Local Enhancement

- Local Enhancement
  - Median filtering (see notes/slides, 3.5.2)
- HW4 due next Wednesday
- Required Reading: Sections 3.3, 3.4, 3.5, 3.6, 3.7

Local enhancement

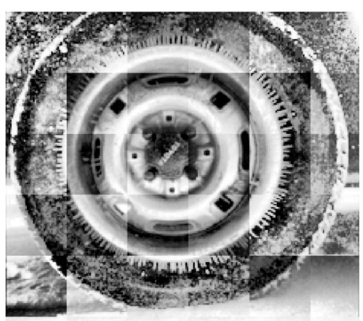
Sometimes Local Enhancement is Preferred.

Malab: BlkProc operation for block processing.

Left: original “tire” image.

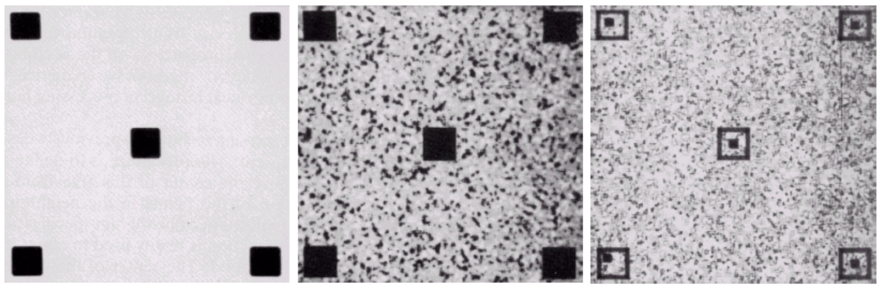
Histogram equalized

Local histogram equalized



```
F=@ histeq;
I=imread('tire.tif');
J=blkproc(I,[20 20], F);
```

Fig 3.23: Another example



a b c

FIGURE 3.23 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a 7 × 7 neighborhood about each pixel.

Local Contrast Enhancement

- Enhancing local contrast

  $g(x,y) = A(x,y)\ [\, f(x,y) - m(x,y)\,] + m(x,y)$

$$A(x,y) = k\ M / \sigma(x,y) \qquad 0 < k < 1$$

M : Global mean

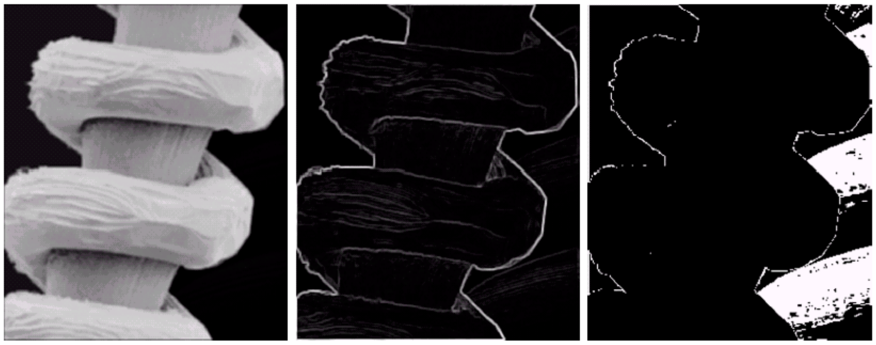
m (x,y) , σ (x,y) : Local mean and standard dev.

Areas with low contrast ➔ Larger gain A (x,y) (fig 3.24-3.26)

Fig 3.24

FIGURE 3.24 SEM image of a tungsten filament and support, magnified approximately 130×. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene).

Fig 3.25



a b c

FIGURE 3.25 (a) Image formed from all local means obtained from Fig. 3.24 using Eq. (3.3-21). (b) Image formed from all local standard deviations obtained from Fig. 3.24 using Eq. (3.3-22). (c) Image formed from all multiplication constants used to produce the enhanced image shown in Fig. 3.26.

Fig 3.26

FIGURE 3.26 Enhanced SEM image. Compare with Fig. 3.24. Note in particular the enhanced area on the right side of the image.

Image Subtraction

g (x,y) = f (x,y) - h (x,y)

h(x,y)—a low pass filtered version of f(x,y).

- Application in medical imaging --“mask mode radiography”
- H(x,y) is the mask, e.g., an X-ray image of part of a body; f(x,y) –incoming image after injecting a contrast medium.

Subtraction: an example

a b
c d

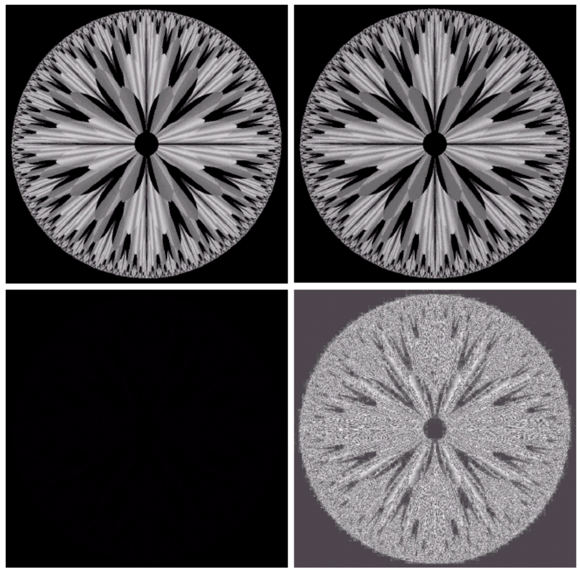
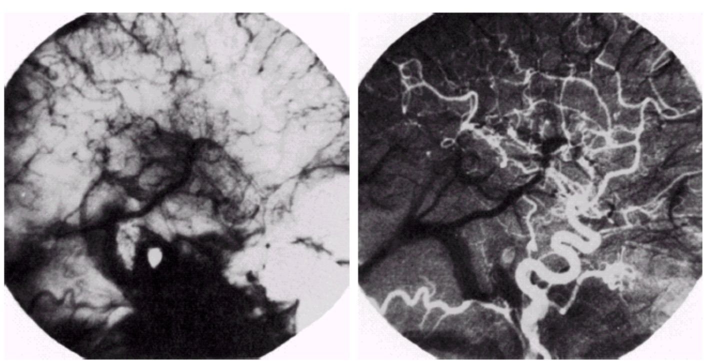


FIGURE 3.28 (a) Original fractal image. (b) Result of setting the four lower-order bit planes to zero. (c) Difference between (a) and (b). (d) Histogram-equalized difference image. (Original image courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA).

Fig 3.28: mask mode radiography



a b

FIGURE 3.29 Enhancement by image subtraction. (a) Mask image. (b) An image (taken after injection of a contrast medium into the bloodstream) with mask subtracted out.

Averaging

$$g(x,y) = f(x,y) + \eta(x,y)$$

$$\bar{g}(x,y) = \frac{1}{M}\sum_{i=1}^{M} g_i(x,y)$$

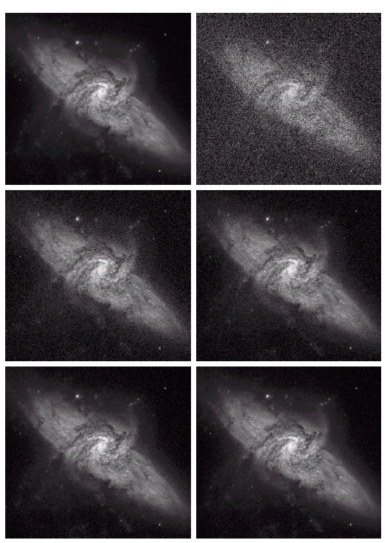
$$E(\bar{g}(x,y)) = f(x,y) \text{ and } \sigma^2{}_g = \frac{1}{M}\sigma^2{}_\eta(x,y)$$

$\eta(x,y) \rightarrow$ Uncorrelated zero mean

$\sigma^2{}_\eta(x,y) \rightarrow$ Reduces the noise variance

Fig 3.30

Fig 3.30



a b
c d
e f

FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64$, and 128 noisy images. (Original image courtesy of NASA.)

Another example

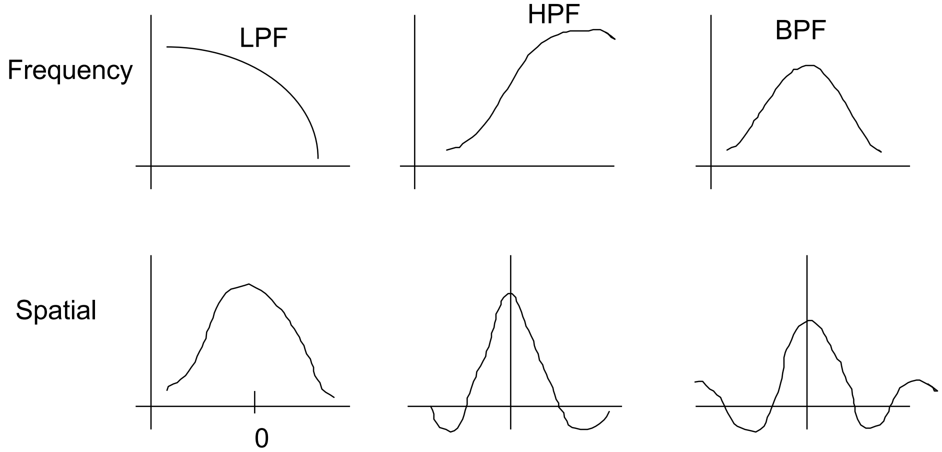
Images with additive Gausian Noise; Independent Samples.

I=imnoise(J,'Gaussian');

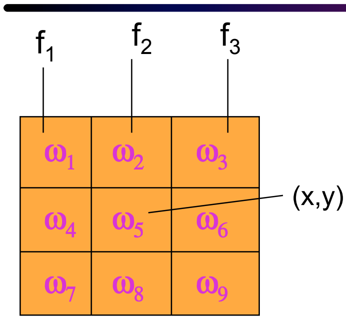
Averaged image

Left: averaged image (10 samples);
Right: original image

Spatial filtering



Smoothing (Low Pass) Filtering



Replace f (x,y) with

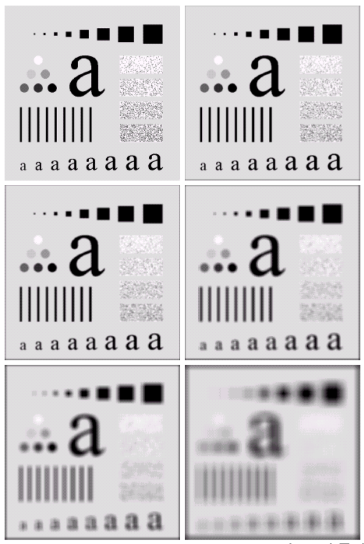
$$\hat{f}(x,y) = \sum_i \omega_i f_i$$

Linear filter

LPF: reduces additive noise → blurs the image
→ sharpness details are lost
(Example: Local averaging)

Fig 3.35

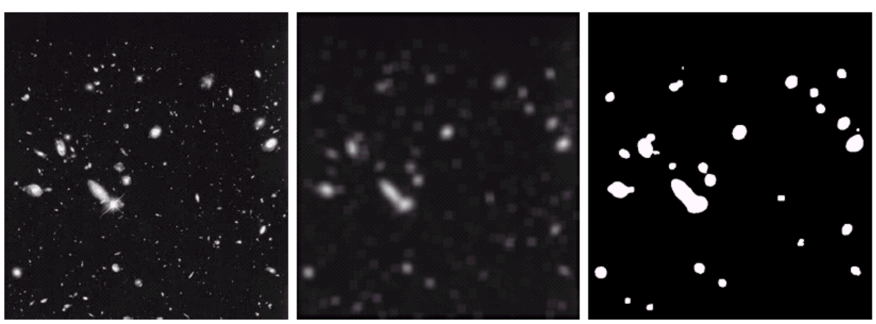
Fig 3.35: smoothing



a b
c d
e f

FIGURE 3.35 (a) Original image, of size 500×500 pixels. (b)–(f) Results of smoothing with square averaging filter masks of sizes $n = 3, 5, 9, 15$, and 35, respectively. The black squares at the top are of sizes 3, 5, 9, 15, 25, 35, 45, and 55 pixels, respectively; their borders are 25 pixels apart. The letters at the bottom range in size from 10 to 24 points, in increments of 2 points; the large letter at the top is 60 points. The vertical bars are 5 pixels wide and 100 pixels high; their separation is 20 pixels. The diameter of the circles is 25 pixels, and their borders are 15 pixels apart; their gray levels range from 0% to 100% black in increments of 20%. The background of the image is 10% black. The noisy rectangles are of size 50×120 pixels.

Fig 3.36: another example



a b c

FIGURE 3.36 (a) Image from the Hubble Space Telescope. (b) Image processed by a 15×15 averaging mask. (c) Result of thresholding (b). (Original image courtesy of NASA.)

Image Dithering

- Dithering: to produce visually pleasing signals from heavily quantized data.
  - Halftoning: convert a gray scale image to a binary image by thresholding.
  - Dithering to "add" noise so that the resulting image is smoother than just thresholding (but still it is a binary image)
  - Your homework #4 explores this further with a MATLAB exercise.

Median filtering

Replace f (x,y) with median [f (x' , y')]
(x' , y') $\in$ neighbourhood

- Useful in eliminating intensity spikes. (salt & pepper noise)
- Better at preserving edges.

Example:

10	20	20
20	15	20
25	20	100

→ (10,15,20,20,20,20,20,25,100)

Median=20

So replace (15) with (20)

Median Filter: Root Signal

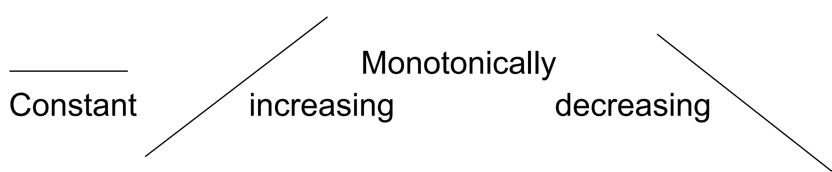
Repeated applications of median filter to a signal results in an invariant signal called the "root signal".
A root signal is invariant to further application of the medina filter.

Example: 1-D signal: Median filter length = 3

0	0	0	1	2	1	2	1	2	1	0	0	0	
0	0	0	1	1	2	1	2	1	1	0	0	0	
0	0	0	1	1	1	2	1	1	1	0	0	0	
0	0	0	1	1	1	1	1	1	1	0	0	0	<u>root signal</u>

Invariant Signals

Invariant signals to a median filter:



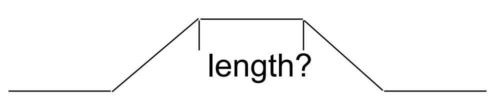
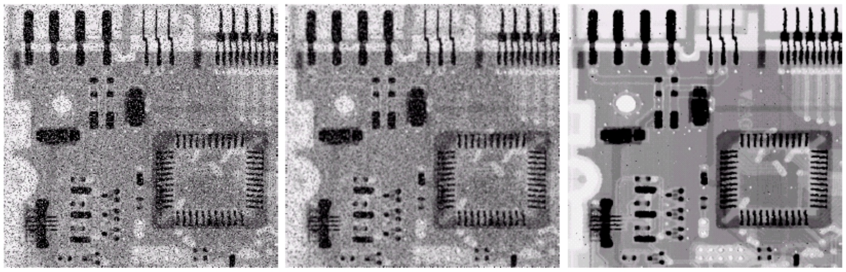


Fig 3.37: Median Filtering example



a b c

FIGURE 3.37 (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3 × 3 averaging mask. (c) Noise reduction with a 3 × 3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

Media Filter: another example

Original and with salt & pepper noise
imnoise(image, 'salt & pepper');

Donoised images

Local averaging
K=filter2(fspecial('average',3),image)/255.

Median filtered
L=medfil2(image, [3 3]);

Sharpening Filters

- Enhance finer image details (such as edges)
- Detect region /object boundaries.

Example:

−1	−1	−1
−1	8	−1
−1	−1	−1

Edges (Fig 3.38)

a b
c

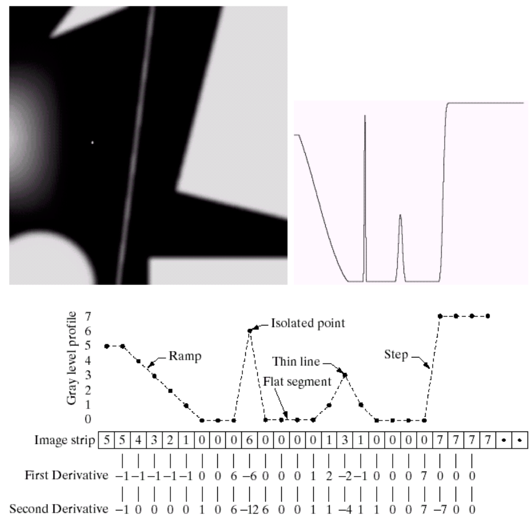


FIGURE 3.38 (a) A simple image. (b) 1-D horizontal gray-level profile along the center of the image and including the isolated noise point. (c) Simplified profile (the points are joined by dashed lines to simplify interpretation).

Unsharp Masking

Subtract Low pass filtered version from the original
emphasizes high frequency information

I’ = A (Original) - Low pass

HP = O - LP A > 1

I’ = (A - 1) O + HP

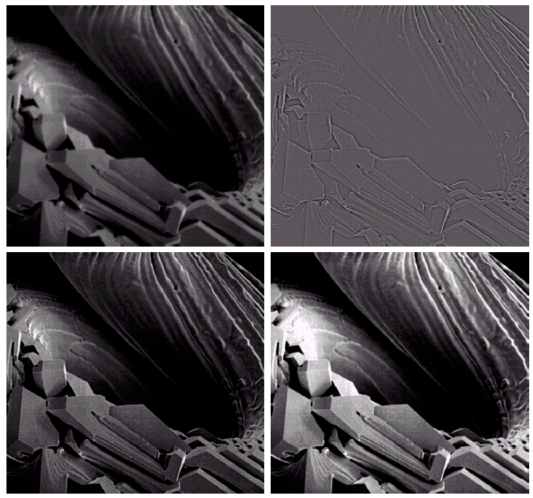
A = 1 => I’ = HP

A > 1 => LF components added back.

Fig 3.43 –example of unsharp masking

a b
c d

FIGURE 3.43 (a) Same as Fig. 3.41(c), but darker. (a) Laplacian of (a) computed with the mask in Fig. 3.42(b) using $A = 0$. (c) Laplacian enhanced image using the mask in Fig. 3.42(b) with $A = 1$. (d) Same as (c), but using $A = 1.7$.



Derivative Filters

1/9

−1	−1	−1
−1	ω	−1
−1	−1	−1

Gradient

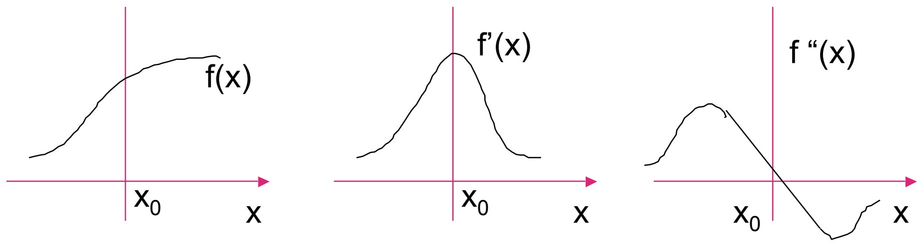
$$\nabla f = \left[\frac{\partial f}{\partial x} \quad \frac{\partial f}{\partial y} \right]^T$$

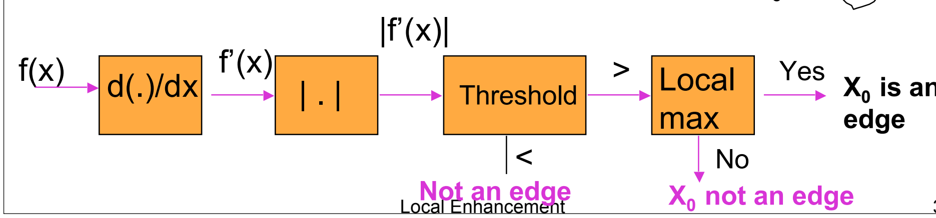
$$\|\nabla f\| = \left[\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right]^{1/2}$$

Edge Detection

Gradient based methods

$$\nabla f = \left(\frac{\partial f}{\partial x} \;\; \frac{\partial f}{\partial y} \right)^T$$





Digital edge detectors

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

$$|\nabla f| \approx \left[(z_5 - z_8)^2 + (z_5 - z_6)^2 \right]^{1/2}$$

$$|\nabla f| \approx |z_5 - z_8| + |z_5 - z_6|$$

Robert's operator

1	0
0	-1

0	1
-1	0

$| z_5 - z_9 |$ $\quad$ $| z_6 - z_8 |$

prewitt

-1	-1	-1
0	0	0
1	1	1

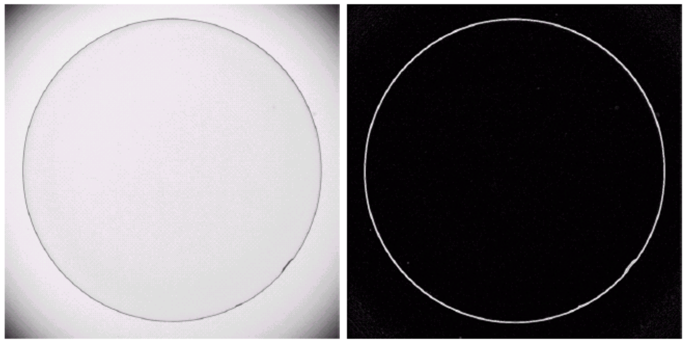
-1	0	1
-1	0	1
-1	0	1

Sobel's

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

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

Fig 3.45: Sobel edge detector



a b

FIGURE 3.45 Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock). (b) Sobel gradient. (Original image courtesy of Mr. Pete Sites, Perceptics Corporation.)

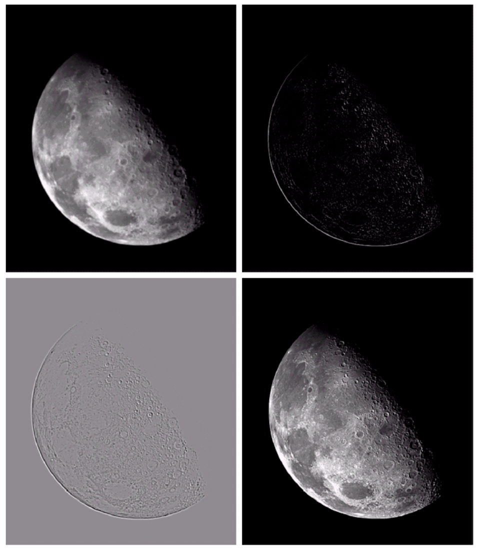
Laplacian based edge detectors

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

	1	
1	-4	1
	1	

- Rotationally symmetric, linear operator
- Check for the zero crossings to detect edges
- Second derivatives => sensitive to noise.

Fig 3.40: an example



a b
c d

FIGURE 3.40
(a) Image of the North Pole of the moon.
(b) Laplacian-filtered image.
(c) Laplacian image scaled for display purposes.
(d) Image enhanced by using Eq. (3.7-5).
(Original image courtesy of NASA.)