EECE5639-HW2

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[830]:
```
# import libraries
import numpy as np
import cv2 as cv
import matplotlib.pyplot as plt
```

\textbf{Problem #1} #Problem #1 The average of the stand. dev. of noise in the images is equal to the sigma we originally set when adding noise. In addition, the maximum stand. dev. of the noise is twice the sigma. These are both reduced by a factor of the width of the box filter after we complete the smoothing. This shows that a box filter is a good way of reducing random noise during image processing.

[831]:
```
# Create 10 images with grayscale value 128
num = 10
rowcol = 256
images = 128*np.ones([rowcol,rowcol,num])

# Add noise to the images
sigma = 5
mean = 0
noise = sigma*np.random.randn(rowcol,rowcol,num) + mean
images = images+noise

# Signal to noise ratio
avg_image = np.mean(images,axis=2)
avg_images = np.repeat(avg_image[:, :, np.newaxis], num, axis=2)

EST_NOISE = np.sqrt( 1/(num-1)*np.sum( (avg_images-images)**2, axis=2) )
avg_EST_NOISE = np.mean(EST_NOISE)
max_EST_NOISE = np.amax(EST_NOISE)

print('Original')
print('The average noise is:', np.round(avg_EST_NOISE,3))
print('The max noise is:', np.round(max_EST_NOISE,3))
print('The max-to-avg noise is:', np.round(max_EST_NOISE/avg_EST_NOISE,3))

# Smooth images with 3x3 box filter
```

```
width = 3
images_smoothed = cv.blur(images, (width, width))
avg_image_smoothed = np.mean(images_smoothed,axis=2)
avg_images_smoothed = np.repeat(avg_image_smoothed[:, :, np.newaxis], num,␣
↪axis=2)

EST_NOISE_smoothed = np.sqrt( 1/(num-1)*np.sum(␣
↪(avg_images_smoothed-images_smoothed)**2, axis=2) )
avg_EST_NOISE_smoothed = np.mean(EST_NOISE_smoothed)
max_EST_NOISE_smoothed = np.amax(EST_NOISE_smoothed)

print('Smoothed')
print('The average noise is:', np.round(avg_EST_NOISE_smoothed,3))
print('The max noise is:', np.round(max_EST_NOISE_smoothed,3))
print('The max-to-avg noise is:', np.round(max_EST_NOISE/avg_EST_NOISE,3))
```

```
Original
The average noise is: 4.856
The max noise is: 10.204
The max-to-avg noise is: 2.101
Smoothed
The average noise is: 1.627
The max noise is: 3.829
The max-to-avg noise is: 2.101
```

#Problem #2 Two 1D guassian filters were calculated by taking the squareroot of the diagonals of a 2D gaussian filter. A width of 5 and 7 were used because this corresponds to 2 and 3 sigma which is ~95% and ~99% of the area of the bell curve.

[832]:
```
def Gauss1D(sigma, factor):
    window = np.int(np.floor(sigma*factor))
    gauss2d = np.ones([window,window])
    offset = np.floor(window/2)
    for i in range(window):
        for j in range(window):
            gauss2d[i,j] = np.exp( -1/(2*sigma**2)*( (i-offset)**2 +␣
↪(j-offset)**2 ) )
    gauss2d = gauss2d/np.sum(gauss2d)

    diag = gauss2d*np.identity(gauss2d.shape[0])
    diag = diag[diag>0]
    gauss1d = np.sqrt(diag)
    return gauss1d

gauss1d = Gauss1D(1.4,5)
print('The 1D gaussian filter with a width of 5 is:')
print(np.around(gauss1d, 3) )
print()
```

```
gauss1d = Gauss1D(1.4,7)
print('The 1D gaussian filter with a width of 7 is:')
print(np.around(gauss1d, 3) )
```

```
The 1D gaussian filter with a width of 5 is:
[0.029 0.104 0.223 0.288 0.223 0.104 0.029]

The 1D gaussian filter with a width of 7 is:
[0.005 0.029 0.103 0.221 0.285 0.221 0.103 0.029 0.005]
```

#Problem #3 Consider the following two averaging filters used to clean images:

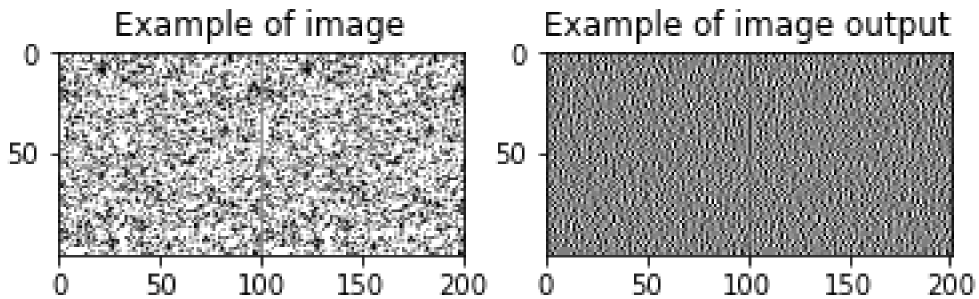
[833]:
```
img = np.array([10.,10.,10.,10.,10.,40.,40.,40.,40.,40.])
pad = np.hstack([0.,0.,img,0.,0.])
avg_const = 1/5*np.array([1,1,1,1,1])

output = np.zeros(img.shape)
for i in range(img.size):
  output[i] = np.dot(pad[i:i+avg_const.size], avg_const)
print('Filter (a) output with zero padding:')
print(output)

avg_gauss = 1/10*np.array([1,2,4,2,1])
output = np.zeros(img.shape)
for i in range(img.size):
  output[i] = np.dot(pad[i:i+avg_gauss.size], avg_gauss)
print('Filter (b) output with zero padding:')
print(output)
```

```
Filter (a) output with zero padding:
[ 6.  8. 10. 16. 22. 28. 34. 40. 32. 24.]
Filter (b) output with zero padding:
[ 7.  9. 10. 13. 19. 31. 37. 40. 36. 28.]
```

#Problem #4

[834]:
```
r = 100
c = 100
salt_pepper = 100*np.random.choice(np.arange(0, 2), r*c, p=[0.3, 0.7])
salt_pepper = np.reshape(salt_pepper, [r,c])

image = np.hstack([salt_pepper, 50*np.ones([r,1]), salt_pepper])
plt.subplot(1,2,1)
plt.title('Example of image')
plt.imshow(image, cmap='gray', vmin=0, vmax=100)

operator = np.array([-1,2,-1])
operator = np.reshape(operator,[1,3])
```

```
output = cv.filter2D(image, -1, operator)
plt.subplot(1,2,2)
plt.title('Example of image output')
plt.imshow(output, cmap='gray', vmin=-100, vmax=100)
plt.show()

line = output[:,c]
#plt.hist(line, [-100, 0, 100, 200])
#plt.show()
```



Operator is on the line

[835]:
```
# Operator input possibilities
options = np.array([[0, 50, 0],
                    [0, 50, 100],
                    [100, 50, 0],
                    [100, 50, 100]])

# Operator output possibilities
output = np.sum(operator*options,axis=1)

# Probabilities
chances = np.array([0.3**2, 0.3*0.7, 0.7*0.3, 0.7**2])

print("Chances of  100 are: ", np.round(chances[0],2))
print("Chances of    0 are: ", np.round(chances[1]+chances[2],2))
print("Chances of -100 are: ", np.round(chances[3],2))
```

```
Chances of  100 are:  0.09
Chances of    0 are:  0.42
Chances of -100 are:  0.49
```

Operator is adjacent to the line

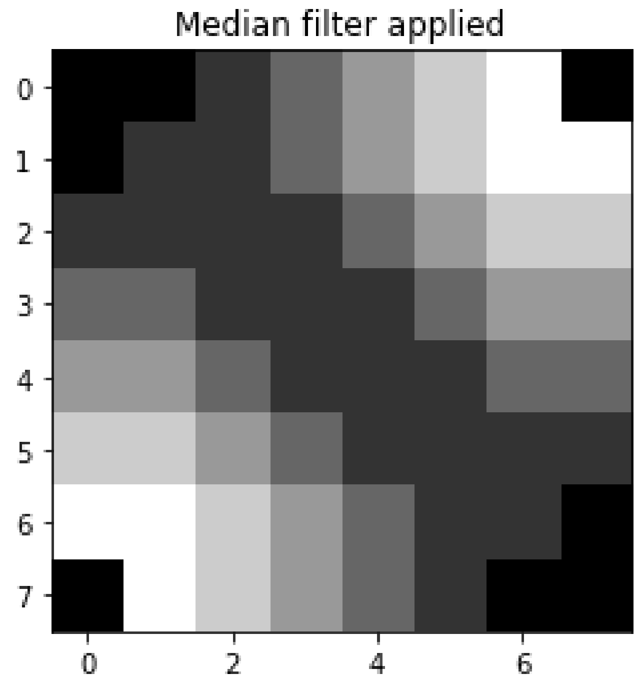
[836]:
```
# Operator input possibilities
options = np.array([[50, 0, 0],
```

```
                    [50, 0, 100],
                    [50, 100, 0],
                    [50, 100, 100]])

# Operator output possibilities
output = np.sum(operator*options,axis=1)

# Probabilities
chances = np.array([0.3**2, 0.3*0.7, 0.7*0.3, 0.7**2])

print("Chances of -150 are: ", np.round(chances[1],2))
print("Chances of  -50 are: ", np.round(chances[0],2))
print("Chances of   50 are: ", np.round(chances[3],2))
print("Chances of  150 are: ", np.round(chances[2],2))
```

```
Chances of -150 are:  0.21
Chances of  -50 are:  0.09
Chances of   50 are:  0.49
Chances of  150 are:  0.21
```

#Problem #5 An 8x8 image I(i, j) has pixel values following the equation $I(i, j) = |i - j|$ with i, j = 0, 1, . . . , 7 Find the output image obtained by applying a 3×3 median filter on the image I. (Assume that the border pixels are not changed)

[837]:
```
fxy = np.zeros([8,8])
for i in range(8):
  for j in range(8):
    fxy[i,j] = abs(i-j)

# Add zero padding
fxy = np.hstack((np.zeros([fxy.shape[0],1]), fxy, np.zeros([fxy.shape[0],1])))
fxy = np.vstack((np.zeros([1,fxy.shape[1]]), fxy, np.zeros([1,fxy.shape[1]])))
fxy = np.uint8(fxy)
fxy_med = cv.medianBlur(fxy,3)

# Remove added border pixels
fxy_med = fxy_med[1:-1,1:-1]

plt.imshow(fxy_med, cmap='gray')
plt.title('Median filter applied')
plt.show()
```



#Problem #6 Consider a 1D step profile f (i) = 4 i [0, 3] 8 i [4, 7] Work out the result of applying the median filtering with n = 3 and compare the result with the output of filtering with the averaging mask 1/4[1 2 1].

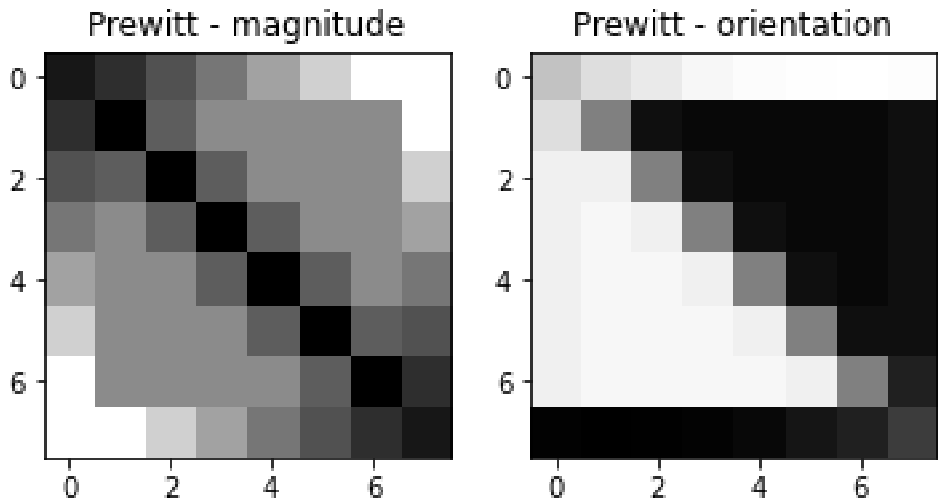
[838]:
```
img = np.array([4.,4.,4.,4.,8.,8.,8.,8.])
pad = np.hstack([0.,img,0.])
avg_const = 1/5*np.array([1,1,1])

pad = np.uint8(pad)
output = cv.medianBlur(pad,3)
output = np.transpose(output[1:-1])
print('Median filter')
print(output)

avg_gauss = 1/4*np.array([1,2,1])
output = np.zeros(img.shape)
for i in range(img.size):
  output[i] = np.dot(pad[i:i+avg_gauss.size], avg_gauss)
print('Averaging mask')
print(output)
```

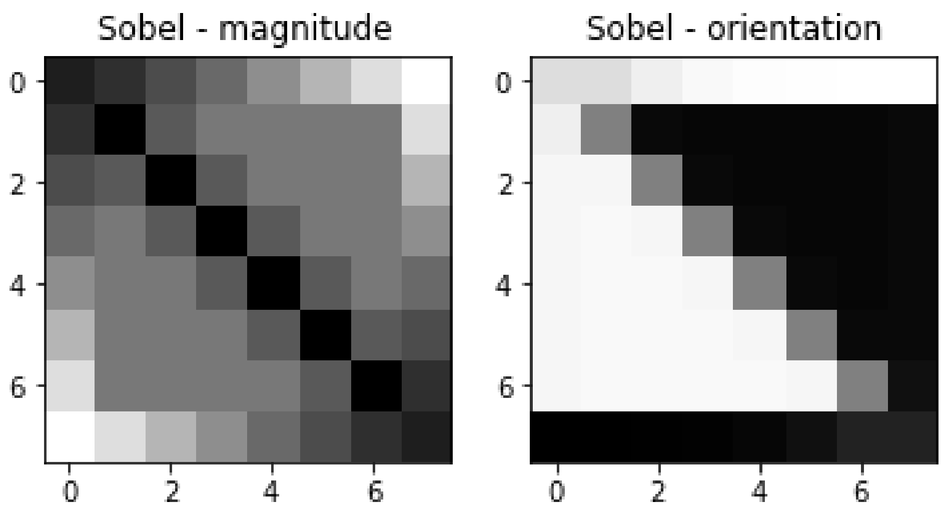
```
Median filter
[[4 4 4 4 8 8 8 8]]
Averaging mask
[3. 4. 4. 5. 7. 8. 8. 6.]
```

#Problem #7 Consider a 8x8 image f(x,y) such that f (x, y) = |x − y| for x, y = 0, 1, . . . , 7 . (a) Find the magnitude and orientation of the gradient by using the Prewitt maks. (Disregard boundaries) (b) Repeat using the Sobel masks.

[839]:
```
fxy = np.zeros([8,8])
for i in range(8):
  for j in range(8):
    fxy[i,j] = abs(i-j)

# Add zero padding
fxy = np.hstack((np.zeros([fxy.shape[0],1]), fxy, np.zeros([fxy.shape[0],1])))
fxy = np.vstack((np.zeros([1,fxy.shape[1]]), fxy, np.zeros([1,fxy.shape[1]])))


Prewittx = np.array([[-1,0,1],
                    [-1,0,1],
                    [-1,0,1]])
Prewitty = np.array([[-1,-1,-1],
                    [0,0,0],
                    [1,1,1]])
Px = cv.filter2D(fxy,-1,Prewittx)
Py = cv.filter2D(fxy,-1,Prewitty)

# Remove added border pixels
Px = Px[1:-1,1:-1]
Py = Py[1:-1,1:-1]

mag = np.sqrt(Px**2+Py**2)
theta = np.arctan(Py,Px)

plt.subplot(1,2,1)
plt.title('Prewitt - magnitude')
plt.imshow(mag, cmap='gray')
plt.subplot(1,2,2)
plt.title('Prewitt - orientation')
plt.imshow(theta, cmap='gray')
plt.show()

Sx = cv.Sobel(fxy,cv.CV_64F,1,0,ksize=3)
Sy = cv.Sobel(fxy,cv.CV_64F,0,1,ksize=3)

# Remove added border pixels
Sx = Sx[1:-1,1:-1]
Sy = Sy[1:-1,1:-1]

mag = np.sqrt(Sx**2+Sy**2)
theta = np.arctan(Sy,Sx)
```

```
plt.subplot(1,2,1)
plt.title('Sobel - magnitude')
plt.imshow(mag, cmap='gray')
plt.subplot(1,2,2)
plt.title('Sobel - orientation')
plt.imshow(theta, cmap='gray')
plt.show()
```

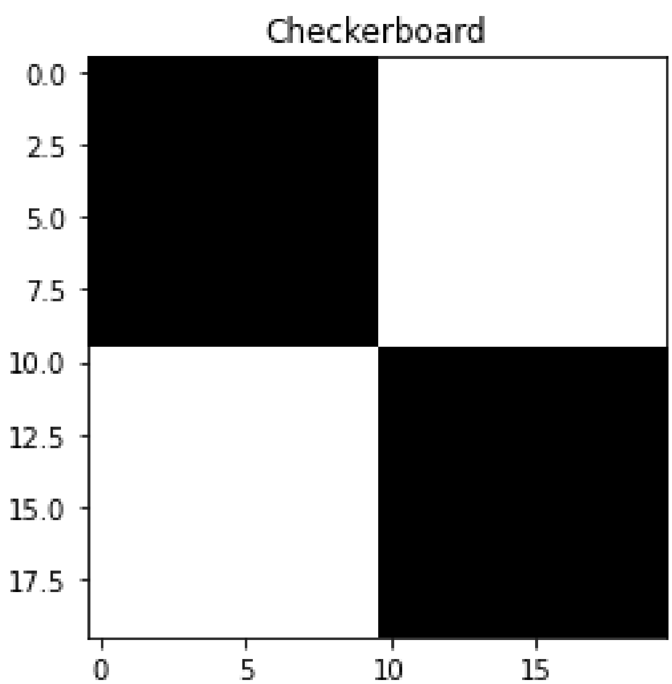


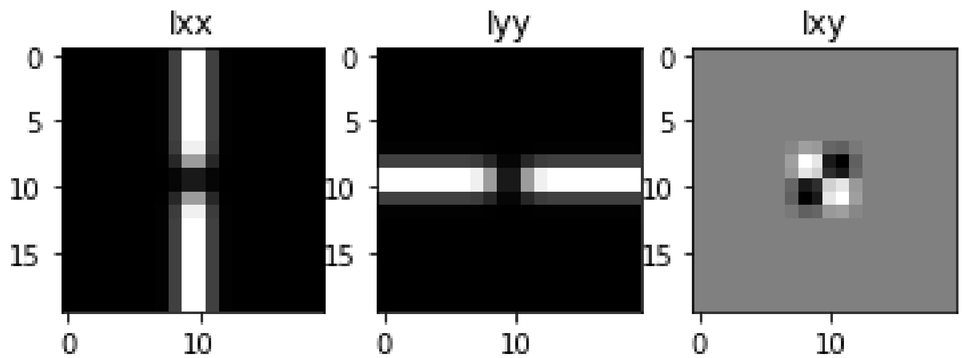


#Problem #8 Compute the C matrix and find its eigenvalues, to detect the corner in the image given in Figure 1, when using a neighborhood of 7×7.

[840]:

```
image = np.hstack([np.zeros([10,10]), 40*np.ones([10,10])])
checker = np.vstack([image, np.fliplr(image)])
plt.title('Checkerboard')
plt.imshow(checker, cmap='gray', vmin=0, vmax=40)
plt.show()

Sx = cv.Sobel(checker,cv.CV_64F,1,0,ksize=7)
Sy = cv.Sobel(checker,cv.CV_64F,0,1,ksize=7)
Sxy = Sx*Sy
R = (Sx**2 * Sy**2) - 0.05*(Sx**2 + Sy**2)

plt.subplot(1,3,1)
plt.title('Ixx')
plt.imshow(Sx**2, cmap='gray')

plt.subplot(1,3,2)
plt.title('Iyy')
plt.imshow(Sy**2, cmap='gray')

plt.subplot(1,3,3)
plt.imshow(Sxy, cmap='gray')
plt.title('Ixy')
plt.show()
```




Ixx
Iyy
Ixy
0
5
10
15
0
10