Canny_Edge_Detection

April 29, 2022

1 Canny Edge Detection – Manually Computed

Five steps in Canny Edge detections:

(i) Noise Reduction:

Using Gaussian kernel:

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i-(k+1))^2+(j-(k+1))^2}{2\sigma^2}\right); 1 \leq i, j \leq (2k+1)$$

for $2k+1 \times 2k+1$ sized kernel.

Our case: $k=1$.

(2) Apply Sobel kernels to image obtained from step (1).

Sobel kernels:

$$k_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \text{ and } k_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Compute Magnitude G of the gradient as:

$$|G| = \sqrt{I_x^2 + I_y^2}$$ (I_x & I_y are gradients obtained from sobel filter).

$$\text{slope}(\theta) = \arctan\left(\frac{I_x}{I_y}\right).$$

(3) Non-Maximum Supression to above output in step (2)

→ Goes through all the points on the above gradient intensity matrix.

→ Find the pixels with max. value in the edge direction.

(4) Double Thresholding: Identify strong, weak and non-relevant pixels. using thresholds.

(5) Hysteresis: Transform weak pixel to strong iff atleast one pixel around is strong.

These steps are used for our 5x5 image patch to compute canny edge detection using python as shown below:

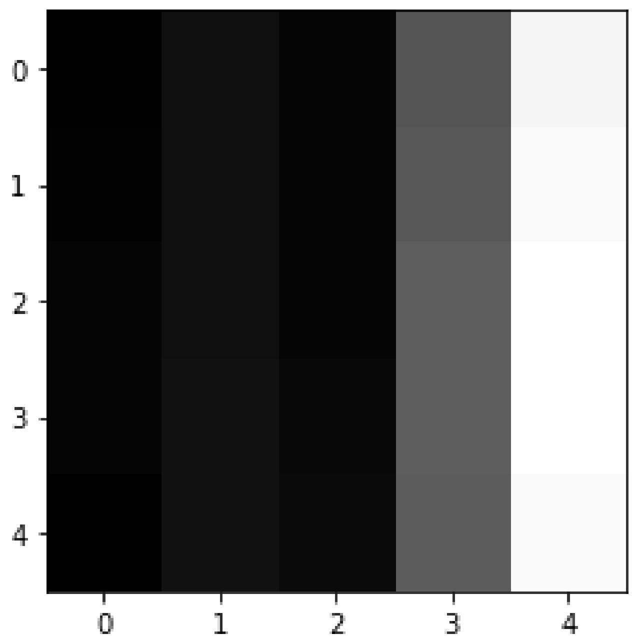
[1]:
```python
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import os
```

2 Read Image

[2]:
```python
img = mpimg.imread('image_patch/e4.jpg')
print(img)
plt.imshow(img, 'gray')
```

```
[[ 28  39  32  87 199]
 [ 30  39  32  89 202]
 [ 32  39  32  93 206]
 [ 32  40  34  94 206]
 [ 28  40  35  92 202]]
```

[2]: <matplotlib.image.AxesImage at 0x7fdbe8f9c7f0>



2.1 Functions to compute each steps defined below sequentially

[3]:
```python
def convolve(img, kernel):

    img_height = img.shape[0]
    img_width = img.shape[1]
    pad_height = kernel.shape[0] // 2
    pad_width = kernel.shape[1] // 2
```

```
    pad = ((pad_height, pad_height), (pad_height, pad_width))
    g = np.empty(img.shape, dtype=np.float64)
    img = np.pad(img, pad, mode='constant', constant_values=0)
    # Do convolution
    for i in np.arange(pad_height, img_height+pad_height):
        for j in np.arange(pad_width, img_width+pad_width):
            roi = img[i - pad_height:i + pad_height +
                      1, j - pad_width:j + pad_width + 1]
            g[i - pad_height, j - pad_width] = (roi*kernel).sum()

    if (g.dtype == np.float64):
        kernel = kernel / 255.0
        kernel = (kernel*255).astype(np.uint8)
    else:
        g = g + abs(np.amin(g))
        g = g / np.amax(g)
        g = (g*255.0)
    return g
```

[4]:
```
def gaussian_kernel(size, sigma=0.5):
    size = int(size) // 2
    x, y = np.mgrid[-size:size+1, -size:size+1]
    normal = 1 / (2.0 * np.pi * sigma**2)
    g =  np.exp(-((x**2 + y**2) / (2.0*sigma**2))) * normal
    return g

g = gaussian_kernel(3)
```

[5]:
```
# from scipy.ndimage.filters import convolve
def sobel_filters(img):
    Kx = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]], np.float32)
    Ky = np.array([[1, 2, 1], [0, 0, 0], [-1, -2, -1]], np.float32)
    Ix = convolve(img, Kx)
    Iy = convolve(img, Ky)

    G = np.hypot(Ix, Iy)
    G = G / G.max() * 255
    theta = np.arctan2(Iy, Ix)

    return (G, theta)
```

[6]:
```
def non_max_suppression(img, D):
    M, N = img.shape
    Z = np.zeros((M,N), dtype=np.int32)
    angle = D * 180. / np.pi
    angle[angle < 0] += 180
```

```python
    for i in range(1,M-1):
        for j in range(1,N-1):
            try:
                q = 255
                r = 255

               #angle 0
                if (0 <= angle[i,j] < 22.5) or (157.5 <= angle[i,j] <= 180):
                    q = img[i, j+1]
                    r = img[i, j-1]
                #angle 45
                elif (22.5 <= angle[i,j] < 67.5):
                    q = img[i+1, j-1]
                    r = img[i-1, j+1]
                #angle 90
                elif (67.5 <= angle[i,j] < 112.5):
                    q = img[i+1, j]
                    r = img[i-1, j]
                #angle 135
                elif (112.5 <= angle[i,j] < 157.5):
                    q = img[i-1, j-1]
                    r = img[i+1, j+1]

                if (img[i,j] >= q) and (img[i,j] >= r):
                    Z[i,j] = img[i,j]
                else:
                    Z[i,j] = 0

            except IndexError as e:
                pass

    return Z
```

[7]:
```python
def threshold(img, lowThresholdRatio=0.05, highThresholdRatio=0.09):

    highThreshold = img.max() * highThresholdRatio;
    lowThreshold = highThreshold * lowThresholdRatio;

    M, N = img.shape
    res = np.zeros((M,N), dtype=np.int32)

    weak = np.int32(25)
    strong = np.int32(255)

    strong_i, strong_j = np.where(img >= highThreshold)
    zeros_i, zeros_j = np.where(img < lowThreshold)
```

```python
    weak_i, weak_j = np.where((img <= highThreshold) & (img >= lowThreshold))

    res[strong_i, strong_j] = strong
    res[weak_i, weak_j] = weak

    return (res, weak, strong)
```

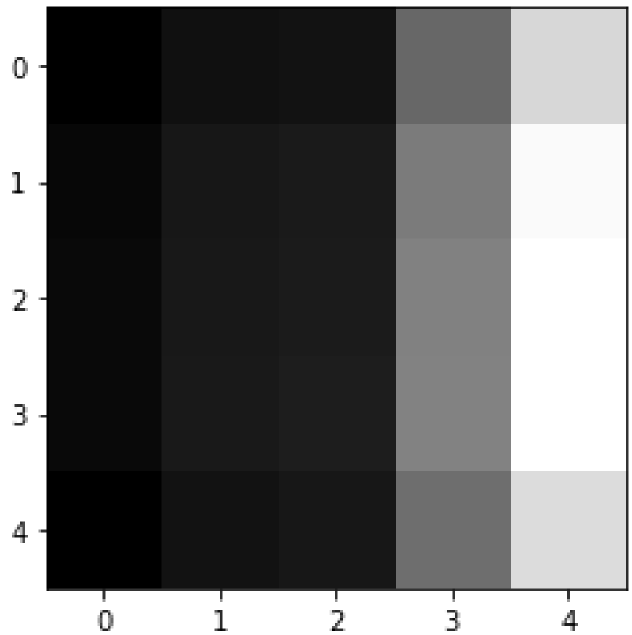
[8]:
```python
def hysteresis(img, weak, strong=255):
    M, N = img.shape
    for i in range(1, M-1):
        for j in range(1, N-1):
            if (img[i,j] == weak):
                try:
                    if ((img[i+1, j-1] == strong) or (img[i+1, j] == strong) or␣
 ↪(img[i+1, j+1] == strong)
                        or (img[i, j-1] == strong) or (img[i, j+1] == strong)
                        or (img[i-1, j-1] == strong) or (img[i-1, j] == strong)␣
 ↪or (img[i-1, j+1] == strong)):
                        img[i, j] = strong
                    else:
                        img[i, j] = 0
                except IndexError as e:
                    pass
    return img
```

3 Step1: Output after applying Gaussian Kernel

[9]:
```python
smoothed_img = convolve(img, gaussian_kernel(3))
print(smoothed_img)
plt.imshow(smoothed_img, 'gray')
```

```
[[ 24.22493853  34.08065179  35.47714976  85.6846606   152.62449028]
 [ 28.53763541  38.33601967  39.92230447  97.79679216 173.25762753]
 [ 29.99484928  38.64113141  40.48588756 101.00467156 176.44218674]
 [ 29.90869217  39.43840532  42.04091865 101.9975799  176.55166405]
 [ 24.49506998  35.10854043  38.1462266   89.88544834 155.36806414]]
```

[9]: <matplotlib.image.AxesImage at 0x7fdbe6edc580>



4 Step2: Sobel Operation to Compute Gradient and Slope

[10]:
```
grad, slope = sobel_filters(smoothed_img)
print('---------Gradients------------------\n',grad)
print('\n------------------Slope----------------\n', slope)
```

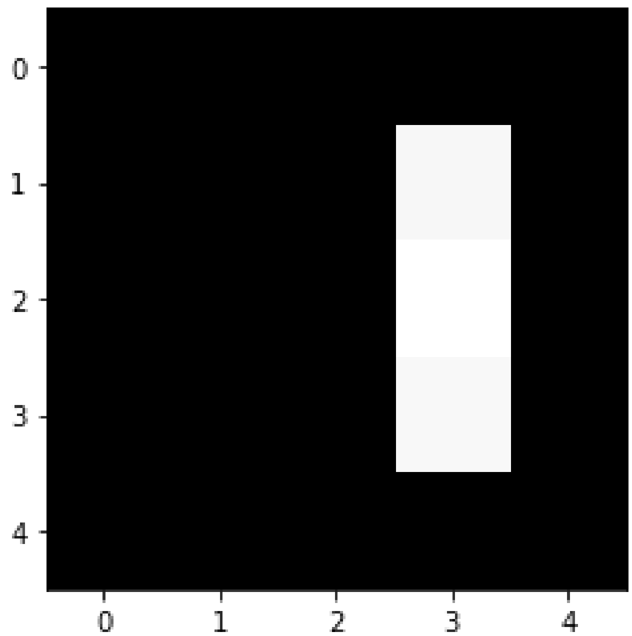
```
---------Gradients------------------
 [[ 64.9949999   67.74511062 122.90429673 249.90093865 236.1340412 ]
 [ 68.30093148  22.16329718 106.72968973 237.80725169 176.10919083]
 [ 70.50345571  20.3921768  112.24390427 245.43034896 182.70772159]
 [ 69.69089828  23.022892   110.46997801 238.27380823 181.12280929]
 [ 67.2311872   70.86349709 128.9536358  255.         243.30810674]]

------------------Slope----------------
 [[-0.73054705 -1.34140128 -0.92526632 -0.83834108 -2.11547271]
 [-0.10735651 -0.42040278 -0.12768018 -0.11391294 -2.97837489]
 [-0.02478907 -0.12727621 -0.03864546 -0.02558775 -3.11474803]
 [ 0.09492764  0.29869271  0.07962668  0.08720124  3.00750849]
 [ 0.73565878  1.31506453  0.9189068   0.85305276  2.12516632]]
```

5 Step3: Non-Maximum Supression

[11]:
```
non_max_img = non_max_suppression(grad, slope)
print(non_max_img)
plt.imshow(non_max_img, 'gray')
```

```
[[  0   0   0   0   0]
 [  0   0   0 237   0]
 [  0   0   0 245   0]
 [  0   0   0 238   0]
 [  0   0   0   0   0]]
```

[11]: <matplotlib.image.AxesImage at 0x7fdbe6ebeb80>

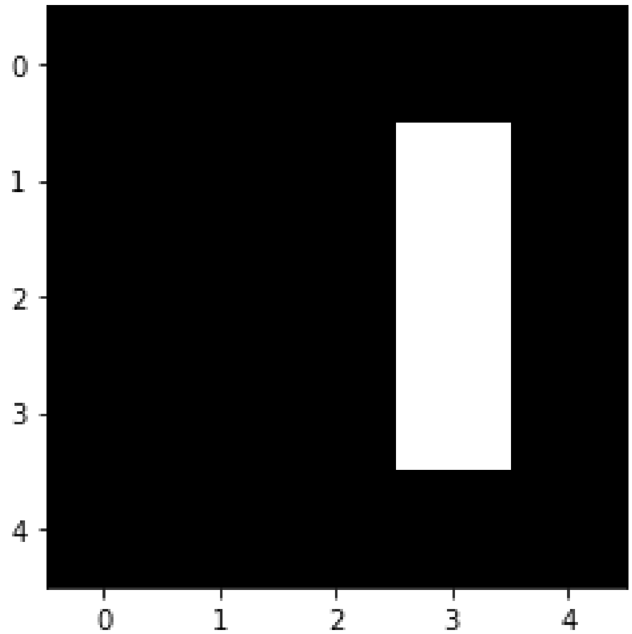


6 Step4: Double Thresholding

[12]:
```
thres_img, weak, strong = threshold(non_max_img)
print(thres_img)
plt.imshow(thres_img, 'gray')
```

```
[[  0   0   0   0   0]
 [  0   0   0 255   0]
 [  0   0   0 255   0]
 [  0   0   0 255   0]
 [  0   0   0   0   0]]
```

[12]: <matplotlib.image.AxesImage at 0x7fdbe6e23280>

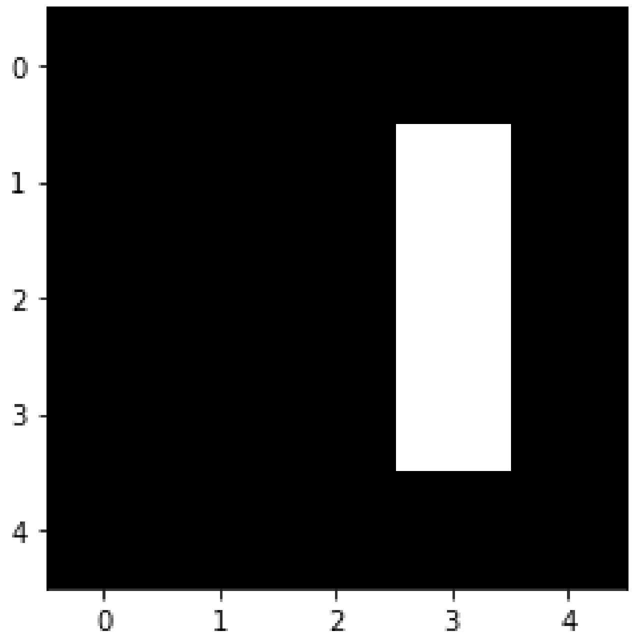


7 Step 5: Final Output with Hysterisis

[13]:
```
final_image = hysteresis(thres_img, weak)
print(final_image)
plt.imshow(final_image, 'gray')
```

```
[[  0   0   0   0   0]
 [  0   0   0 255   0]
 [  0   0   0 255   0]
 [  0   0   0 255   0]
 [  0   0   0   0   0]]
```

[13]: <matplotlib.image.AxesImage at 0x7fdbe6df7850>


0
1
2
3
4
0
1
2
3
4