Digital Image Processing

Image Enhancement in Spatial Domain

Spatial Filtering

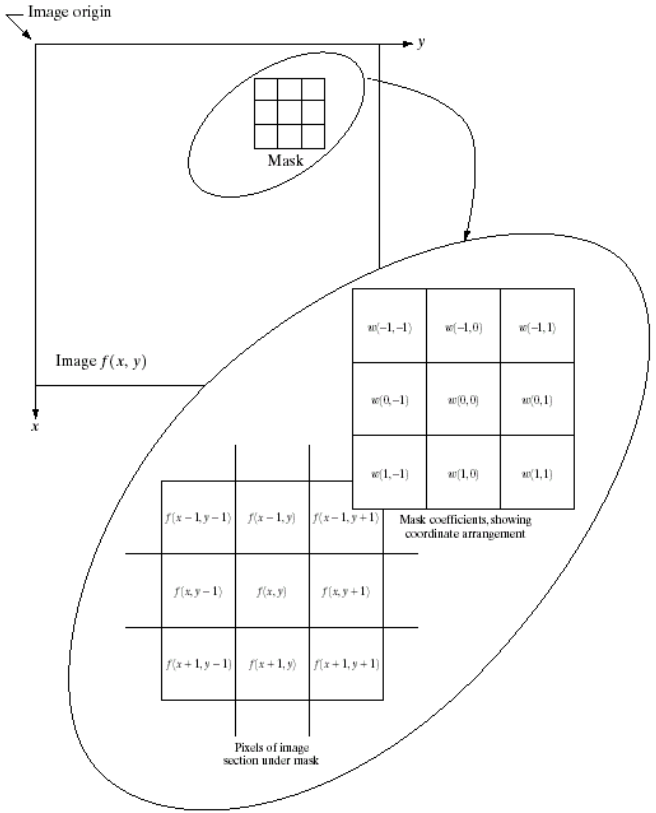
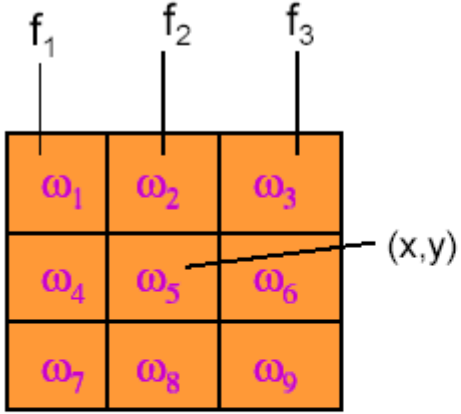


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3×3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

Image Enhancement in Spatial Domain

Spatial Filtering



Replace f (x,y) with

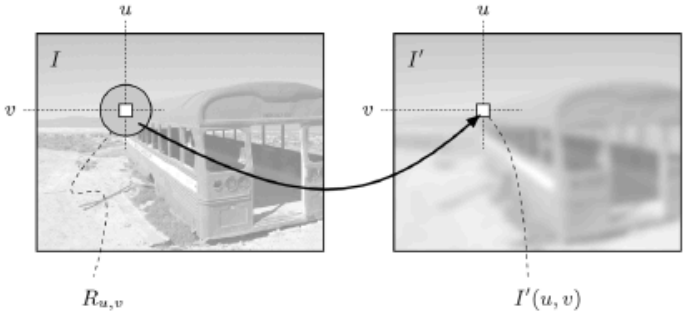
$$\hat{f}(x,y) = \sum_i \omega_i f_i$$

Linear filter

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

Image Enhancement in Spatial Domain

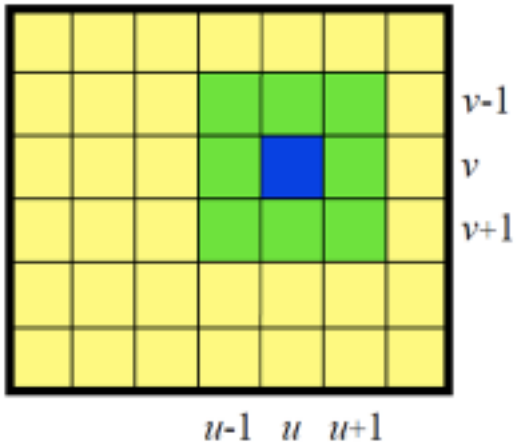
Spatial Filtering



$$I'(u,v) \leftarrow \frac{p_0 + p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8}{9}$$

$$I'(u,v) \leftarrow \tfrac{1}{9} \cdot [\, I(u-1,v-1) + I(u,v-1) + I(u+1,v-1) + I(u-1,v) + I(u,v) + I(u+1,v) + I(u-1,v+1) + I(u,v+1) + I(u+1,v+1) \,]$$

$$I'(u,v) \leftarrow \frac{1}{9} \cdot \sum_{j=-1}^{1} \sum_{i=-1}^{1} I(u+i, v+j)$$



Source https://web.cs.wpi.edu/~emmanuel/courses/cs545/S14/slides/lecture04.pdf

Image Enhancement in Spatial Domain

Spatial Filtering

$\frac{1}{9} \times$

1	1	1
1	1	1
1	1	1

$\frac{1}{16} \times$

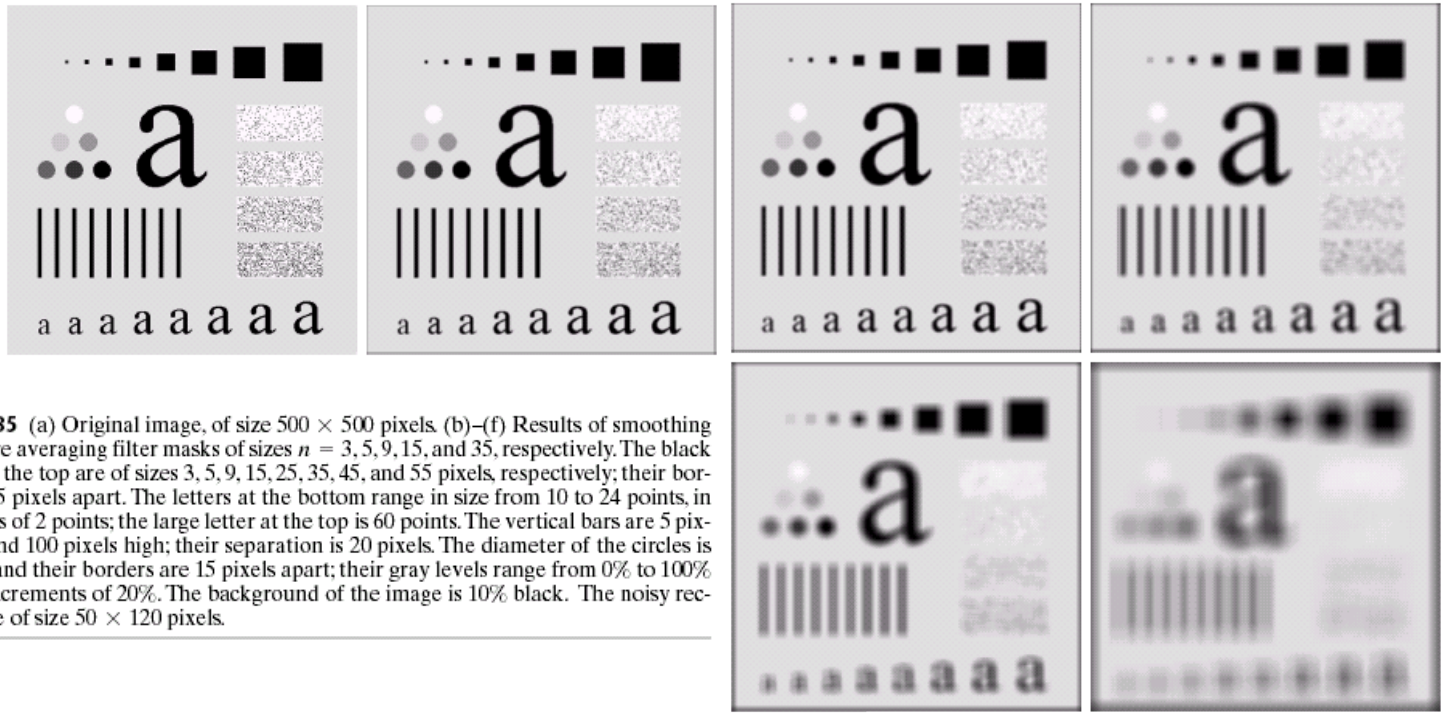
1	2	1
2	4	2
1	2	1

a b

FIGURE 3.34 Two 3×3 smoothing (averaging) filter masks. The constant multiplier in front of each mask is equal to the sum of the values of its coefficients, as is required to compute an average.

Image Enhancement in Spatial Domain

Spatial Filtering: Neighborhood Averaging



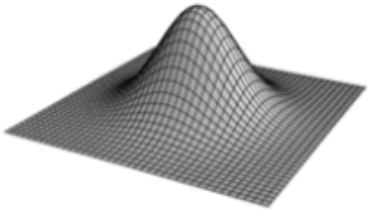
a b
c d
e f

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.

Image Enhancement in Spatial Domain

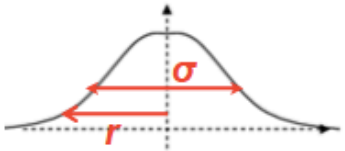
Spatial Filtering

$$G_\sigma(r) = e^{-\frac{r^2}{2\sigma^2}} \quad \text{or} \quad G_\sigma(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}}$$



Gaussian Filter

- where
  - σ is width (standard deviation)
  - r is distance from center



0	1	2	1	0
1	3	5	3	1
2	5	9	5	2
1	3	5	3	1
0	1	2	1	0

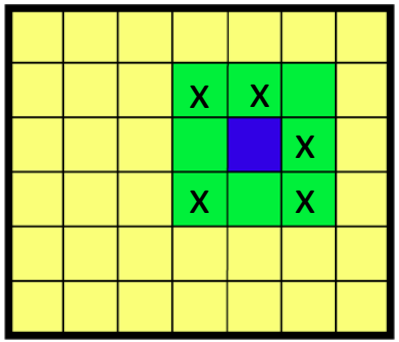
Gaussian filter

Source https://web.cs.wpi.edu/~emmanuel/courses/cs545/S14/slides/lecture04.pdf

Image Enhancement in Spatial Domain

Spatial Filtering: Neighborhood Averaging

Data validation: Do not consider the pixels which do not have “valid” values. Replace values which are not valid by considering the average of valid values.



x: valid

Image Enhancement in Spatial Domain

Median Filter

Replace f (x,y) with median [f (x' , y')]

(x' , y') ε 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)

Image Enhancement in Spatial Domain

Median Filter

Original image

Noised image

Average filter

Median filter

Image Enhancement in Spatial Domain

Sharpening Filter

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

Example:

−1	−1	−1
−1	8	−1
−1	−1	−1

Image Enhancement in Spatial Domain

Highboost Filter

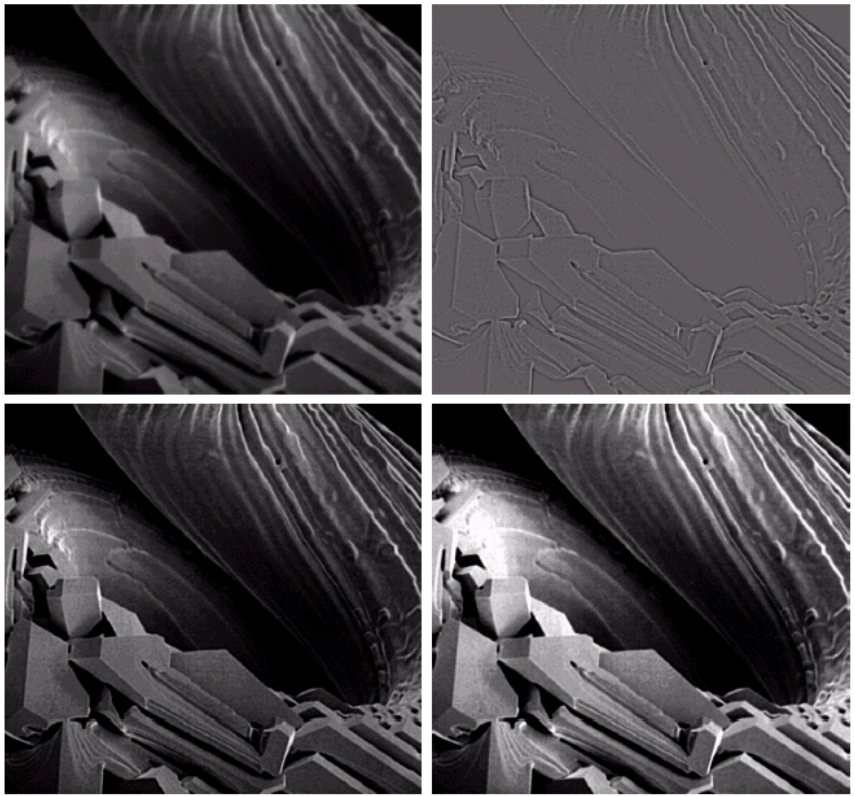
0	−1	0	−1	−1	−1
−1	$A + 4$	−1	−1	$A + 8$	−1
0	−1	0	−1	−1	−1

a b

FIGURE 3.42 The high-boost filtering technique can be implemented with either one of these masks, with $A \geq 1$.

Image Enhancement in Spatial Domain

Highboost Filter



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 $A = 1.7$.

Image Enhancement in Spatial Domain

Gradient Filter

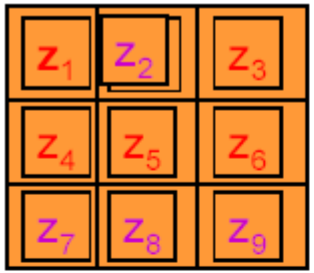
Gradient

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

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

Image Enhancement in Spatial Domain

Gradient Filter



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

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

Robert's operator

1	0	0	1
0	-1	-1	0

$|z_5 - z_9|$ $|z_6 - z_8|$

prewitt

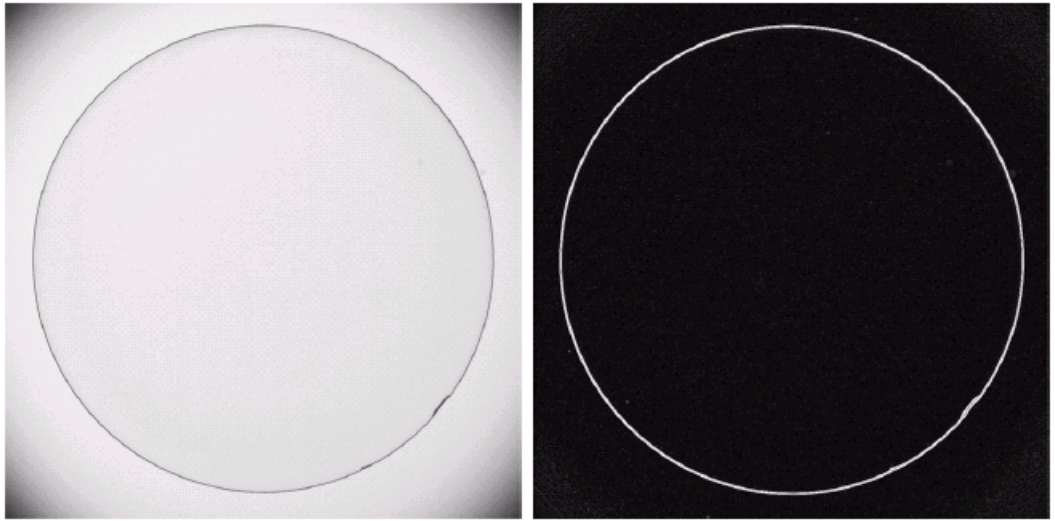
-1	-1	-1		-1	0	1		
0	0	0		-1	0	1		
1	1	1		-1	0	1		

Sobel's

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

Image Enhancement in Spatial Domain

Gradient Filter



a b

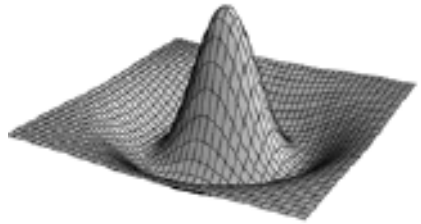
FIGURE 3.45 Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock). (b) Sobel gradient. (Original image courtesy of Mr. Pete Sites, Perceptics Corporation.)

Image Enhancement in Spatial Domain

Laplace Filter

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

	1	
1	-4	1
	1	



0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0