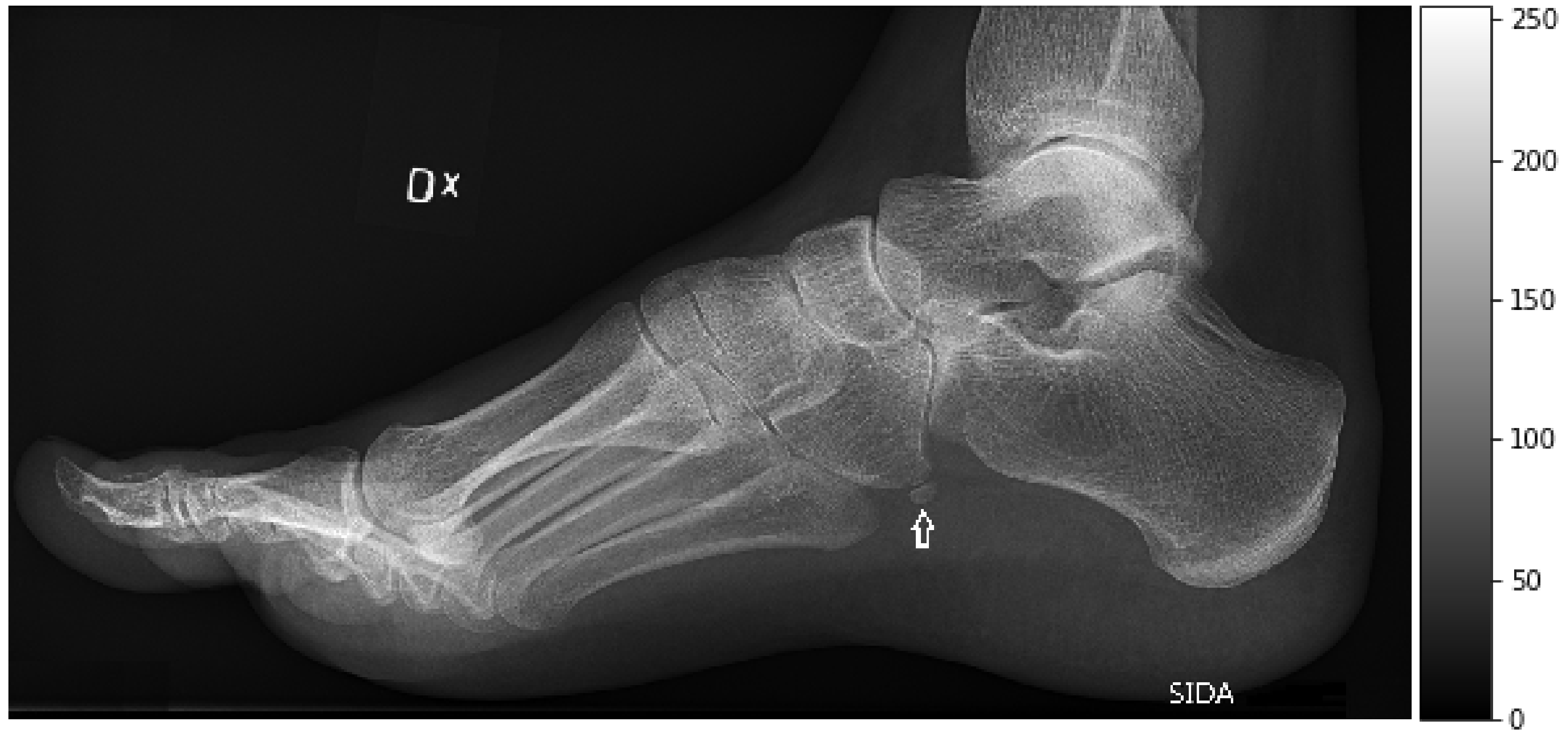
Intensity Values

BIOMEDICAL IMAGE ANALYSIS IN PYTHON

Stephen Bailey
Instructor

Pixels and voxels

- **Pixels** are 2D picture elements
- **Voxels** are 3D volume elements
- Two properties: intensity and location



Data types and image size

Array's data type controls range of possible intensities

Type	Range	No. Val.
uint8	**0, 255**	**256**
int8	- 128, 127	256
uint16	0, 2^{16}	2^{16}
int16	-2^{15}, 2^{15}	2^{16}
float16	~-2^{16}, ~2^{16}	>>2^{16}

```
import imageio

im=imageio.imread('foot-xray.jpg')

im.dtype
    dtype('uint8')
im.size
```

```
153600
```

```
im_int64 = im.astype(np.uint64)
im_int64.size
```

```
1228800
```

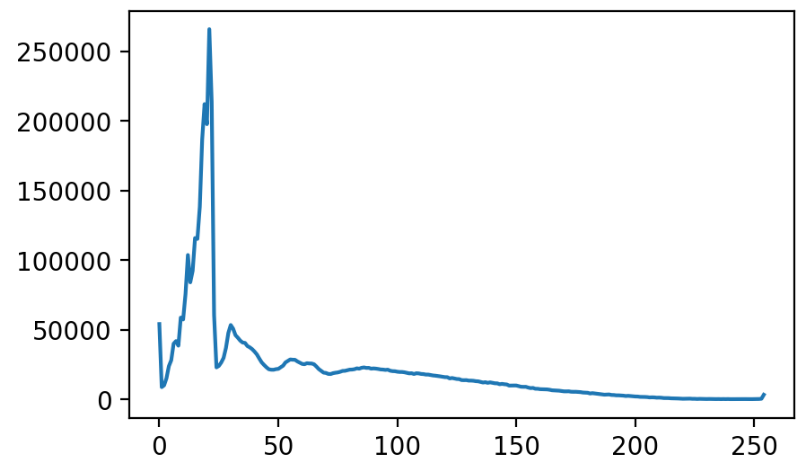
Histograms

- **Histograms:** count number of pixels at each intensity value.
- Implemented in `scipy.ndimage`
  - higher-dimensional arrays
  - masked data
- Advanced techniques and functionality in `scikit-image`.

```
import scipy.ndimage as ndi
hist=ndi.histogram(im, min=0,
                       max=255,
                       bins=256)
hist.shape
```

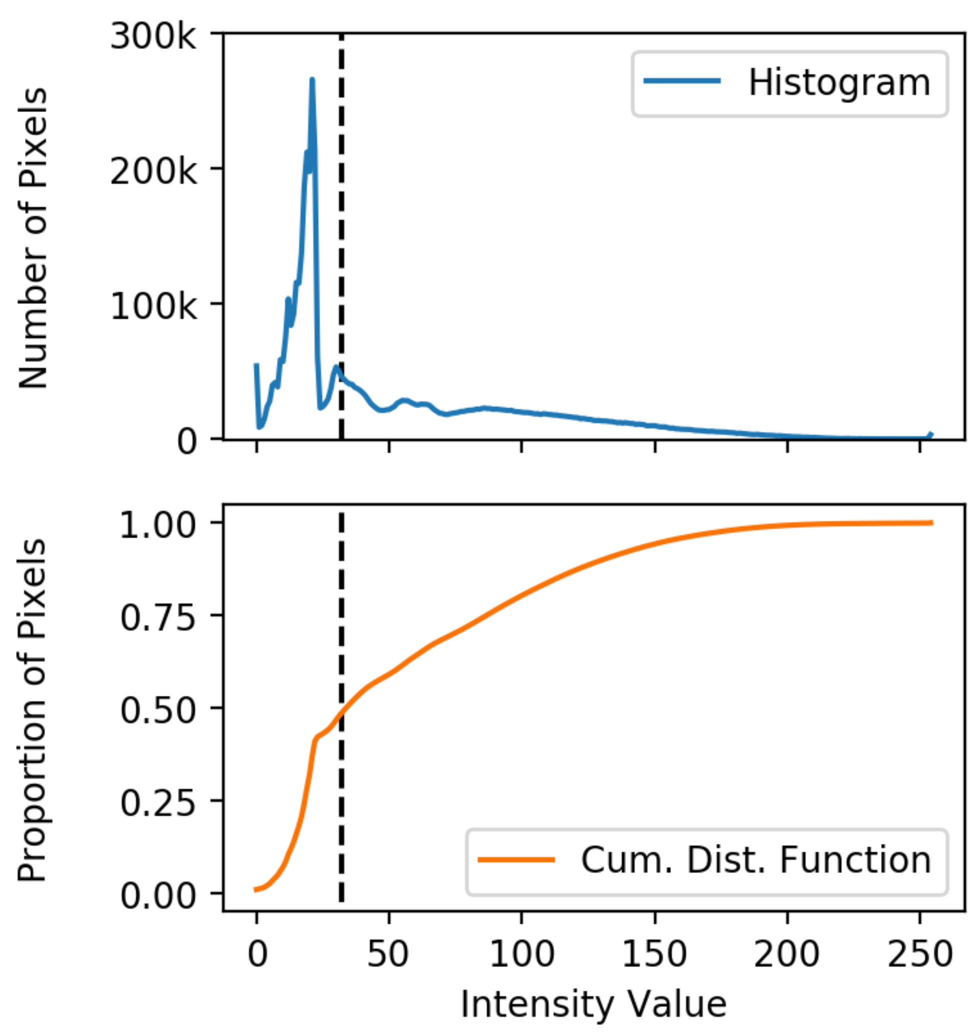
```
(256,)
```

```
plt.plot(hist)
plt.show()
```



Equalization

- Distributions often skewed toward low intensities (background values).
- **Equalization:** redistribute values to optimize full intensity range.
- **Cumulative distribution function:** (CDF) shows proportion of pixels in range.

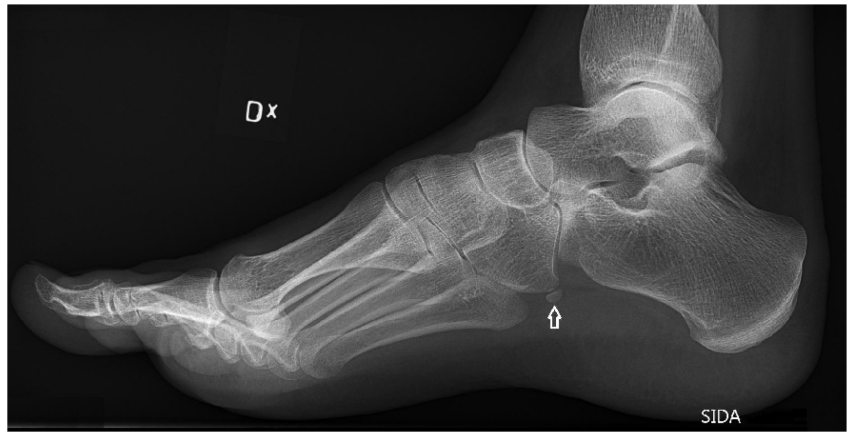


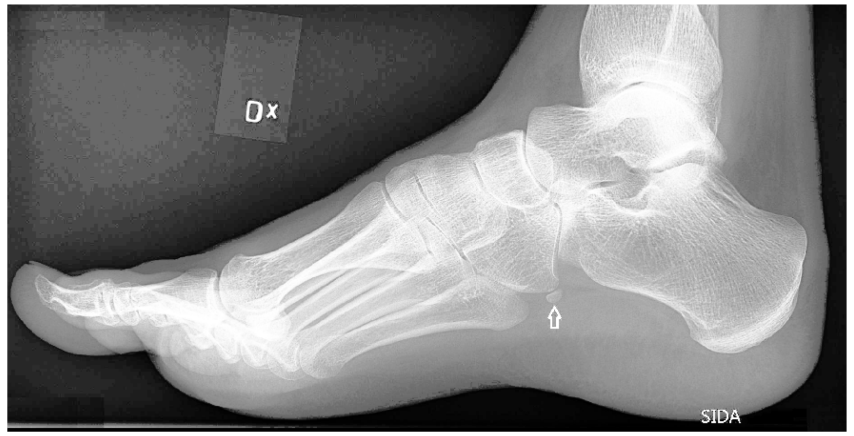
Equalization

```
import scipy.ndimage as ndi
hist = ndi.histogram(im, min=0,
                         max=255,
                        bins=256)
cdf = hist.cumsum() / hist.sum()
cdf.shape
```

```
(256,)
```

```
im_equalized = cdf[im] * 255
fig, axes = plt.subplots(2, 1)
axes[0].imshow(im)
axes[1].imshow(im_equalized)
plt.show()
```





Let's practice!

BIOMEDICAL IMAGE ANALYSIS IN PYTHON

Masks

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Masks

Raw image

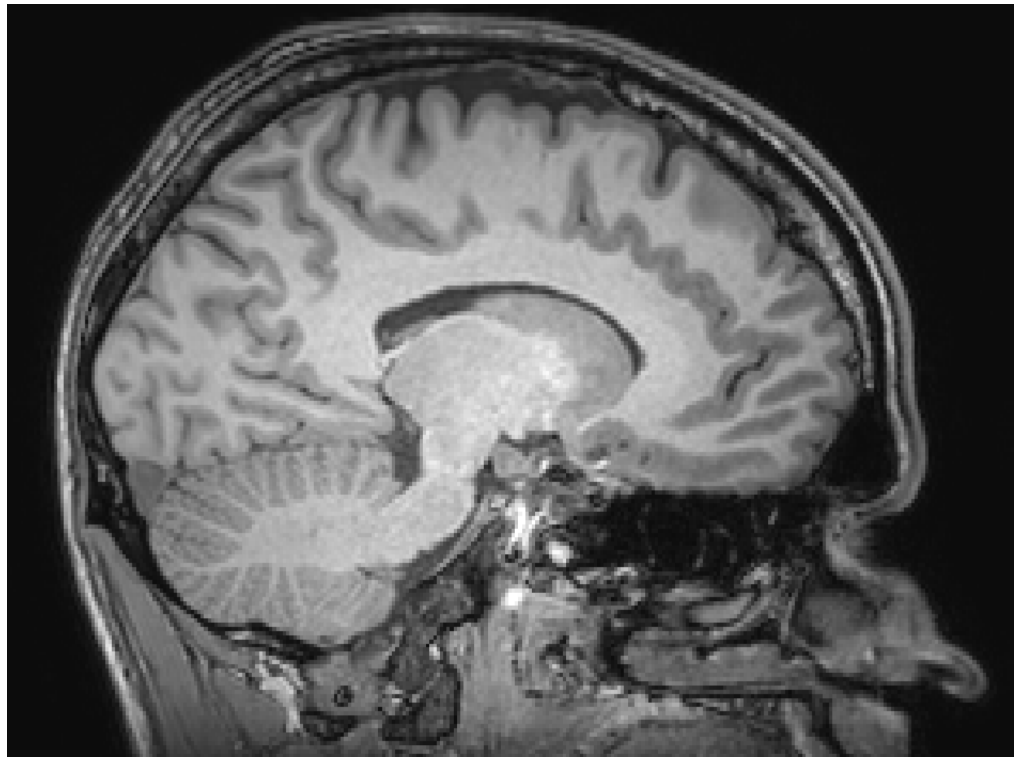
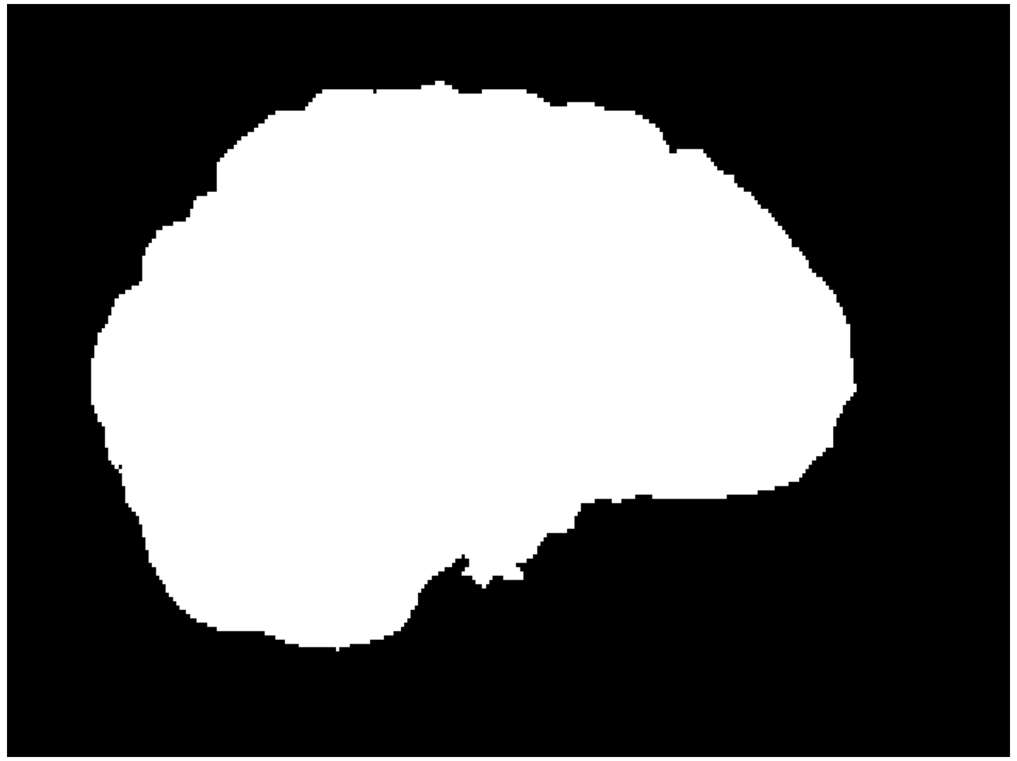


Image mask



Creating masks

Logical operations result in `True` / `False` at each pixel

```
mat = np.array([[1, 2, 3],
                [4, 5, 6],
                [7, 8, 9]])
mat > 5
```

```
np.array([[False, False, False],
          [False, False, True ],
          [True,  True,  True ]])
```

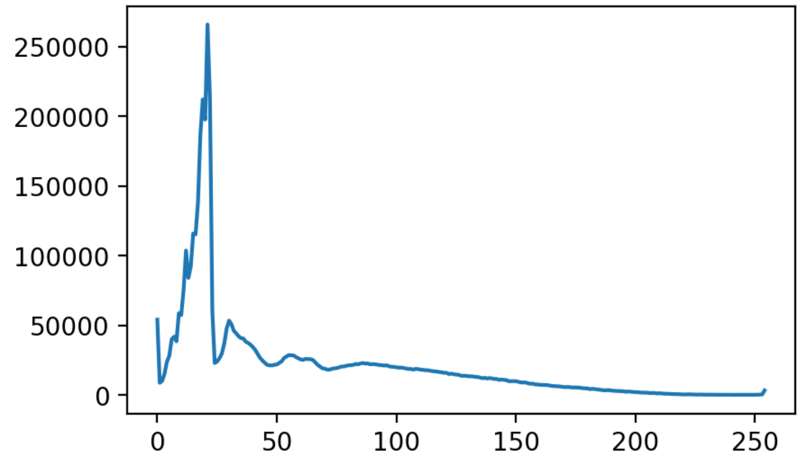
Sample Operations

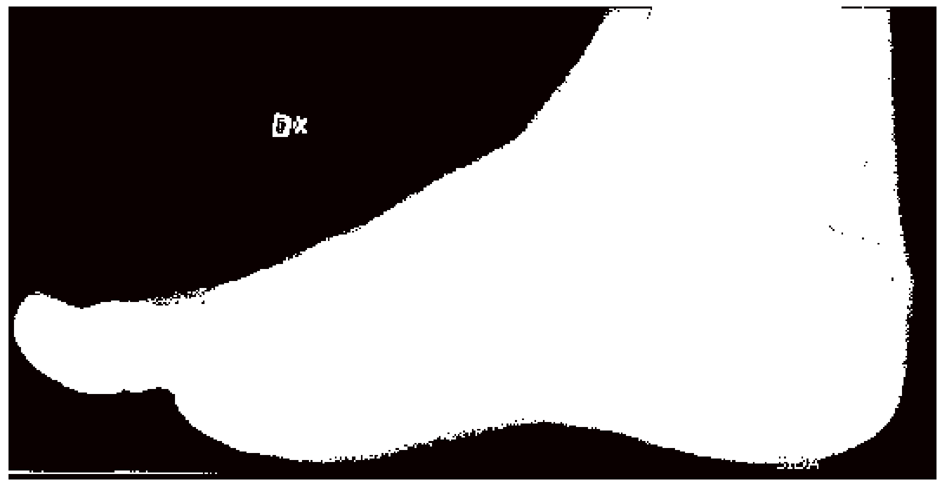
Operation	Example
Greater	`im > 0`
Equal to	`im == 1`
X and Y	`(im > 0) & (im < 5)`
X or Y	`(im > 10) | (im < 5)`

Creating masks

```
hist=ndi.histogram(im, 0, 255, 256)
```

```
mask1 = im > 32
```

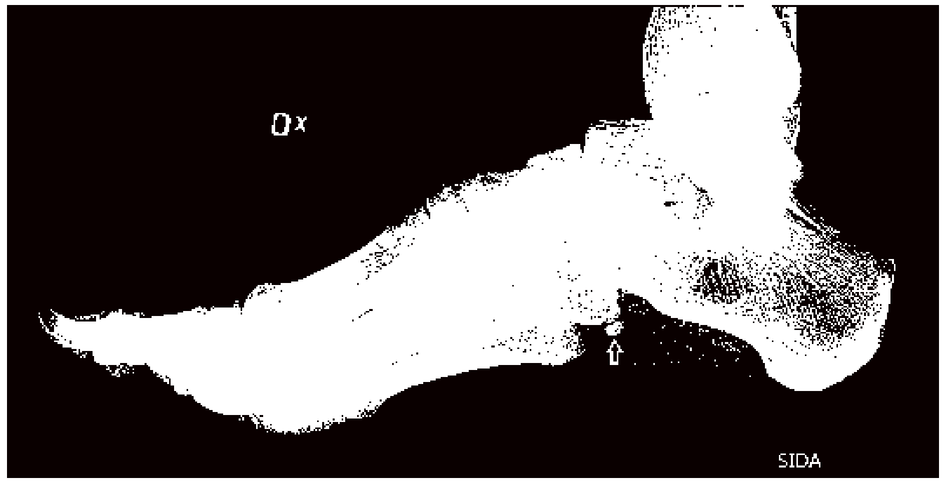


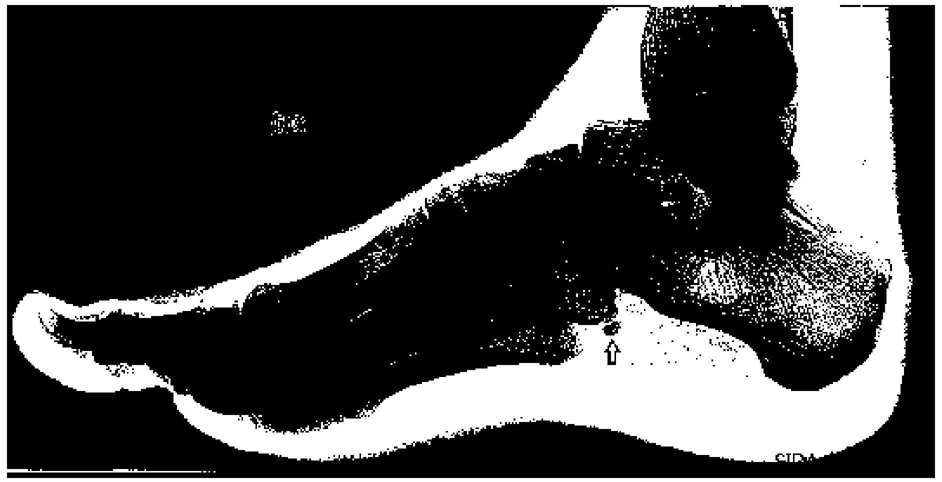


Creating masks

```python
mask2 = im > 64
```

```python
mask3 = mask1 & ~mask2
```



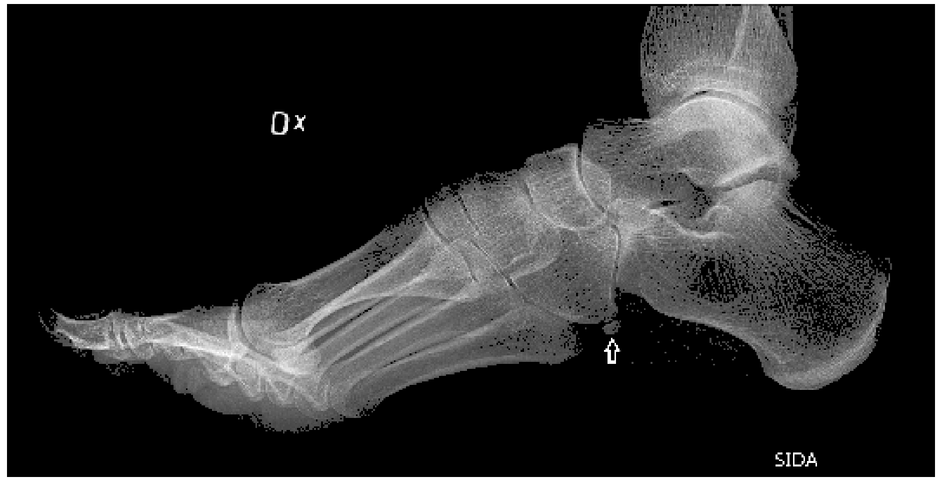


Applying masks

`np.where(condition, x, y)` controls what data passes through the mask.

```python
import numpy as np
im_bone = np.where(im > 64, im, 0)
```

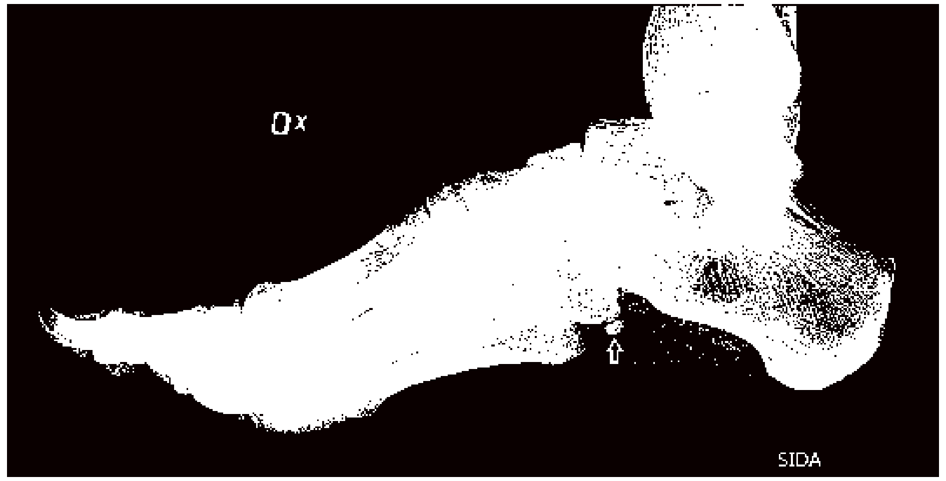
```python
plt.imshow(im_bone, cmap='gray')
plt.axis('off')
plt.show()
```

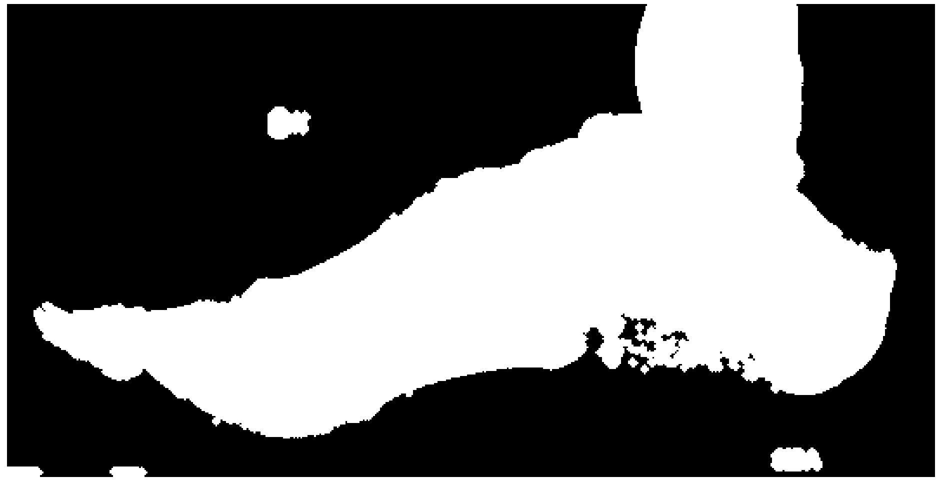


Tuning masks

```
m = np.where(im > 64, 1, 0)
```

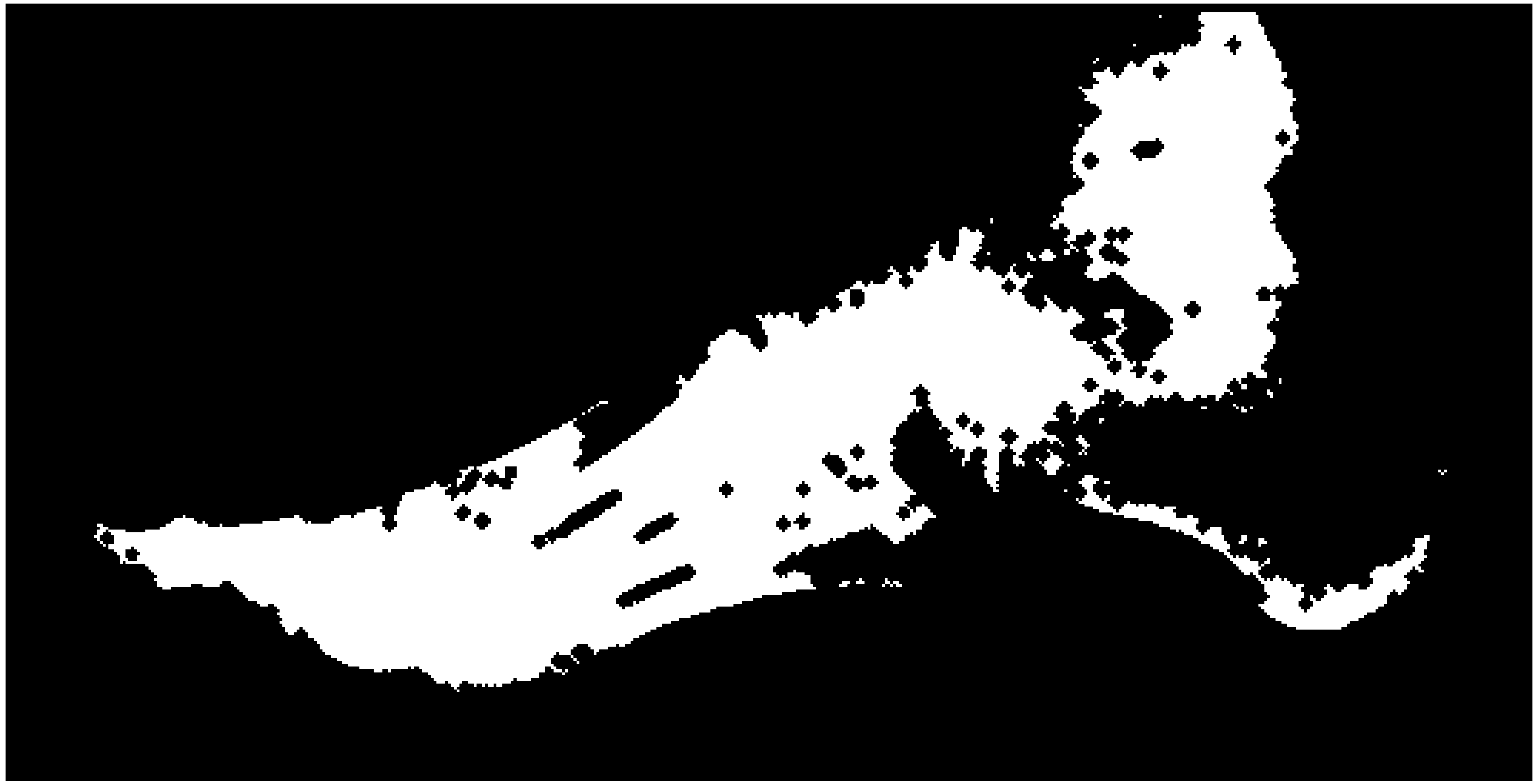
```
ndi.binary_dilation(m,iterations=5)
```





Tuning masks

```
ndi.binary_erosion(m,iterations=5)
```



datacamp

Let's practice!

Filters

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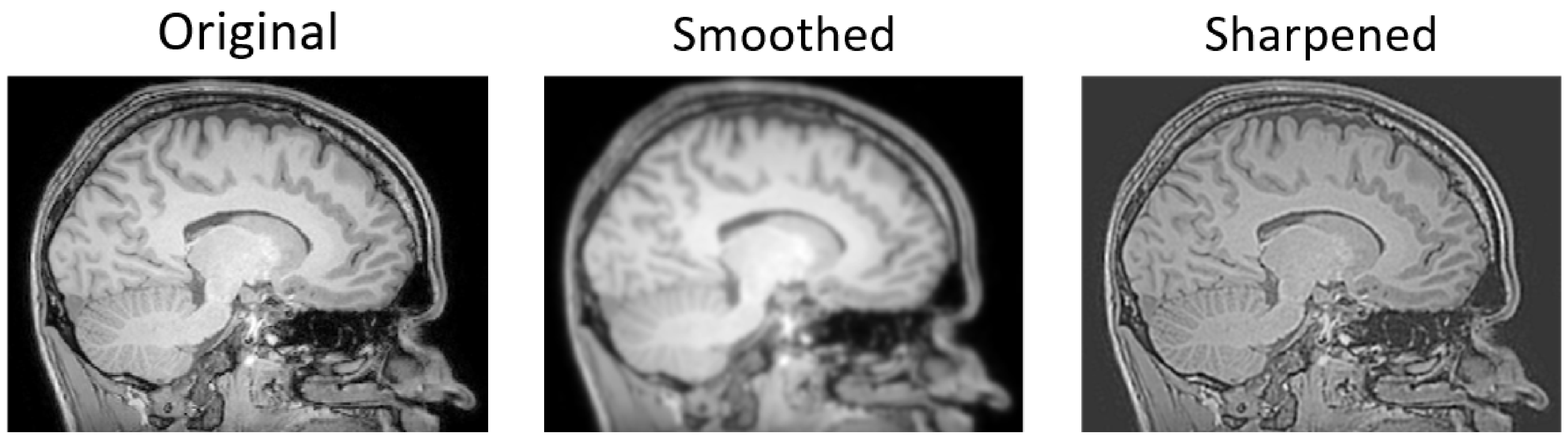
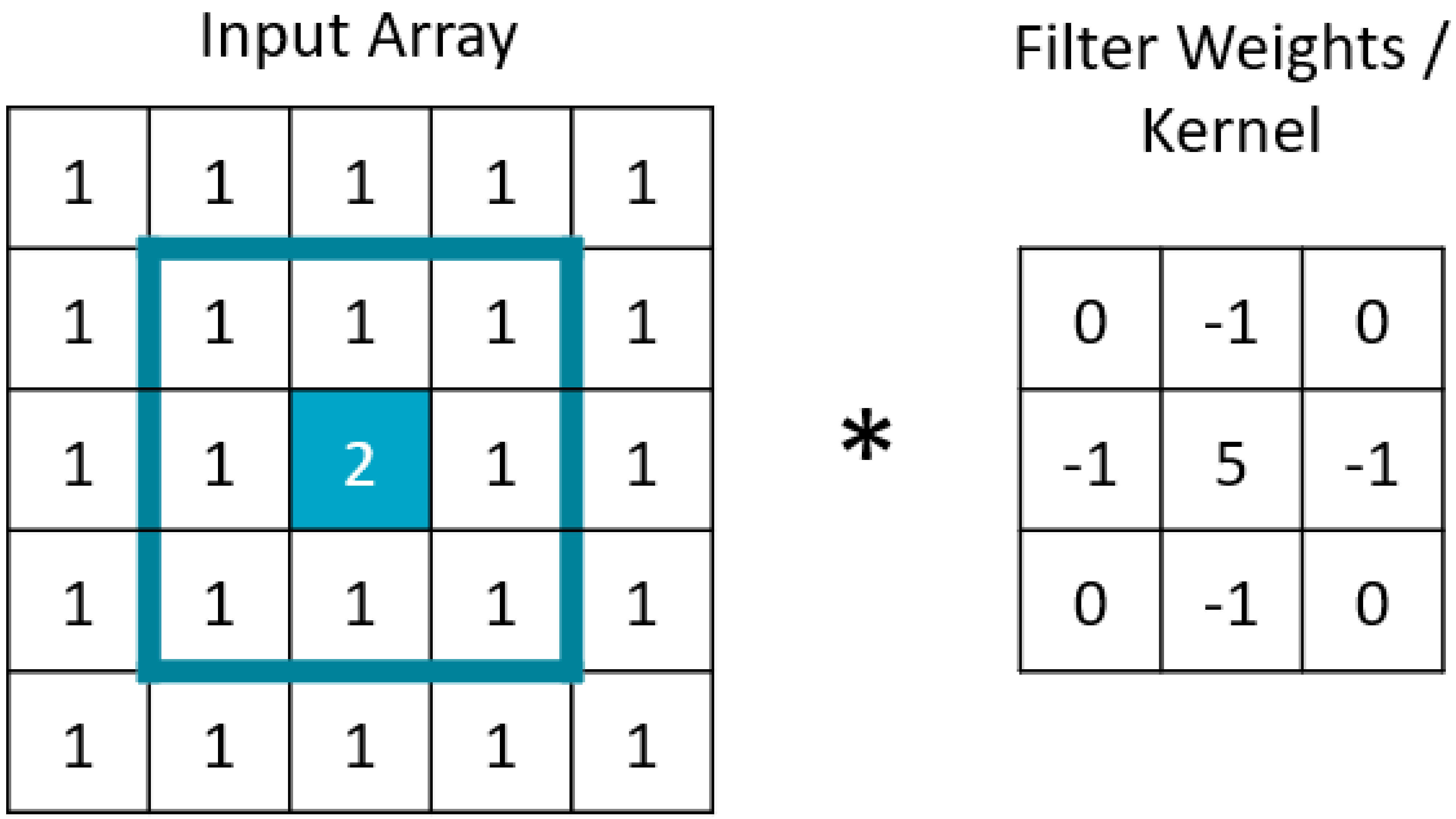
Instructor

Filters



Convolution with a sharpening filter



Input Array

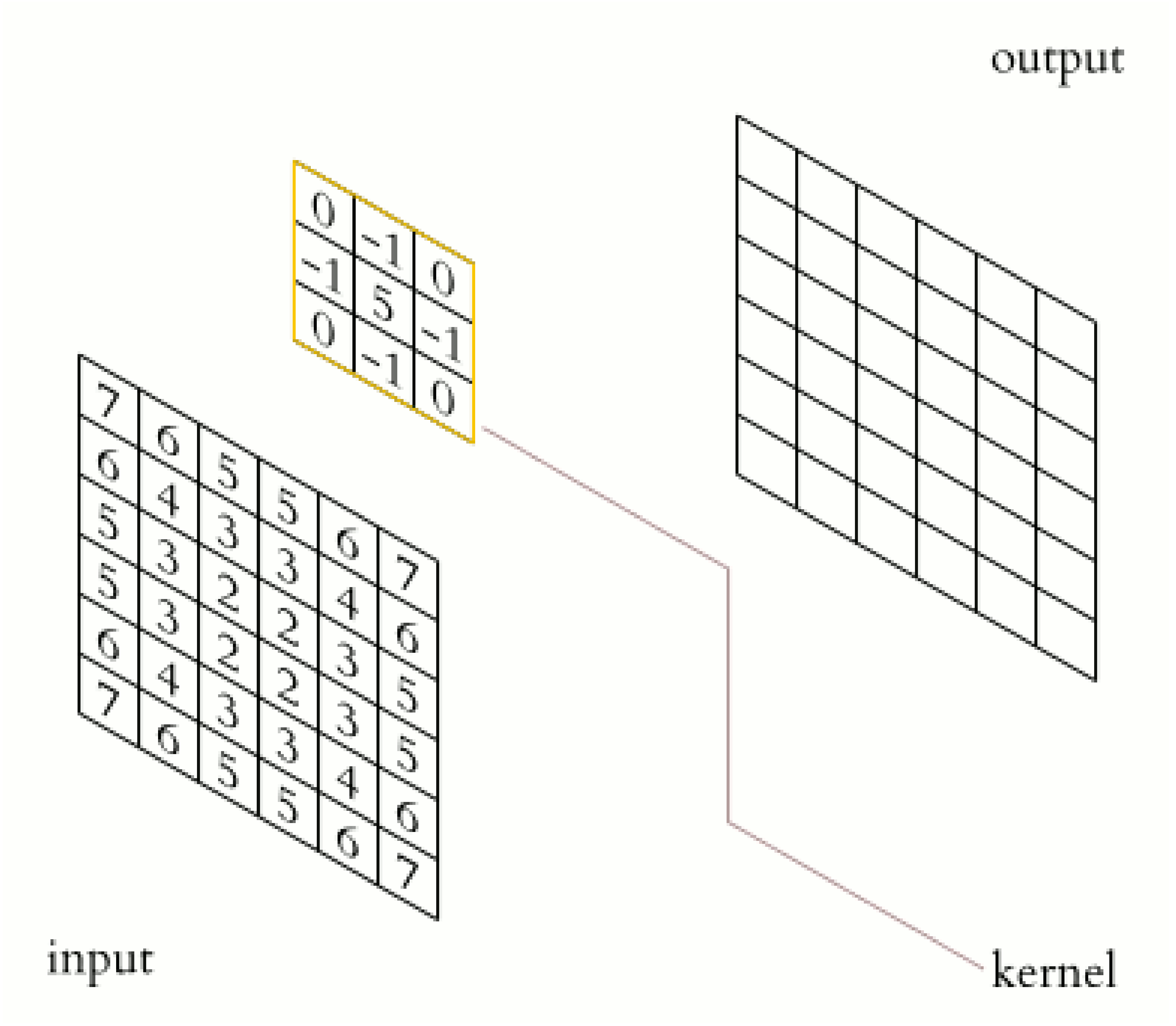
1	1	1	1	1
1	1	1	1	1
1	1	2	1	1
1	1	1	1	1
1	1	1	1	1

Filter Weights / Kernel

0	-1	0
-1	5	-1
0	-1	0

Convolution with a sharpening filter

$$\text{Sum}\begin{pmatrix} 1 * 0 & 1 * -1 & 1 * 0 \\ 1 * -1 & 2 * 5 & 1 * -1 \\ 1 * 0 & 1 * -1 & 1 * 0 \end{pmatrix} = \boxed{6}$$


output
0 -1 0
-1 5 -1
0 -1 0
7 6 5 5 6 7
6 4 3 3 4 6
5 3 2 2 3 5
5 3 2 2 3 5
6 4 3 3 4 6
7 6 5 5 6 7
input
kernel

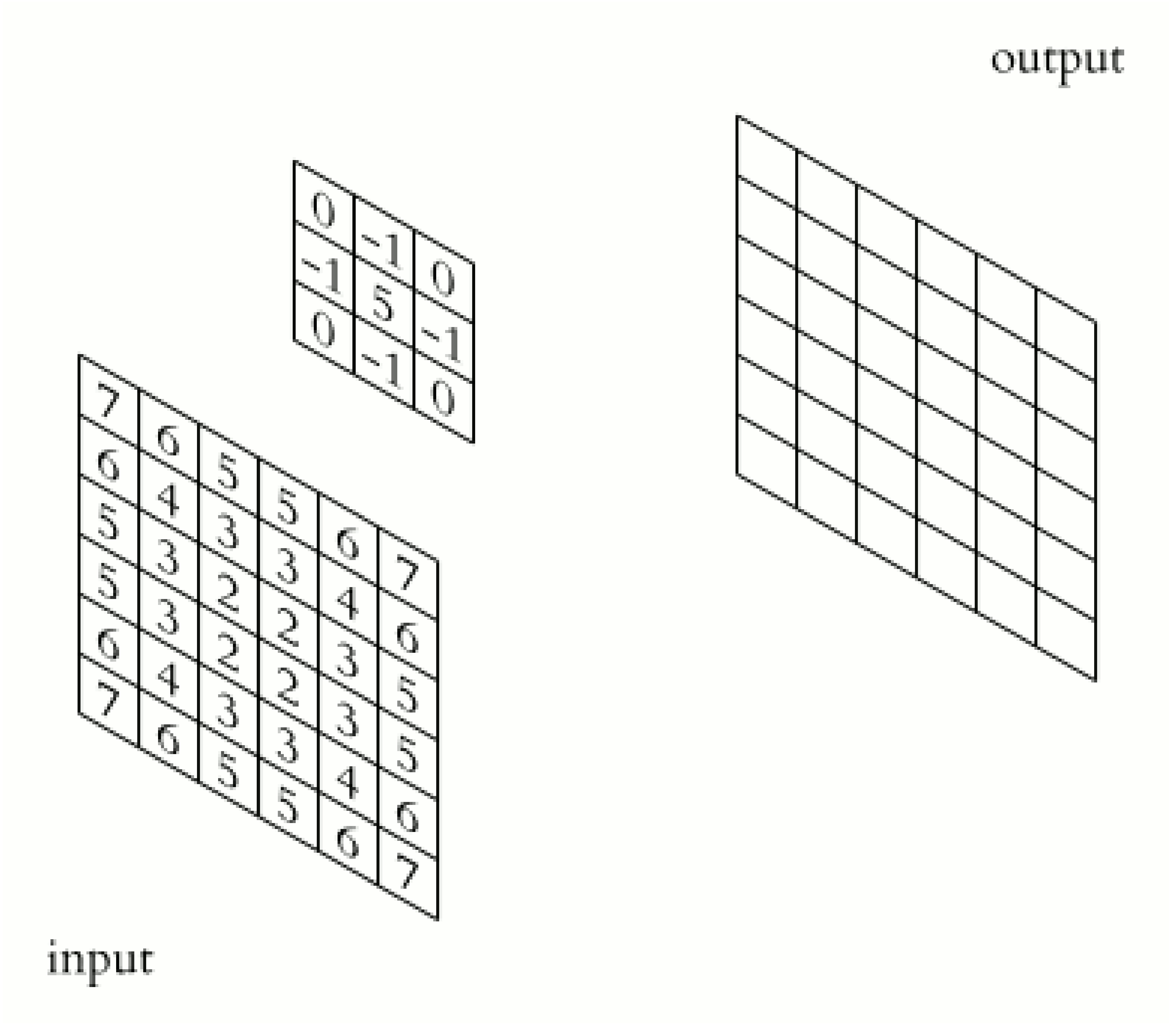
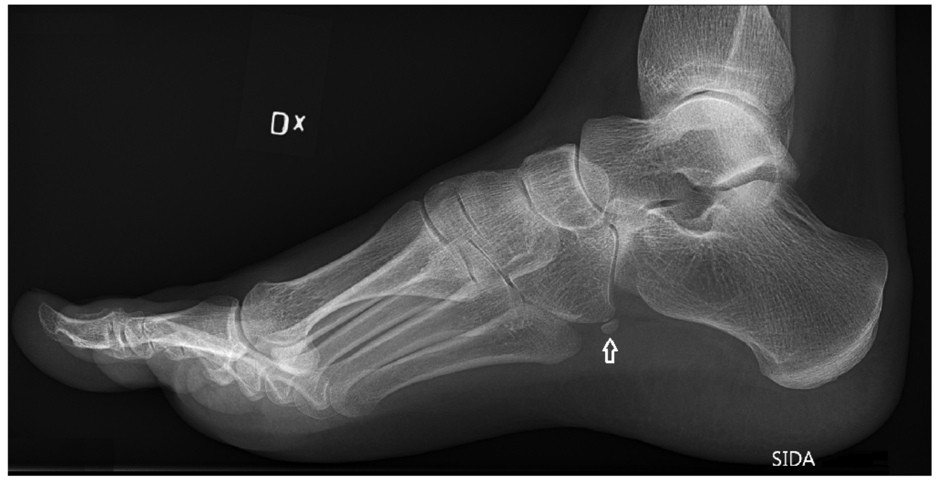

output
0
-1
0
-1
5
-1
0
-1
0
7
6
5
5
6
7
6
4
3
3
4
6
5
3
2
2
3
5
5
3
2
2
3
5
6
4
3
3
4
6
7
6
5
5
6
7
input

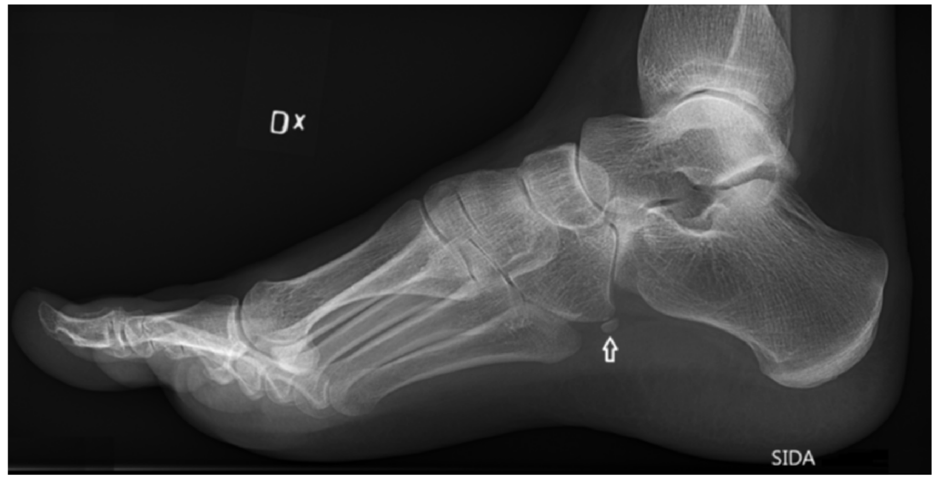
Image convolution

```
import imageio
import scipy.ndimage as ndi

im=imageio.imread('foot-xray.jpg')
weights = [[.11,  .11, .11],
           [.11,  .12, .11],
           [.11,  .11, .11]]
im_filt = ndi.convolve(im, weights)
```

```
fig, axes = plt.subplots(2, 1)
axes[0].imshow(im, cmap='gray')
axes[1].imshow(im_filt,cmap='gray')
plt.imshow()
```



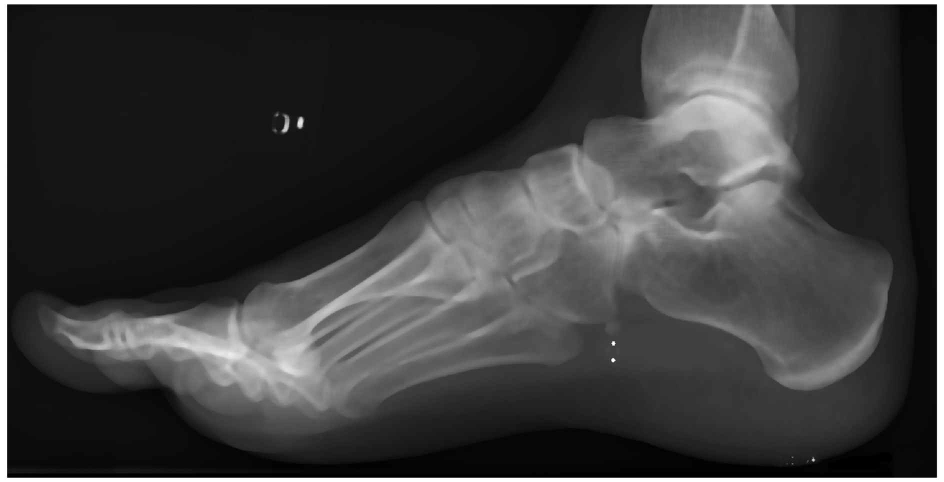


Filtering functions

`scipy.ndimage.filters` includes:

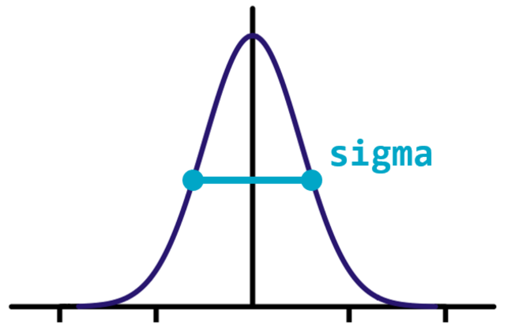
- `median_filter()`
- `uniform_filter()`
- `maximum_filter()`
- `percentile_filter()`

```
ndi.median_filter(im, size=10)
```

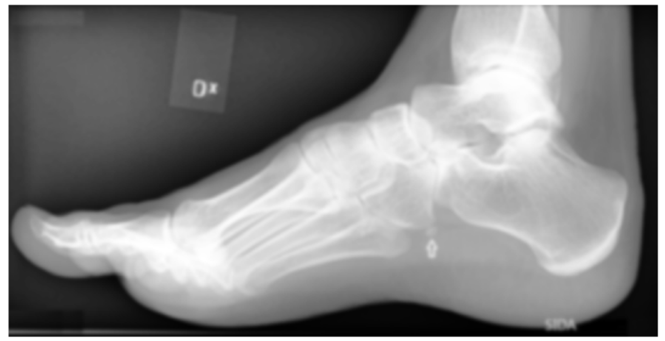


Gaussian filtering

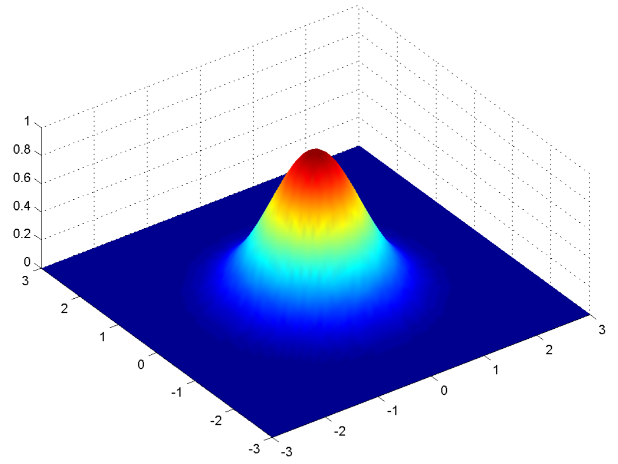
Gaussian distribution in 1 dimension



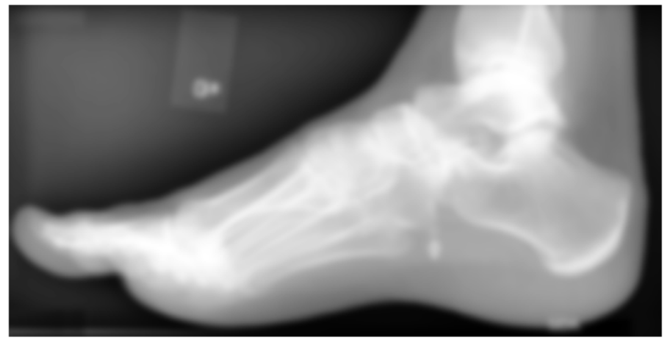
```
ndi.gaussian_filter(im, sigma=5)
```



Gaussian distribution in 2 dimensions



```
ndi.gaussian_filter(im, sigma=10)
```



Let's practice!

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Feature detection

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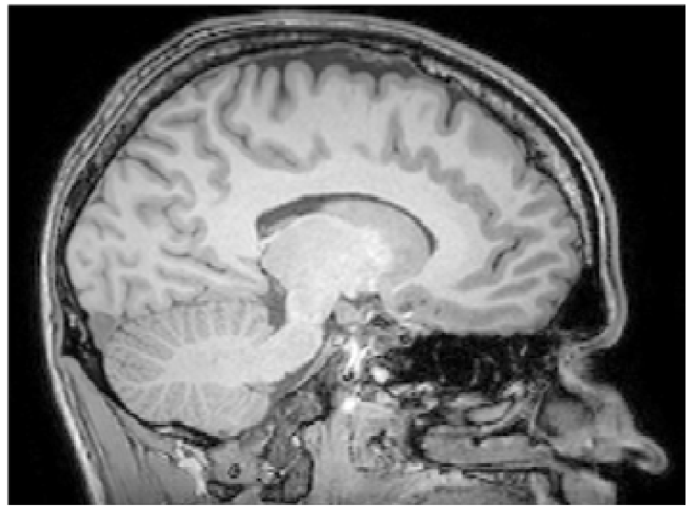
Edges: sharp changes in intensity

Original



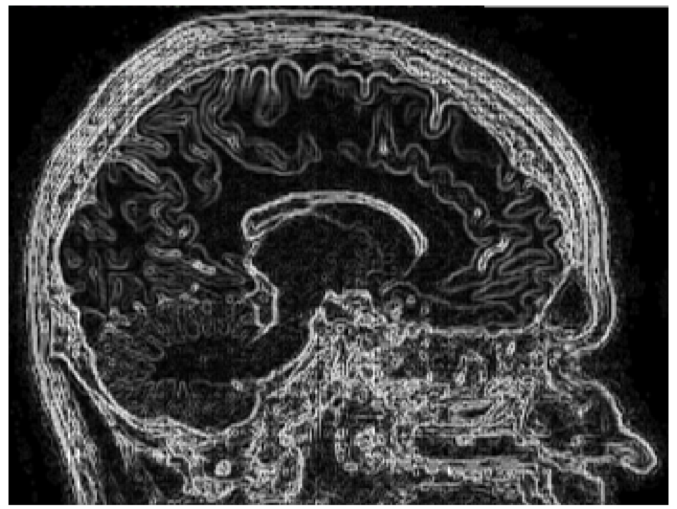
*

Kernel

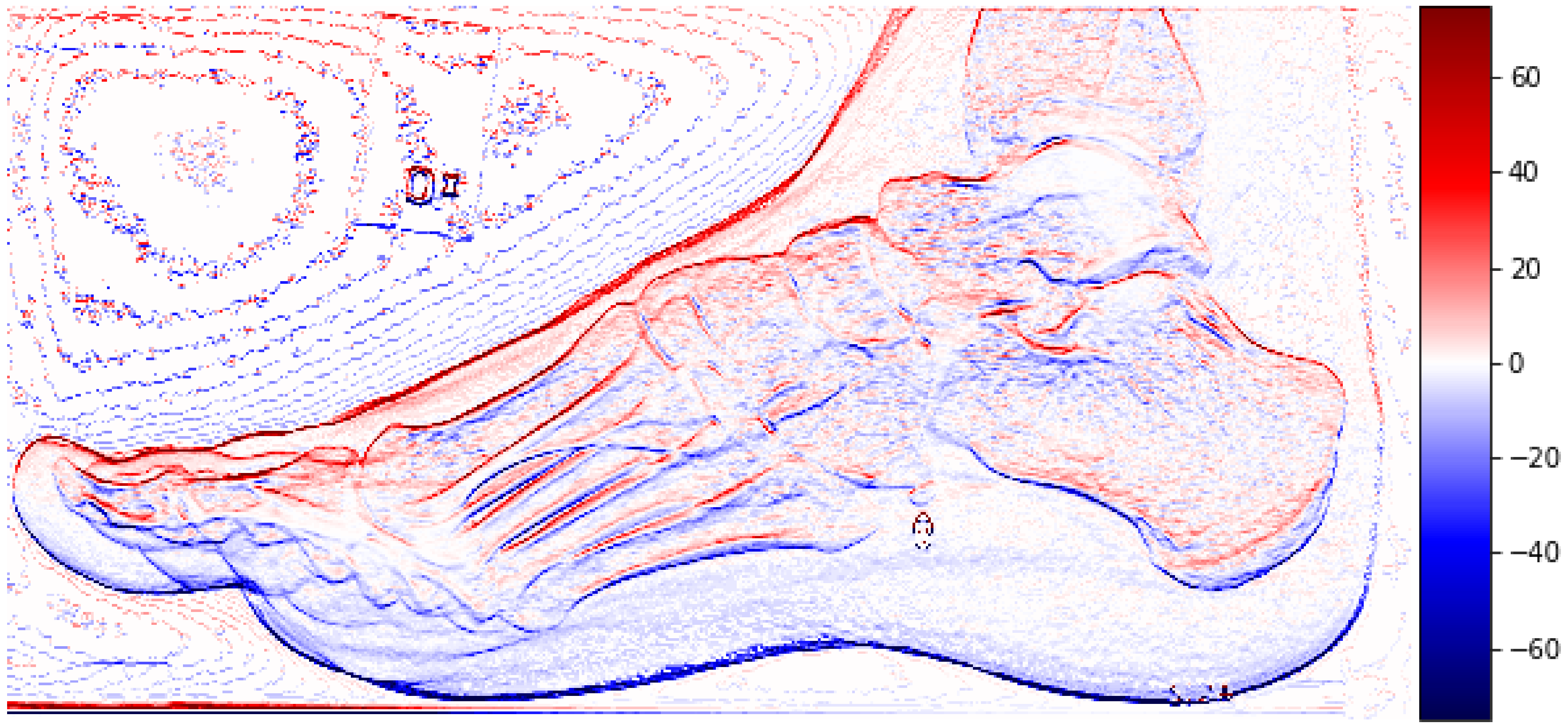
?	?	?
?	?	?
?	?	?

=

Edges



```
im=imageio.imread('foot-xray.jpg')
weights = [[+1, +1, +1],
           [ 0,  0,  0],
           [-1, -1, -1]]
edges = ndi.convolve(im, weights)
plt.imshow(edges, cmap='seismic')
```



Sobel filters

Sobel (H)

1	2	1
0	0	0
-1	-2	-1

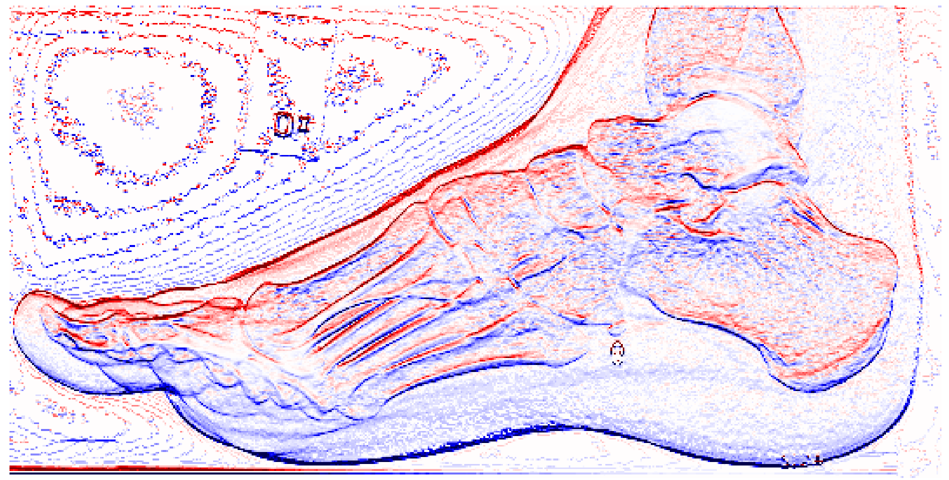
Sobel (V)

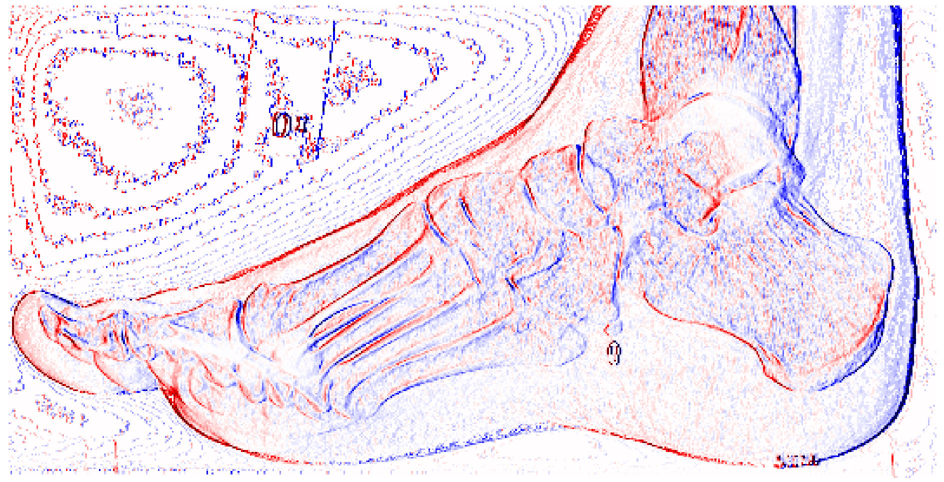
1	0	-1
2	0	-2
1	0	-1

Sobel filters

```
ndi.sobel(im, axis=0)
```

```
ndi.sobel(im, axis=1)
```





Sobel filter magnitude

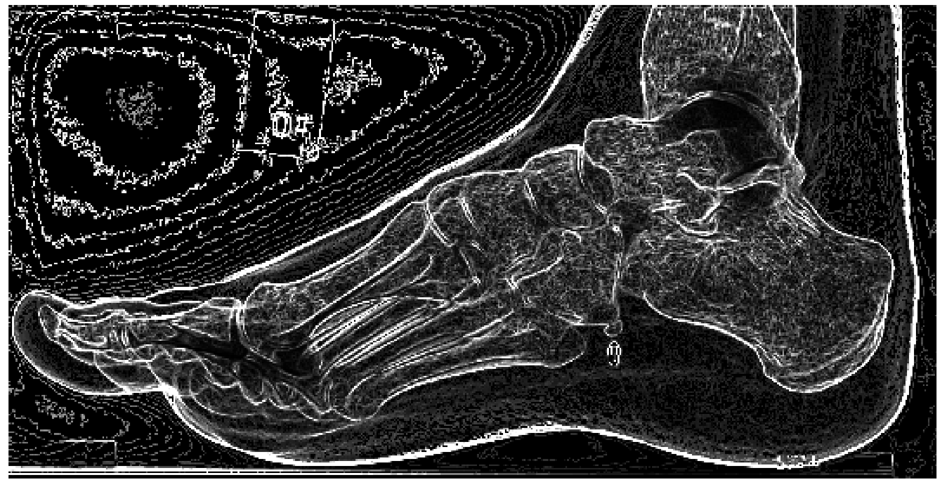
Combine horizontal and vertical edge data by calculating distance:

$$z = \sqrt{x^2 + y^2}$$

```
edges0=ndi.sobel(im, axis=0)
edges1=ndi.sobel(im, axis=1)

edges=np.sqrt(np.square(edges0) +
              np.square(edges1))
```

```
plt.imshow(edges, cmap='gray')
```



Let's practice!

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