Overview

- Contrast enhancement
  - Image filtering
  - Low pass spatial filtering
    - Linear spatial filters
    - Non linear spatial filters

Image filtering

Images are often corrupted by random variations in intensity, illumination or have poor contrast. It is difficult, in this case, to analyse the physical content of the image.

Filtering : transform pixel intensity values to reveal image characteristic and recover image information

- Image enhancement : improve contrast
- Image smoothing : remove noise
- Template matching : detect known patterns

Spatial filtering

- Spatial filtering tansforms each pixel of the image by a function of the values of the pixel and its neighborhood
- If the function is linear then the filter is called linear spatial filtering otherwise it is a non-linear spatial filtering

Ex : filtering of the image f of size M x N by a by a kernel W of size mxn =2a+1 x 2b+1

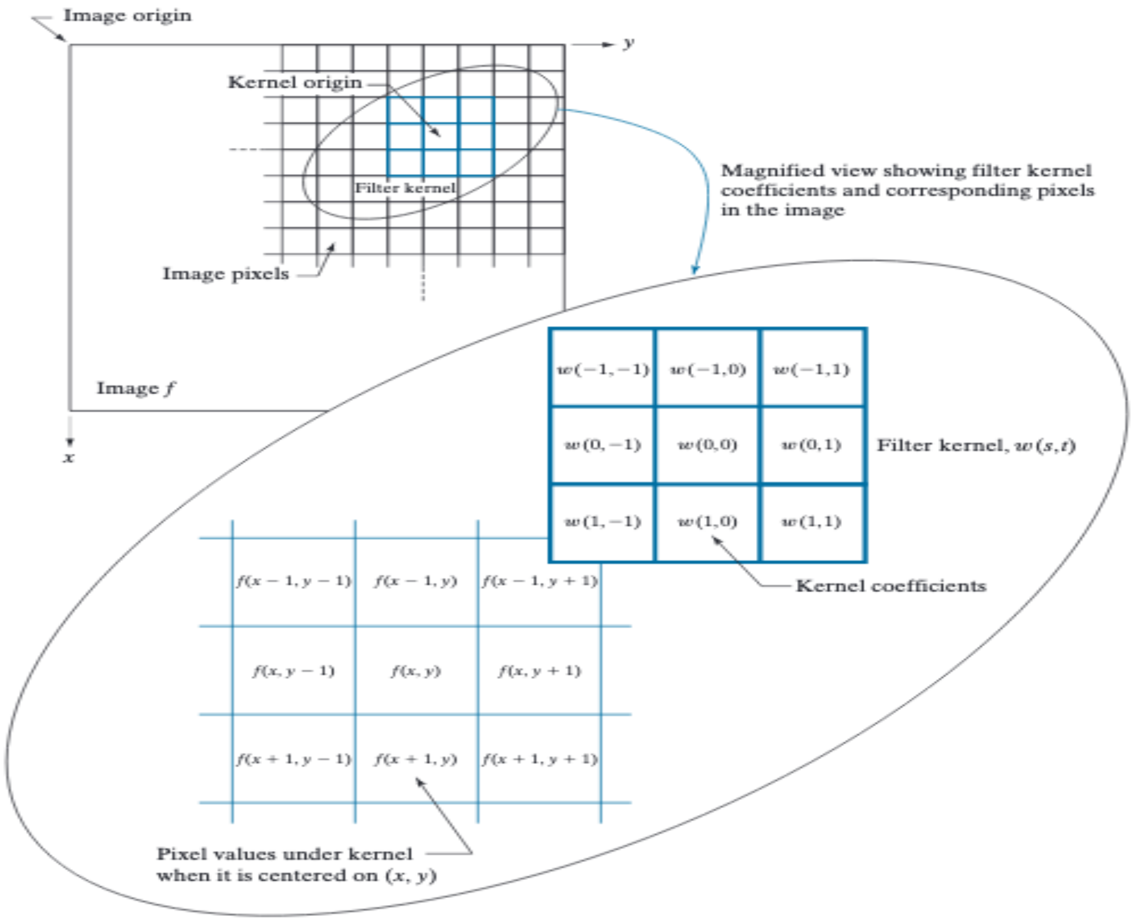
$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

The center of the kernel w(0,0) should align with the pixel at location (x,y)

$$\begin{aligned} g(x,y) = {} & w(-1,-1)f(x-1,y-1) + w(-1,0)f(x-1,y) + \dots \\ & + w(0,0)f(x,y) + \dots + w(1,1)f(x+1,y+1) \end{aligned}$$

Spatial filtering

- The kernel (window) w is sliding so that the center of the Kernel visits every pixel in f once



Spatial filtering

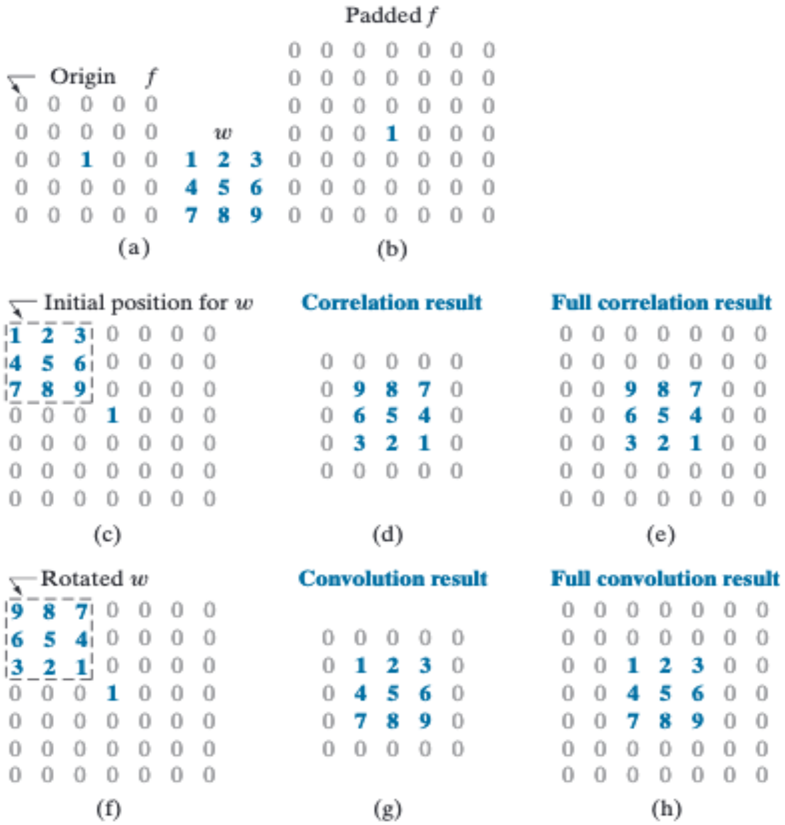
- Convolution = correlation rotated by 180°

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x-s, y-t)$$

- Convulution is commutative and associative, the correlation is not
- When the Kernel is symmetric correlation=convolution
- In general, by convention spatial filtering means convolution of the image with a Kernel

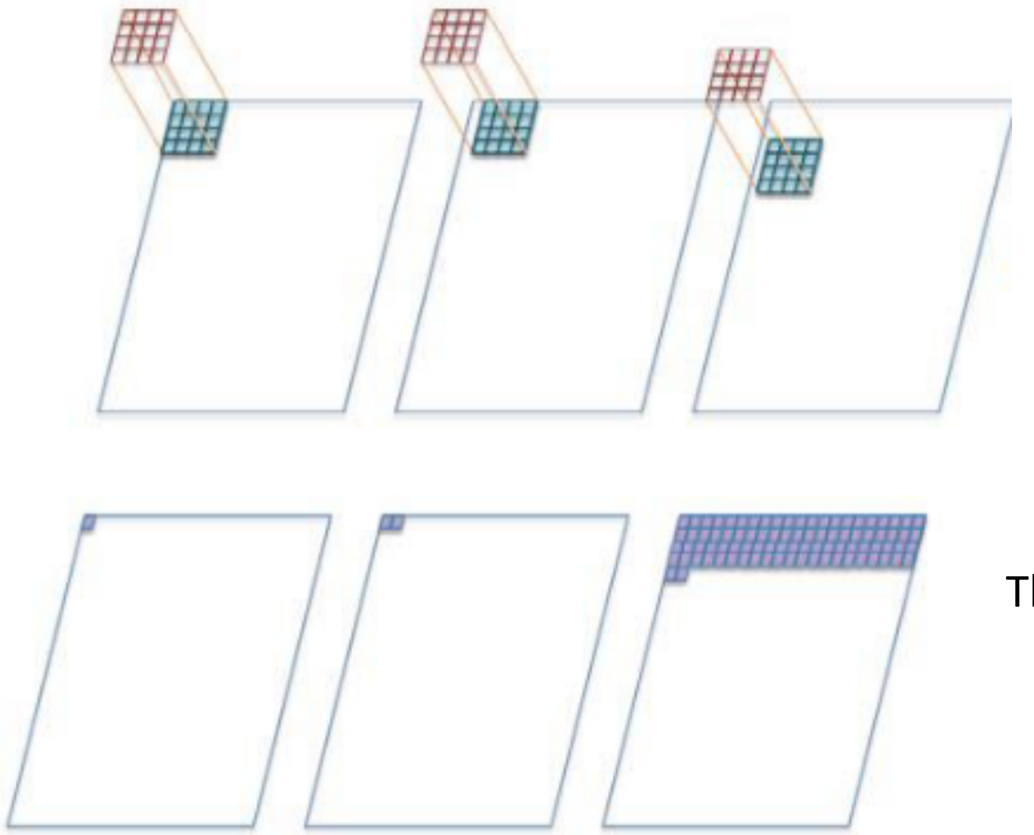
Spatial filtering

- Borders problem : a part of the Kernel lies outside the image f at the corners
- Solution : Padding of the image to handle the borders with(m-1)/2 x (n-1)/2 zeros
- 3X3=(2xa+1)x(2xb+1), a=1,b=1



Spatial filtering

- The final results is given by a sliding window on the whole image



The filtered image

Image filtering - smoothing

NOISE

- Noise is random values that affect the acquired image and thus pixels. It is due to non-perfect camera acquisition or external environmental conditions
- For each noise type, there is its convenient Kernel filter remedy

Common types of noises :

- Salt and pepper: random occurrence of black and white intensity values, like salt and pepper
- Impulse noise: random occurrence of white intensity values
- Gaussian noise: Impulse noise with gaussian distribution

Spatial filtering

- Low pass filter : mean filter

- It is designed to smooth the image
- The new pixel is replaced by the normalized mean corresponding to the kernel window
- It eliminates high frequencies but highlight the blur

Examples

3x3

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$

5x5

$$\frac{1}{25}\begin{bmatrix}1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1 & 1 & 1 & 1\end{bmatrix}$$

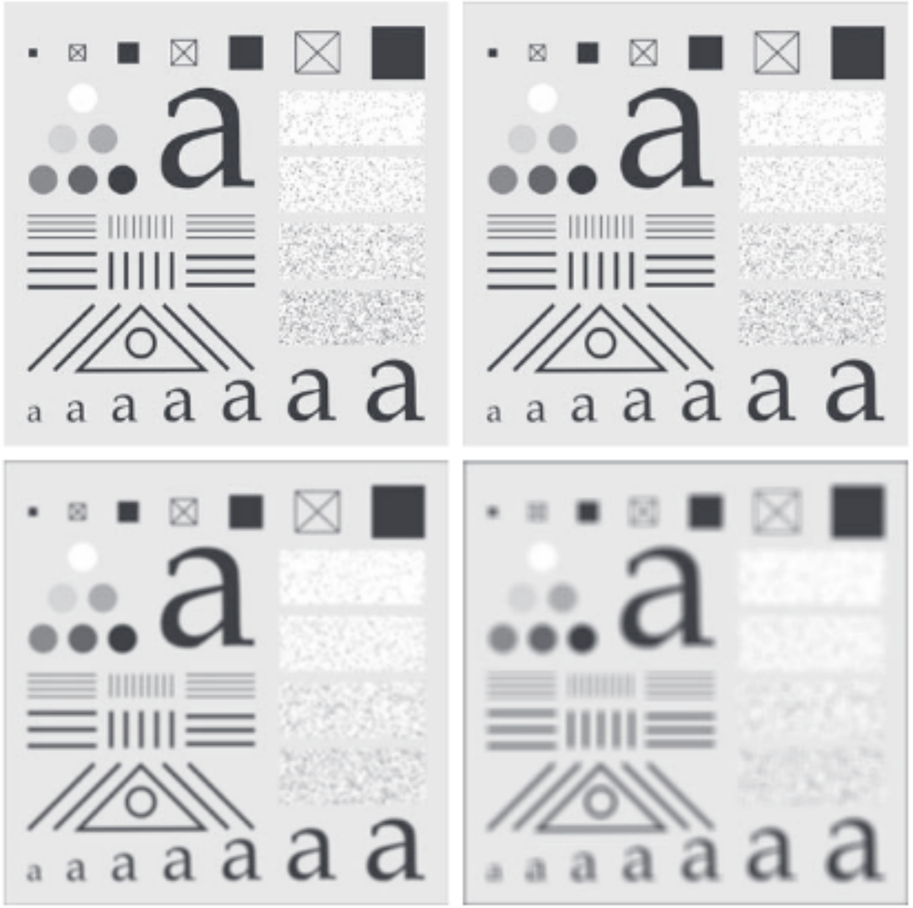
Ponderated 3x3

$$\frac{1}{16}\begin{bmatrix}1 & 2 & 1\\ 2 & 4 & 2\\ 1 & 2 & 1\end{bmatrix}$$

Spatial filtering

- Low pass filter

3x3

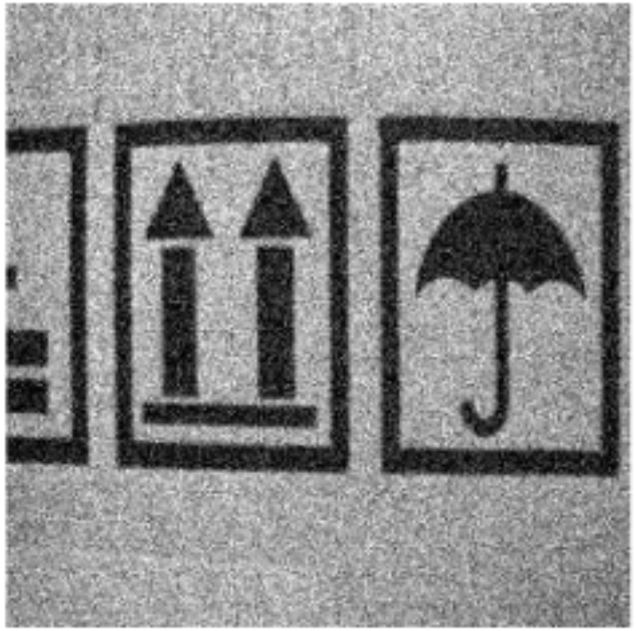


11x11

25x25

Spatial filtering

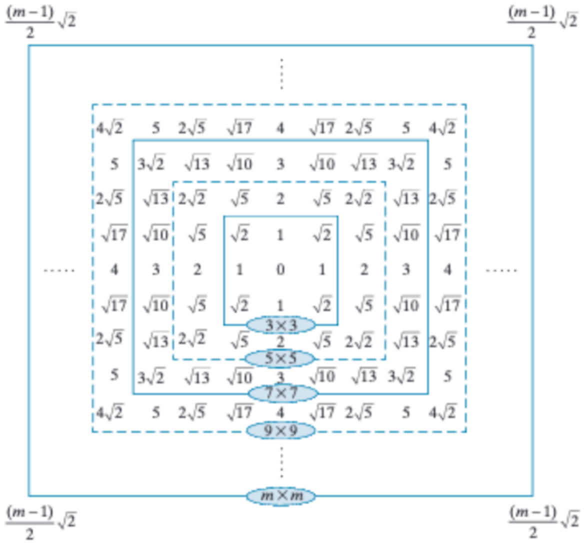
- Low pass filter



Spatial filtering

- Gaussian filter

$$h(x,y) = Ke^{-\frac{x^2+y^2}{2\sigma^2}} \quad K > 0, \quad x, y \in \mathcal{R}$$

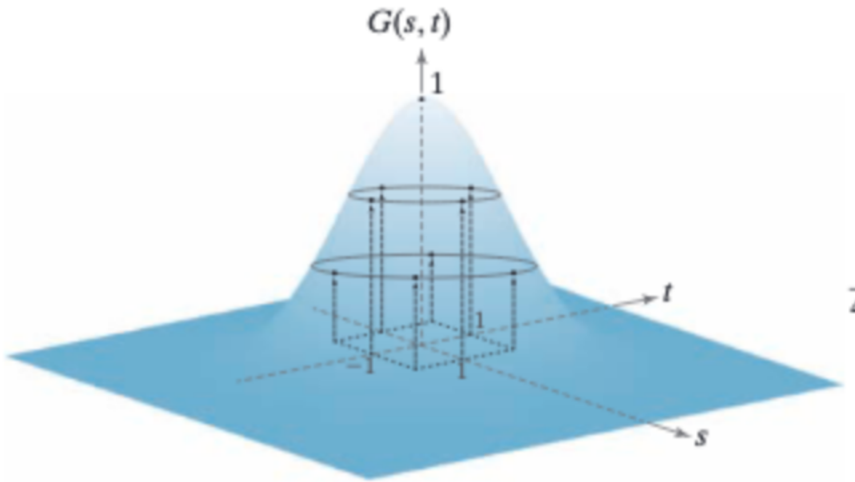


The gaussian Kernel is isotropic, it is independent from the orientation

The gaussian Kernel is got by descritizing the Gaussian function with a predifines mask size and well choised σ

Spatial filtering

- Gaussian filter



$\frac{1}{4.8976} \times$

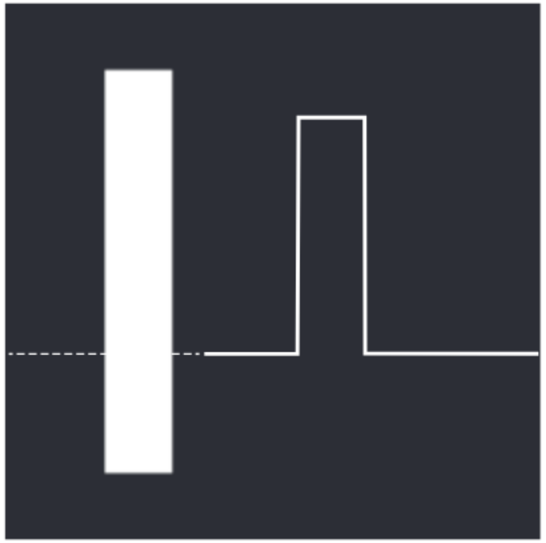
0.3679	0.6065	0.3679
0.6065	1.0000	0.6065
0.3679	0.6065	0.3679

Example for K=1 and $\sigma = 1,\ resulting\ in\ 3x3\ gaussian\ Kernel$

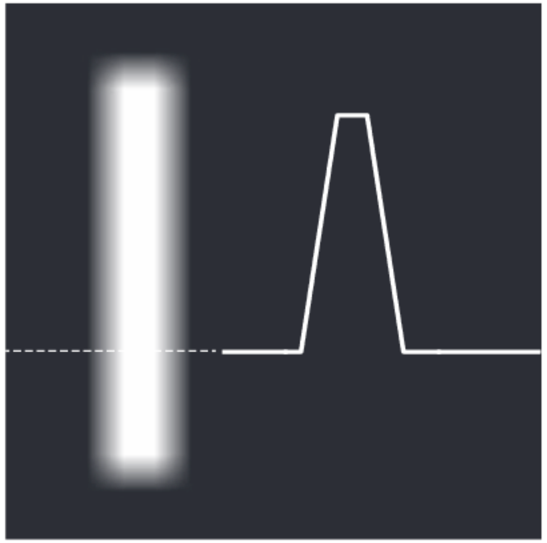
The Gaussian Kernel is suitable for homogeneous areas but smooth to much the corners

Spatial filtering

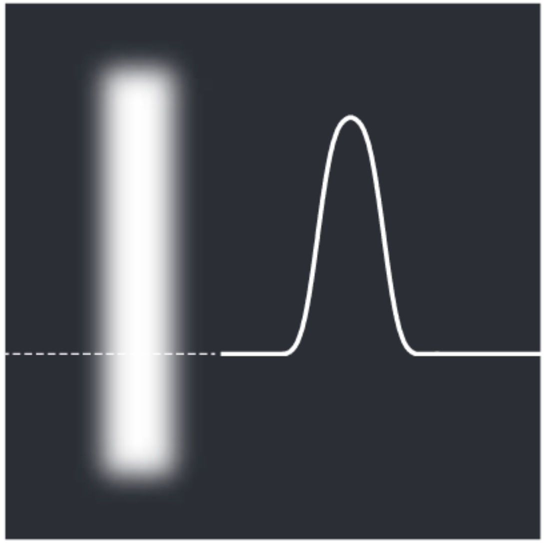
- Gaussian filter



Original image



Kernel of 71x71



Kernel of 151x151

K=1 and $\sigma = 25$,

The Gaussian Kernel is suitable for homogeneous areas but smooth to much the corners

Spatial filtering

- Gaussian filter

Original image 4096x4096

Kernel of 187x187

K=1 and $\sigma = 31$,

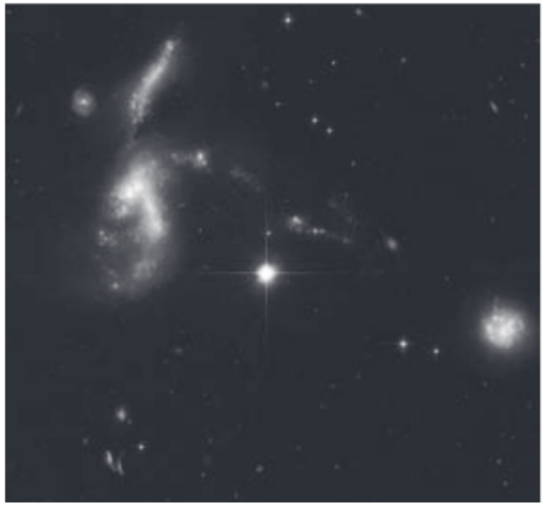
Kernel of 745x745

K=1 and $\sigma = 124$,

The Gaussian Kernel is suitable for homogeneous areas but smooth to much the corners

Spatial filtering

- Gaussian filter



2566x2566 Hubble Telescope image

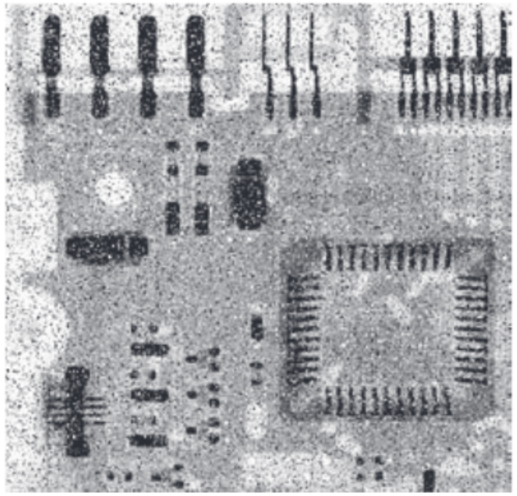
Gaussian Kernel

Thresholded image

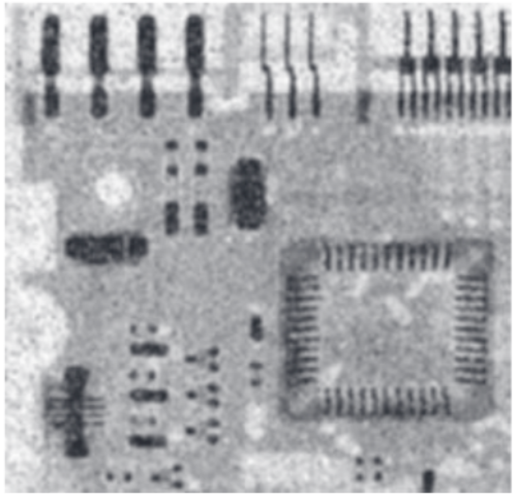
Images courtesy from the NASA

Non linear spatial filtering

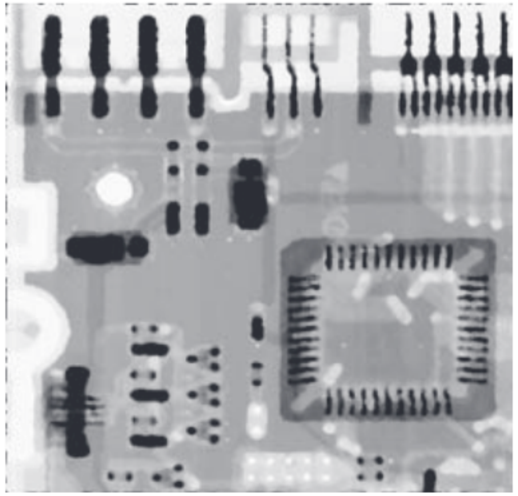
- Median filter vs Gaussian filter



X ray images noised with salt and pepper noise



Filtering with a 19x19 Gaussian filter $\sigma = 3$



7x7 median filter

courtesy of Mr. Joseph E. Pascente, Lixi, Inc.

Non linear spatial filtering

- Median filter

Replace the value of the new pixel by the median of the chosen neighborhood

Effective in the presence of impulse noise (ex. salt and pepper)

Sharpening Highpass spatial filtering

- The purpose of low pass filtering is to smooth the image
- Sharpening filters aim to highlight transition in intensities
- Very used in computer vision applications
- So called Edge detection