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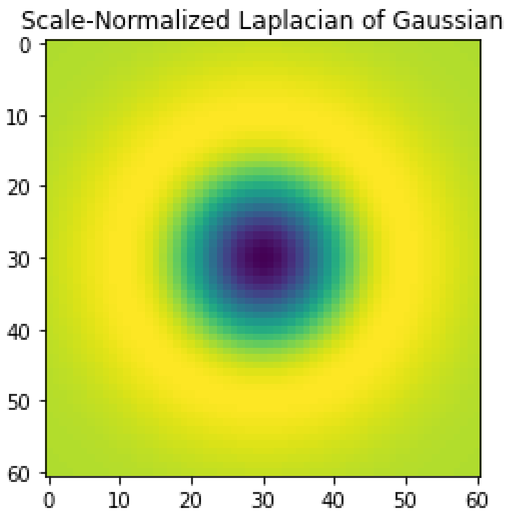
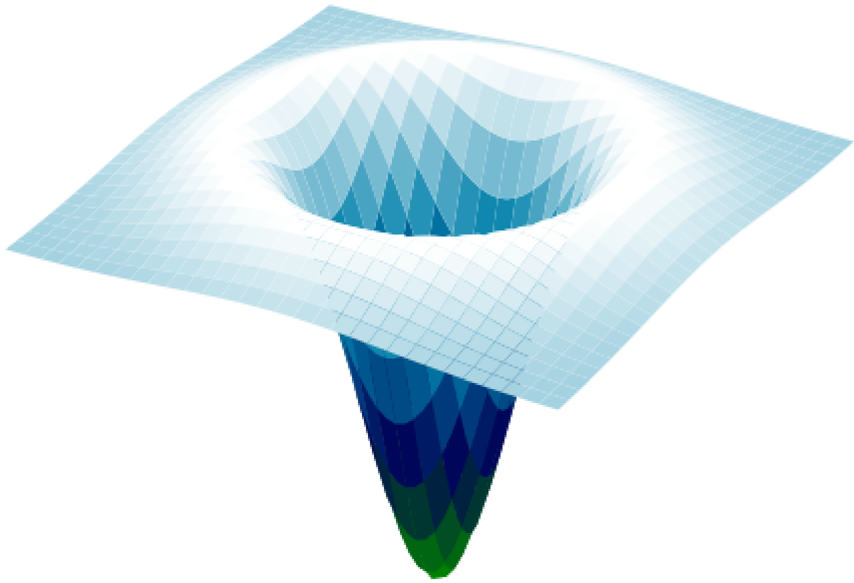
In [63]:

```
#Q1
import numpy as np
import matplotlib.pyplot as plt

sigma=10;
hw=3*sigma
x,y=np.meshgrid(np.arange(-hw,hw+1,1),np.arange(-hw,hw+1,1))
log = 1/(2*np.pi*sigma**2)*(x**2/(sigma**2)+y**2/(sigma**2)-2)*np.exp(-(x**2+y**2)/(2*s
plt.imshow(log)
plt.title("Scale-Normalized Laplacian of Gaussian")
plt.show()
```



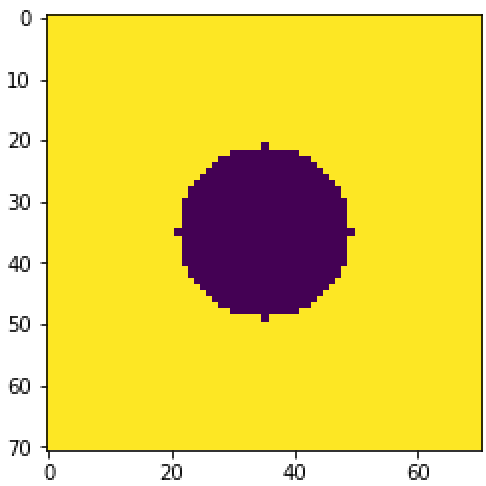
In [64]:

```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from matplotlib import cm
from matplotlib.ticker import LinearLocator, FormatStrFormatter

fig = plt.figure(figsize=(10,10))
ax = fig.add_subplot(111, projection='3d')
surf = ax.plot_surface(x, y, log, cmap=cm.ocean, linewidth = 0, antialiased=True)
ax.zaxis.set_major_locator(LinearLocator(10))
ax.zaxis.set_major_formatter(FormatStrFormatter('%.02f'))

plt.axis("off")
plt.show()
```



In [70]:

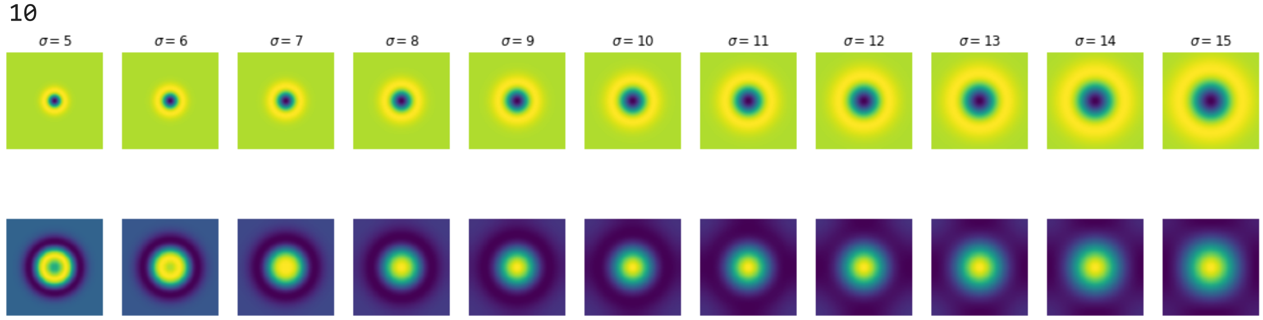
```
#Q2
# Generating the circle
import numpy as np
import cv2 as cv
import matplotlib.pyplot as plt

w, h = 71, 71
hw, hh = w//2, h//2
f = np.ones((h,w), dtype=np.float32)*255
X, Y = np.meshgrid(np.arange(-hh, hh + 1, 1), np.arange(-hw, hw + 1, 1))
r = w//5 # 14

f *= X**2 + Y**2 > r**2
plt.imshow(f)
plt.show()
```



In [71]:

```python
import numpy as np
import cv2 as cv
s = 11
fig, ax = plt.subplots (2, s, figsize=(20,5))
scale_space= np.empty((h, w, s), dtype=np.float32)

sigmas = np.arange (5, 16, 1)

for i, sigma in enumerate(sigmas):
    log_hw=3*np.max(sigmas)
    X, Y = np.meshgrid(np. arange(-log_hw, log_hw + 1, 1), np.arange(-log_hw, log_hw +
    log = 1/(2*np.pi*sigma**2)*(X**2/(sigma**2)+Y**2/(sigma**2) - 2)*np.exp(-(X**2 + Y*
    f_log = cv.filter2D(f,-1,log)
    scale_space[:, :, i] = f_log
    ax[0, i].imshow(log)
    ax[0, i].axis ('off')
    ax[0, i].set_title(r'$\sigma = {}$'.format(sigma))
    ax[1, i].imshow (f_log)
    ax[1, i].axis ('off')

indices= np.unravel_index(np.argmax(scale_space, axis=None), scale_space.shape)
print(indices) # r= \sqrt{2}*sigma
print (sigmas[indices[2]])
```

```
(35, 35, 5)
10
```



In [78]:

```python
#Q3
import cv2
import matplotlib.pyplot as plt

img1 = cv2.imread('img1.ppm')
img2 = cv2.imread('img2.ppm')
```

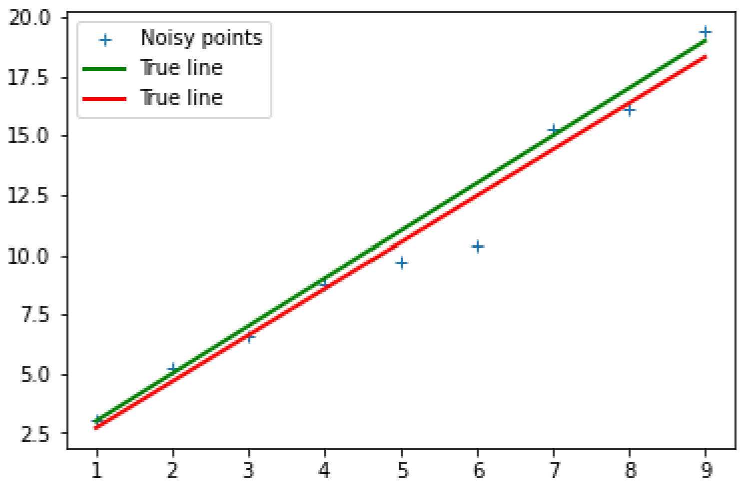
```python
img1 = cv2.cvtColor(img1, cv2.COLOR_BGR2GRAY)
img2 = cv2.cvtColor(img2, cv2.COLOR_BGR2GRAY)

sift = cv2.SIFT_create()

keypoints_1, descriptors_1 = sift.detectAndCompute(img1,None)
keypoints_2, descriptors_2 = sift.detectAndCompute(img2,None)

bf = cv2.BFMatcher(cv2.NORM_L1, crossCheck=True)

matches = bf.match(descriptors_1,descriptors_2)
matches = sorted(matches, key = lambda x:x.distance)

img3 = cv2.drawMatches(img1, keypoints_1, img2, keypoints_2, matches[:50], img2, flags=
plt.figure(figsize=(15,15))
plt.imshow(img3)
plt.xticks([]), plt.yticks([])
plt.show()
```

In [73]:

```python
#Q4
m = 2 # Line equation : y = m*x + c . m i s the s lope . c i s the int e r c ept .
c = 1
x = np.arange(1 ,10 , 1)
np.random.seed(45)
sigma=1
noise=sigma*np.random.randn(len(x))
n = 2.*np.random.randn( len( x ) )
o= np.zeros(x.shape)
# o[=1] = 20
y = m*x + c + noise + o
n=len(x)
X=np.concatenate([x.reshape(n,1),np.ones((n,1))],axis=1)
B=np.linalg.pinv(X.T @ X)@X.T@y
mster=B[0]
cstar=B[1]

plt.plot(x,y,'+',label='Noisy points')
plt.plot([x[0],x[-1]],[m*x[0]+c , m*x[-1]+c], color='g',linewidth=2, label=r'True line'
plt.plot([x[0],x[-1]],[mster*x[0]+cstar , mster*x[-1]+cstar], color='r',linewidth=2, la
```

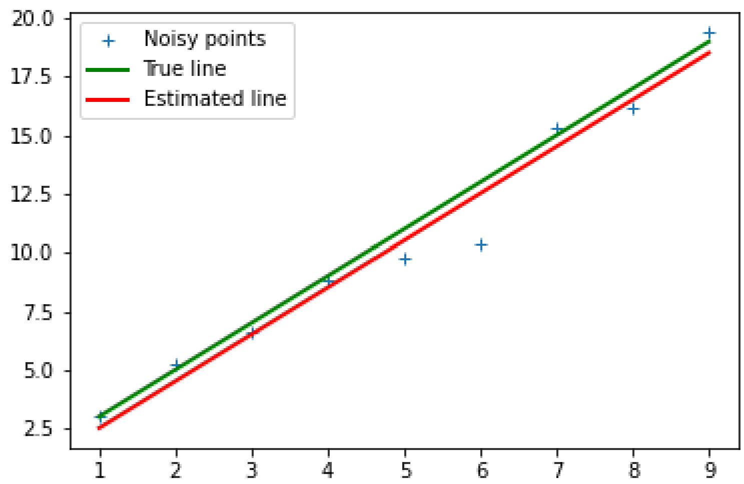
```
plt.legend()
plt.plot()
```

Out[73]: []



In [75]:

```
#Q5
m = 2 # gradient
c = 1 # intercept
x = np.arange(1, 10, 1)
np.random.seed(45)
noise = np.random.randn(len(x))
o = np.zeros(x.shape)
# o[-1] = 20
y = m*x + c + noise + o

n = len(x)
u11 = np.sum((x - np.mean(x))**2)
u12 = np.sum((x - np.mean(x))*(y - np.mean(y)))
u21 = u12
u22 = np.sum((y - np.mean(y))**2)

U = np.array([[u11, u12], [u21, u22]])
W, V = np.linalg.eig(U)
ev_corresponding_to_smallest_ev = V[:, np.argmin(W)]

a = ev_corresponding_to_smallest_ev[0]
b = ev_corresponding_to_smallest_ev[1]
d = a*np.mean(x) + b*np.mean(y)

mstar = -a/b
cstar = d/b

plt.plot(x, y, '+', label = 'Noisy points')
plt.plot([x[0], x[-1]], [m*x[0] + c, m*x[-1] + c], color = 'g', linewidth = 2, label =
plt.plot([x[0], x[-1]], [mstar*x[0] + cstar, mstar*x[-1] + cstar], color = 'r', linewid
plt.legend(loc = 'best')
plt.show()
```



Noisy points
True line
Estimated line
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
1
2
3
4
5
6
7
8
9