

COL783: Digital Image Processing

Prem Kalra

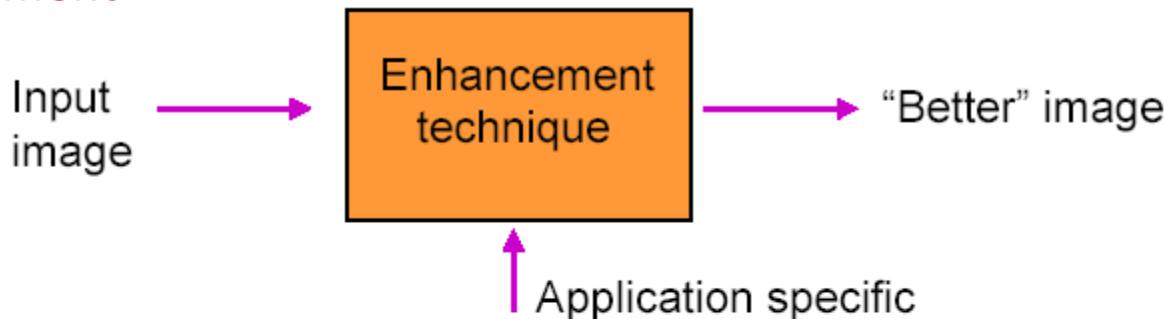
pkalra@cse.iitd.ac.in

<http://www.cse.iitd.ac.in/~pkalra/col783>

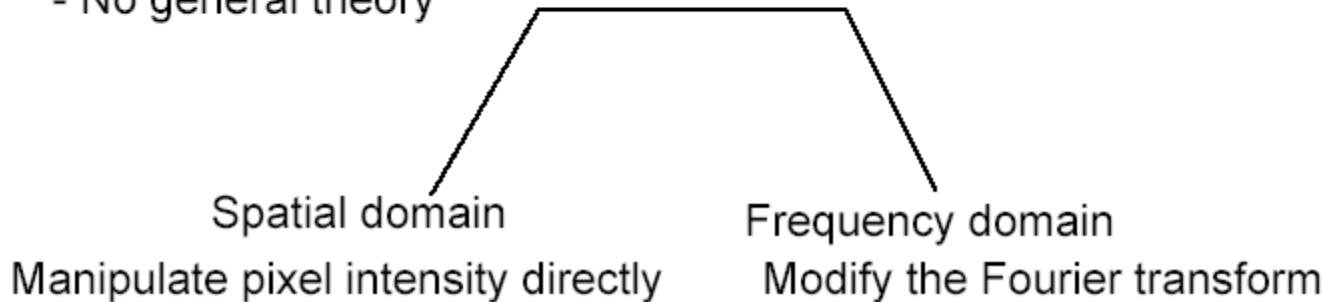
Department of Computer Science and Engineering
Indian Institute of Technology Delhi

Recap

Image Enhancement

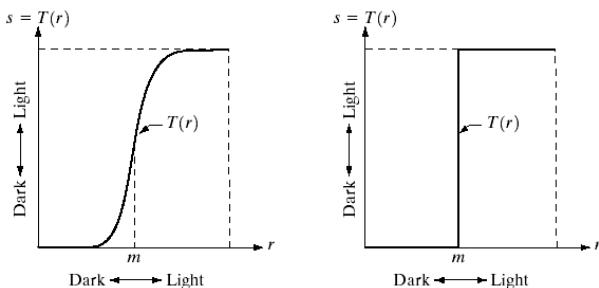


- No general theory



Recap

Image Enhancement in Spatial Domain Point Processing Gray Level Transformations



a | b
FIGURE 3.2 Gray-level transformation functions for contrast enhancement.

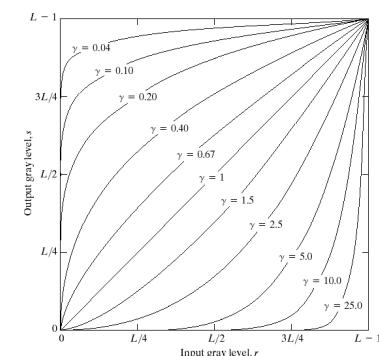
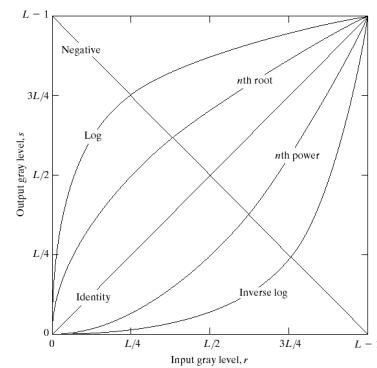
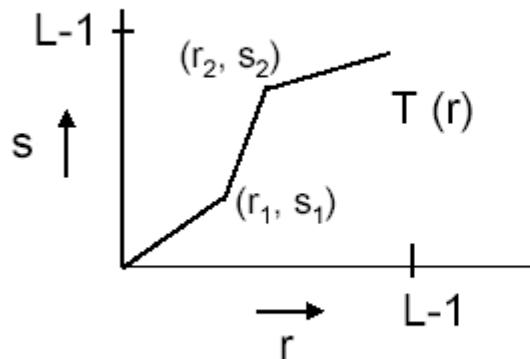


FIGURE 3.6 Plots of the equation $s = cr^\gamma$ for various values of γ ($c = 1$ in all cases).

Recap

Image Enhancement in Spatial Domain

Contrast Stretching



$$\begin{aligned}r_1 &= s_1 \\r_2 &= s_2\end{aligned}$$

no change

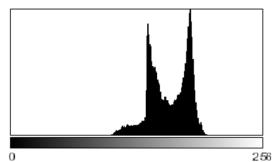
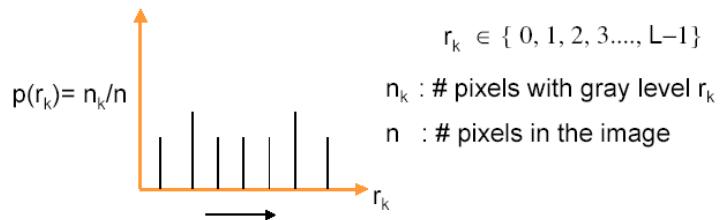
$$\begin{aligned}r_1 &= r_2 \\s_1 &= 0 \\s_2 &= L-1\end{aligned}$$

Thresholding
at r_1

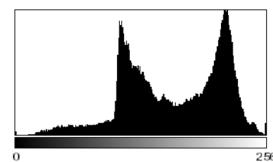
Recap

Image Enhancement in Spatial Domain

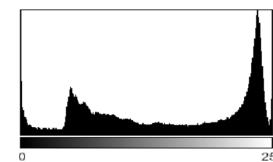
Histogram Processing



(a)



(b)



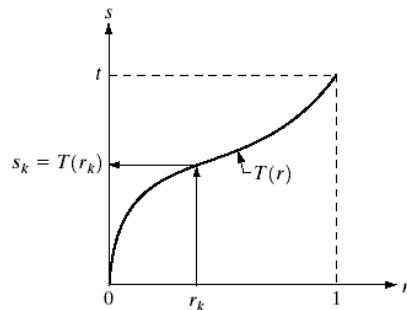
(c)

Recap

Image Enhancement in Spatial Domain

Histogram Processing

Histogram Equalization



$$s = T(r) = \int_0^r p_r(w) dw \quad 0 \leq r \leq 1$$

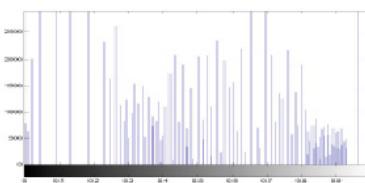
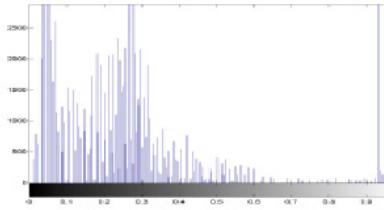


Image Enhancement in Spatial Domain

Histogram Specification

$$\text{Suppose } s = T(r) = \int_0^r p_r(w) dw$$

$p_r(r) \rightarrow$ Original histogram ; $p_z(z) \rightarrow$ Desired histogram

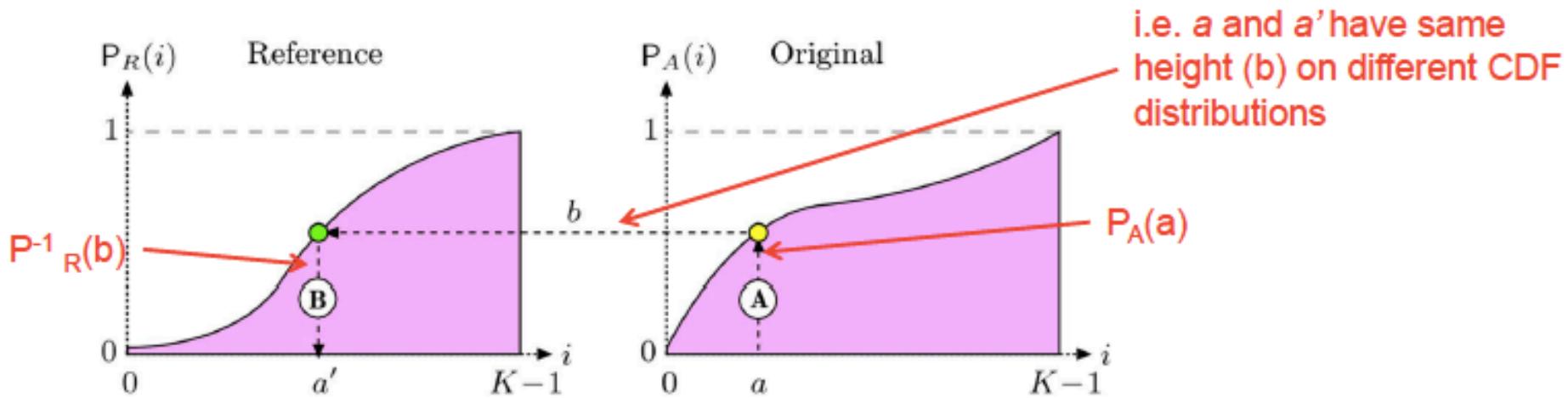
$$\text{Let } v = G(z) = \int_0^z p_z(w) dw \quad \text{and} \quad z = G^{-1}(v)$$

But s and v are identical p.d.f.

$$\therefore z = G^{-1}(v) = G^{-1}(s) = G^{-1}(T(r))$$

Image Enhancement in Spatial Domain

Histogram Specification



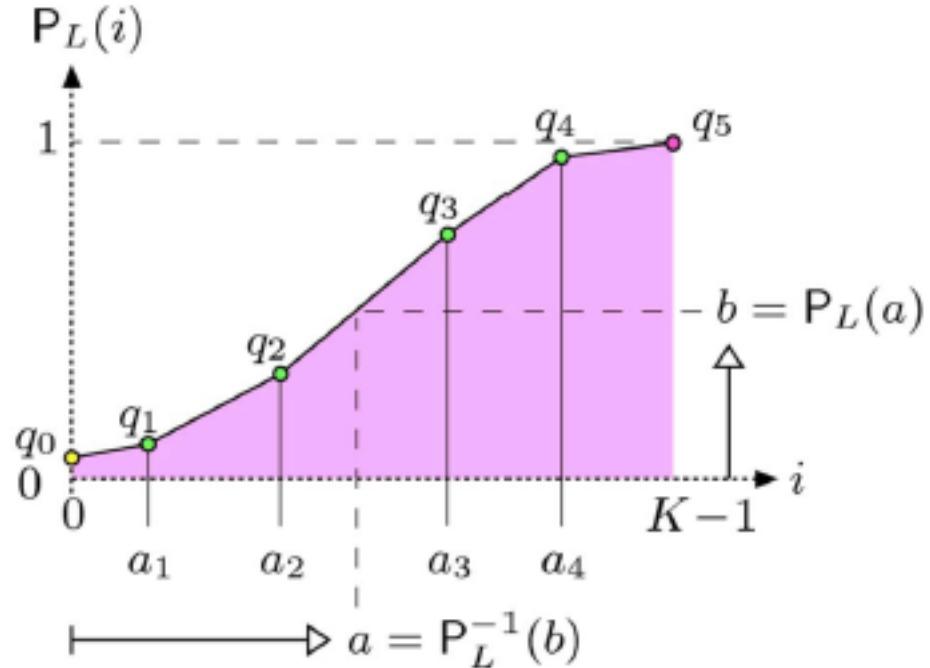
$$f_{hs}(a) = a' = P_R^{-1}(P_A(a))$$

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

Image Enhancement in Spatial Domain

Histogram Specification

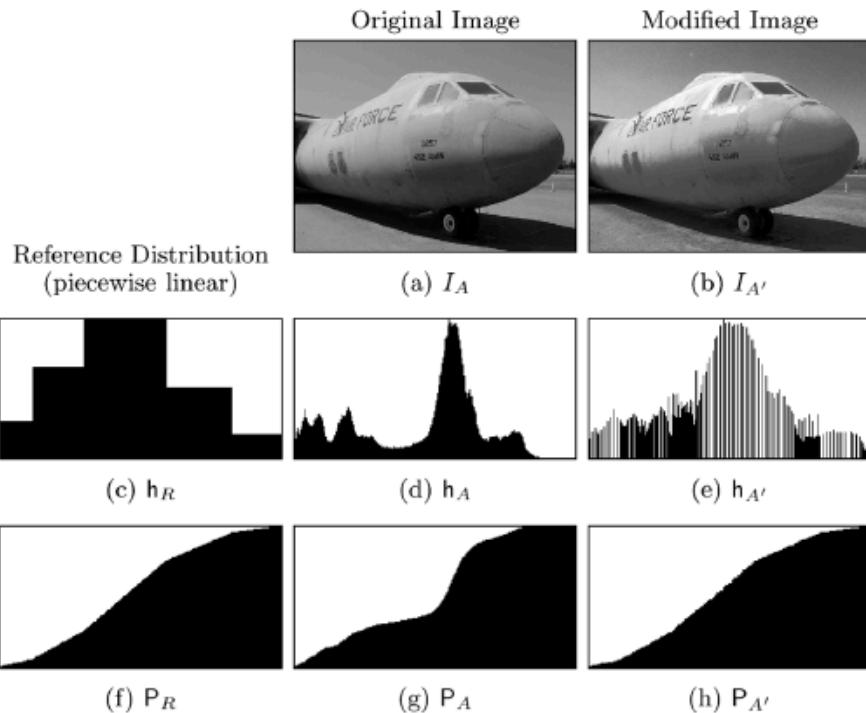
Piece wise linear approximation



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

Image Enhancement in Spatial Domain

Histogram Specification



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

Digital Image Processing

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Image Enhancement in Spatial Domain

Local Histogram Equalization

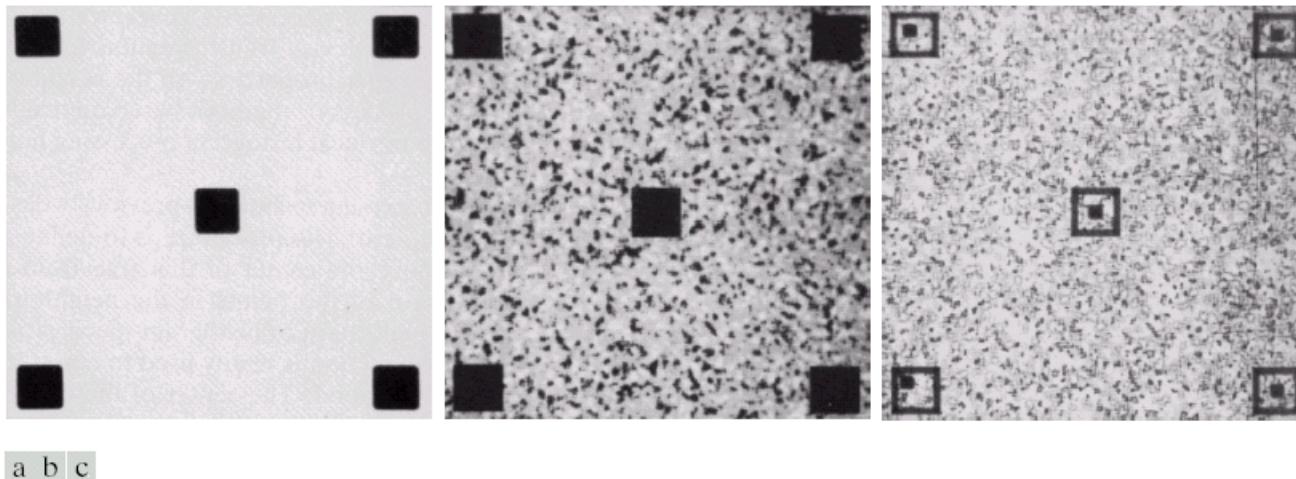


FIGURE 3.23 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization using a 7×7 neighborhood about each pixel.

Image Enhancement in Spatial Domain

Spatial Filtering

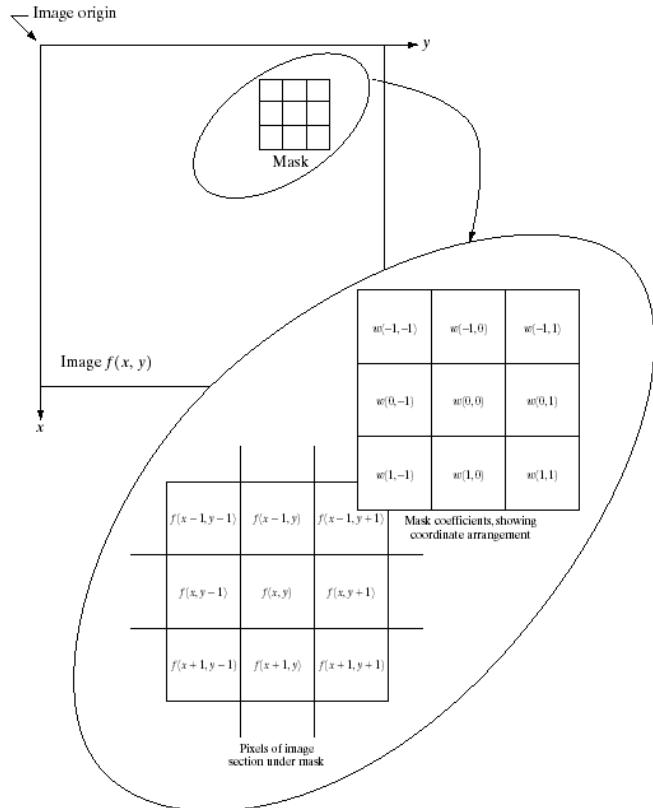
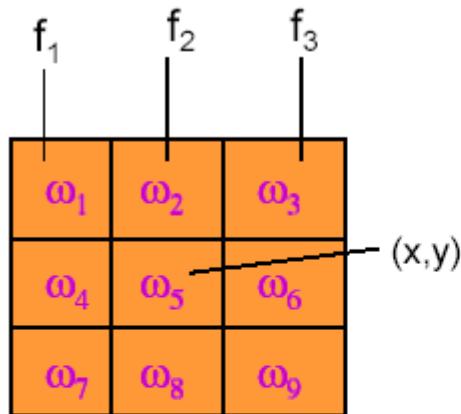


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3×3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

Image Enhancement in Spatial Domain

Spatial Filtering



Replace $f(x,y)$ with

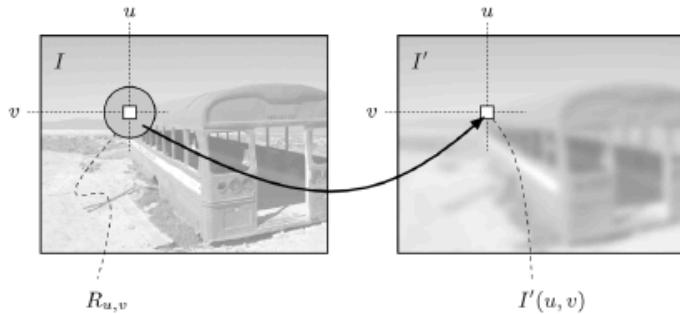
$$\hat{f}(x,y) = \sum_i \omega_i f_i$$

Linear filter

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

Image Enhancement in Spatial Domain

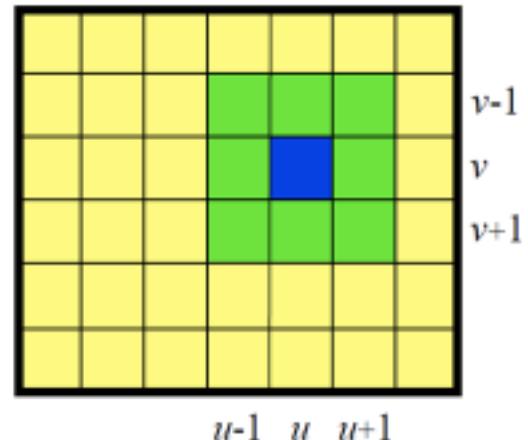
Spatial Filtering



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

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

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



Source <https://web.cs.wpi.edu/~emmanuel/courses/cs545/S14/slides/lecture04.pdf>
Digital Image Processing

<http://www.cse.iitd.ac.in/~pkalra/col783>

Image Enhancement in Spatial Domain

Spatial Filtering

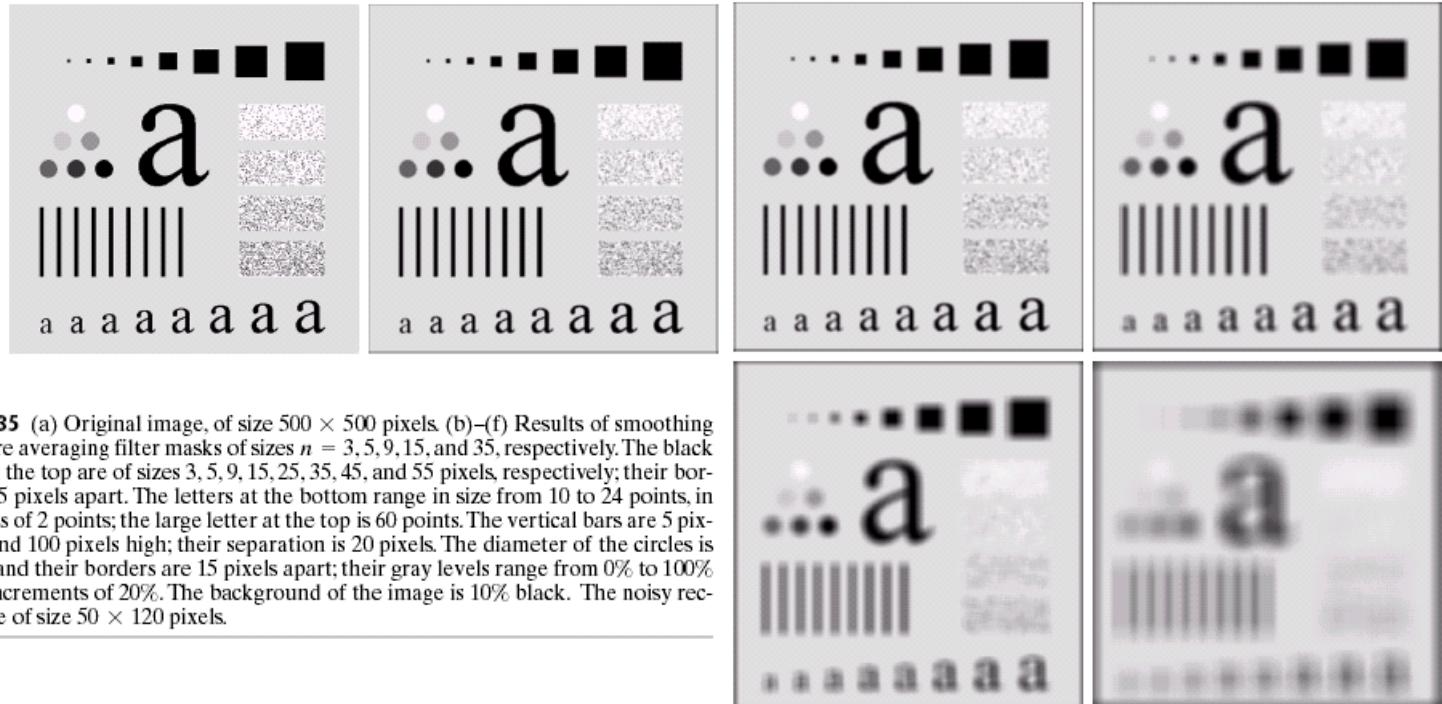
$$\frac{1}{9} \times \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array} \quad \frac{1}{16} \times \begin{array}{|c|c|c|} \hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

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



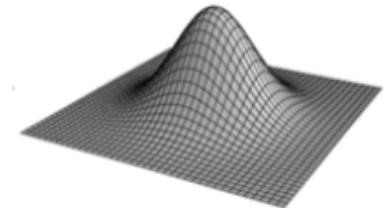
a b
c d
e f

FIGURE 3.35 (a) Original image, of size 500×500 pixels. (b)–(f) Results of smoothing with square averaging filter masks of sizes $n = 3, 5, 9, 15, 25, 35, 45$, and 55 , 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

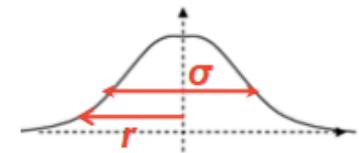
Spatial Filtering

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



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

Gaussian Filter



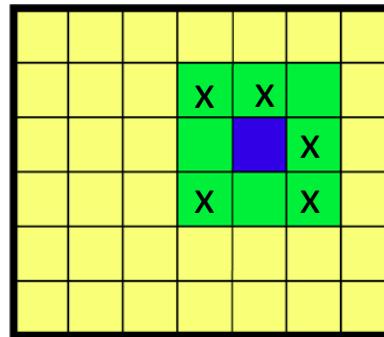
0	1	2	1	0
1	3	5	3	1
2	5	9	5	2
1	3	5	3	1
0	1	2	1	0

Gaussian
filter

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') \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)

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	$A + 4$	-1
0	-1	0

-1	-1	-1
-1	$A + 8$	-1
-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 $A = 1.7$.

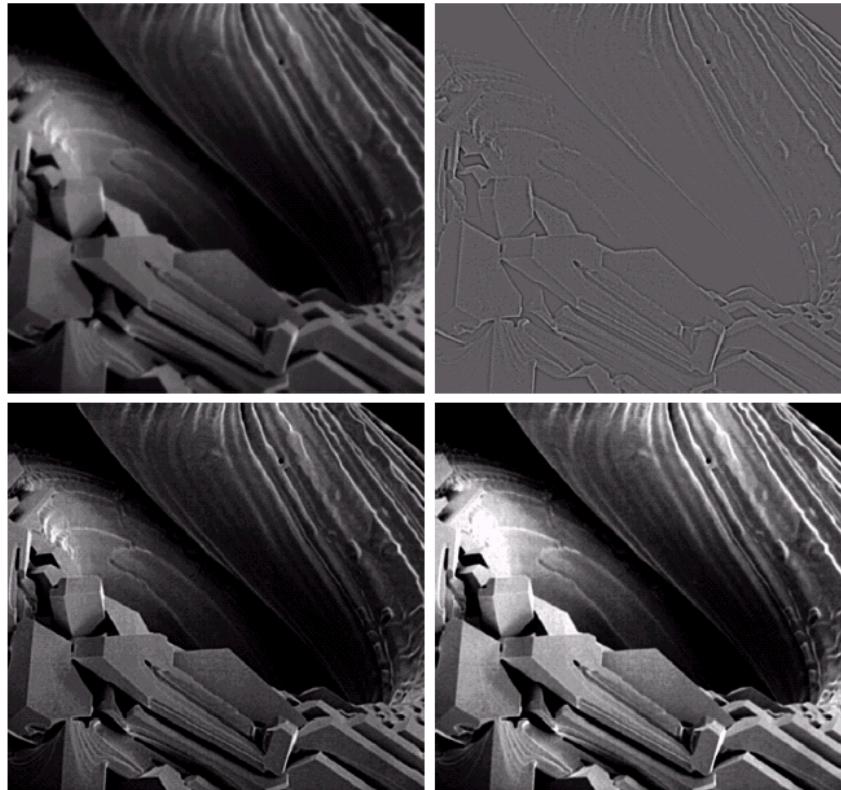


Image Enhancement in Spatial Domain

Gradient Filter

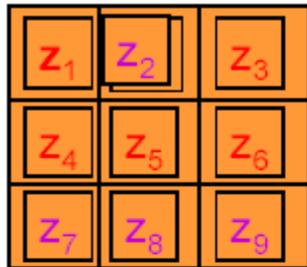
Gradient

$$\nabla f = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \end{bmatrix}^T$$

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

Image Enhancement in Spatial Domain

Gradient Filter



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

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

Robert's operator

Two 3x3 kernel matrices for Robert's operator:
Left matrix: $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 0 \end{bmatrix}$
Right matrix: $\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$

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

prewitt

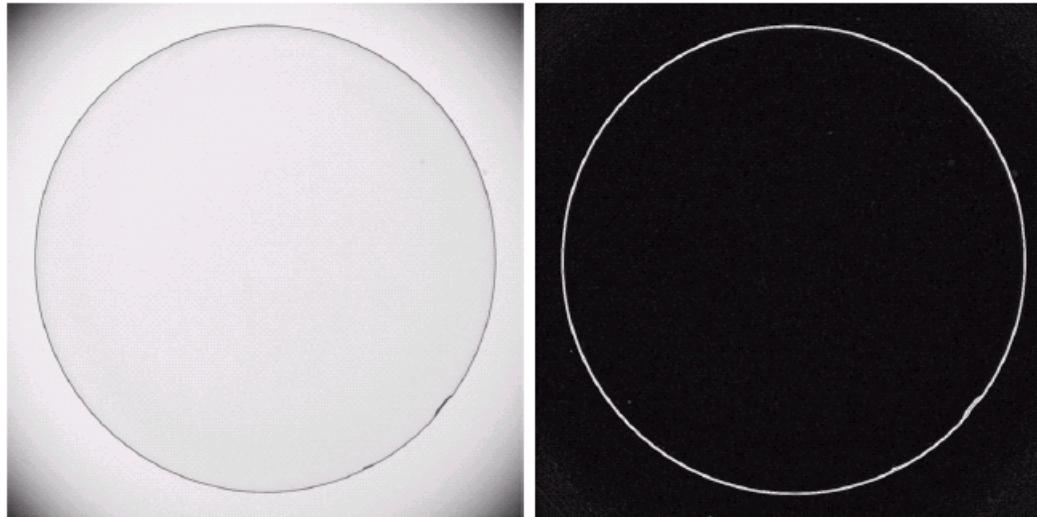
Two 3x3 kernel matrices for Prewitt's operator:
Left matrix: $\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$
Right matrix: $\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$

Sobel's

Two 3x3 kernel matrices for Sobel's operator:
Left matrix: $\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$
Right matrix: $\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$

Image Enhancement in Spatial Domain

Gradient Filter



a b

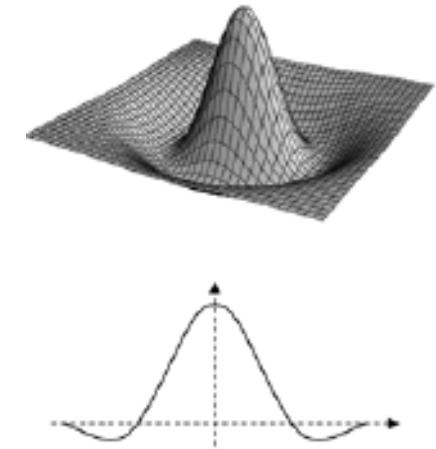
FIGURE 3.45
Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock).
(b) Sobel gradient.
(Original image courtesy of Mr. Pete Sites, Perceptics Corporation.)

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	-4	1
1	-4	1
1	-4	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