Computer Exercises

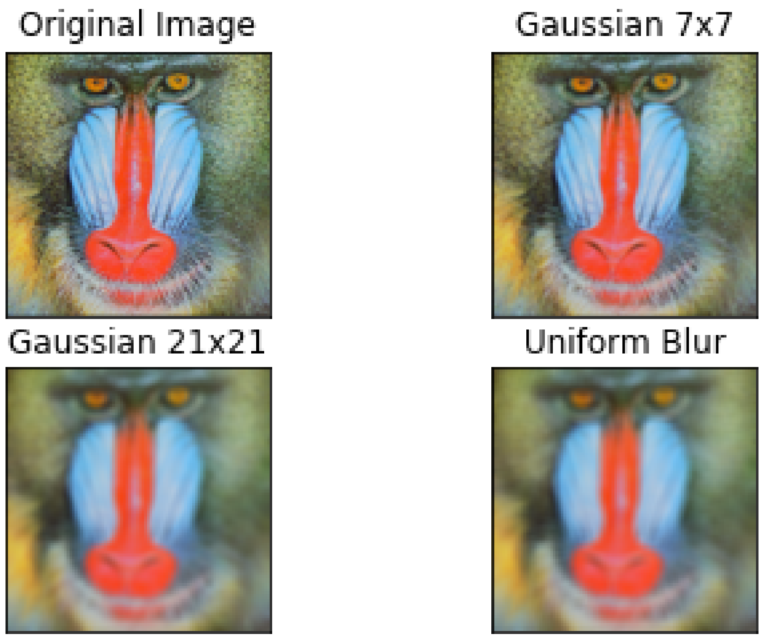
April 22, 2020

1 Computer Exercise 1

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

[2]:
```
inp_img = cv2.imread("./hw2_data/mandrill.png")
image = inp_img[:,:,::-1]

output = [(image, "Original Image")]

output.append((cv2.GaussianBlur(image,(7,7),3), "Gaussian 7x7"))
output.append((cv2.GaussianBlur(image,(21,21),10), "Gaussian 21x21"))
output.append((cv2.blur(image, (21, 21)), "Uniform Blur"))
```

[3]:
```
for i in range(len(output)):
    plt.subplot(2, 2, i+1)
    plt.imshow(output[i][0], interpolation=None), plt.title(output[i][1]), plt.
↪xticks([]), plt.yticks([])

plt.show()
```



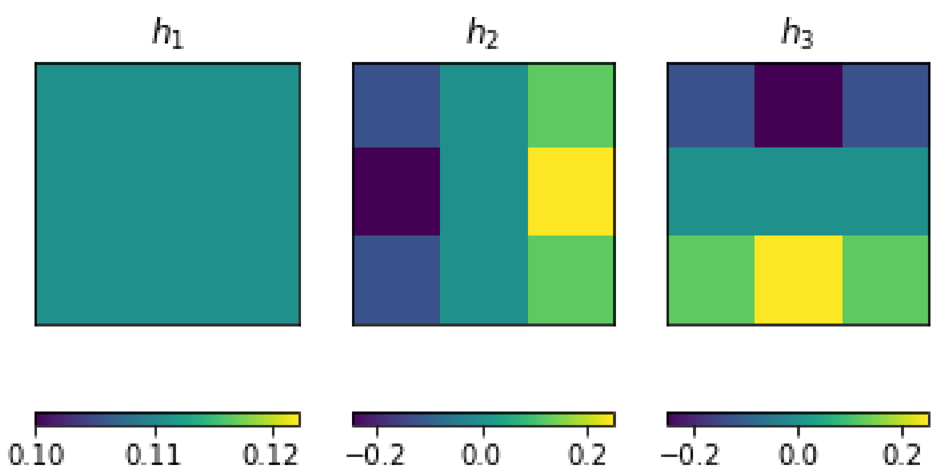
2 Computer Exercise 2

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

[2]:
```
M = 12
N = 16

def print_h(mat, name):
#     print(name + ":\n" + str(mat))
    _ = plt.imshow(mat, interpolation=None)
    plt.colorbar()
    _ = plt.title("$" + name[0] + "_" + name[1] + "$")


def create_H(h):
    H = np.zeros((M*N, M*N))
    for i in range(M*N):
        for k in [-1, 0, 1]:
            for l in [-1, 0, 1]:
                j = i-N*k-l
                if 0 <= j < M*N:
```

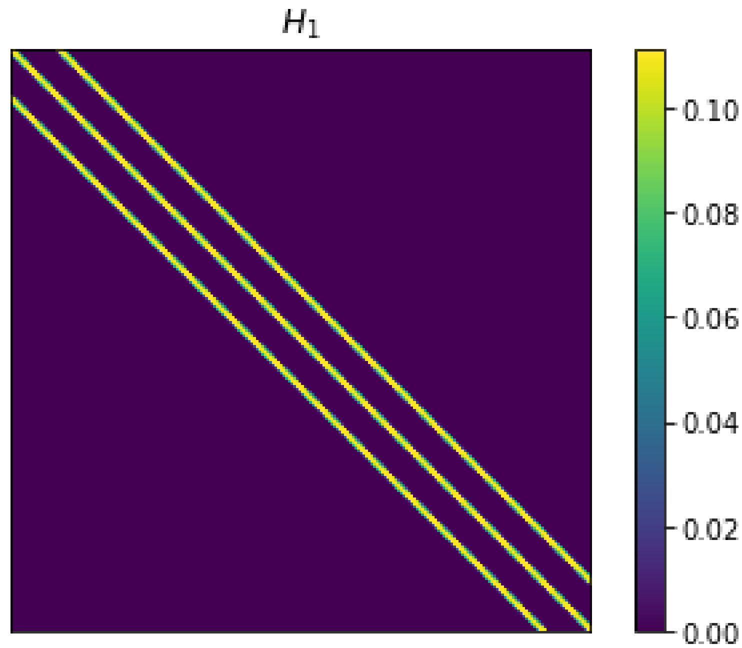
```
                    H[i,j] = h[k+1,l+1]
    return H
```

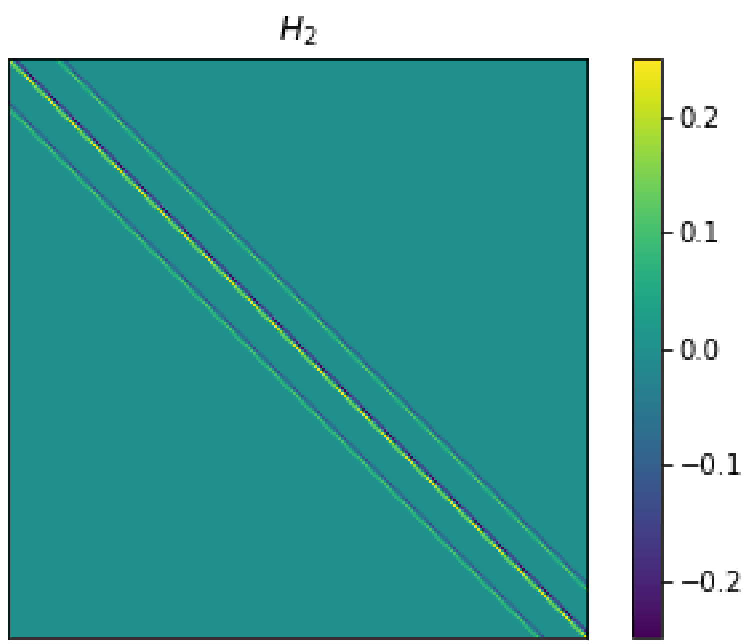
[3]:
```
hs = []

hs.append(((1.0/9.0)*np.ones((3,3)), "$h_1$"))
hs.append(((1.0/8.0)*np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]]), "$h_2$"))
hs.append((np.transpose(hs[1][0]), "$h_3$"))

fig = plt.figure()
for i in range(len(hs)):
    a = fig.add_subplot(1, 3, i+1)
    implot = plt.imshow(hs[i][0], interpolation=None)
    a.set_title(hs[i][1])
    plt.xticks([]), plt.yticks([])
    plt.colorbar(orientation='horizontal')

plt.show()
```

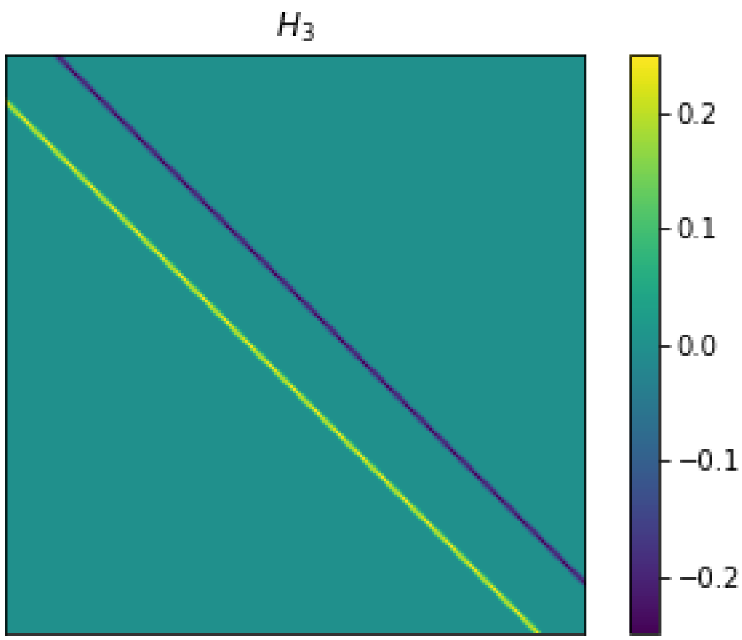


[4]:
```
H1 = create_H(hs[0][0])
H2 = create_H(hs[1][0])
H3 = create_H(hs[2][0])

Hs = []

Hs.append((H1,"$H_1$"))
Hs.append((H2,"$H_2$"))
Hs.append((H3,"$H_3$"))

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

```
    fig, a = plt.subplots()
    implot = plt.imshow(Hs[i][0], interpolation=None)
    a.set_title(Hs[i][1])
    a.set_xticks([]), a.set_yticks([])
    plt.colorbar()
    plt.show()
```







3 Computer Exercise 3

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

[2]:
```
import copy
import scipy.io as sio
```

[3]:
```
mdict = sio.loadmat("./hw2_data/are_these_separable_filters.mat")
K1 = mdict["K1"]
K2 = mdict["K2"]
K3 = mdict["K3"]

def zeroSmallNumbers(arr):
    newarr = []
    count = 0
    for item in arr:
        if np.abs(item) < 0.000000000001:
            newarr.append(0)
        else:
```

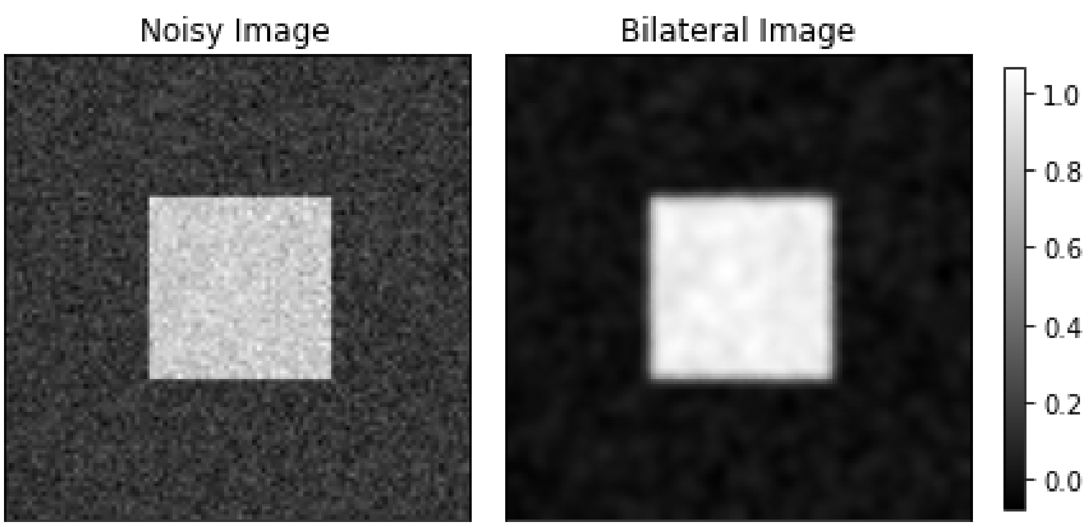
```python
            newarr.append(item)
            count += 1
    return newarr, count


U1, s1, V1 = np.linalg.svd(K1, full_matrices=True)
U2, s2, V2 = np.linalg.svd(K2, full_matrices=True)
U3, s3, V3 = np.linalg.svd(K3, full_matrices=True)

singular1, count1 = zeroSmallNumbers(s1)
singular2, count2 = zeroSmallNumbers(s2)
singular3, count3 = zeroSmallNumbers(s3)

print("Singular Values for K1:\n" + str(np.diag(singular1)))
print("Kernel is separable\n" if count1 == 1 else "Kernel is not separable\n")
print("Singular Values for K2:\n" + str(np.diag(singular2)))
print("Kernel is separable\n" if count2 == 1 else "Kernel is not separable\n")
print("Singular Values for K3:\n" + str(np.diag(singular3)))
print("Kernel is separable\n" if count3 == 1 else "Kernel is not separable\n")
```

```
Singular Values for K1:
[[1.15572864 0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]]
Kernel is separable

Singular Values for K2:
[[2.39244588 0.         0.         0.         0.        ]
 [0.         0.98749722 0.         0.         0.        ]
 [0.         0.         0.67563127 0.         0.        ]
 [0.         0.         0.         0.13996899 0.        ]
 [0.         0.         0.         0.         0.07304454]]
Kernel is not separable

Singular Values for K3:
[[3.6587224  0.         0.         0.         0.        ]
 [0.         0.29429662 0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]
 [0.         0.         0.         0.         0.        ]]
Kernel is not separable
```

4 Computer Exercise 4

[3]:
```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import copy
import scipy.io as sio
```

[4]:
```
mdict = sio.loadmat("./hw2_data/bilateral.mat")
image = mdict["img_noisy"]

bilateral = cv2.bilateralFilter(image, 7, 1.5, 1.5)

fig, (ax1, ax2) = plt.subplots(1, 2, constrained_layout=True)

ax1.imshow(image, cmap="gray", interpolation=None)
ax1.set_title("Noisy Image")
ax1.set_xticks([]), ax1.set_yticks([])

pcm = ax2.imshow(bilateral, cmap="gray", interpolation=None)
ax2.set_title("Bilateral Image")
ax2.set_xticks([]), ax2.set_yticks([])

# ax = plt.gca()
fig.colorbar(pcm, ax=[ax1, ax2], location='right', shrink=0.6)
plt.show()
```



5 Computer Exercise 5

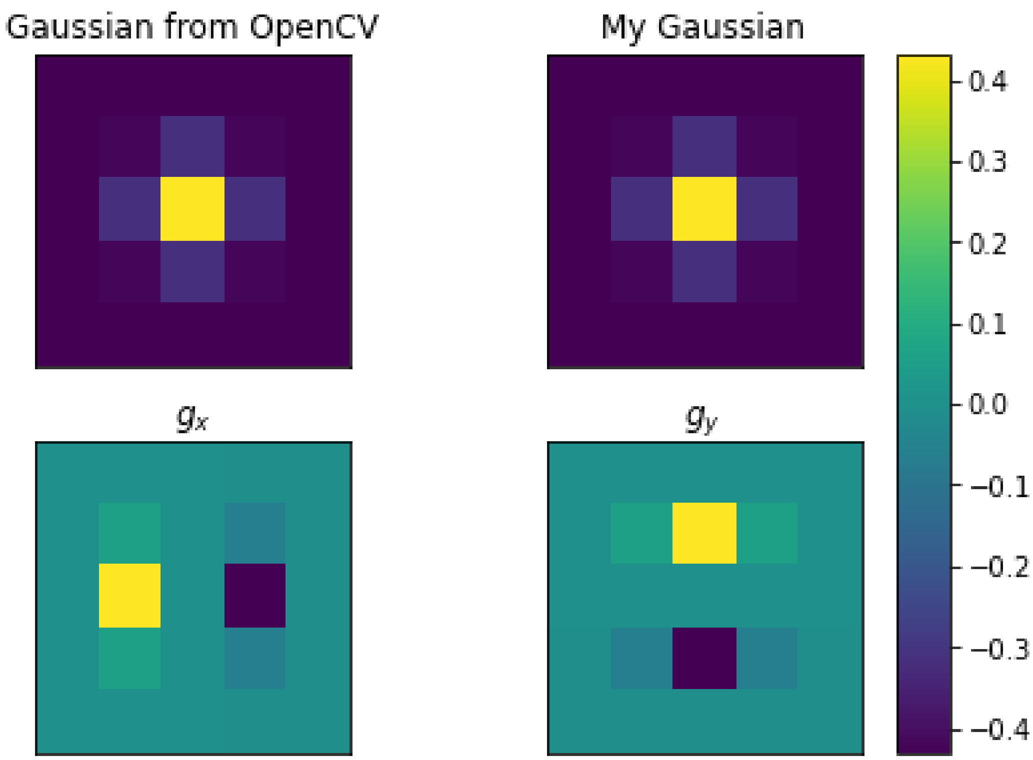
[88]:
```
import cv2
import numpy as np
from matplotlib import pyplot as plt
```

[89]:
```
def print_img_subplot(ax, img, title, is_gray):
    if is_gray:
        im_plt = ax.imshow(img, cmap='gray', interpolation=None)
    else:
        im_plt = ax.imshow(img, interpolation=None)
    ax.set_title(title)
    ax.set_xticks([])
    ax.set_yticks([])
    return im_plt
```

5.0.1 Creating Gaussian

[90]:
```
ksize = 5
sigma = 0.5

g = cv2.getGaussianKernel(ksize, sigma)
gg = g.dot(g.T)

outputs = [(gg, "Gaussian from OpenCV")]

my_gg = np.zeros((ksize,ksize))
for i, row in enumerate(my_gg):
    for j, val in enumerate(row):
        y = i - (ksize-1)/2
        x = j - (ksize-1)/2
        my_gg[i,j] = (1.0/(np.sqrt(2*np.pi*sigma**2)))*np.exp(-0.5*((x**2+y**2)/
 ↪(sigma**2)))
outputs.append((my_gg, "My Gaussian"))

deriv_x = np.zeros((ksize,ksize))
for i, row in enumerate(deriv_x):
    for j, val in enumerate(row):
        y = i - (ksize-1)/2
        x = j - (ksize-1)/2
        deriv_x[i,j] = (-x/(sigma**2))*my_gg[i,j]
outputs.append((deriv_x, "$g_x$"))

deriv_y = np.zeros((ksize,ksize))
for i, row in enumerate(deriv_y):
    for j, val in enumerate(row):
```

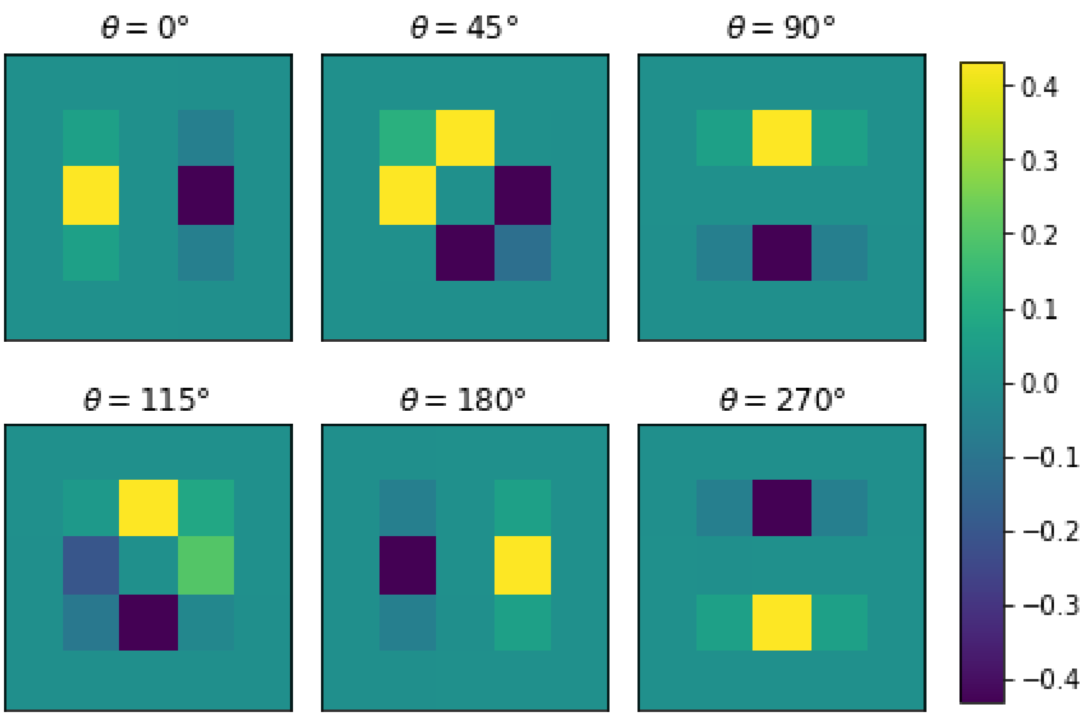
```
        y = i - (ksize-1)/2
        x = j - (ksize-1)/2
        deriv_y[i,j] = (-y/(sigma**2))*my_gg[i,j]
outputs.append((deriv_y, "$g_y$"))

fig1, axs1 = plt.subplots(2, 2, constrained_layout=True)

for i, out in enumerate(outputs):
    im_plt = print_img_subplot(axs1[int(i/2),i%2], out[0], out[1], False)

fig1.colorbar(im_plt, ax=axs1, location='right', shrink=1.)
plt.show()
```



5.0.2 Directional Filters

[91]:
```
def create_theta_filter(theta):
    deriv_theta = np.zeros((ksize,ksize))
    for i, row in enumerate(deriv_theta):
        for j, val in enumerate(row):
            y = i - (ksize-1)/2
            x = j - (ksize-1)/2
```

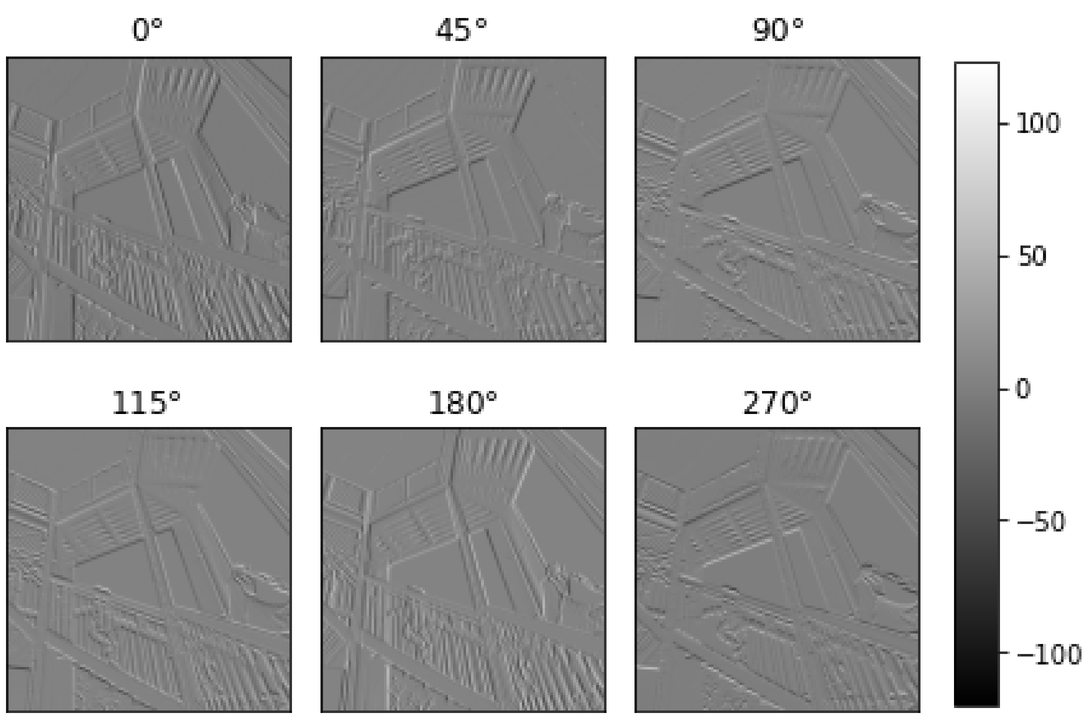
```
            deriv_theta[i,j] = np.cos(theta)*deriv_x[i,j] + np.
↪sin(theta)*deriv_y[i,j]
    return deriv_theta


angles = [0, 45, 90, 115, 180, 270]
theta_filters = []

fig1, axs1 = plt.subplots(2, 3, constrained_layout=True)

for i, theta in enumerate(angles):
    deriv_theta = create_theta_filter(theta*((np.pi)/(180)))
    theta_filters.append((theta, deriv_theta))
    im_plt = print_img_subplot(axs1[int(i/3),i%3], deriv_theta, "$\\theta = " +␣
↪str(theta) + "\degree$", False)

fig1.colorbar(im_plt, ax=axs1, location='right', shrink=0.9)
plt.show()
```



5.0.3 Results

[92]:
```
img = cv2.imread("./hw2_data/ascent.jpg", 0)
img = np.float64(img)
cv2_gblur = cv2.GaussianBlur(img, (ksize,ksize), sigma)
cv2_gkernel = cv2.getGaussianKernel(ksize, sigma)
cv2_gfilter = cv2.filter2D(img, -1, cv_kernel)
my_gfilter = cv2.filter2D(img, -1, my_gg)

fig1, axs1 = plt.subplots(2, 2, constrained_layout=True)

print_img_subplot(axs1[0,0], img, "Original", True)
print_img_subplot(axs1[0,1], cv2_gblur, "cv2 GaussianBlur", True)
print_img_subplot(axs1[1,0], cv2_gfilter, "cv_kernel filter2D", True)
im_plt = print_img_subplot(axs1[1,1], my_gfilter, "my filter2D", True)

fig1.colorbar(im_plt, ax=axs1, location='right', shrink=1.)
plt.show()

fig2, axs2 = plt.subplots(2, 3, constrained_layout=True)

for i, theta_filter in enumerate(theta_filters):
    res = cv2.filter2D(my_gfilter, -1, theta_filter[1])
    im_plt = print_img_subplot(axs2[int(i/3),i%3], res, "$" +␣
 ↪str(theta_filter[0]) + "\degree$", True)

fig2.colorbar(im_plt, ax=axs2, location='right', shrink=0.9)
plt.show()
```


Original
cv2 GaussianBlur
cv_kernel filter2D
my filter2D
250
200
150
100
50


0°
45°
90°
115°
180°
270°
100
50
0
−50
−100

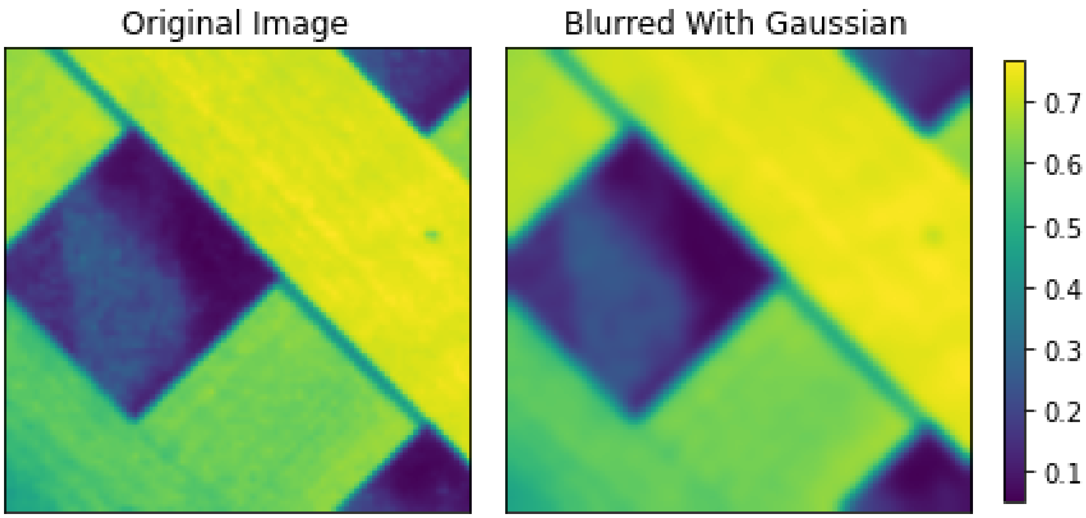
6 Computer Exercise 6

[20]:
```
import cv2
import numpy as np
from matplotlib import pyplot as plt
import copy
import scipy.io as sio
```

[21]:
```
mdict = sio.loadmat("./hw2_data/imgs_for_optical_flow.mat")
```

[22]:
```
def print_img(img, title):
    _ = plt.imshow(img, interpolation=None)
    plt.colorbar()
    plt.title(title)
    plt.xticks([]), plt.yticks([])
    plt.show()

def print_img_subplot(ax, img, title, is_gray):
    if is_gray:
        im_plt = ax.imshow(img, cmap='gray', interpolation=None)
    else:
        im_plt = ax.imshow(img, interpolation=None)
    ax.set_title(title)
    ax.set_xticks([])
    ax.set_yticks([])
    return im_plt
```

[23]:
```
img = mdict["img1"]

blurred_img = cv2.GaussianBlur(img,(5,5),0)

fig1, axs1 = plt.subplots(1, 2, constrained_layout=True)

print_img_subplot(axs1[0], img, "Original Image", False)
im_plt = print_img_subplot(axs1[1], blurred_img, "Blurred With Gaussian", False)

fig1.colorbar(im_plt, ax=axs1, location='right', shrink=0.6)
plt.show()
```



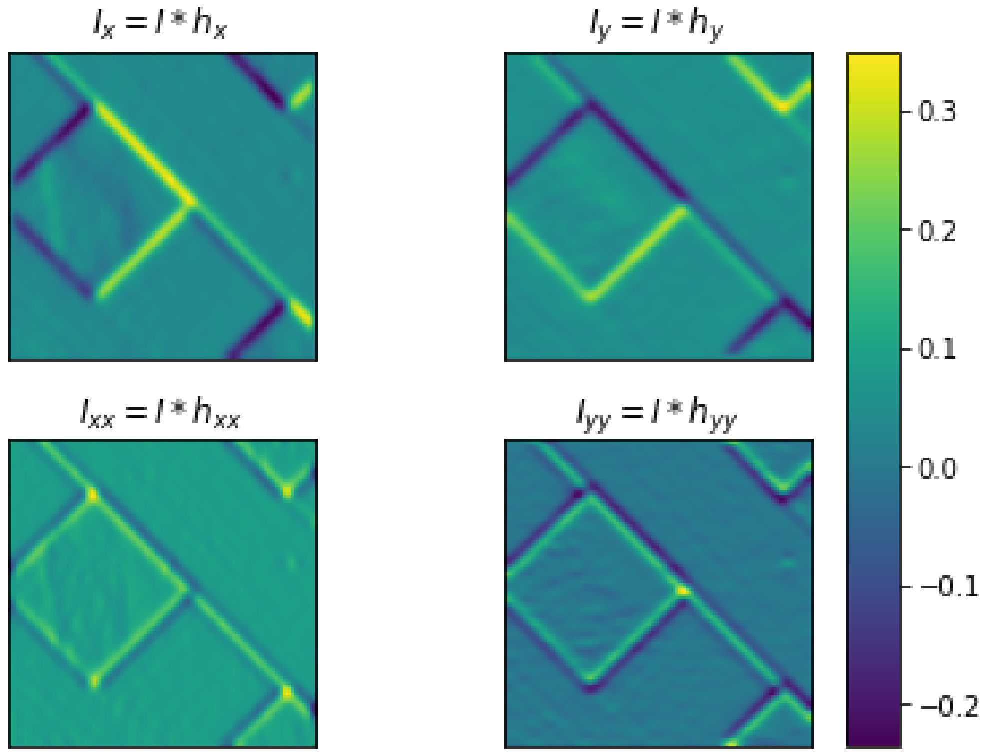
6.0.1 Getting Derivative Filters

[24]:
```
hx1, hy0 = cv2.getDerivKernels(1,0,3)
hx0, hy1 = cv2.getDerivKernels(0,1,3)
hx2, _ = cv2.getDerivKernels(2,0,3)
_, hy2 = cv2.getDerivKernels(0,2,3)
```

6.0.2 Results

[25]:
```
res_x1 = cv2.sepFilter2D(blurred_img,-1,hx1,hy0)
res_y1 = cv2.sepFilter2D(blurred_img,-1,hx0,hy1)
res_x2 = cv2.sepFilter2D(blurred_img,-1,hx2,hy0)
res_y2 = cv2.sepFilter2D(blurred_img,-1,hx0,hy2)
```

[26]:
```
fig2, axs2 = plt.subplots(2, 2, constrained_layout=True)

print_img_subplot(axs2[0,0], res_x1, "$I_x = I * h_x$", False)
print_img_subplot(axs2[0,1], res_y1, "$I_y = I * h_y$", False)
print_img_subplot(axs2[1,0], res_x2, "$I_{xx} = I * h_{xx}$", False)
im_plt = print_img_subplot(axs2[1,1], res_y2, "$I_{yy} = I * h_{yy}$", False)

fig2.colorbar(im_plt, ax=axs2, location='right', shrink=1.0)
plt.show()
```


$I_x = I * h_x$
$I_y = I * h_y$
$I_{xx} = I * h_{xx}$
$I_{yy} = I * h_{yy}$
0.3
0.2
0.1
0.0
−0.1
−0.2