BIOMEDICAL IMAGE ANALYSIS IN PYTHON

Intensity Values

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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

Data Type	Range	No. Values
uint8	**0, 255**	**256**
int8	-128, 127	256
uint16	0, 2^{16}	2^{16}
int16	-2^{15}, 2^{15}	2^{16}
float16	$\sim -2^{16}$, $\sim 2^{16}$	$>>2^{16}$

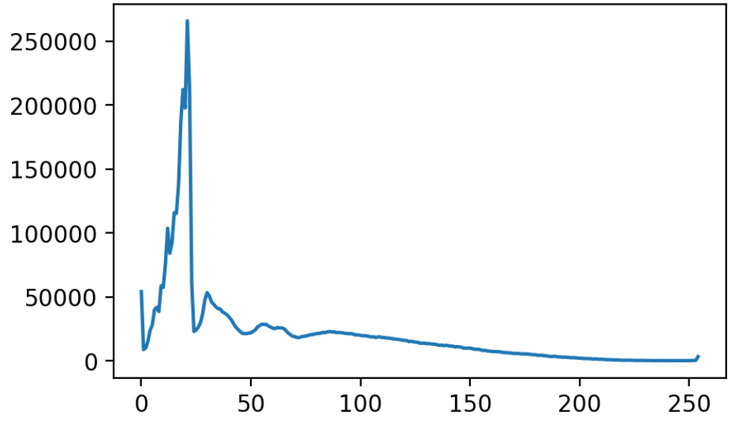
```
import imageio

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`.

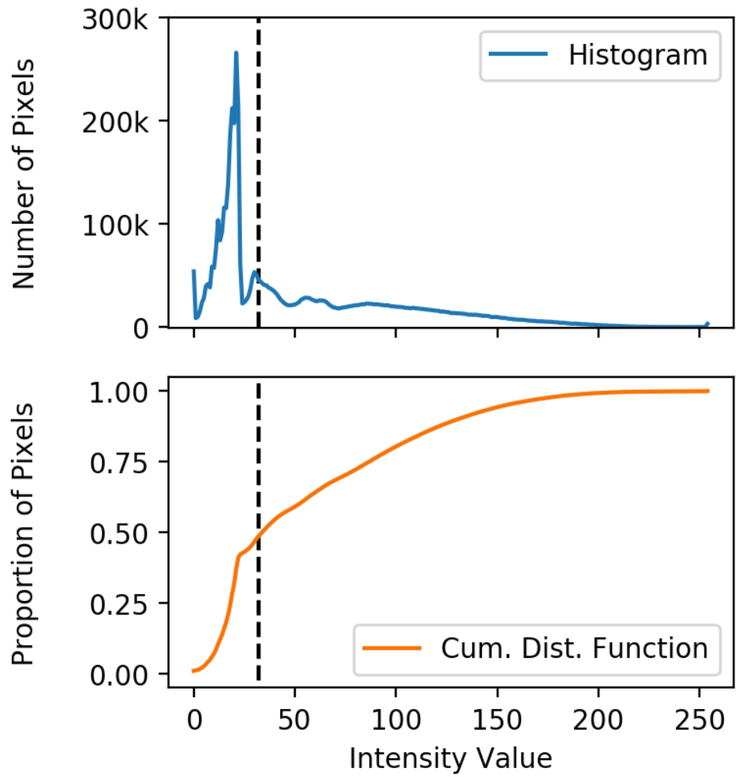
```
import scipy.ndimage as ndi

hist = ndi.histogram(im, min=0,
                         max=255,
                         bins=256)

hist.shape
    (256,)
```

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



Equalization

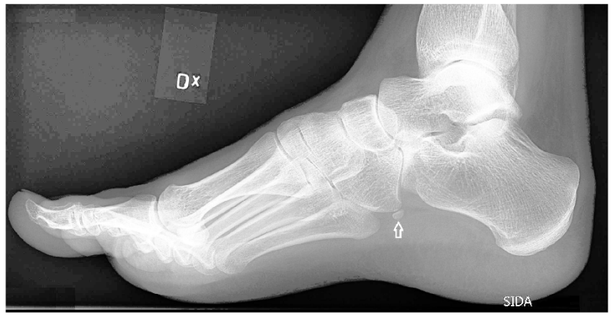
- Distributions often skewed toward low intensities (background values).
- **Equalization**: redistribute values to optimize full intensity range.
- **Cumulative distribution function**: (CDF) shows proportion of pixels in range.



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()
```



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Masks

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Masks

Raw image

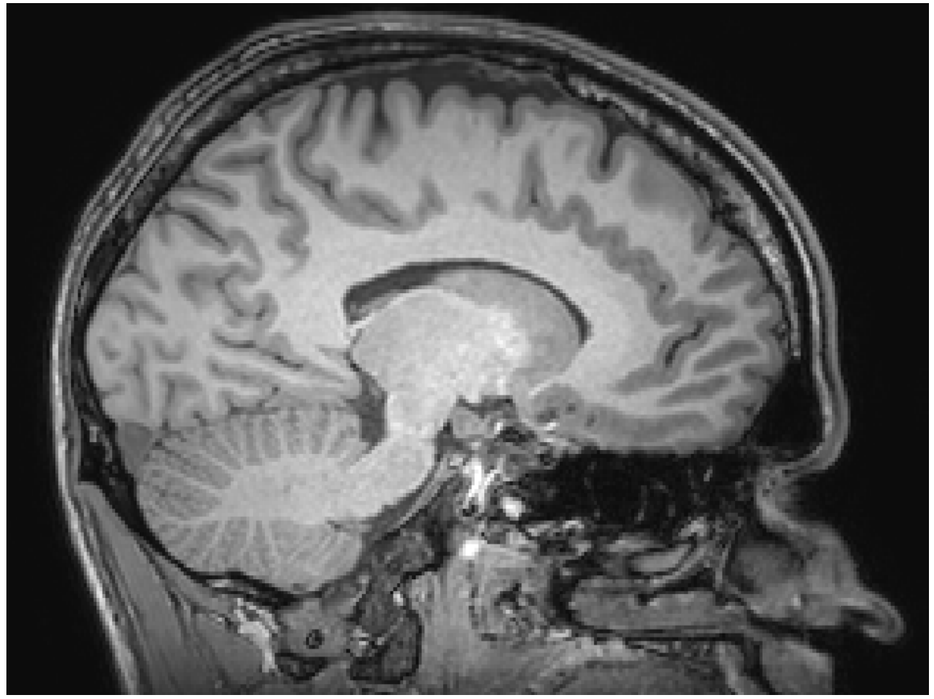
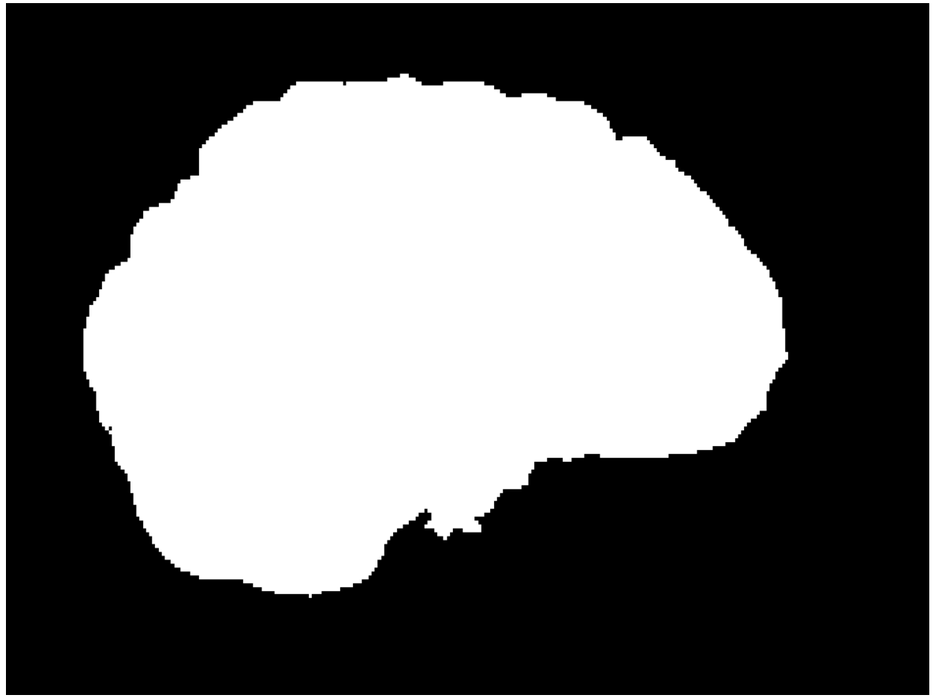


Image mask



Creating masks

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

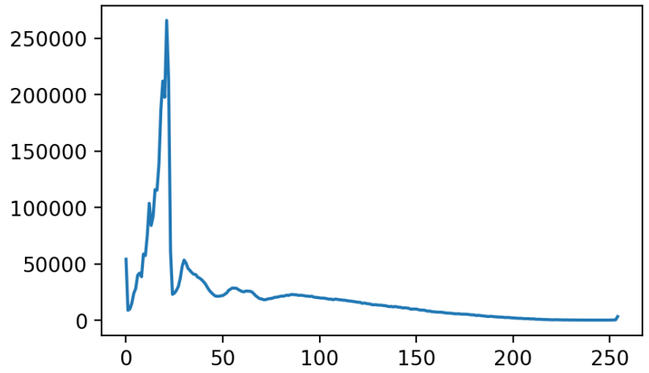
```
mat = np.array([[1, 2, 3],
                [4, 5, 6],
                [7, 8, 9]])

mat > 5
np.array([[False, False, False],
          [False, False, True ],
          [True,  True,  True ]])
```

Sample Operations

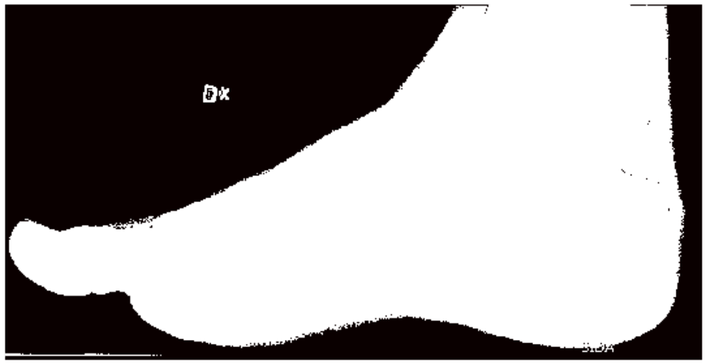
Operation	Example
Greater	`im > 0`
Equal to	`im == 1`
X and Y	`(im > 0) & (im < 5)`
X or Y	`(im > 10) | (im < 5)`

Creating masks

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

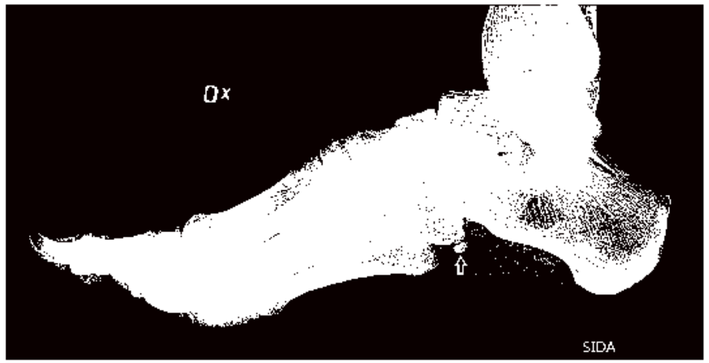



```
mask1 = im > 32
```



Creating masks

```
mask2 = im > 64
```




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

Applying masks

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

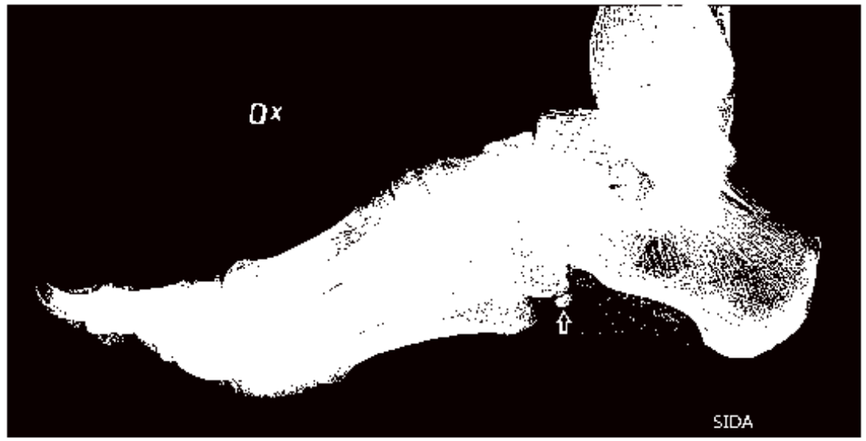
```
import numpy as np

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

```
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)
```

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Filters

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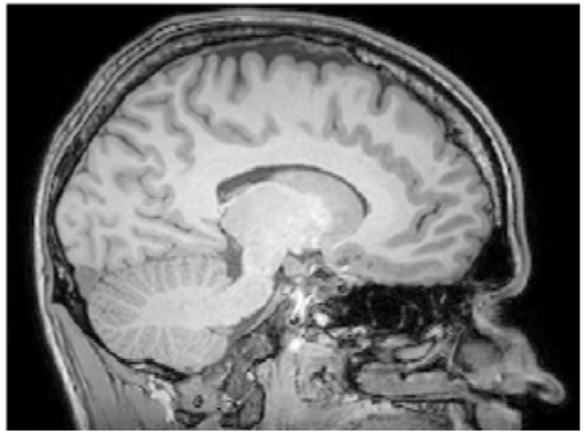
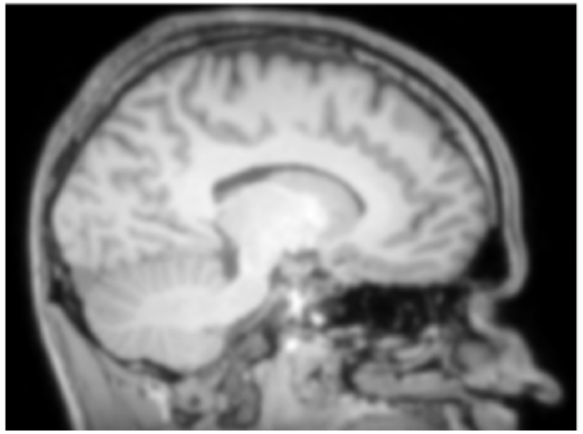
Filters

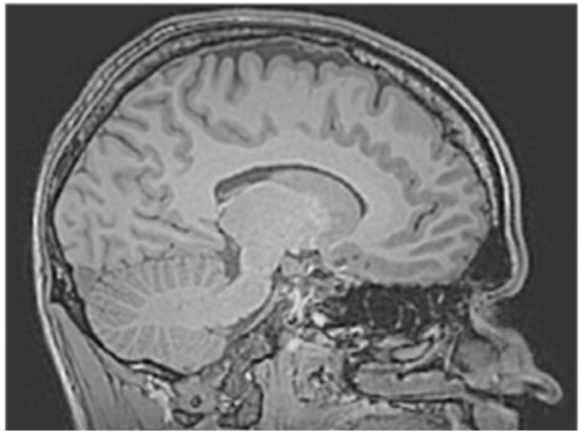
Original



Smoothed



Sharpened



Convolution with a sharpening filter

Input Array

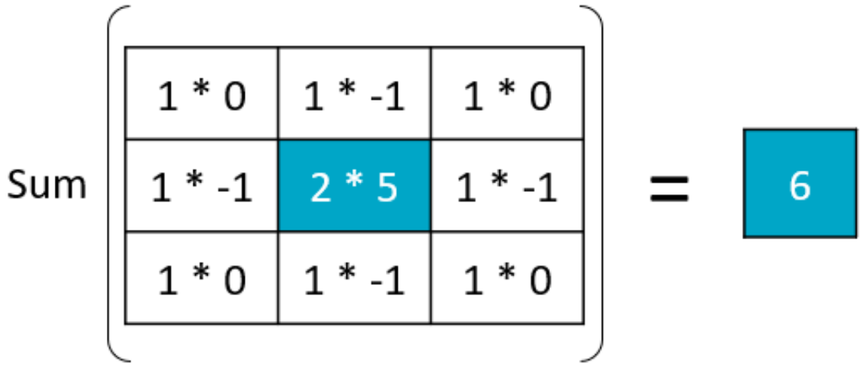
1	1	1	1	1
1	1	1	1	1
1	1	2	1	1
1	1	1	1	1
1	1	1	1	1

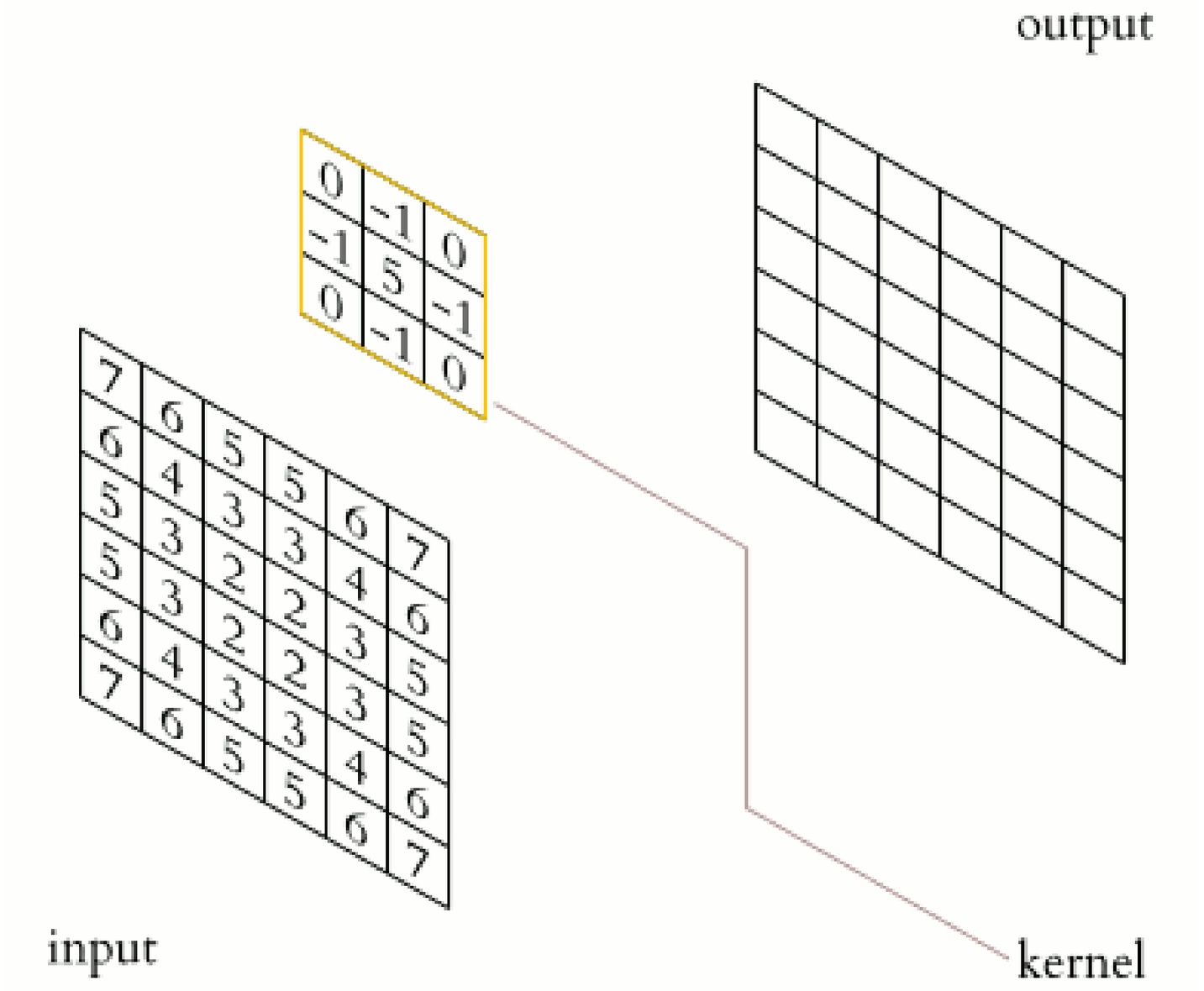
*

Filter Weights / Kernel

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

Convolution with a sharpening filter




output
input
kernel

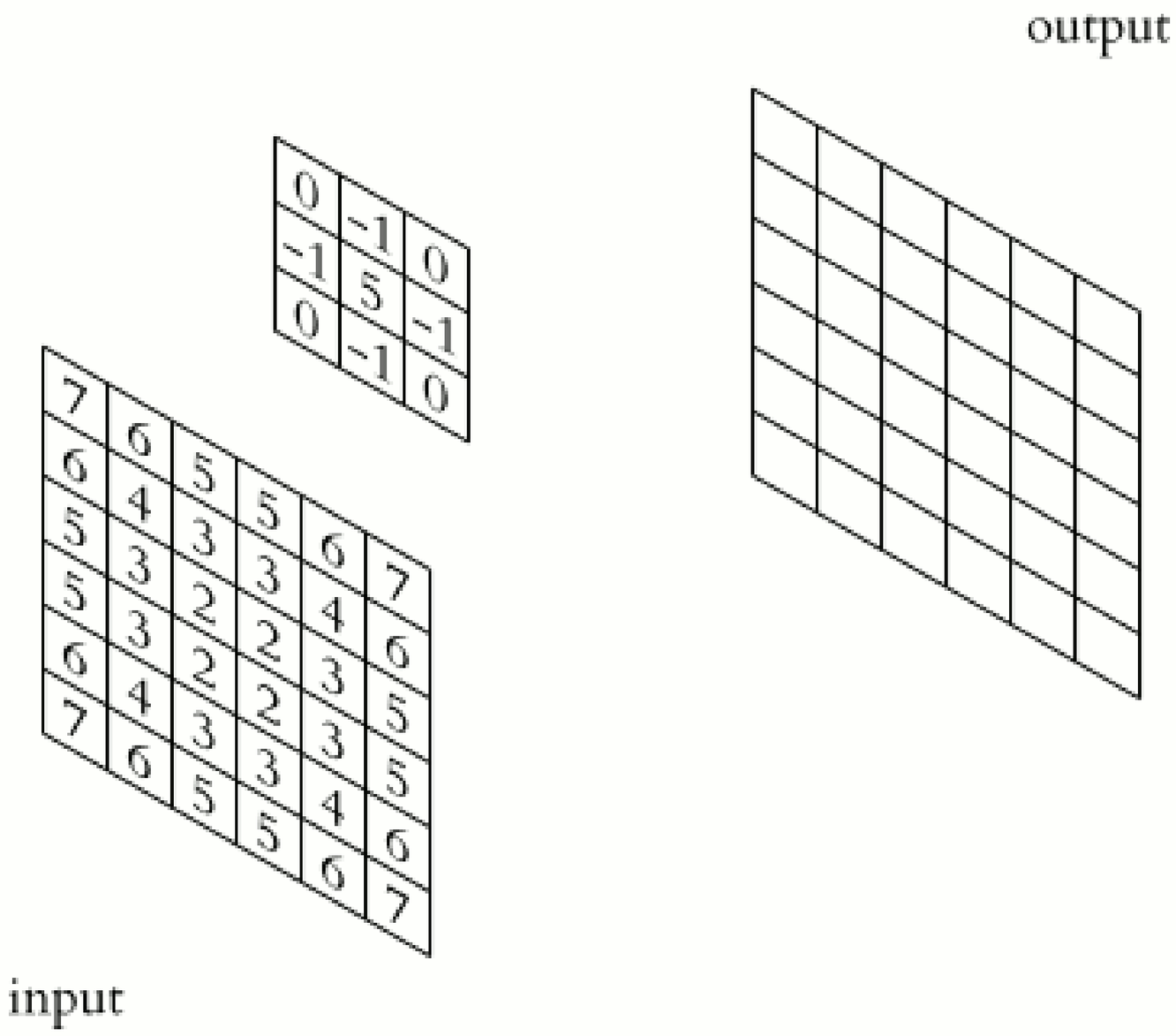

output
input

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

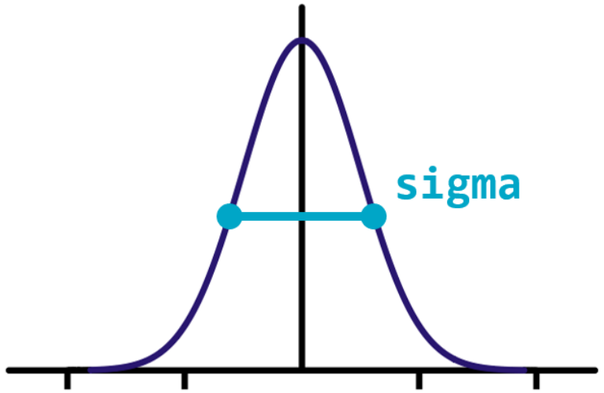
`scipy.ndimage.filters` includes:

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

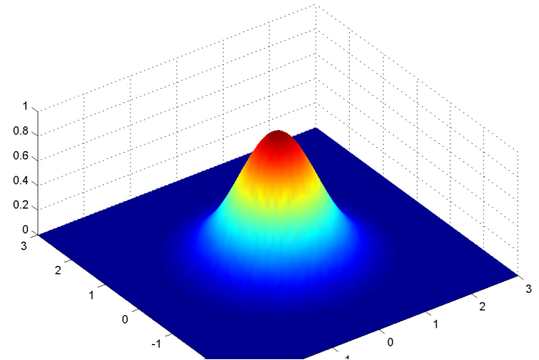
```
ndi.median_filter(im, size=10)
```

Gaussian filtering

Gaussian distribution in 1 dimension

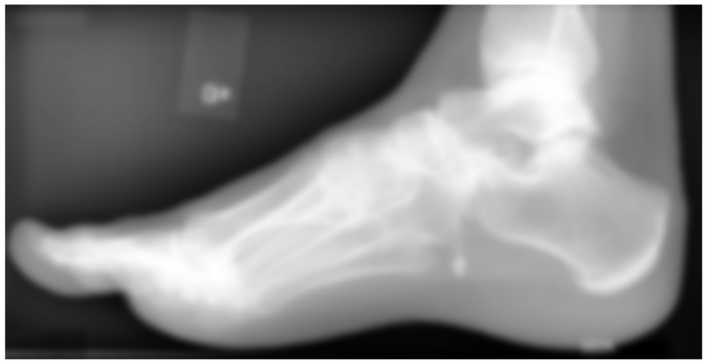


Gaussian distribution in 2 dimensions




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

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



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Feature Detection

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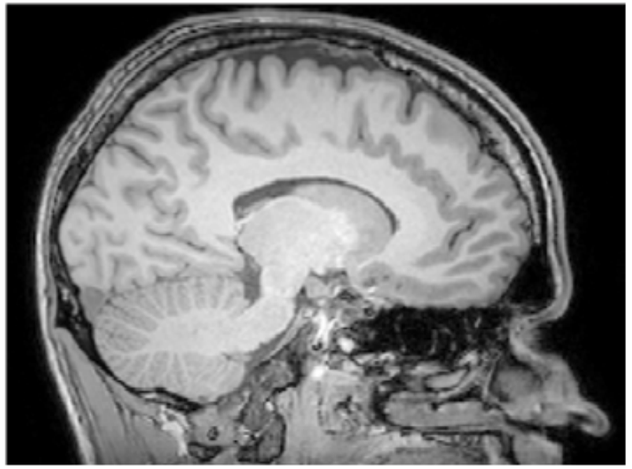
Edges: sharp changes in intensity

Original



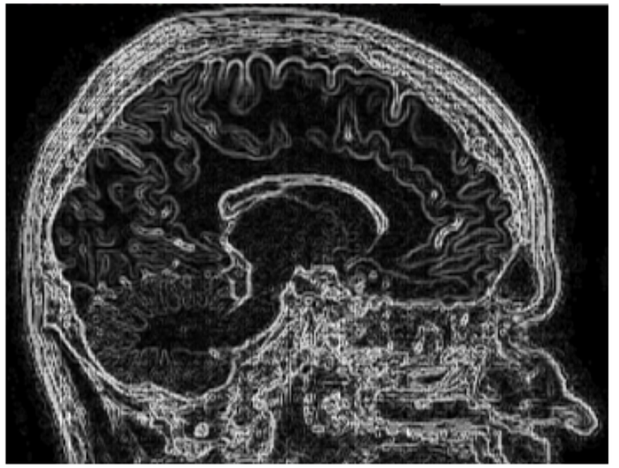
*

Kernel

?	?	?
?	?	?
?	?	?

=

Edges



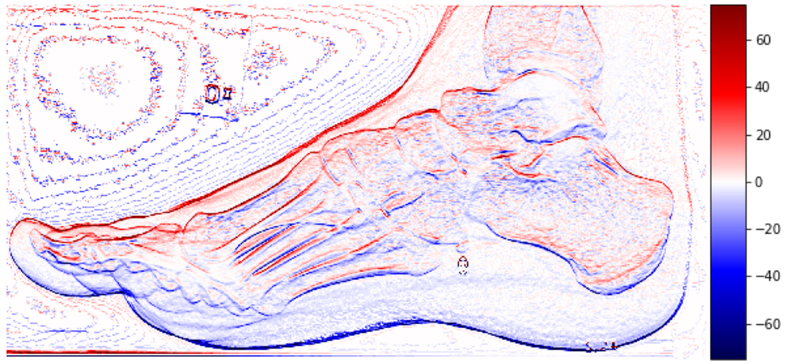
Edge detection

```
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)

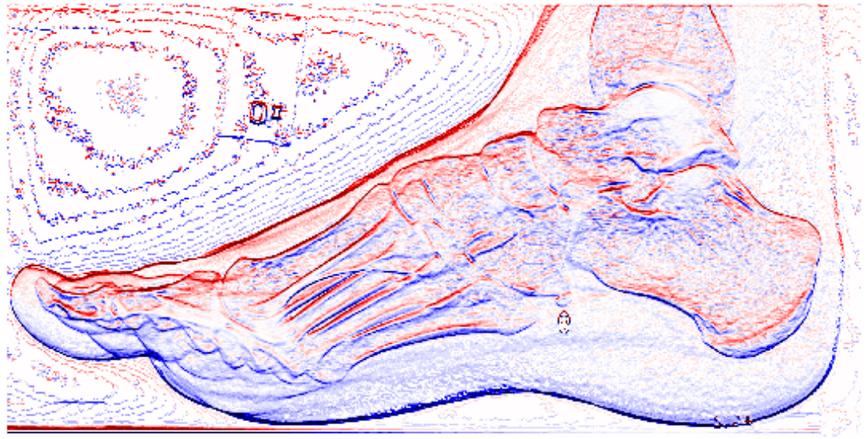
1	2	1
0	0	0
-1	-2	-1

Sobel (V)

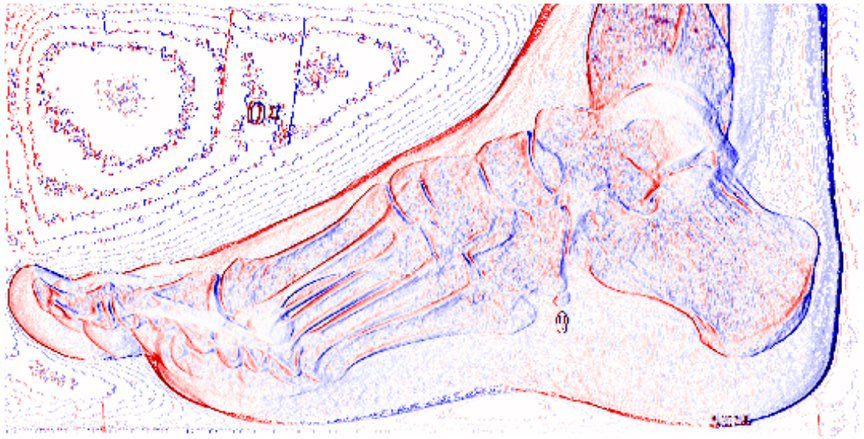
1	0	-1
2	0	-2
1	0	-1

Sobel filters

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



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



Sobel filter magnitude

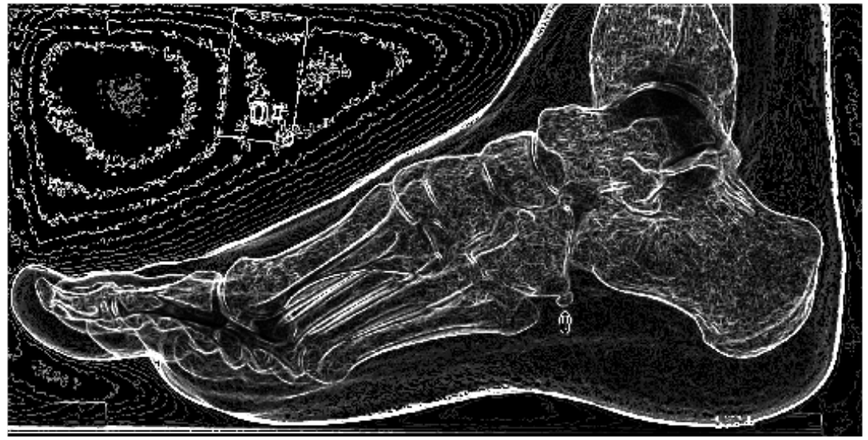
Combine horizontal and vertical edge data by calculating distance:

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

```
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')
```



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