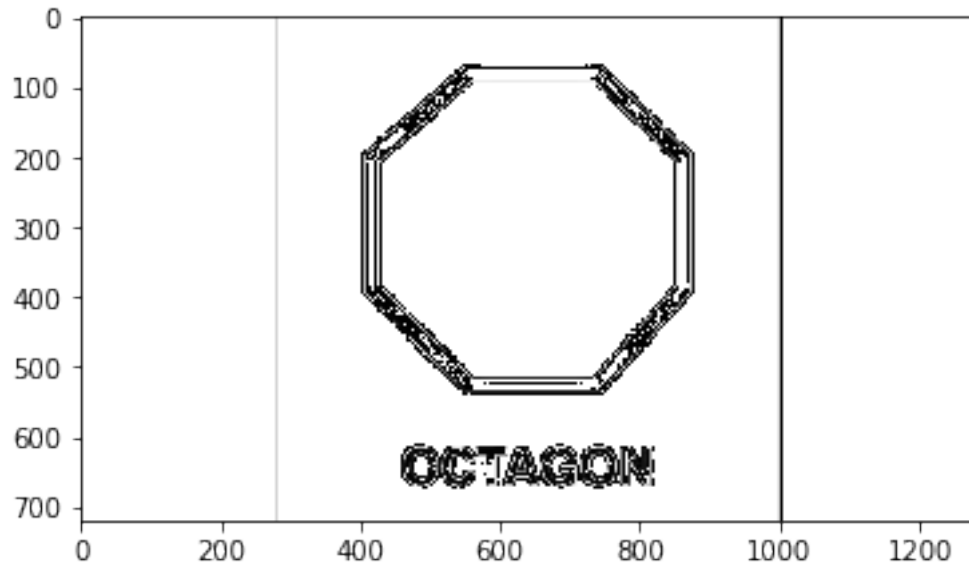
```
Out[16]: array([[255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                ...,
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255],
                [255, 255, 255, ..., 255, 255, 255]], dtype=uint8)
```

```
In [17]: grad_matrix.shape[0]
```

```
Out[17]: 720
```

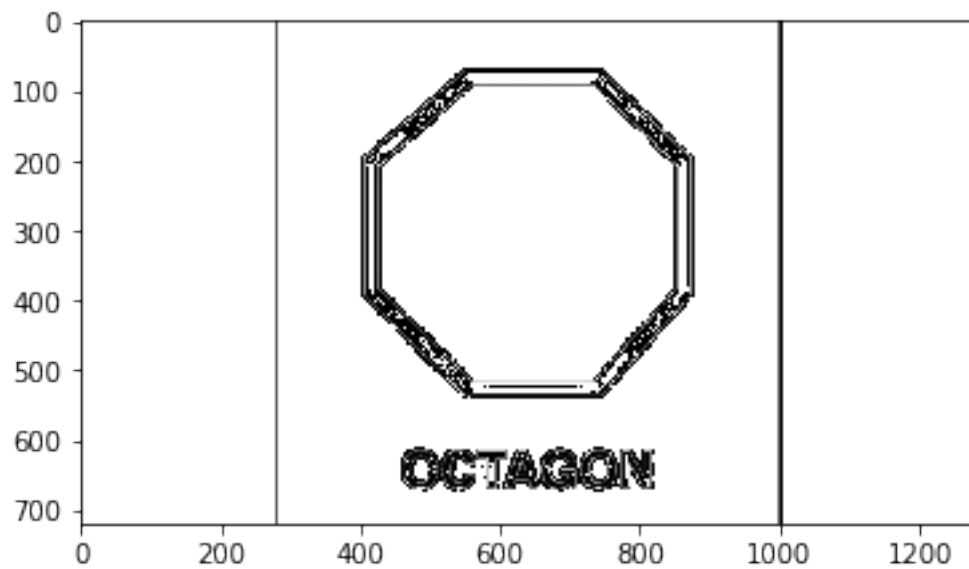
```
In [18]: plt.imshow(output, cmap='gray')
```

```
Out[18]: <matplotlib.image.AxesImage at 0x11b1843c8>
```



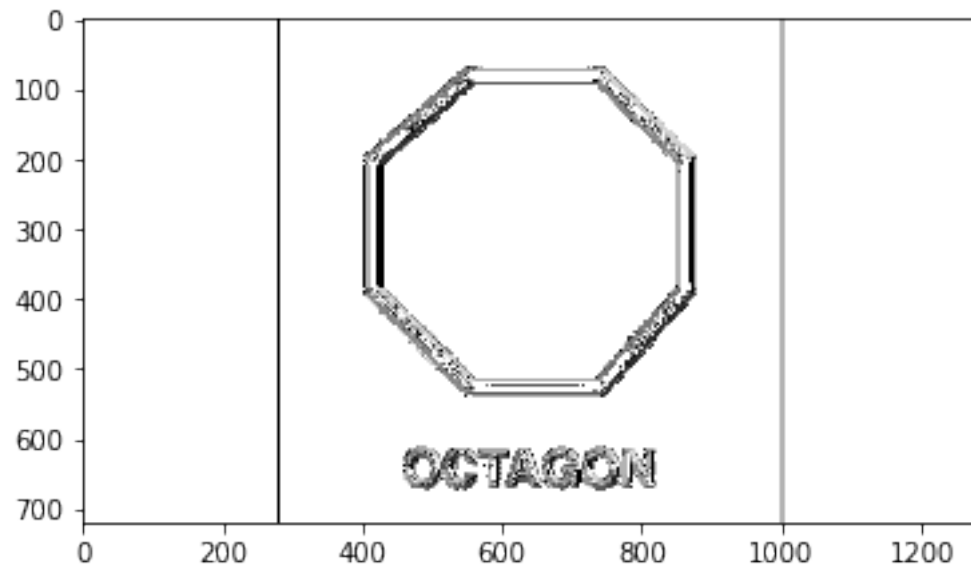
```
In [19]: plt.imshow(output2, cmap='gray')
```

```
Out[19]: <matplotlib.image.AxesImage at 0x11b576860>
```



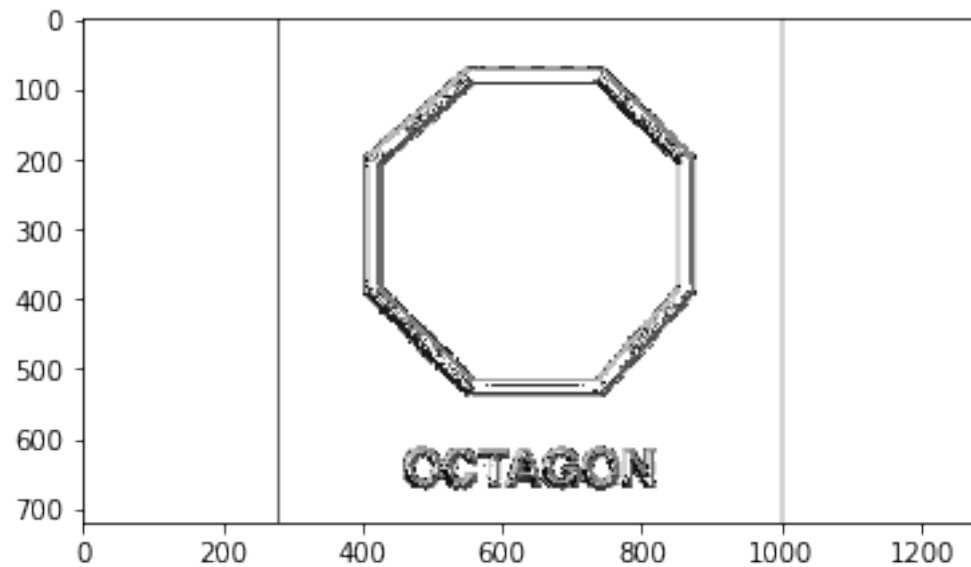
```
In [20]: plt.imshow(grad_matrix,cmap='gray')
```

```
Out[20]: <matplotlib.image.AxesImage at 0x118fd1d68>
```



```
In [21]: plt.imshow(grad_matrix2,cmap='gray')
```

```
Out[21]: <matplotlib.image.AxesImage at 0x11b303898>
```



```
In [22]: def threshold(grad_matrix, angle_min, angle_max):

    output = np.zeros(grad_matrix.shape)
    for i in range(grad_matrix.shape[0]):
        for j in range(grad_matrix.shape[1]):

            if grad_matrix[i][j] <= angle_max and grad_matrix[i][j] >= angle_min:
                output[i][j] = 255
                print(grad_matrix[i][j])
            else:
                output[i][j] = 0
    return output
```

```
In [23]: filtered = threshold(grad_matrix,30,60)
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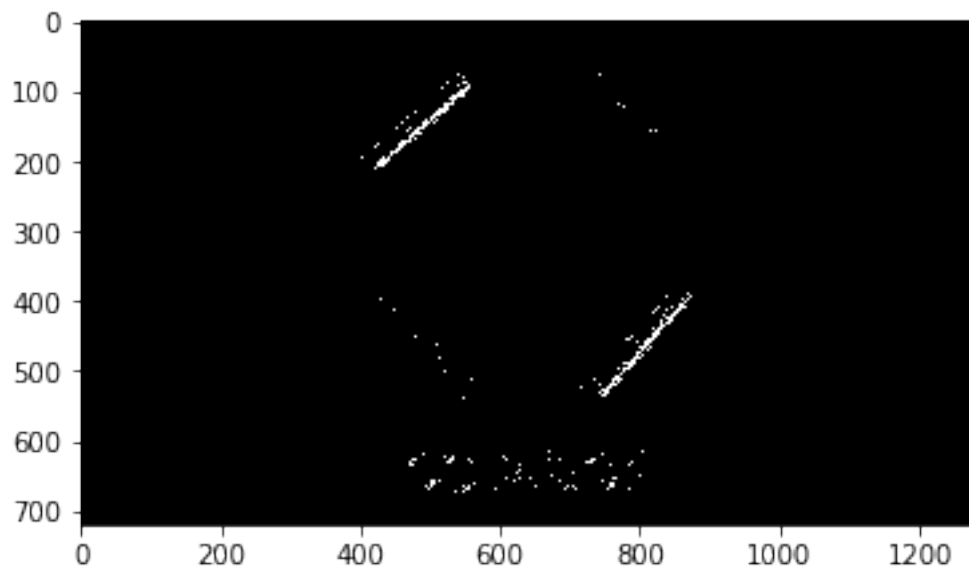
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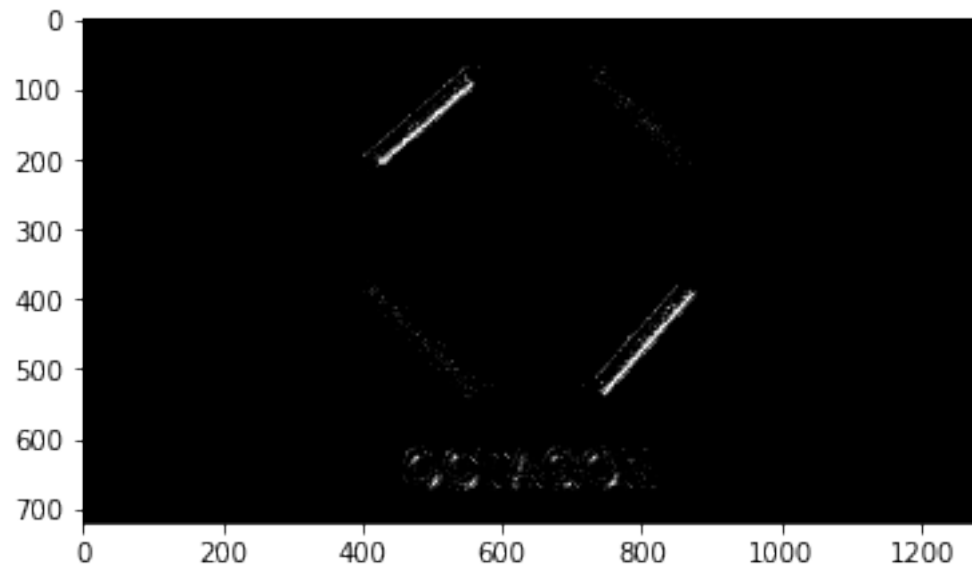

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```

```
In [25]: plt.imshow(filtered2,cmap="gray")
         cv2.imshow('image',filtered2)
         cv2.waitKey()
         cv2.destroyAllWindows()
```



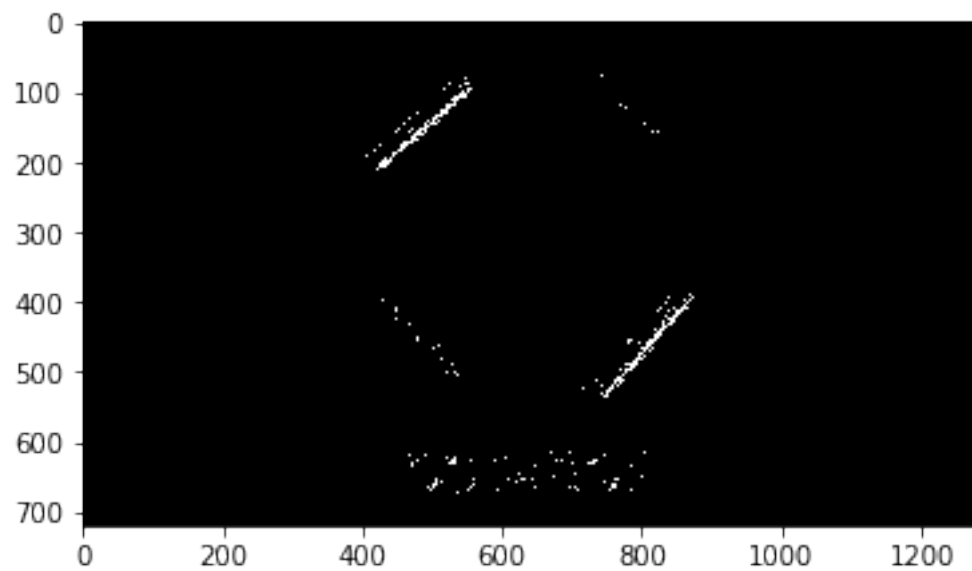
```
In [26]: smo_fil = cv2.GaussianBlur(filtered2,(5,5),0)
```

```
In [27]: plt.imshow(smo_fil,cmap='gray')
         plt.imsave('output_edge.png',smo_fil,cmap='gray')
```



In []:

```
In [28]: plt.imshow(filtered,cmap="gray")
cv2.imshow('image',filtered)
cv2.waitKey()
cv2.destroyAllWindows()
```



```
In [29]: x = np.array([-1, +1, +1, -1])
          y = np.array([-1, -1, +1, +1])

          np.arctan2(y,x)*180/np.pi

Out[29]: array([-135.,  -45.,   45.,  135.])

In [ ]:

In [ ]:
```

Histogram equalisation

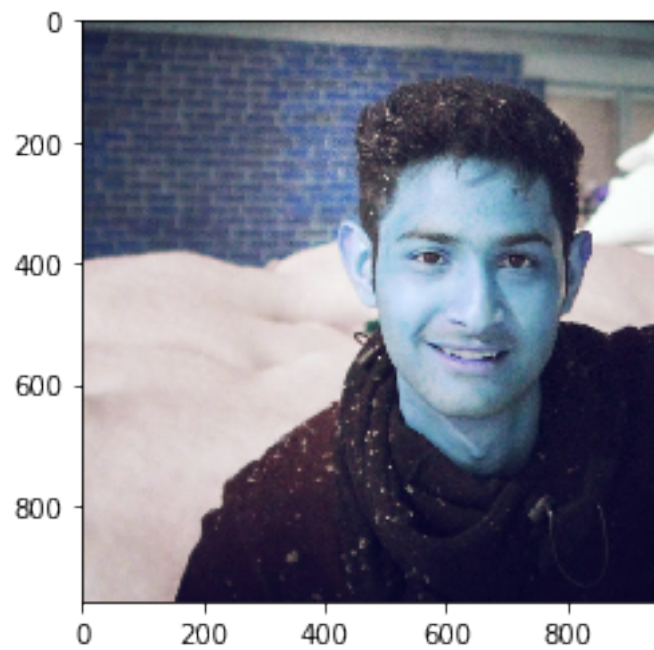
April 28, 2019

```
In [2]: import cv2
import numpy as np
import matplotlib.pyplot as plt
```

```
In [3]: image = cv2.imread('sample7.jpg')
```

```
In [4]: plt.imshow(image)
```

```
Out[4]: <matplotlib.image.AxesImage at 0x123bbe5f8>
```



```
In [5]: image.shape
```

```
Out[5]: (959, 960, 3)
```

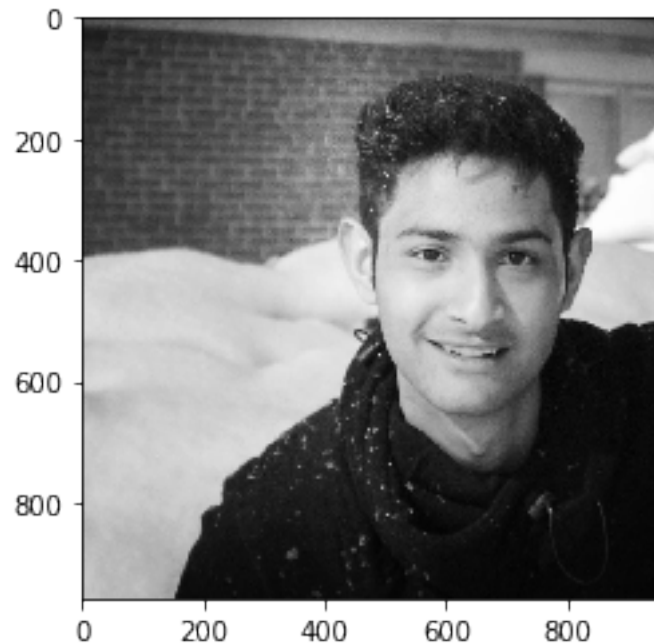
```
In [6]: gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
```

```
In [7]: gray.shape
```

```
Out[7]: (959, 960)
```

```
In [8]: plt.imshow(gray,cmap='gray')
```

```
Out[8]: <matplotlib.image.AxesImage at 0x12499f7f0>
```



```
In [9]: gray.shape
```

```
Out[9]: (959, 960)
```

```
In [10]: hist = np.zeros(256)
```

```
    for i in range(gray.shape[0]):  
        for j in range(gray.shape[1]):  
            hist[gray[i][j]] = hist[gray[i][j]]+1
```

```
In [11]: hist
```

```
Out[11]: array([0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,  
                0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,  
                0.0000e+00, 4.0000e+00, 1.4000e+01, 4.1000e+01, 1.3900e+02,  
                5.3000e+02, 1.9360e+03, 5.4010e+03, 1.0821e+04, 1.4391e+04,  
                1.6384e+04, 1.5396e+04, 1.5370e+04, 1.5431e+04, 1.4197e+04,  
                1.2152e+04, 1.0335e+04, 8.9400e+03, 8.0950e+03, 7.4570e+03,  
                7.2320e+03, 7.0980e+03, 6.8880e+03, 6.5340e+03, 6.1070e+03,
```

```

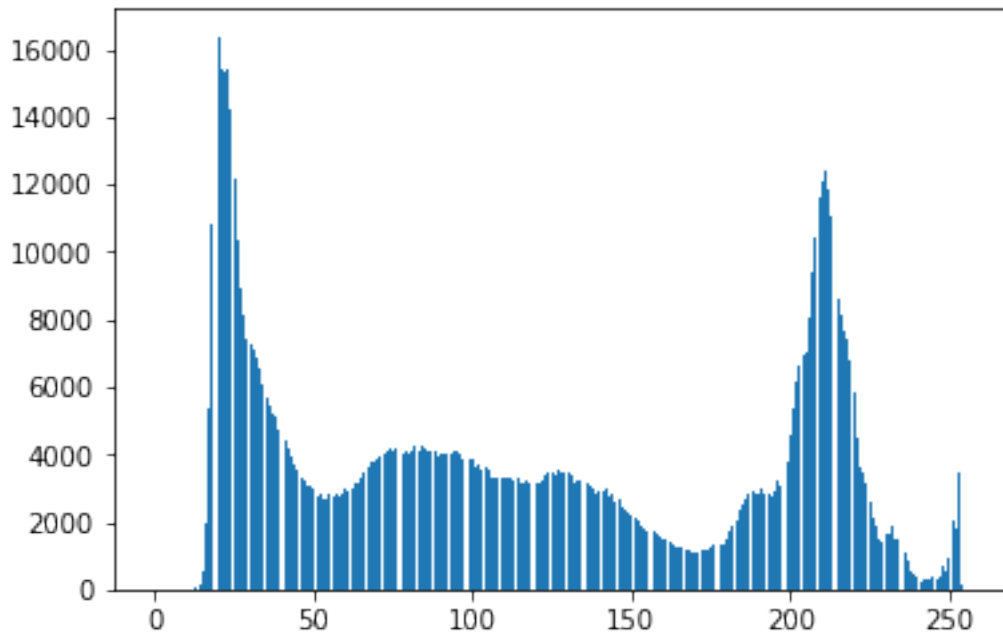
5.6790e+03, 5.4360e+03, 5.1730e+03, 5.0900e+03, 4.7480e+03,
4.4260e+03, 4.3900e+03, 4.1620e+03, 3.9660e+03, 3.6680e+03,
3.5500e+03, 3.2820e+03, 3.2280e+03, 3.0660e+03, 3.0590e+03,
2.9810e+03, 2.7740e+03, 2.8010e+03, 2.7070e+03, 2.6940e+03,
2.8070e+03, 2.7780e+03, 2.7930e+03, 2.7750e+03, 2.8080e+03,
2.9620e+03, 2.9490e+03, 2.9780e+03, 3.1340e+03, 3.1530e+03,
3.3280e+03, 3.4790e+03, 3.6340e+03, 3.8070e+03, 3.8160e+03,
3.8480e+03, 3.9350e+03, 3.9990e+03, 4.0850e+03, 4.1750e+03,
4.0950e+03, 4.1620e+03, 4.0940e+03, 3.9930e+03, 4.0690e+03,
3.9880e+03, 4.1040e+03, 4.2280e+03, 4.1020e+03, 4.2210e+03,
4.1830e+03, 4.0910e+03, 4.1350e+03, 4.0990e+03, 3.9790e+03,
4.0110e+03, 4.0540e+03, 4.0350e+03, 4.0300e+03, 4.1130e+03,
4.1030e+03, 3.9810e+03, 3.8950e+03, 3.8410e+03, 3.8920e+03,
3.8270e+03, 3.6620e+03, 3.7050e+03, 3.5640e+03, 3.6170e+03,
3.5370e+03, 3.3260e+03, 3.3210e+03, 3.3270e+03, 3.3310e+03,
3.2930e+03, 3.3090e+03, 3.2780e+03, 3.2510e+03, 3.2690e+03,
3.1190e+03, 3.1670e+03, 3.2130e+03, 3.1790e+03, 3.2070e+03,
3.1680e+03, 3.1680e+03, 3.2270e+03, 3.3870e+03, 3.4450e+03,
3.4750e+03, 3.3830e+03, 3.5060e+03, 3.4310e+03, 3.4800e+03,
3.4670e+03, 3.4230e+03, 3.1820e+03, 3.2260e+03, 3.2200e+03,
3.1090e+03, 3.1170e+03, 3.0980e+03, 2.9830e+03, 2.8660e+03,
2.8860e+03, 2.9300e+03, 2.9830e+03, 2.7810e+03, 2.8090e+03,
2.6030e+03, 2.6710e+03, 2.4640e+03, 2.3790e+03, 2.3130e+03,
2.1720e+03, 2.1240e+03, 2.0690e+03, 1.8860e+03, 1.8370e+03,
1.7160e+03, 1.7500e+03, 1.7540e+03, 1.6800e+03, 1.5720e+03,
1.4550e+03, 1.4500e+03, 1.4180e+03, 1.3210e+03, 1.2840e+03,
1.2180e+03, 1.2120e+03, 1.1840e+03, 1.1950e+03, 1.0960e+03,
1.0740e+03, 1.0900e+03, 1.1620e+03, 1.1720e+03, 1.1790e+03,
1.2720e+03, 1.2930e+03, 1.2640e+03, 1.3320e+03, 1.3540e+03,
1.5240e+03, 1.6960e+03, 1.8470e+03, 2.0300e+03, 2.3390e+03,
2.4810e+03, 2.7110e+03, 2.7930e+03, 2.8720e+03, 2.8440e+03,
2.8310e+03, 3.0060e+03, 2.8070e+03, 2.8200e+03, 2.7230e+03,
2.9290e+03, 3.1890e+03, 3.0830e+03, 3.3730e+03, 3.7540e+03,
4.5340e+03, 5.3890e+03, 6.1430e+03, 6.5910e+03, 6.9450e+03,
7.0540e+03, 8.0210e+03, 9.3930e+03, 1.0456e+04, 1.1643e+04,
1.2068e+04, 1.2370e+04, 1.1875e+04, 1.1074e+04, 1.0362e+04,
8.5860e+03, 8.1610e+03, 7.6920e+03, 7.4170e+03, 6.8190e+03,
5.8080e+03, 4.5270e+03, 3.6060e+03, 3.4900e+03, 3.1600e+03,
2.6170e+03, 2.1490e+03, 1.8970e+03, 1.4790e+03, 1.4330e+03,
1.6260e+03, 1.6690e+03, 1.9050e+03, 1.4740e+03, 1.4610e+03,
1.1510e+03, 1.0960e+03, 8.4300e+02, 5.2100e+02, 4.3000e+02,
3.5700e+02, 2.4500e+02, 2.7500e+02, 2.6800e+02, 3.3800e+02,
3.5000e+02, 3.4000e+02, 4.0700e+02, 7.1200e+02, 5.7700e+02,
9.2300e+02, 2.0710e+03, 1.8130e+03, 3.4500e+03, 1.3800e+02,
8.0000e+00))

```

```

In [12]: index = np.arange(len(hist))
         plot1 = plt.bar(index, hist)

```



```
In [13]: pdf = [np.around(i/(gray.shape[0]*gray.shape[1]),decimals=5) for i in hist];pdf
```

```
Out[13]: [0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
0.0,
2e-05,
4e-05,
0.00015,
0.00058,
0.0021,
0.00587,
0.01175,
0.01563,
0.0178,
0.01672,
0.01669,
0.01676,
```

0.01542,
0.0132,
0.01123,
0.00971,
0.00879,
0.0081,
0.00786,
0.00771,
0.00748,
0.0071,
0.00663,
0.00617,
0.0059,
0.00562,
0.00553,
0.00516,
0.00481,
0.00477,
0.00452,
0.00431,
0.00398,
0.00386,
0.00356,
0.00351,
0.00333,
0.00332,
0.00324,
0.00301,
0.00304,
0.00294,
0.00293,
0.00305,
0.00302,
0.00303,
0.00301,
0.00305,
0.00322,
0.0032,
0.00323,
0.0034,
0.00342,
0.00361,
0.00378,
0.00395,
0.00414,
0.00414,
0.00418,
0.00427,

0.00434,
0.00444,
0.00453,
0.00445,
0.00452,
0.00445,
0.00434,
0.00442,
0.00433,
0.00446,
0.00459,
0.00446,
0.00458,
0.00454,
0.00444,
0.00449,
0.00445,
0.00432,
0.00436,
0.0044,
0.00438,
0.00438,
0.00447,
0.00446,
0.00432,
0.00423,
0.00417,
0.00423,
0.00416,
0.00398,
0.00402,
0.00387,
0.00393,
0.00384,
0.00361,
0.00361,
0.00361,
0.00362,
0.00358,
0.00359,
0.00356,
0.00353,
0.00355,
0.00339,
0.00344,
0.00349,
0.00345,
0.00348,

0.00344,
0.00344,
0.00351,
0.00368,
0.00374,
0.00377,
0.00367,
0.00381,
0.00373,
0.00378,
0.00377,
0.00372,
0.00346,
0.0035,
0.0035,
0.00338,
0.00339,
0.00337,
0.00324,
0.00311,
0.00313,
0.00318,
0.00324,
0.00302,
0.00305,
0.00283,
0.0029,
0.00268,
0.00258,
0.00251,
0.00236,
0.00231,
0.00225,
0.00205,
0.002,
0.00186,
0.0019,
0.00191,
0.00182,
0.00171,
0.00158,
0.00157,
0.00154,
0.00143,
0.00139,
0.00132,
0.00132,
0.00129,

0.0013,
0.00119,
0.00117,
0.00118,
0.00126,
0.00127,
0.00128,
0.00138,
0.0014,
0.00137,
0.00145,
0.00147,
0.00166,
0.00184,
0.00201,
0.0022,
0.00254,
0.00269,
0.00294,
0.00303,
0.00312,
0.00309,
0.00308,
0.00327,
0.00305,
0.00306,
0.00296,
0.00318,
0.00346,
0.00335,
0.00366,
0.00408,
0.00492,
0.00585,
0.00667,
0.00716,
0.00754,
0.00766,
0.00871,
0.0102,
0.01136,
0.01265,
0.01311,
0.01344,
0.0129,
0.01203,
0.01126,
0.00933,

```
0.00886,  
0.00836,  
0.00806,  
0.00741,  
0.00631,  
0.00492,  
0.00392,  
0.00379,  
0.00343,  
0.00284,  
0.00233,  
0.00206,  
0.00161,  
0.00156,  
0.00177,  
0.00181,  
0.00207,  
0.0016,  
0.00159,  
0.00125,  
0.00119,  
0.00092,  
0.00057,  
0.00047,  
0.00039,  
0.00027,  
0.0003,  
0.00029,  
0.00037,  
0.00038,  
0.00037,  
0.00044,  
0.00077,  
0.00063,  
0.001,  
0.00225,  
0.00197,  
0.00375,  
0.00015,  
1e-05]
```

```
In [14]: cdf = []  
         cdf.append(pdf[0])  
  
         for i in range(1,len(pdf)):  
             cdf.append(np.around(cdf[i-1]+pdf[i],decimals=6))  
  
         cdf
```

```
Out[14]: [0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          0.0,  
          2e-05,  
          6e-05,  
          0.00021,  
          0.00079,  
          0.00289,  
          0.00876,  
          0.02051,  
          0.03614,  
          0.05394,  
          0.07066,  
          0.08735,  
          0.10411,  
          0.11953,  
          0.13273,  
          0.14396,  
          0.15367,  
          0.16246,  
          0.17056,  
          0.17842,  
          0.18613,  
          0.19361,  
          0.20071,  
          0.20734,  
          0.21351,  
          0.21941,  
          0.22503,  
          0.23056,  
          0.23572,  
          0.24053,  
          0.2453,  
          0.24982,  
          0.25413,  
          0.25811,  
          0.26197,  
          0.26553,  
          0.26904,
```

0.27237,
0.27569,
0.27893,
0.28194,
0.28498,
0.28792,
0.29085,
0.2939,
0.29692,
0.29995,
0.30296,
0.30601,
0.30923,
0.31243,
0.31566,
0.31906,
0.32248,
0.32609,
0.32987,
0.33382,
0.33796,
0.3421,
0.34628,
0.35055,
0.35489,
0.35933,
0.36386,
0.36831,
0.37283,
0.37728,
0.38162,
0.38604,
0.39037,
0.39483,
0.39942,
0.40388,
0.40846,
0.413,
0.41744,
0.42193,
0.42638,
0.4307,
0.43506,
0.43946,
0.44384,
0.44822,
0.45269,
0.45715,

0.46147,
0.4657,
0.46987,
0.4741,
0.47826,
0.48224,
0.48626,
0.49013,
0.49406,
0.4979,
0.50151,
0.50512,
0.50873,
0.51235,
0.51593,
0.51952,
0.52308,
0.52661,
0.53016,
0.53355,
0.53699,
0.54048,
0.54393,
0.54741,
0.55085,
0.55429,
0.5578,
0.56148,
0.56522,
0.56899,
0.57266,
0.57647,
0.5802,
0.58398,
0.58775,
0.59147,
0.59493,
0.59843,
0.60193,
0.60531,
0.6087,
0.61207,
0.61531,
0.61842,
0.62155,
0.62473,
0.62797,
0.63099,

0.63404,
0.63687,
0.63977,
0.64245,
0.64503,
0.64754,
0.6499,
0.65221,
0.65446,
0.65651,
0.65851,
0.66037,
0.66227,
0.66418,
0.666,
0.66771,
0.66929,
0.67086,
0.6724,
0.67383,
0.67522,
0.67654,
0.67786,
0.67915,
0.68045,
0.68164,
0.68281,
0.68399,
0.68525,
0.68652,
0.6878,
0.68918,
0.69058,
0.69195,
0.6934,
0.69487,
0.69653,
0.69837,
0.70038,
0.70258,
0.70512,
0.70781,
0.71075,
0.71378,
0.7169,
0.71999,
0.72307,
0.72634,

0.72939,
0.73245,
0.73541,
0.73859,
0.74205,
0.7454,
0.74906,
0.75314,
0.75806,
0.76391,
0.77058,
0.77774,
0.78528,
0.79294,
0.80165,
0.81185,
0.82321,
0.83586,
0.84897,
0.86241,
0.87531,
0.88734,
0.8986,
0.90793,
0.91679,
0.92515,
0.93321,
0.94062,
0.94693,
0.95185,
0.95577,
0.95956,
0.96299,
0.96583,
0.96816,
0.97022,
0.97183,
0.97339,
0.97516,
0.97697,
0.97904,
0.98064,
0.98223,
0.98348,
0.98467,
0.98559,
0.98616,
0.98663,

```
0.98702,  
0.98729,  
0.98759,  
0.98788,  
0.98825,  
0.98863,  
0.989,  
0.98944,  
0.99021,  
0.99084,  
0.99184,  
0.99409,  
0.99606,  
0.99981,  
0.99996,  
0.99997]
```

```
In [15]: eq_levels = np.around(np.multiply(cdf,255))
```

```
In [16]: eq_levels
```

```
Out[16]: array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  
    0.,  0.,  0.,  0.,  0.,  1.,  2.,  5.,  9., 14., 18.,  
   22., 27., 30., 34., 37., 39., 41., 43., 45., 47., 49.,  
   51., 53., 54., 56., 57., 59., 60., 61., 63., 64., 65.,  
   66., 67., 68., 69., 69., 70., 71., 72., 73., 73., 74.,  
   75., 76., 76., 77., 78., 79., 80., 80., 81., 82., 83.,  
   84., 85., 86., 87., 88., 89., 90., 92., 93., 94., 95.,  
   96., 97., 98., 100., 101., 102., 103., 104., 105., 106., 108.,  
  109., 110., 111., 112., 113., 114., 115., 117., 118., 119., 120.,  
  121., 122., 123., 124., 125., 126., 127., 128., 129., 130., 131.,  
  132., 132., 133., 134., 135., 136., 137., 138., 139., 140., 140.,  
  141., 142., 143., 144., 145., 146., 147., 148., 149., 150., 151.,  
  152., 153., 153., 154., 155., 156., 157., 158., 158., 159., 160.,  
  161., 162., 162., 163., 164., 164., 165., 166., 166., 167., 167.,  
  168., 168., 169., 169., 170., 170., 171., 171., 171., 172., 172.,  
  173., 173., 173., 174., 174., 174., 174., 175., 175., 175., 176.,  
  176., 176., 177., 177., 178., 178., 179., 179., 180., 180., 181.,  
  182., 183., 184., 184., 185., 186., 187., 188., 188., 189., 190.,  
  191., 192., 193., 195., 196., 198., 200., 202., 204., 207., 210.,  
  213., 216., 220., 223., 226., 229., 232., 234., 236., 238., 240.,  
  241., 243., 244., 245., 246., 246., 247., 247., 248., 248., 249.,  
  249., 250., 250., 250., 251., 251., 251., 251., 252., 252., 252.,  
  252., 252., 252., 252., 252., 252., 253., 253., 253., 253., 254.,  
  255., 255., 255.]])
```

```
In [27]: eq_hist = np.zeros(hist.shape)
```

```
for i in range(len(eq_hist)):
```

```
eq_hist[i] = eq_levels[i]
```

```
eq_hist = np.array(eq_hist,dtype=np.uint8)
```

```
In [28]: eq_hist
```

```
Out[28]: array([ 0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
                0,  0,  0,  1,  2,  5,  9, 14, 18, 22, 27, 30, 34,
                37, 39, 41, 43, 45, 47, 49, 51, 53, 54, 56, 57, 59,
                60, 61, 63, 64, 65, 66, 67, 68, 69, 69, 70, 71, 72,
                73, 73, 74, 75, 76, 76, 77, 78, 79, 80, 80, 81, 82,
                83, 84, 85, 86, 87, 88, 89, 90, 92, 93, 94, 95, 96,
                97, 98,100,101,102,103,104,105,106,108,109,110,111,
                112,113,114,115,117,118,119,120,121,122,123,124,125,
                126,127,128,129,130,131,132,132,133,134,135,136,137,
                138,139,140,140,141,142,143,144,145,146,147,148,149,
                150,151,152,153,153,154,155,156,157,158,158,159,160,
                161,162,162,163,164,164,165,166,166,167,167,168,168,
                169,169,170,170,171,171,171,172,172,173,173,173,174,
                174,174,174,175,175,175,176,176,176,177,177,178,178,
                179,179,180,180,181,182,183,184,184,185,186,187,188,
                188,189,190,191,192,193,195,196,198,200,202,204,207,
                210,213,216,220,223,226,229,232,234,236,238,240,241,
                243,244,245,246,246,247,247,248,248,249,249,250,250,
                250,251,251,251,251,252,252,252,252,252,252,252,252,
                252,253,253,253,253,254,255,255,255], dtype=uint8)
```

```
In [29]: final_hist = np.zeros(256)
```

```
for i in range(len(final_hist)):
    final_hist[eq_hist[i]]+=hist[i]
```

```
final_hist
```

```
Out[29]: array([ 728., 1936., 5401.,    0.,    0.,10821.,    0.,    0.,
                0.,14391.,    0.,    0.,    0.,    0.,16384.,    0.,
                0.,    0.,15396.,    0.,    0.,    0.,15370.,    0.,
                0.,    0.,    0.,15431.,    0.,    0.,14197.,    0.,
                0.,    0.,12152.,    0.,    0.,10335.,    0., 8940.,
                0., 8095.,    0., 7457.,    0., 7232.,    0., 7098.,
                0., 6888.,    0., 6534.,    0., 6107., 5679.,    0.,
                5436., 5173.,    0., 5090., 4748., 4426.,    0., 4390.,
                4162., 3966., 3668., 3550., 3282., 6294., 3059., 2981.,
                2774., 5508., 2694., 2807., 5571., 2775., 2808., 2962.,
                5927., 3134., 3153., 3328., 3479., 3634., 3807., 3816.,
                3848., 3935., 3999.,    0., 4085., 4175., 4095., 4162.,
                4094., 3993., 4069.,    0., 3988., 4104., 4228., 4102.,
                4221., 4183., 4091.,    0., 4135., 4099., 3979., 4011.,
                4054., 4035., 4030., 4113.,    0., 4103., 3981., 3895.,
```

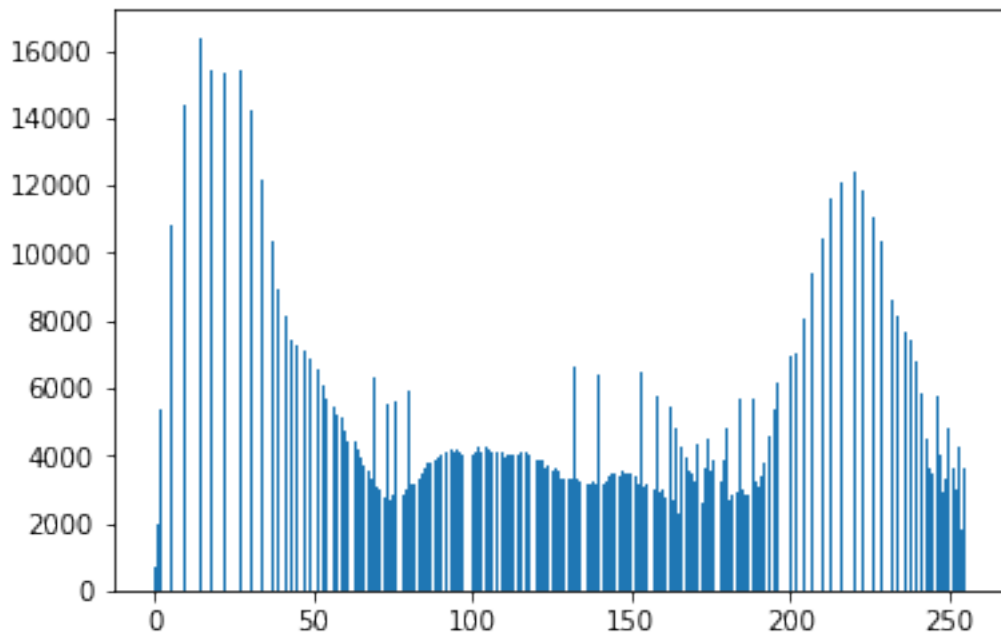
```

3841., 3892., 3827., 3662., 3705., 3564., 3617., 3537.,
3326., 3321., 3327., 3331., 6602., 3278., 3251., 3269.,
3119., 3167., 3213., 3179., 6375., 3168., 3227., 3387.,
3445., 3475., 3383., 3506., 3431., 3480., 3467., 3423.,
3182., 6446., 3109., 3117., 3098., 2983., 5752., 2930.,
2983., 2781., 5412., 2671., 4843., 2313., 4296., 3955.,
3553., 3504., 3252., 4323., 2605., 3614., 4455., 3513.,
3829., 2686., 3220., 3877., 4820., 2711., 2793., 2872.,
5675., 3006., 2807., 2820., 5652., 3189., 3083., 3373.,
3754., 4534., 0., 5389., 6143., 0., 6591., 0.,
6945., 0., 7054., 0., 8021., 0., 0., 9393.,
0., 0., 10456., 0., 0., 11643., 0., 0.,
12068., 0., 0., 0., 12370., 0., 0., 11875.,
0., 0., 11074., 0., 0., 10362., 0., 0.,
8586., 0., 8161., 0., 7692., 0., 7417., 0.,
6819., 5808., 0., 4527., 3606., 3490., 5777., 4046.,
2912., 3295., 4840., 3611., 3010., 4283., 1813., 3596.])

```

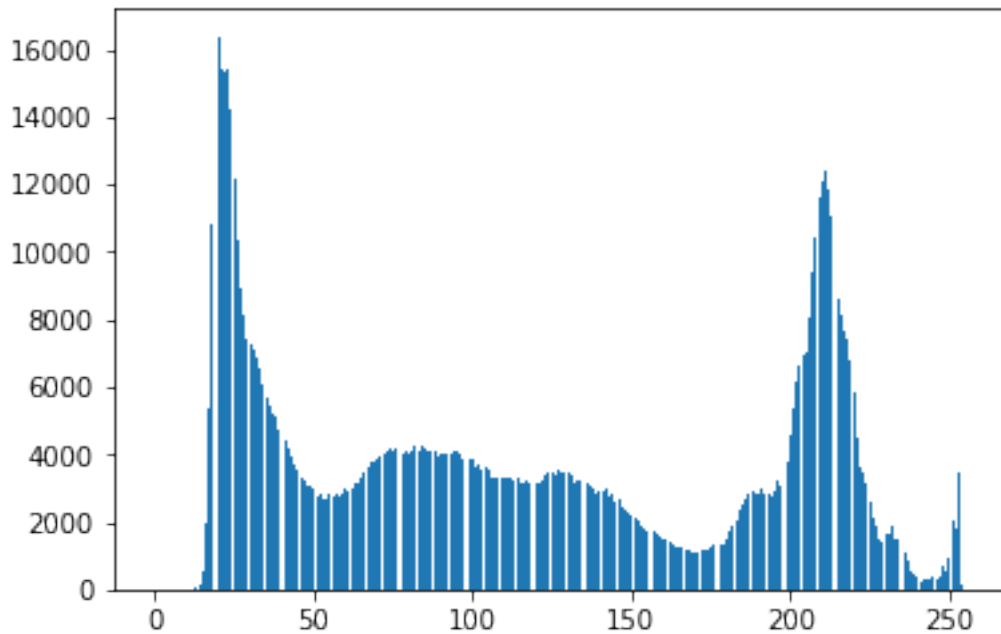
```
In [30]: plt.bar(index,final_hist)
```

```
Out[30]: <BarContainer object of 256 artists>
```



```
In [22]: plt.bar(index,hist)
```

```
Out[22]: <BarContainer object of 256 artists>
```



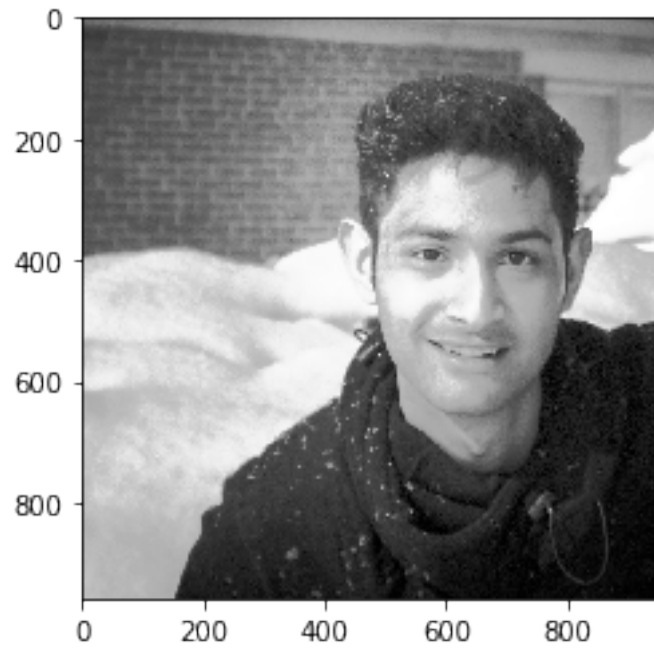
```
In [46]: out=np.zeros(gray.shape)
         for i in range(gray.shape[0]):
             for j in range(gray.shape[1]):
                 out[i][j]=eq_levels[gray[i][j]]
         out = np.array(out,dtype=np.uint8)
```

```
In [47]: out
```

```
Out[47]: array([[ 92, 100, 105, ...,  80,  86,  96],
                [ 98, 102, 102, ...,  80,  83,  90],
                [106, 105, 100, ...,  80,  81,  85],
                ...,
                [193, 193, 193, ...,   1,   2,   5],
                [195, 195, 195, ...,   1,   2,   5],
                [195, 195, 195, ...,   1,   2,   5]], dtype=uint8)
```

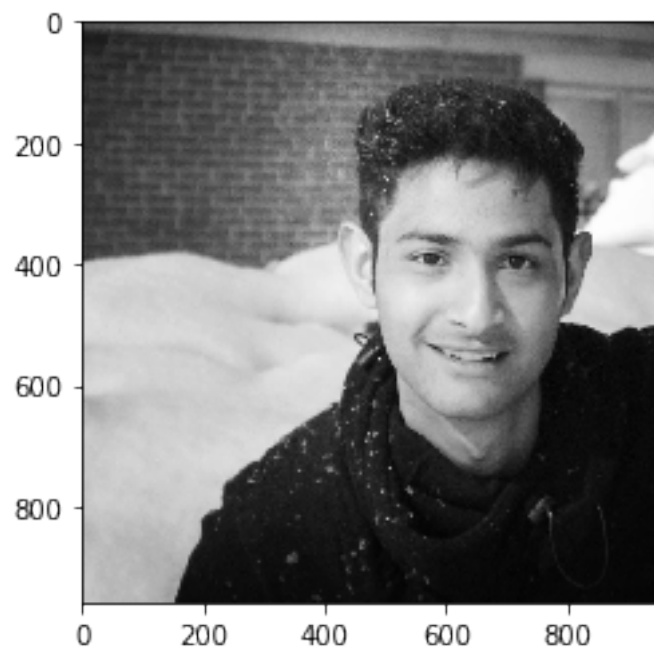
```
In [48]: plt.imshow(out,cmap='gray')
```

```
Out[48]: <matplotlib.image.AxesImage at 0x1286f5358>
```



```
In [49]: plt.imshow(gray,cmap='gray')
```

```
Out[49]: <matplotlib.image.AxesImage at 0x1287c15f8>
```



```

In [50]: out_hist = np.zeros(256)
         for i in range(out.shape[0]):
             for j in range(out.shape[1]):
                 out_hist[out[i,j]] = out_hist[out[i,j]]+1

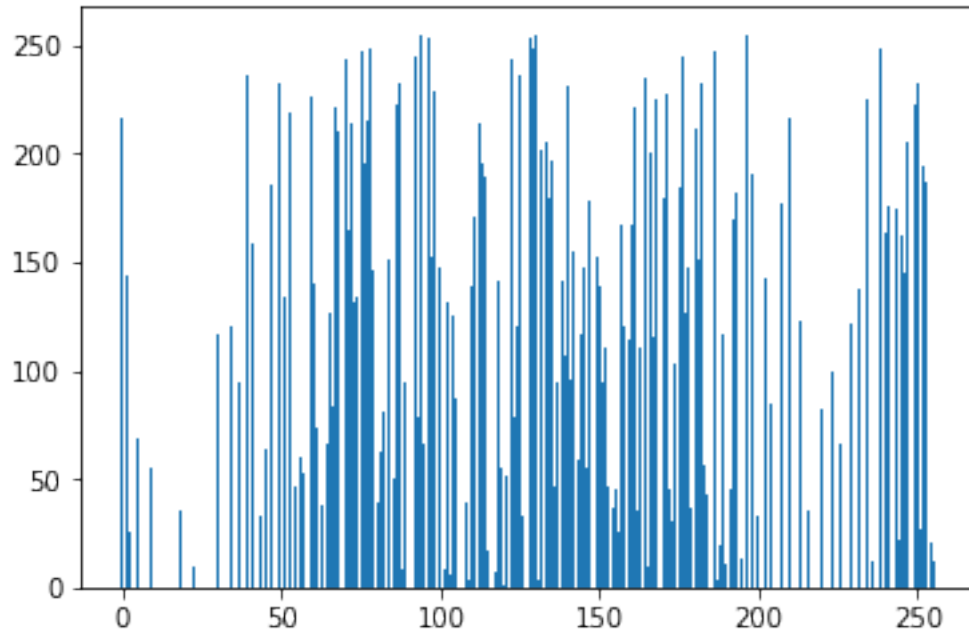
In [51]: out_hist = np.array(out_hist,dtype=np.uint8)
         out_hist

Out[51]: array([216, 144, 25, 0, 0, 69, 0, 0, 0, 55, 0, 0, 0,
                0, 0, 0, 0, 0, 36, 0, 0, 0, 10, 0, 0, 0,
                0, 71, 0, 0, 117, 0, 0, 0, 120, 0, 0, 95, 0,
                236, 0, 159, 0, 33, 0, 64, 0, 186, 0, 232, 0, 134,
                0, 219, 47, 0, 60, 53, 0, 226, 140, 74, 0, 38, 66,
                126, 84, 222, 210, 150, 243, 165, 214, 132, 134, 247, 195, 215,
                248, 146, 39, 62, 81, 0, 151, 50, 223, 232, 8, 95, 159,
                0, 245, 79, 255, 66, 254, 153, 229, 0, 148, 8, 132, 6,
                125, 87, 251, 0, 39, 3, 139, 171, 214, 195, 190, 17, 0,
                7, 141, 55, 1, 52, 243, 78, 121, 236, 33, 209, 254, 249,
                255, 3, 202, 206, 179, 197, 47, 95, 141, 107, 231, 96, 155,
                59, 117, 147, 55, 178, 103, 152, 139, 95, 110, 46, 37, 45,
                26, 167, 120, 114, 167, 221, 36, 111, 235, 9, 200, 115, 225,
                176, 180, 227, 45, 30, 103, 185, 245, 126, 148, 37, 212, 151,
                233, 56, 43, 190, 247, 4, 20, 117, 11, 45, 170, 182, 0,
                13, 255, 0, 191, 0, 33, 0, 142, 0, 85, 0, 0, 177,
                0, 0, 216, 0, 0, 123, 0, 0, 36, 0, 0, 0, 82,
                0, 0, 99, 0, 0, 66, 0, 0, 122, 0, 0, 138, 0,
                225, 0, 12, 0, 249, 0, 163, 176, 0, 175, 22, 162, 145,
                206, 96, 223, 232, 27, 194, 187, 21, 12], dtype=uint8)

In [52]: plt.bar(index,out_hist)

Out[52]: <BarContainer object of 256 artists>

```



```
In [53]: plt.hist(out.ravel(),256,[0,256])
```

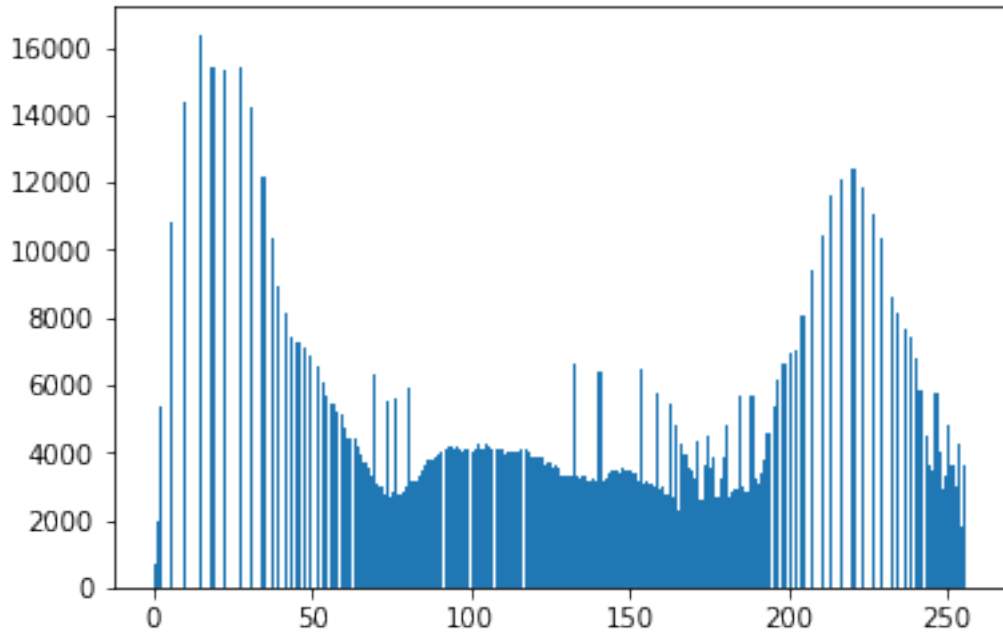
```
Out[53]: (array([ 728., 1936., 5401.,    0.,    0., 10821.,    0.,    0.,
      0., 14391.,    0.,    0.,    0.,    0., 16384.,    0.,
      0.,    0., 15396.,    0.,    0.,    0., 15370.,    0.,
      0.,    0.,    0., 15431.,    0.,    0., 14197.,    0.,
      0.,    0., 12152.,    0.,    0., 10335.,    0., 8940.,
      0., 8095.,    0., 7457.,    0., 7232.,    0., 7098.,
      0., 6888.,    0., 6534.,    0., 6107., 5679.,    0.,
 5436., 5173.,    0., 5090., 4748., 4426.,    0., 4390.,
 4162., 3966., 3668., 3550., 3282., 6294., 3059., 2981.,
 2774., 5508., 2694., 2807., 5571., 2775., 2808., 2962.,
 5927., 3134., 3153., 3328., 3479., 3634., 3807., 3816.,
 3848., 3935., 3999.,    0., 4085., 4175., 4095., 4162.,
 4094., 3993., 4069.,    0., 3988., 4104., 4228., 4102.,
 4221., 4183., 4091.,    0., 4135., 4099., 3979., 4011.,
 4054., 4035., 4030., 4113.,    0., 4103., 3981., 3895.,
 3841., 3892., 3827., 3662., 3705., 3564., 3617., 3537.,
 3326., 3321., 3327., 3331., 6602., 3278., 3251., 3269.,
 3119., 3167., 3213., 3179., 6375., 3168., 3227., 3387.,
 3445., 3475., 3383., 3506., 3431., 3480., 3467., 3423.,
 3182., 6446., 3109., 3117., 3098., 2983., 5752., 2930.,
 2983., 2781., 5412., 2671., 4843., 2313., 4296., 3955.,
 3553., 3504., 3252., 4323., 2605., 3614., 4455., 3513.,
 3829., 2686., 3220., 3877., 4820., 2711., 2793., 2872.,
 5675., 3006., 2807., 2820., 5652., 3189., 3083., 3373.,
```



```

3754., 4534., 0., 5389., 6143., 0., 6591., 0.,
6945., 0., 7054., 0., 8021., 0., 0., 9393.,
0., 0., 10456., 0., 0., 11643., 0., 0.,
12068., 0., 0., 0., 12370., 0., 0., 11875.,
0., 0., 11074., 0., 0., 10362., 0., 0.,
8586., 0., 8161., 0., 7692., 0., 7417., 0.,
6819., 5808., 0., 4527., 3606., 3490., 5777., 4046.,
2912., 3295., 4840., 3611., 3010., 4283., 1813., 3596.] ),
array([ 0., 1., 2., 3., 4., 5., 6., 7., 8., 9., 10.,
11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21.,
22., 23., 24., 25., 26., 27., 28., 29., 30., 31., 32.,
33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
99., 100., 101., 102., 103., 104., 105., 106., 107., 108., 109.,
110., 111., 112., 113., 114., 115., 116., 117., 118., 119., 120.,
121., 122., 123., 124., 125., 126., 127., 128., 129., 130., 131.,
132., 133., 134., 135., 136., 137., 138., 139., 140., 141., 142.,
143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
165., 166., 167., 168., 169., 170., 171., 172., 173., 174., 175.,
176., 177., 178., 179., 180., 181., 182., 183., 184., 185., 186.,
187., 188., 189., 190., 191., 192., 193., 194., 195., 196., 197.,
198., 199., 200., 201., 202., 203., 204., 205., 206., 207., 208.,
209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,
220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,
253., 254., 255., 256.] ),
<a list of 256 Patch objects>)

```



```
In [54]: plt.hist(image.ravel(),256,[0,256])
```

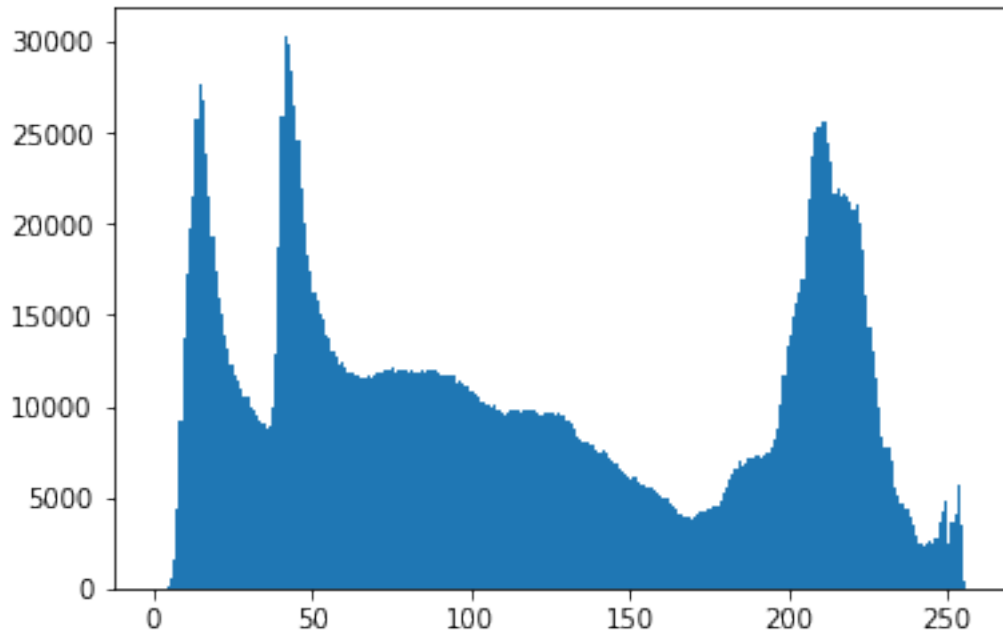
```
Out[54]: (array([1.0000e+00, 3.0000e+00, 1.1000e+01, 3.6000e+01, 1.3600e+02,
5.6400e+02, 1.6230e+03, 4.3590e+03, 9.2610e+03, 1.3725e+04,
1.7203e+04, 1.9697e+04, 2.1563e+04, 2.5752e+04, 2.7741e+04,
2.6778e+04, 2.3856e+04, 2.1448e+04, 1.9279e+04, 1.7449e+04,
1.6002e+04, 1.5037e+04, 1.3903e+04, 1.3218e+04, 1.2298e+04,
1.1694e+04, 1.1451e+04, 1.0985e+04, 1.0499e+04, 1.0584e+04,
9.9930e+03, 9.7670e+03, 9.4280e+03, 9.2190e+03, 9.0150e+03,
8.7210e+03, 8.9560e+03, 9.9120e+03, 1.2814e+04, 1.8721e+04,
2.5932e+04, 3.0355e+04, 2.9881e+04, 2.8446e+04, 2.6528e+04,
2.4577e+04, 2.1939e+04, 2.0000e+04, 1.8323e+04, 1.7394e+04,
1.6267e+04, 1.5848e+04, 1.5051e+04, 1.4769e+04, 1.3840e+04,
1.3717e+04, 1.3040e+04, 1.2698e+04, 1.2313e+04, 1.2416e+04,
1.2076e+04, 1.1903e+04, 1.1871e+04, 1.1764e+04, 1.1654e+04,
1.1616e+04, 1.1490e+04, 1.1664e+04, 1.1596e+04, 1.1751e+04,
1.1830e+04, 1.1907e+04, 1.1918e+04, 1.1971e+04, 1.2051e+04,
1.2086e+04, 1.1887e+04, 1.2054e+04, 1.2045e+04, 1.1950e+04,
1.1877e+04, 1.1963e+04, 1.1916e+04, 1.1820e+04, 1.2002e+04,
1.1802e+04, 1.1939e+04, 1.2020e+04, 1.2028e+04, 1.1790e+04,
1.1703e+04, 1.1687e+04, 1.1759e+04, 1.1672e+04, 1.1714e+04,
1.1325e+04, 1.1396e+04, 1.1267e+04, 1.1069e+04, 1.0861e+04,
1.0786e+04, 1.0725e+04, 1.0469e+04, 1.0190e+04, 1.0117e+04,
1.0044e+04, 9.8820e+03, 1.0126e+04, 9.8470e+03, 9.6230e+03,
9.4930e+03, 9.6140e+03, 9.8550e+03, 9.7420e+03, 9.7550e+03,
9.7080e+03, 9.7800e+03, 9.7520e+03, 9.8470e+03, 9.7300e+03,
```

```

9.7080e+03, 9.5240e+03, 9.5490e+03, 9.6560e+03, 9.6250e+03,
9.5850e+03, 9.4810e+03, 9.6010e+03, 9.5480e+03, 9.4350e+03,
9.2060e+03, 9.0970e+03, 8.7810e+03, 8.3940e+03, 8.2500e+03,
7.9640e+03, 7.9960e+03, 7.8940e+03, 7.8460e+03, 7.6050e+03,
7.5130e+03, 7.5610e+03, 7.3850e+03, 7.1510e+03, 6.9760e+03,
6.8790e+03, 6.5170e+03, 6.4170e+03, 6.2190e+03, 6.1560e+03,
6.0380e+03, 6.0940e+03, 5.8900e+03, 5.6710e+03, 5.7190e+03,
5.5430e+03, 5.6000e+03, 5.4570e+03, 5.2950e+03, 5.1310e+03,
4.9750e+03, 4.8830e+03, 4.7140e+03, 4.4980e+03, 4.3420e+03,
4.0420e+03, 4.0760e+03, 3.9840e+03, 3.9940e+03, 3.8130e+03,
3.9550e+03, 4.0100e+03, 4.1760e+03, 4.1590e+03, 4.3050e+03,
4.4060e+03, 4.4710e+03, 4.5170e+03, 4.8100e+03, 5.2020e+03,
5.5220e+03, 5.9230e+03, 6.2150e+03, 6.5960e+03, 6.9390e+03,
6.7770e+03, 6.8780e+03, 7.2110e+03, 7.1220e+03, 7.3160e+03,
7.2600e+03, 7.1840e+03, 7.3630e+03, 7.4980e+03, 7.7910e+03,
8.2060e+03, 8.8030e+03, 1.0022e+04, 1.1720e+04, 1.3329e+04,
1.3956e+04, 1.4900e+04, 1.5681e+04, 1.6289e+04, 1.7004e+04,
1.9289e+04, 2.1375e+04, 2.3741e+04, 2.4990e+04, 2.5335e+04,
2.5610e+04, 2.5646e+04, 2.4449e+04, 2.3451e+04, 2.1688e+04,
2.1891e+04, 2.1551e+04, 2.1633e+04, 2.1568e+04, 2.1183e+04,
2.0715e+04, 2.1077e+04, 2.0071e+04, 1.8596e+04, 1.6092e+04,
1.4393e+04, 1.3026e+04, 1.1503e+04, 9.9660e+03, 8.2790e+03,
7.7190e+03, 7.7200e+03, 6.9430e+03, 5.5660e+03, 5.0940e+03,
4.7120e+03, 4.3880e+03, 4.3420e+03, 3.8980e+03, 3.5120e+03,
2.8970e+03, 2.5100e+03, 2.3760e+03, 2.4630e+03, 2.5780e+03,
2.4980e+03, 2.6890e+03, 3.6340e+03, 4.2020e+03, 4.7830e+03,
2.4340e+03, 3.6320e+03, 4.1280e+03, 5.6280e+03, 3.4350e+03,
4.1200e+02]),
array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9., 10.,
11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21.,
22., 23., 24., 25., 26., 27., 28., 29., 30., 31., 32.,
33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
99., 100., 101., 102., 103., 104., 105., 106., 107., 108., 109.,
110., 111., 112., 113., 114., 115., 116., 117., 118., 119., 120.,
121., 122., 123., 124., 125., 126., 127., 128., 129., 130., 131.,
132., 133., 134., 135., 136., 137., 138., 139., 140., 141., 142.,
143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
165., 166., 167., 168., 169., 170., 171., 172., 173., 174., 175.,
176., 177., 178., 179., 180., 181., 182., 183., 184., 185., 186.,
187., 188., 189., 190., 191., 192., 193., 194., 195., 196., 197.,
198., 199., 200., 201., 202., 203., 204., 205., 206., 207., 208.,
209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,

```

```
220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,  
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,  
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,  
253., 254., 255., 256.]),  
<a list of 256 Patch objects>)
```



In []:

Histogram specification

April 28, 2019

```
In [1]: import cv2
import numpy as np
import matplotlib.pyplot as plt

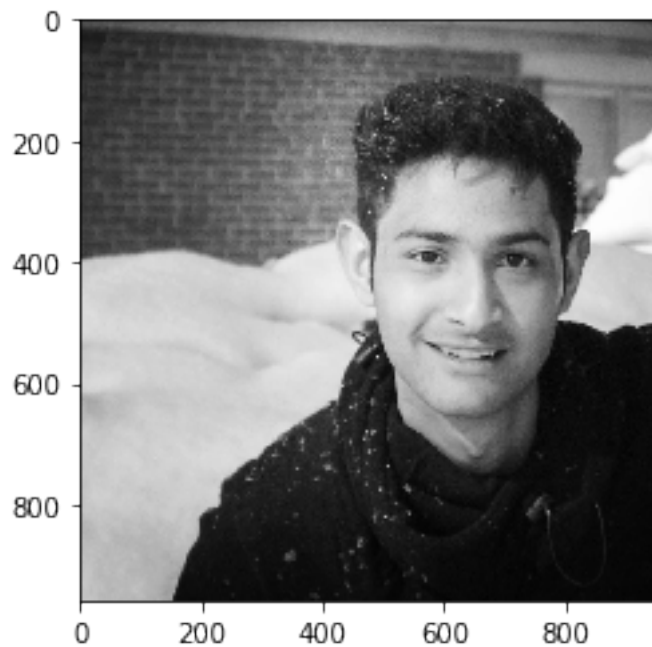
In [12]: image1 = cv2.imread('sample7.jpg')
image1 = cv2.cvtColor(image1,cv2.COLOR_BGR2GRAY)

In [16]: image1.shape

Out[16]: (959, 960)

In [13]: plt.imshow(image1,cmap='gray')

Out[13]: <matplotlib.image.AxesImage at 0x13195c780>
```



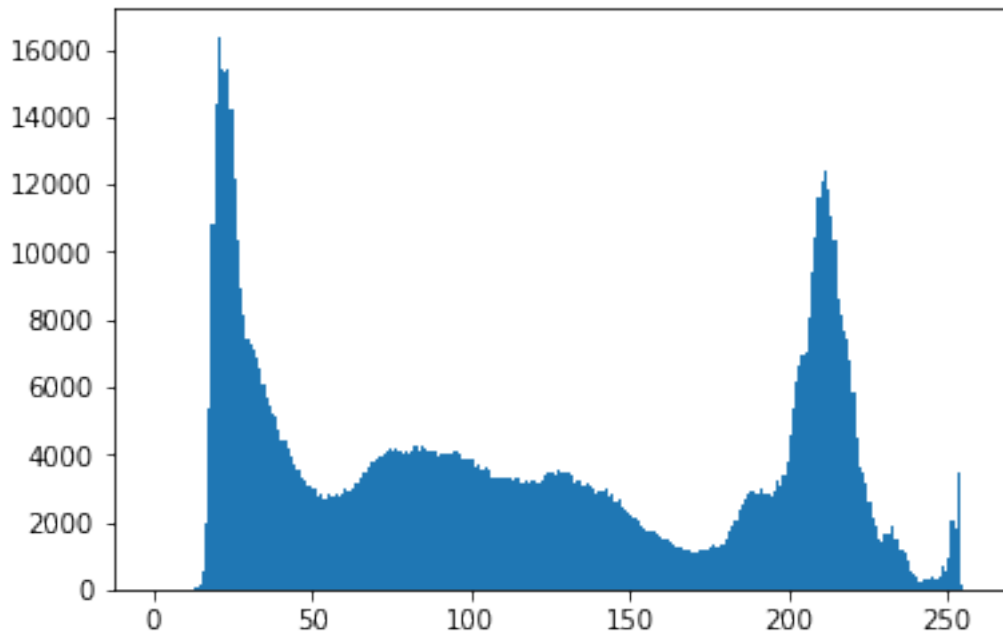
```
In [18]: plt.hist(image1.ravel(),256,[0,256])
```

```
Out[18]: (array([0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,
0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,
0.0000e+00, 4.0000e+00, 1.4000e+01, 4.1000e+01, 1.3900e+02,
5.3000e+02, 1.9360e+03, 5.4010e+03, 1.0821e+04, 1.4391e+04,
1.6384e+04, 1.5396e+04, 1.5370e+04, 1.5431e+04, 1.4197e+04,
1.2152e+04, 1.0335e+04, 8.9400e+03, 8.0950e+03, 7.4570e+03,
7.2320e+03, 7.0980e+03, 6.8880e+03, 6.5340e+03, 6.1070e+03,
5.6790e+03, 5.4360e+03, 5.1730e+03, 5.0900e+03, 4.7480e+03,
4.4260e+03, 4.3900e+03, 4.1620e+03, 3.9660e+03, 3.6680e+03,
3.5500e+03, 3.2820e+03, 3.2280e+03, 3.0660e+03, 3.0590e+03,
2.9810e+03, 2.7740e+03, 2.8010e+03, 2.7070e+03, 2.6940e+03,
2.8070e+03, 2.7780e+03, 2.7930e+03, 2.7750e+03, 2.8080e+03,
2.9620e+03, 2.9490e+03, 2.9780e+03, 3.1340e+03, 3.1530e+03,
3.3280e+03, 3.4790e+03, 3.6340e+03, 3.8070e+03, 3.8160e+03,
3.8480e+03, 3.9350e+03, 3.9990e+03, 4.0850e+03, 4.1750e+03,
4.0950e+03, 4.1620e+03, 4.0940e+03, 3.9930e+03, 4.0690e+03,
3.9880e+03, 4.1040e+03, 4.2280e+03, 4.1020e+03, 4.2210e+03,
4.1830e+03, 4.0910e+03, 4.1350e+03, 4.0990e+03, 3.9790e+03,
4.0110e+03, 4.0540e+03, 4.0350e+03, 4.0300e+03, 4.1130e+03,
4.1030e+03, 3.9810e+03, 3.8950e+03, 3.8410e+03, 3.8920e+03,
3.8270e+03, 3.6620e+03, 3.7050e+03, 3.5640e+03, 3.6170e+03,
3.5370e+03, 3.3260e+03, 3.3210e+03, 3.3270e+03, 3.3310e+03,
3.2930e+03, 3.3090e+03, 3.2780e+03, 3.2510e+03, 3.2690e+03,
3.1190e+03, 3.1670e+03, 3.2130e+03, 3.1790e+03, 3.2070e+03,
3.1680e+03, 3.1680e+03, 3.2270e+03, 3.3870e+03, 3.4450e+03,
3.4750e+03, 3.3830e+03, 3.5060e+03, 3.4310e+03, 3.4800e+03,
3.4670e+03, 3.4230e+03, 3.1820e+03, 3.2260e+03, 3.2200e+03,
3.1090e+03, 3.1170e+03, 3.0980e+03, 2.9830e+03, 2.8660e+03,
2.8860e+03, 2.9300e+03, 2.9830e+03, 2.7810e+03, 2.8090e+03,
2.6030e+03, 2.6710e+03, 2.4640e+03, 2.3790e+03, 2.3130e+03,
2.1720e+03, 2.1240e+03, 2.0690e+03, 1.8860e+03, 1.8370e+03,
1.7160e+03, 1.7500e+03, 1.7540e+03, 1.6800e+03, 1.5720e+03,
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1.0740e+03, 1.0900e+03, 1.1620e+03, 1.1720e+03, 1.1790e+03,
1.2720e+03, 1.2930e+03, 1.2640e+03, 1.3320e+03, 1.3540e+03,
1.5240e+03, 1.6960e+03, 1.8470e+03, 2.0300e+03, 2.3390e+03,
2.4810e+03, 2.7110e+03, 2.7930e+03, 2.8720e+03, 2.8440e+03,
2.8310e+03, 3.0060e+03, 2.8070e+03, 2.8200e+03, 2.7230e+03,
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7.0540e+03, 8.0210e+03, 9.3930e+03, 1.0456e+04, 1.1643e+04,
1.2068e+04, 1.2370e+04, 1.1875e+04, 1.1074e+04, 1.0362e+04,
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5.8080e+03, 4.5270e+03, 3.6060e+03, 3.4900e+03, 3.1600e+03,
2.6170e+03, 2.1490e+03, 1.8970e+03, 1.4790e+03, 1.4330e+03,
1.6260e+03, 1.6690e+03, 1.9050e+03, 1.4740e+03, 1.4610e+03,
1.1510e+03, 1.0960e+03, 8.4300e+02, 5.2100e+02, 4.3000e+02,
```

```

3.5700e+02, 2.4500e+02, 2.7500e+02, 2.6800e+02, 3.3800e+02,
3.5000e+02, 3.4000e+02, 4.0700e+02, 7.1200e+02, 5.7700e+02,
9.2300e+02, 2.0710e+03, 1.8130e+03, 3.4500e+03, 1.3800e+02,
8.0000e+00]),
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11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21.,
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44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
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66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
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110., 111., 112., 113., 114., 115., 116., 117., 118., 119., 120.,
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143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
165., 166., 167., 168., 169., 170., 171., 172., 173., 174., 175.,
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209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,
220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,
253., 254., 255., 256.]),
<a list of 256 Patch objects>)

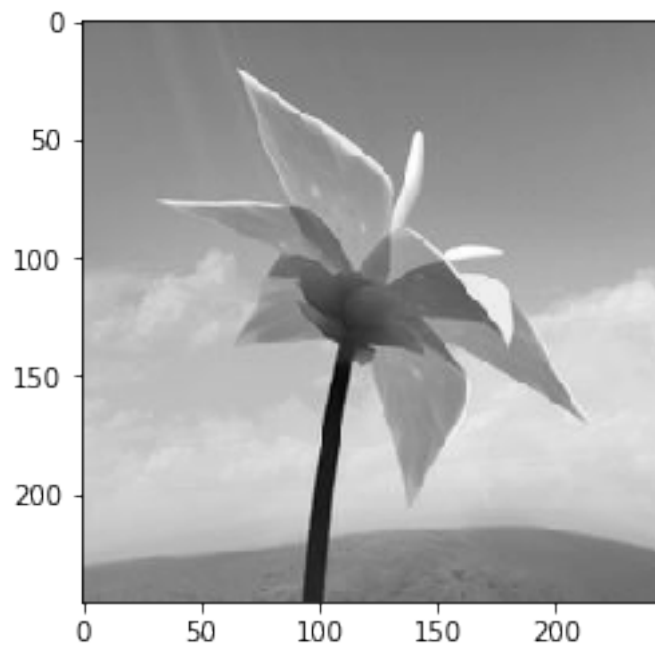
```



```
In [14]: image2 = cv2.imread('flower1.jpg')  
         image2 = cv2.cvtColor(image2,cv2.COLOR_BGR2GRAY)
```

```
In [15]: plt.imshow(image2,cmap='gray')
```

```
Out[15]: <matplotlib.image.AxesImage at 0x131d64a58>
```



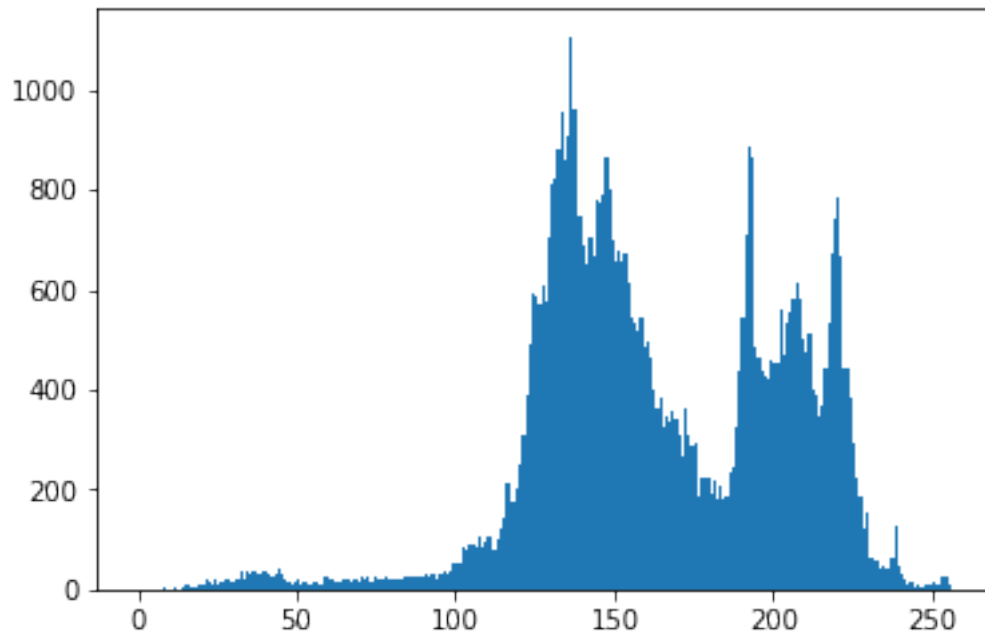

```
In [19]: plt.hist(image2.ravel(),256,[0,256])
```

```
Out[19]: (array([0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
0.000e+00, 0.000e+00, 2.000e+00, 0.000e+00, 1.000e+00, 3.000e+00,
1.000e+00, 1.000e+00, 6.000e+00, 7.000e+00, 3.000e+00, 4.000e+00,
5.000e+00, 8.000e+00, 9.000e+00, 1.800e+01, 1.300e+01, 1.000e+01,
2.000e+01, 1.100e+01, 1.400e+01, 2.100e+01, 2.100e+01, 1.700e+01,
1.700e+01, 2.200e+01, 3.400e+01, 1.800e+01, 3.400e+01, 3.200e+01,
3.700e+01, 2.900e+01, 3.300e+01, 3.800e+01, 3.500e+01, 3.100e+01,
2.600e+01, 3.200e+01, 4.200e+01, 2.900e+01, 1.900e+01, 1.600e+01,
1.100e+01, 1.700e+01, 1.900e+01, 9.000e+00, 1.700e+01, 1.200e+01,
1.200e+01, 1.500e+01, 1.600e+01, 7.000e+00, 2.300e+01, 2.600e+01,
1.900e+01, 2.100e+01, 1.500e+01, 1.700e+01, 2.200e+01, 2.000e+01,
2.000e+01, 1.600e+01, 1.900e+01, 1.300e+01, 2.400e+01, 1.800e+01,
2.500e+01, 1.600e+01, 2.300e+01, 1.800e+01, 2.200e+01, 2.100e+01,
2.400e+01, 2.100e+01, 2.000e+01, 2.100e+01, 1.800e+01, 1.900e+01,
2.400e+01, 2.600e+01, 2.500e+01, 2.300e+01, 2.800e+01, 2.500e+01,
3.300e+01, 2.300e+01, 3.300e+01, 3.000e+01, 2.000e+01, 3.100e+01,
3.400e+01, 3.000e+01, 3.900e+01, 5.200e+01, 5.100e+01, 5.200e+01,
8.200e+01, 8.000e+01, 9.000e+01, 9.100e+01, 8.500e+01, 1.040e+02,
8.500e+01, 9.400e+01, 1.040e+02, 8.000e+01, 7.900e+01, 9.800e+01,
1.240e+02, 1.420e+02, 2.140e+02, 1.770e+02, 1.750e+02, 2.030e+02,
2.490e+02, 3.080e+02, 3.900e+02, 4.910e+02, 5.900e+02, 5.850e+02,
5.710e+02, 6.090e+02, 5.760e+02, 7.050e+02, 8.130e+02, 8.210e+02,
8.790e+02, 9.540e+02, 8.570e+02, 9.090e+02, 1.107e+03, 9.590e+02,
7.480e+02, 7.460e+02, 6.900e+02, 6.500e+02, 7.040e+02, 6.690e+02,
7.820e+02, 7.760e+02, 7.920e+02, 8.630e+02, 7.990e+02, 7.000e+02,
6.560e+02, 6.790e+02, 6.590e+02, 6.720e+02, 6.160e+02, 5.430e+02,
5.350e+02, 5.150e+02, 5.440e+02, 4.860e+02, 4.940e+02, 4.660e+02,
4.000e+02, 3.600e+02, 3.820e+02, 3.250e+02, 3.490e+02, 3.350e+02,
3.590e+02, 3.410e+02, 3.080e+02, 2.660e+02, 3.600e+02, 3.090e+02,
2.850e+02, 2.950e+02, 1.880e+02, 2.260e+02, 2.220e+02, 2.240e+02,
1.920e+02, 2.160e+02, 1.790e+02, 2.080e+02, 1.800e+02, 1.870e+02,
2.320e+02, 2.460e+02, 3.260e+02, 4.380e+02, 5.450e+02, 7.080e+02,
8.850e+02, 8.630e+02, 4.840e+02, 4.650e+02, 4.360e+02, 4.250e+02,
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4.420e+02, 5.350e+02, 6.700e+02, 7.430e+02, 7.870e+02, 6.650e+02,
4.450e+02, 4.400e+02, 3.820e+02, 2.920e+02, 2.240e+02, 1.860e+02,
1.210e+02, 1.550e+02, 6.100e+01, 6.400e+01, 5.900e+01, 4.400e+01,
4.500e+01, 4.200e+01, 4.100e+01, 6.400e+01, 1.280e+02, 4.800e+01,
3.000e+01, 2.200e+01, 7.000e+00, 1.600e+01, 6.000e+00, 8.000e+00,
5.000e+00, 3.000e+00, 7.000e+00, 7.000e+00, 1.400e+01, 1.100e+01,
1.200e+01, 2.600e+01, 2.400e+01, 8.000e+00])),
```

```

array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9., 10.,
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       22., 23., 24., 25., 26., 27., 28., 29., 30., 31., 32.,
       33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
       44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
       55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
       66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
       77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
       88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
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      110., 111., 112., 113., 114., 115., 116., 117., 118., 119., 120.,
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      132., 133., 134., 135., 136., 137., 138., 139., 140., 141., 142.,
      143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
      154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
      165., 166., 167., 168., 169., 170., 171., 172., 173., 174., 175.,
      176., 177., 178., 179., 180., 181., 182., 183., 184., 185., 186.,
      187., 188., 189., 190., 191., 192., 193., 194., 195., 196., 197.,
      198., 199., 200., 201., 202., 203., 204., 205., 206., 207., 208.,
      209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,
      220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
      231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
      242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,
      253., 254., 255., 256.] ),
      <a list of 256 Patch objects>)

```



```

In [36]: def equalisation(image):
          hist = np.zeros(256)

          for i in range(image.shape[0]):
              for j in range(image.shape[1]):
                  hist[image[i][j]] = hist[image[i][j]]+1

          pdf = [np.around(i/(image.shape[0]*image.shape[1]),decimals=5) for i in hist]
          cdf = []
          cdf.append(pdf[0])

          for i in range(1,len(pdf1)):
              cdf.append(np.around(cdf[i-1]+pdf[i],decimals=6))

          eq_levels = np.around(np.multiply(cdf,255))

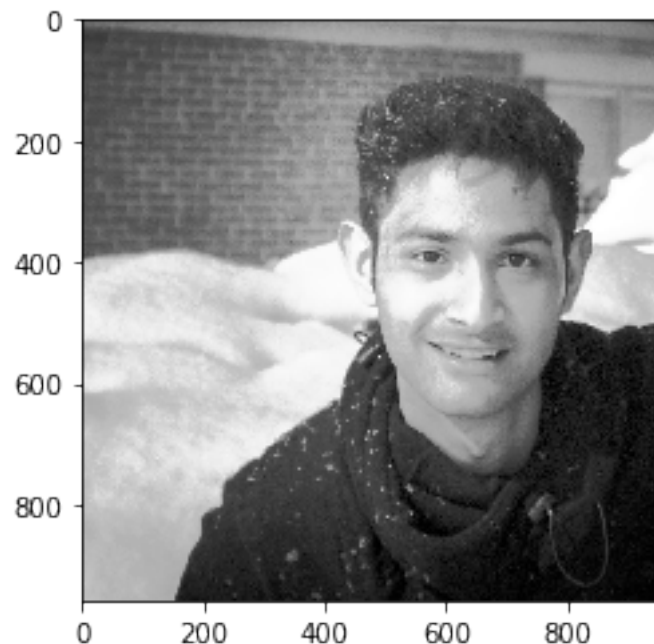
          out=np.zeros(image.shape)
          for i in range(image.shape[0]):
              for j in range(image.shape[1]):
                  out[i][j]=eq_levels[image[i][j]]
          out = np.array(out,dtype=np.uint8)
          return out,eq_levels

In [37]: out1,levels1 = equalisation(image1)

In [38]: plt.imshow(out1,cmap='gray')

Out[38]: <matplotlib.image.AxesImage at 0x128f4ce48>

```



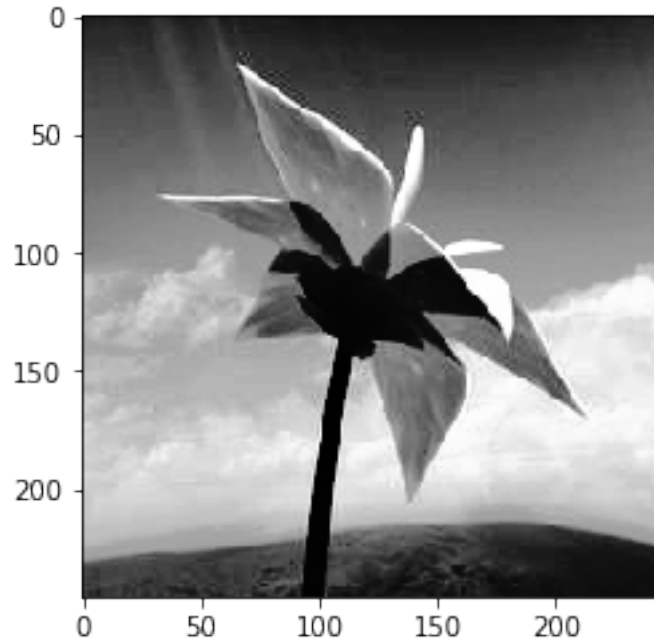
```
In [39]: levels1
```

```
Out[39]: array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,
                  0.,  0.,  0.,  0.,  0.,  1.,  2.,  5.,  9., 14., 18.,
                  22., 27., 30., 34., 37., 39., 41., 43., 45., 47., 49.,
                  51., 53., 54., 56., 57., 59., 60., 61., 63., 64., 65.,
                  66., 67., 68., 69., 69., 70., 71., 72., 73., 73., 74.,
                  75., 76., 76., 77., 78., 79., 80., 80., 81., 82., 83.,
                  84., 85., 86., 87., 88., 89., 90., 92., 93., 94., 95.,
                  96., 97., 98., 100., 101., 102., 103., 104., 105., 106., 108.,
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                  132., 132., 133., 134., 135., 136., 137., 138., 139., 140., 140.,
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                  249., 250., 250., 250., 251., 251., 251., 251., 252., 252., 252.,
                  252., 252., 252., 252., 253., 253., 253., 253., 254.,
                  255., 255., 255.]])
```

```
In [40]: out2, levels2 = equalisation(image2)
```

```
In [41]: plt.imshow(out2, cmap='gray')
```

```
Out[41]: <matplotlib.image.AxesImage at 0x129004278>
```



```
In [42]: levels2
```

```
Out[42]: array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,
  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,
  0.,  0.,  0.,  1.,  1.,  1.,  1.,  1.,  1.,  1.,  1.,
  1.,  1.,  1.,  2.,  2.,  2.,  2.,  2.,  2.,  2.,  2.,  3.,
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  4.,  4.,  5.,  5.,  5.,  5.,  5.,  5.,  5.,  5.,  5.,  5.,
  5.,  5.,  5.,  6.,  6.,  6.,  6.,  6.,  6.,  6.,  6.,  6.,
  6.,  6.,  7.,  7.,  7.,  7.,  7.,  7.,  7.,  7.,  7.,  8.,
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252., 252., 253., 253., 253., 253., 253., 254., 254., 254., 254.,
254., 254., 254., 254., 255., 255., 255., 255., 255., 255.,
255., 255., 255.]])
```

```
In [51]: final_mapping = np.zeros(256)
```

```
j = 0
i = 0
while i<256:
    if levels2[j]>=levels1[i]:
        final_mapping[i]=j
        i+=1
        continue
    else:
        j+=1
```

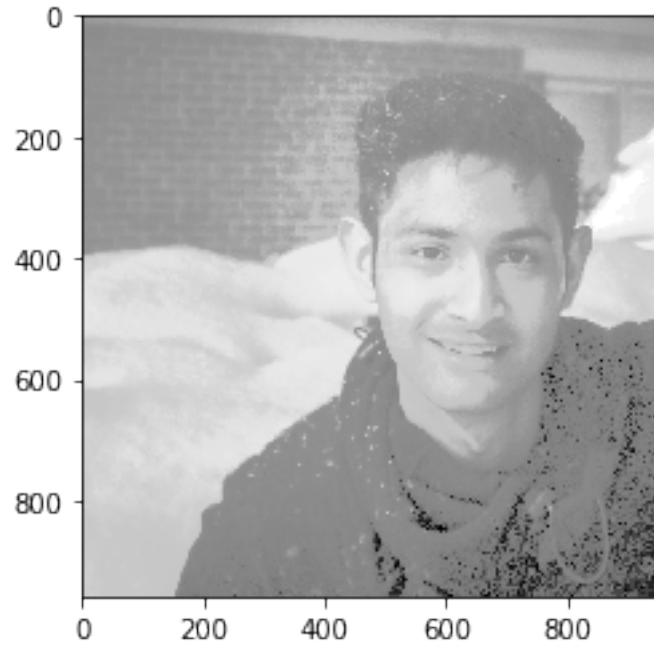
```
In [52]: final_mapping
```

```
Out[52]: array([ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,
                0.,  0.,  0.,  0.,  0., 25., 36., 68., 102., 115., 120.,
                123., 125., 126., 128., 129., 130., 130., 131., 131., 132., 132.,
                133., 133., 134., 134., 134., 135., 135., 135., 136., 136., 136.,
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                193., 194., 194., 194., 195., 195., 196., 196., 196., 197., 198.,
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                208., 210., 211., 213., 215., 217., 218., 219., 219., 220., 221.,
                221., 222., 222., 223., 223., 223., 224., 224., 225., 225., 225.,
                225., 226., 226., 226., 228., 228., 228., 228., 229., 229., 229.,
                229., 229., 229., 229., 229., 229., 233., 233., 233., 233., 238.,
                246., 246., 246.] )
```

```
In [53]: final_out=np.zeros(image1.shape)
for i in range(image1.shape[0]):
    for j in range(image1.shape[1]):
        final_out[i][j]=final_mapping[image1[i][j]]
final_out = np.array(final_out,dtype=np.uint8)
```

```
In [55]: plt.imshow(final_out,cmap='gray')
```

```
Out[55]: <matplotlib.image.AxesImage at 0x12945eeb8>
```



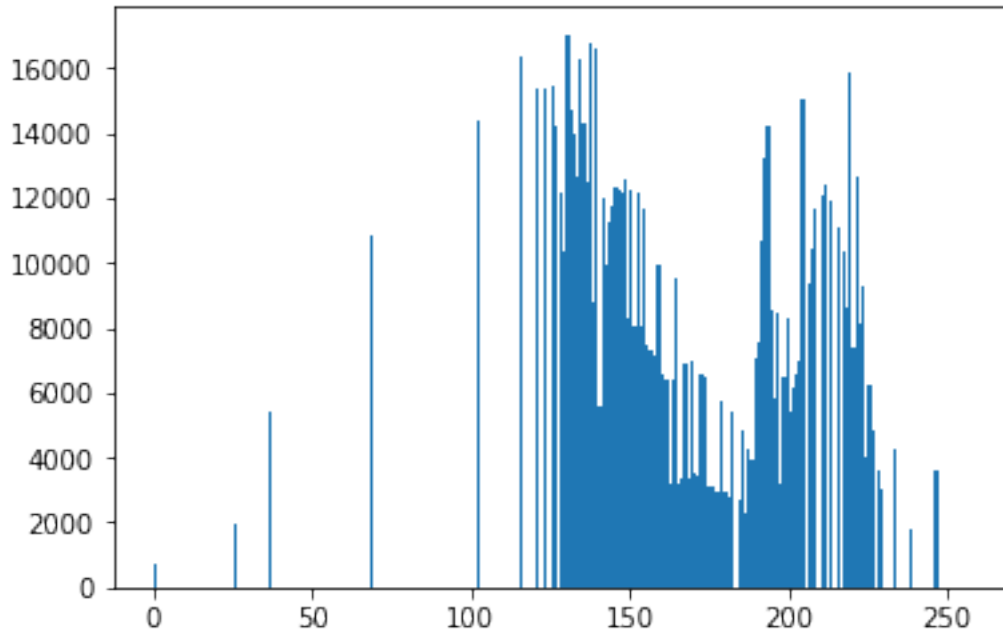
```
In [56]: plt.hist(final_out.ravel(),256,[0,256])
```

```
Out[56]: (array([ 728.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0., 1936.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0., 5401.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0.,    0.,    0.,    0., 14391.,    0.,
    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
    0.,    0.,    0., 16384.,    0.,    0.,    0.,    0.,
15396.,    0.,    0., 15370.,    0., 15431., 14197.,    0.,
12152., 10335., 17035., 14689., 13986., 12641., 16288., 14264.,
12518., 16794.,  8814., 16580.,  5583., 12023.,  9960., 11257.,
11782., 12355., 12249., 12161., 12551.,  8274., 12213.,  8065.,
12178.,  8084., 11628.,  7489.,  7269.,  7154.,  9974.,  9933.,
 6529.,  6388.,  3167.,  6392.,  9543.,  3227.,  3387.,  6920.,
 3383.,  6937.,  3480.,  3467.,  6605.,  6446.,  3109.,  3117.,
 3098.,  2983.,  5752.,  2930.,  2983.,  2781.,  5412.,    0.,
 2671.,  4843.,  2313.,  4296.,  3955.,  7057.,  7575., 10674.,
```

```

13248., 14201., 8547., 5813., 8472., 3189., 6456., 8288.,
5389., 6143., 6591., 6945., 15075., 0., 9393., 10456.,
11643., 0., 12068., 12370., 0., 11875., 0., 11074.,
0., 10362., 8586., 15853., 7417., 12627., 8133., 9267.,
4046., 6207., 4840., 0., 3611., 3010., 0., 0.,
0., 4283., 0., 0., 0., 0., 1813., 0.,
0., 0., 0., 0., 0., 0., 3596., 0.,
0., 0., 0., 0., 0., 0., 0., 0.]),
array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9., 10.,
11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21.,
22., 23., 24., 25., 26., 27., 28., 29., 30., 31., 32.,
33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
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132., 133., 134., 135., 136., 137., 138., 139., 140., 141., 142.,
143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
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187., 188., 189., 190., 191., 192., 193., 194., 195., 196., 197.,
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209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,
220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,
253., 254., 255., 256.]),
<a list of 256 Patch objects>)

```

```
In [57]: plt.hist(image1.ravel(),256,[0,256])
```

```
Out[57]: (array([0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,
0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00, 0.0000e+00,
0.0000e+00, 4.0000e+00, 1.4000e+01, 4.1000e+01, 1.3900e+02,
5.3000e+02, 1.9360e+03, 5.4010e+03, 1.0821e+04, 1.4391e+04,
1.6384e+04, 1.5396e+04, 1.5370e+04, 1.5431e+04, 1.4197e+04,
1.2152e+04, 1.0335e+04, 8.9400e+03, 8.0950e+03, 7.4570e+03,
7.2320e+03, 7.0980e+03, 6.8880e+03, 6.5340e+03, 6.1070e+03,
5.6790e+03, 5.4360e+03, 5.1730e+03, 5.0900e+03, 4.7480e+03,
4.4260e+03, 4.3900e+03, 4.1620e+03, 3.9660e+03, 3.6680e+03,
3.5500e+03, 3.2820e+03, 3.2280e+03, 3.0660e+03, 3.0590e+03,
2.9810e+03, 2.7740e+03, 2.8010e+03, 2.7070e+03, 2.6940e+03,
2.8070e+03, 2.7780e+03, 2.7930e+03, 2.7750e+03, 2.8080e+03,
2.9620e+03, 2.9490e+03, 2.9780e+03, 3.1340e+03, 3.1530e+03,
3.3280e+03, 3.4790e+03, 3.6340e+03, 3.8070e+03, 3.8160e+03,
3.8480e+03, 3.9350e+03, 3.9990e+03, 4.0850e+03, 4.1750e+03,
4.0950e+03, 4.1620e+03, 4.0940e+03, 3.9930e+03, 4.0690e+03,
3.9880e+03, 4.1040e+03, 4.2280e+03, 4.1020e+03, 4.2210e+03,
4.1830e+03, 4.0910e+03, 4.1350e+03, 4.0990e+03, 3.9790e+03,
4.0110e+03, 4.0540e+03, 4.0350e+03, 4.0300e+03, 4.1130e+03,
4.1030e+03, 3.9810e+03, 3.8950e+03, 3.8410e+03, 3.8920e+03,
3.8270e+03, 3.6620e+03, 3.7050e+03, 3.5640e+03, 3.6170e+03,
3.5370e+03, 3.3260e+03, 3.3210e+03, 3.3270e+03, 3.3310e+03,
3.2930e+03, 3.3090e+03, 3.2780e+03, 3.2510e+03, 3.2690e+03,
3.1190e+03, 3.1670e+03, 3.2130e+03, 3.1790e+03, 3.2070e+03,
```

```

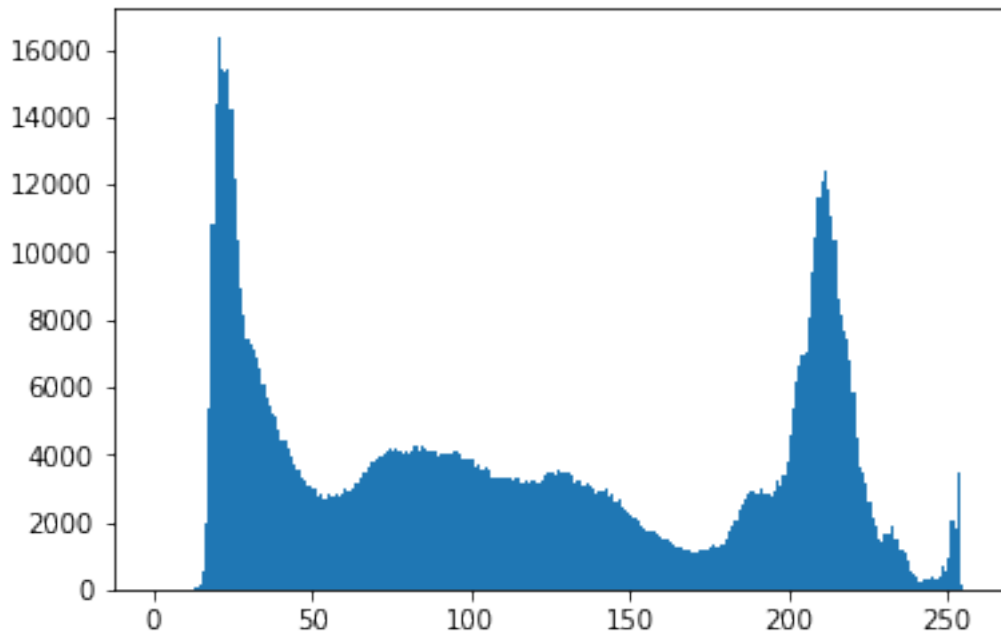
3.1680e+03, 3.1680e+03, 3.2270e+03, 3.3870e+03, 3.4450e+03,
3.4750e+03, 3.3830e+03, 3.5060e+03, 3.4310e+03, 3.4800e+03,
3.4670e+03, 3.4230e+03, 3.1820e+03, 3.2260e+03, 3.2200e+03,
3.1090e+03, 3.1170e+03, 3.0980e+03, 2.9830e+03, 2.8660e+03,
2.8860e+03, 2.9300e+03, 2.9830e+03, 2.7810e+03, 2.8090e+03,
2.6030e+03, 2.6710e+03, 2.4640e+03, 2.3790e+03, 2.3130e+03,
2.1720e+03, 2.1240e+03, 2.0690e+03, 1.8860e+03, 1.8370e+03,
1.7160e+03, 1.7500e+03, 1.7540e+03, 1.6800e+03, 1.5720e+03,
1.4550e+03, 1.4500e+03, 1.4180e+03, 1.3210e+03, 1.2840e+03,
1.2180e+03, 1.2120e+03, 1.1840e+03, 1.1950e+03, 1.0960e+03,
1.0740e+03, 1.0900e+03, 1.1620e+03, 1.1720e+03, 1.1790e+03,
1.2720e+03, 1.2930e+03, 1.2640e+03, 1.3320e+03, 1.3540e+03,
1.5240e+03, 1.6960e+03, 1.8470e+03, 2.0300e+03, 2.3390e+03,
2.4810e+03, 2.7110e+03, 2.7930e+03, 2.8720e+03, 2.8440e+03,
2.8310e+03, 3.0060e+03, 2.8070e+03, 2.8200e+03, 2.7230e+03,
2.9290e+03, 3.1890e+03, 3.0830e+03, 3.3730e+03, 3.7540e+03,
4.5340e+03, 5.3890e+03, 6.1430e+03, 6.5910e+03, 6.9450e+03,
7.0540e+03, 8.0210e+03, 9.3930e+03, 1.0456e+04, 1.1643e+04,
1.2068e+04, 1.2370e+04, 1.1875e+04, 1.1074e+04, 1.0362e+04,
8.5860e+03, 8.1610e+03, 7.6920e+03, 7.4170e+03, 6.8190e+03,
5.8080e+03, 4.5270e+03, 3.6060e+03, 3.4900e+03, 3.1600e+03,
2.6170e+03, 2.1490e+03, 1.8970e+03, 1.4790e+03, 1.4330e+03,
1.6260e+03, 1.6690e+03, 1.9050e+03, 1.4740e+03, 1.4610e+03,
1.1510e+03, 1.0960e+03, 8.4300e+02, 5.2100e+02, 4.3000e+02,
3.5700e+02, 2.4500e+02, 2.7500e+02, 2.6800e+02, 3.3800e+02,
3.5000e+02, 3.4000e+02, 4.0700e+02, 7.1200e+02, 5.7700e+02,
9.2300e+02, 2.0710e+03, 1.8130e+03, 3.4500e+03, 1.3800e+02,
8.0000e+00]),
array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9., 10.,
11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21.,
22., 23., 24., 25., 26., 27., 28., 29., 30., 31., 32.,
33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
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143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
165., 166., 167., 168., 169., 170., 171., 172., 173., 174., 175.,
176., 177., 178., 179., 180., 181., 182., 183., 184., 185., 186.,
187., 188., 189., 190., 191., 192., 193., 194., 195., 196., 197.,
198., 199., 200., 201., 202., 203., 204., 205., 206., 207., 208.,
209., 210., 211., 212., 213., 214., 215., 216., 217., 218., 219.,

```

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220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,
253., 254., 255., 256.]),
<a list of 256 Patch objects>)

```



```
In [58]: plt.hist(image2.ravel(),256,[0,256])
```

```

Out[58]: (array([0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
0.000e+00, 0.000e+00, 2.000e+00, 0.000e+00, 1.000e+00, 3.000e+00,
1.000e+00, 1.000e+00, 6.000e+00, 7.000e+00, 3.000e+00, 4.000e+00,
5.000e+00, 8.000e+00, 9.000e+00, 1.800e+01, 1.300e+01, 1.000e+01,
2.000e+01, 1.100e+01, 1.400e+01, 2.100e+01, 2.100e+01, 1.700e+01,
1.700e+01, 2.200e+01, 3.400e+01, 1.800e+01, 3.400e+01, 3.200e+01,
3.700e+01, 2.900e+01, 3.300e+01, 3.800e+01, 3.500e+01, 3.100e+01,
2.600e+01, 3.200e+01, 4.200e+01, 2.900e+01, 1.900e+01, 1.600e+01,
1.100e+01, 1.700e+01, 1.900e+01, 9.000e+00, 1.700e+01, 1.200e+01,
1.200e+01, 1.500e+01, 1.600e+01, 7.000e+00, 2.300e+01, 2.600e+01,
1.900e+01, 2.100e+01, 1.500e+01, 1.700e+01, 2.200e+01, 2.000e+01,
2.000e+01, 1.600e+01, 1.900e+01, 1.300e+01, 2.400e+01, 1.800e+01,
2.500e+01, 1.600e+01, 2.300e+01, 1.800e+01, 2.200e+01, 2.100e+01,
2.400e+01, 2.100e+01, 2.000e+01, 2.100e+01, 1.800e+01, 1.900e+01,
2.400e+01, 2.600e+01, 2.500e+01, 2.300e+01, 2.800e+01, 2.500e+01,
3.300e+01, 2.300e+01, 3.300e+01, 3.000e+01, 2.000e+01, 3.100e+01,
3.400e+01, 3.000e+01, 3.900e+01, 5.200e+01, 5.100e+01, 5.200e+01,
8.200e+01, 8.000e+01, 9.000e+01, 9.100e+01, 8.500e+01, 1.040e+02,

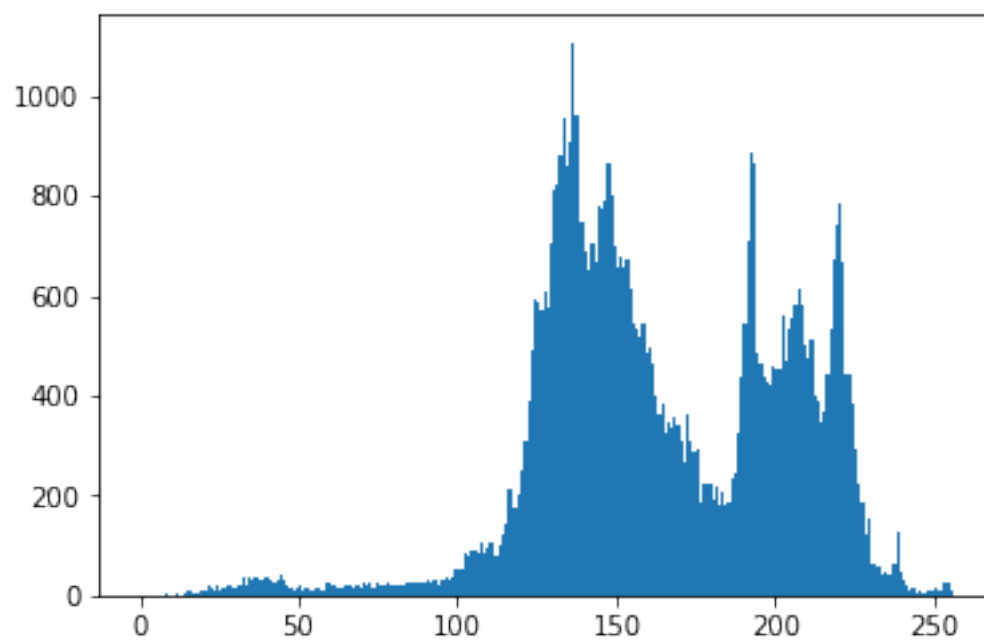
```

```

8.500e+01, 9.400e+01, 1.040e+02, 8.000e+01, 7.900e+01, 9.800e+01,
1.240e+02, 1.420e+02, 2.140e+02, 1.770e+02, 1.750e+02, 2.030e+02,
2.490e+02, 3.080e+02, 3.900e+02, 4.910e+02, 5.900e+02, 5.850e+02,
5.710e+02, 6.090e+02, 5.760e+02, 7.050e+02, 8.130e+02, 8.210e+02,
8.790e+02, 9.540e+02, 8.570e+02, 9.090e+02, 1.107e+03, 9.590e+02,
7.480e+02, 7.460e+02, 6.900e+02, 6.500e+02, 7.040e+02, 6.690e+02,
7.820e+02, 7.760e+02, 7.920e+02, 8.630e+02, 7.990e+02, 7.000e+02,
6.560e+02, 6.790e+02, 6.590e+02, 6.720e+02, 6.160e+02, 5.430e+02,
5.350e+02, 5.150e+02, 5.440e+02, 4.860e+02, 4.940e+02, 4.660e+02,
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3.590e+02, 3.410e+02, 3.080e+02, 2.660e+02, 3.600e+02, 3.090e+02,
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1.920e+02, 2.160e+02, 1.790e+02, 2.080e+02, 1.800e+02, 1.870e+02,
2.320e+02, 2.460e+02, 3.260e+02, 4.380e+02, 5.450e+02, 7.080e+02,
8.850e+02, 8.630e+02, 4.840e+02, 4.650e+02, 4.360e+02, 4.250e+02,
4.220e+02, 4.580e+02, 4.510e+02, 4.520e+02, 5.580e+02, 4.720e+02,
5.320e+02, 5.530e+02, 5.840e+02, 6.120e+02, 5.790e+02, 4.990e+02,
4.760e+02, 5.110e+02, 3.990e+02, 3.870e+02, 3.460e+02, 3.690e+02,
4.420e+02, 5.350e+02, 6.700e+02, 7.430e+02, 7.870e+02, 6.650e+02,
4.450e+02, 4.400e+02, 3.820e+02, 2.920e+02, 2.240e+02, 1.860e+02,
1.210e+02, 1.550e+02, 6.100e+01, 6.400e+01, 5.900e+01, 4.400e+01,
4.500e+01, 4.200e+01, 4.100e+01, 6.400e+01, 1.280e+02, 4.800e+01,
3.000e+01, 2.200e+01, 7.000e+00, 1.600e+01, 6.000e+00, 8.000e+00,
5.000e+00, 3.000e+00, 7.000e+00, 7.000e+00, 1.400e+01, 1.100e+01,
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33., 34., 35., 36., 37., 38., 39., 40., 41., 42., 43.,
44., 45., 46., 47., 48., 49., 50., 51., 52., 53., 54.,
55., 56., 57., 58., 59., 60., 61., 62., 63., 64., 65.,
66., 67., 68., 69., 70., 71., 72., 73., 74., 75., 76.,
77., 78., 79., 80., 81., 82., 83., 84., 85., 86., 87.,
88., 89., 90., 91., 92., 93., 94., 95., 96., 97., 98.,
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132., 133., 134., 135., 136., 137., 138., 139., 140., 141., 142.,
143., 144., 145., 146., 147., 148., 149., 150., 151., 152., 153.,
154., 155., 156., 157., 158., 159., 160., 161., 162., 163., 164.,
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220., 221., 222., 223., 224., 225., 226., 227., 228., 229., 230.,
231., 232., 233., 234., 235., 236., 237., 238., 239., 240., 241.,
242., 243., 244., 245., 246., 247., 248., 249., 250., 251., 252.,

```

```
253., 254., 255., 256.] ),  
<a list of 256 Patch objects>)
```



```
In [ ]:
```

Dilation

April 28, 2019

```
In [3]: import numpy as np
import cv2
def pad(img,shp):
    p=np.zeros((shp[0]+1,shp[1]+1))
    p[1:,1:]=np.copy(img)
    p[0,1:]=img[0]
    p[1:,0]=img[:,0]
    p[0,0]=img[0,0]
    p[-1,0]=img[-1,0]
    return p

def comp(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]==metric[i,j]:
                return True
    return False

def slice(img):
    temp=np.array(img)
    print(temp.shape)
    int_slice=np.zeros((temp.shape[0],temp.shape[1],8))
    for x in range(8):
        int_slice[:, :, x]=temp%(2)
        temp=(temp/2).astype(int)
    return int_slice

def stitch(int_slice,shp):
    out=np.zeros(shp)
    for x in range(8):
        out=out+int_slice[:, :, x]*(2**x)
    return out

img=cv2.imread('edges_detected.png',0)
shp=img.shape
temp=pad(img,shp)
int_slice=slice(temp)
```

```

struct_el=np.array([[1,1],[1,1]])
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp(int_slice[i:i+2,j:j+2,x],struct_el):
                int_slice_new[i,j,x]=1

out=stitch(int_slice_new,shp)
out=np.array(out, dtype = np.uint8)
print(img)
print(out)
cv2.imshow('image', img)
cv2.imshow('dilated', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

(289, 433)
[[255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 ...
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]]
[[255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 ...
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]
 [255 255 255 ... 255 255 255]]

```

In []:

Erosion

April 28, 2019

```
In [2]: import numpy as np
import cv2
def pad(img,shp):
    p=np.zeros((shp[0]+1,shp[1]+1))
    p[1:,1:]=np.copy(img)
    p[0,1:]=img[0]
    p[1:,0]=img[:,0]
    p[0,0]=img[0,0]
    p[-1,0]=img[-1,0]
    return p

def comp(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]!=metric[i,j]:
                return False
    return True

def slice(img):
    temp=np.array(img)
    print(temp.shape)
    int_slice=np.zeros((temp.shape[0],temp.shape[1],8))
    for x in range(8):
        int_slice[:, :, x]=temp%(2)
        temp=(temp/2).astype(int)
    return int_slice

def stitch(int_slice,shp):
    out=np.zeros(shp)
    for x in range(8):
        out=out+int_slice[:, :, x]*(2**x)
    return out

img=cv2.imread('cat.jpeg',0)
shp=img.shape
temp=pad(img,shp)
int_slice=slice(temp)
```



```

struct_el=np.array([[1,1],[1,1]])
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp(int_slice[i:i+2,j:j+2,x],struct_el):
                int_slice_new[i,j,x]=1

out=stitch(int_slice_new,shp)
out=np.array(out, dtype = np.uint8)
print(img)
print(out)
cv2.imshow('image', img)
cv2.imshow('eroded', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

(351, 529)
[[14 21 29 ... 7 7 7]
 [13 20 28 ... 6 6 6]
 [12 19 28 ... 6 6 6]
 ...
 [ 8 7 5 ... 0 0 0]
 [ 9 8 6 ... 0 0 0]
 [10 9 7 ... 0 0 0]]
[[14 4 21 ... 7 7 7]
 [12 4 20 ... 6 6 6]
 [12 0 16 ... 6 6 6]
 ...
 [ 0 0 4 ... 0 0 0]
 [ 8 0 0 ... 0 0 0]
 [ 8 8 0 ... 0 0 0]]

```

In []:

Closing

April 28, 2019

```
In [ ]: import numpy as np
import cv2
def pad(img,shp):
    p=np.zeros((shp[0]+1,shp[1]+1))
    p[1:,1:]=np.copy(img)
    p[0,1:]=img[0]
    p[1:,0]=img[:,0]
    p[0,0]=img[0,0]
    p[-1,0]=img[-1,0]
    return p

def comp_erosion(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]!=metric[i,j]:
                return False
    return True

def comp_dilation(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]==metric[i,j]:
                return True
    return False

def slice(img):
    temp=np.array(img)
    print(temp.shape)
    int_slice=np.zeros((temp.shape[0],temp.shape[1],8))
    for x in range(8):
        int_slice[:, :,x]=temp%(2)
        temp=(temp/2).astype(int)
    return int_slice

def stitch(int_slice,shp):
    out=np.zeros(shp)
    for x in range(8):
```

```

        out=out+int_slice[:, :, x]*(2**x)
    return out

img=cv2.imread('cat.jpeg',0)
shp=img.shape
temp=pad(img,shp)
int_slice=slice(temp)
struct_el=np.array([[1,1],[1,1]])
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp_dilation(int_slice[i:i+2,j:j+2,x],struct_el):
                int_slice_new[i,j,x]=1

int_slice=np.array(int_slice_new)
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    test=pad(int_slice[:, :, x],shp)
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp_erosion(test[i:i+2,j:j+2],struct_el):
                int_slice_new[i,j,x]=1

out=stitch(int_slice_new,shp)
out=np.array(out, dtype = np.uint8)
print(img)
print(out)
cv2.imshow('image', img)
cv2.imshow('closed', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

(351, 529)
[[14 21 29 ...  7  7  7]
 [13 20 28 ...  6  6  6]
 [12 19 28 ...  6  6  6]
 ...
 [ 8  7  5 ...  0  0  0]
 [ 9  8  6 ...  0  0  0]
 [10  9  7 ...  0  0  0]]
[[14 14 29 ...  7  7  7]
 [14 14 29 ...  7  7  7]
 [13 13 29 ...  6  6  6]
 ...
 [ 7  7  6 ...  0  0  0]
 [ 9  9  7 ...  0  0  0]]

```

```
[ 9  9 11 ...  0  0  0]
```

```
In [ ]:
```

Opening

April 28, 2019

```
In [ ]: import numpy as np
import cv2
def pad(img,shp):
    p=np.zeros((shp[0]+1,shp[1]+1))
    p[1:,1:]=np.copy(img)
    p[0,1:]=img[0]
    p[1:,0]=img[:,0]
    p[0,0]=img[0,0]
    p[-1,0]=img[-1,0]
    return p

def comp_erosion(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]!=metric[i,j]:
                return False
    return True

def comp_dilation(sample,metric):
    for i in range(2):
        for j in range(2):
            if sample[i,j]==metric[i,j]:
                return True
    return False

def slice(img):
    temp=np.array(img)
    print(temp.shape)
    int_slice=np.zeros((temp.shape[0],temp.shape[1],8))
    for x in range(8):
        int_slice[:, :,x]=temp%(2)
        temp=(temp/2).astype(int)
    return int_slice

def stitch(int_slice,shp):
    out=np.zeros(shp)
    for x in range(8):
```

```

        out=out+int_slice[:, :, x]*(2**x)
    return out

img=cv2.imread('morph1.jpg',0)
shp=img.shape
temp=pad(img,shp)
int_slice=slice(temp)
struct_el=np.array([[1,1],[1,1]])
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp_erosion(int_slice[i:i+2,j:j+2,x],struct_el):
                int_slice_new[i,j,x]=1

int_slice=np.array(int_slice_new)
int_slice_new=np.zeros((shp[0],shp[1],8))
for x in range(8):
    test=pad(int_slice[:, :, x],shp)
    for i in range(shp[0]):
        for j in range(shp[1]):
            if comp_dilation(test[i:i+2,j:j+2],struct_el):
                int_slice_new[i,j,x]=1

out=stitch(int_slice_new,shp)
out=np.array(out, dtype = np.uint8)
print(img)
print(out)
cv2.imshow('image', img)
cv2.imshow('opened', out)
cv2.waitKey(0)
cv2.destroyAllWindows()

(451, 451)
[[0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 4 0 0]
 ...
 [2 0 2 ... 1 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]]
[[0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 ...
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]]

```

```
[0 0 0 ... 0 0 0]
```

```
In [ ]:
```