

## Lecture 4

Reading:

Image Enhancement: G&W Chap 3, Jain Chap 7

Image Transform: G&W Chap 4.6, Jain 5.4-5.11



# Digital Image Processing

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**<http://www.ee.columbia.edu/dvmm>**

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Most images are downloaded from the web site of the Gonzalez/Woods textbook

1



# Image Enhancement

- Given an image, improve the subjective quality
  - Contrast
  - Noise reduction
  - Edge sharpening
  - Filtering
  - pseudo-coloring
- No general theories partly because of the lack of analytic measurement of subjective quality

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2



## Quality Enhancement: Spatial Domain Simple Op. – Power-Law Transform

- Common problem: intensity values concentrated in a small region

- How to fix this?
- Stretch the dark region

$$s = cr^\gamma$$

$$\gamma < 1$$

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**FIGURE 3.8**  
(a) Magnetic resonance (MR) image of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with  $c = 1$  and  $\gamma = 0.6, 0.4,$  and  $0.3,$  respectively. (Original image for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

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## Power-Law Transform

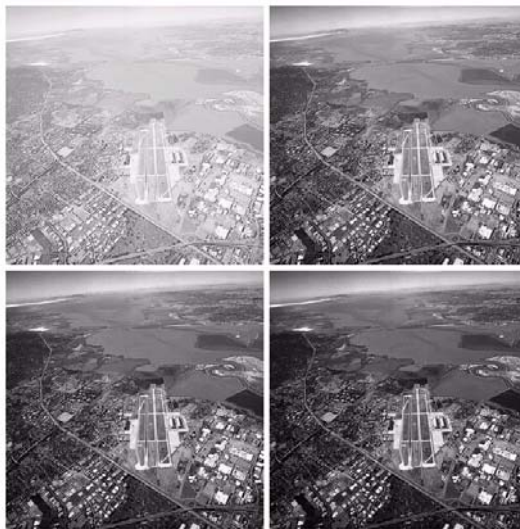
- Stretch the bright region

$$s = cr^\gamma$$

$$\gamma > 1$$

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**FIGURE 3.9**  
(a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with  $c = 1$  and  $\gamma = 3.0, 4.0,$  and  $5.0,$  respectively. (Original image for this example courtesy of NASA.)



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# Point Intensity Transformation

FIGURE 3.1 A  $3 \times 3$  neighborhood about a point  $(x, y)$  in an image.

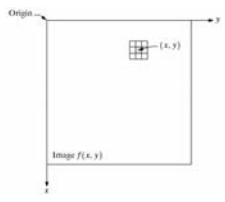
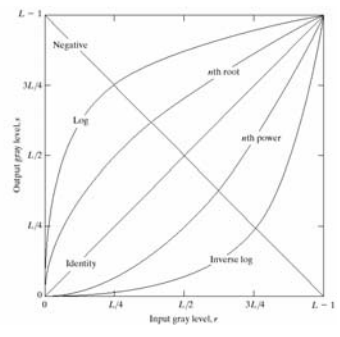


FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



- Point by point operation
- Simple but effective operations
- Different rules achieve different enhancement effects
- Trial and error process to achieve desired effects

# Piece-Wise Contrast Stretching

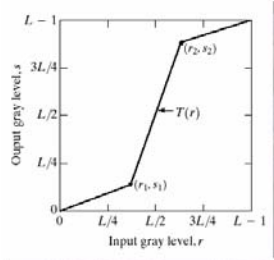
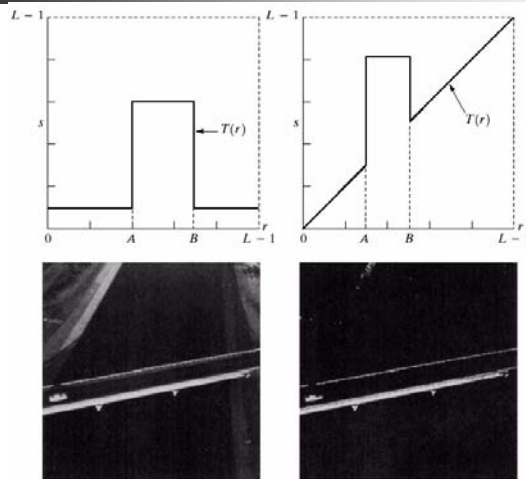


FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

## Intensity Slicing



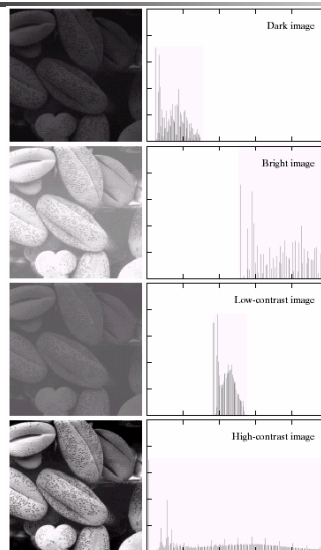
**FIGURE 3.11**  
 (a) This transformation highlights range  $[A, B]$  of gray levels and reduces all others to a constant level.  
 (b) This transformation highlights range  $[A, B]$  but preserves all other levels.  
 (c) An image.  
 (d) Result of using the transformation in (a).

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7



## Relation between Contrast and Histogram

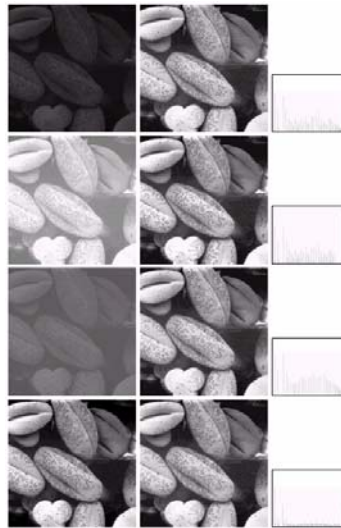


- Definition of histogram
- Note contrast increases when distribution is spread out

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**FIGURE 3.15** Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

## Histogram Equalization



- Note the output still does not have ideal uniform distribution due to discrete domains

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FIGURE 3.17 (a) Images from Fig. 3.15. (b) Results of histogram equalization. (c) Corresponding histograms.

## Spatial domain filtering – averaging multiple frames

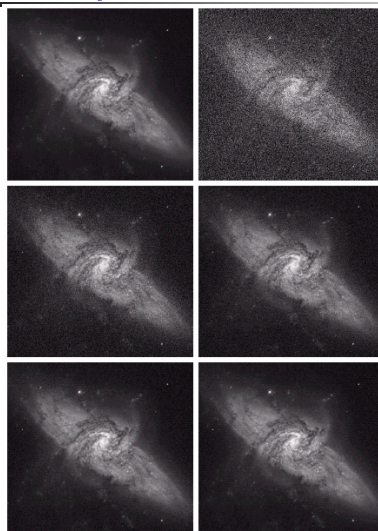


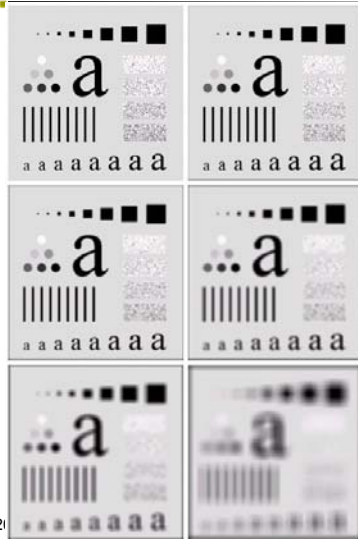
FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging  $K = 8, 16, 64,$  and  $128$  noisy images. (Original image courtesy of NASA.)

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## Spatial domain filtering – averaging multiple pixels

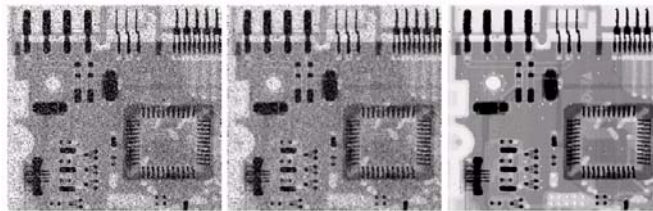


**FIGURE 3.35** (a) Original image, of size  $500 \times 500$  pixels. (b)–(f) Results of smoothing with square averaging filter masks of sizes  $n = 3, 5, 9, 15,$  and  $35$ , respectively. The black squares at the top are of sizes  $3, 5, 9, 15, 25, 35, 45,$  and  $55$  pixels, respectively; their 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  $50 \times 120$  pixels.

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## Spatial domain filtering – mean vs. median



a b c

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

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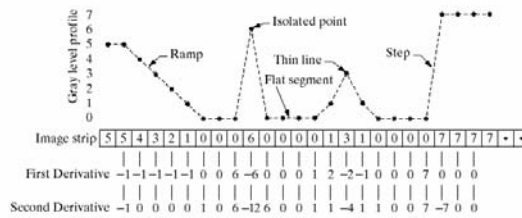
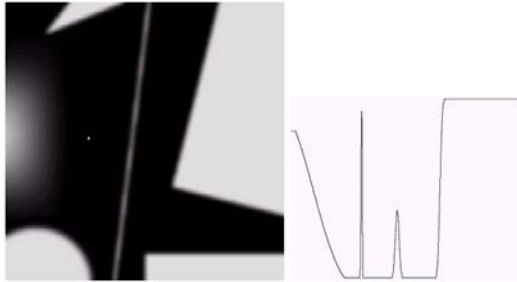
12



## Derivative operations: Laplacian

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).



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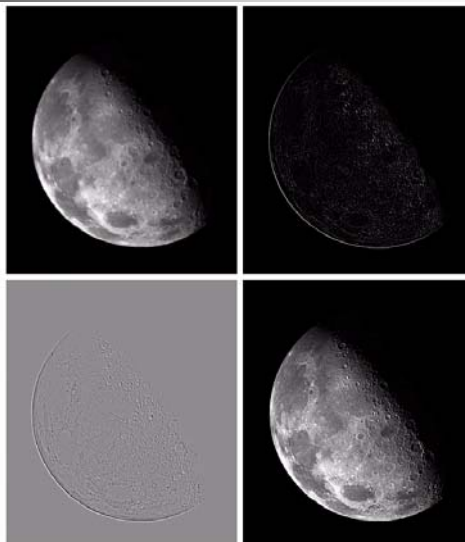
**dvmm**  
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## Derivative operations: Laplacian

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.)



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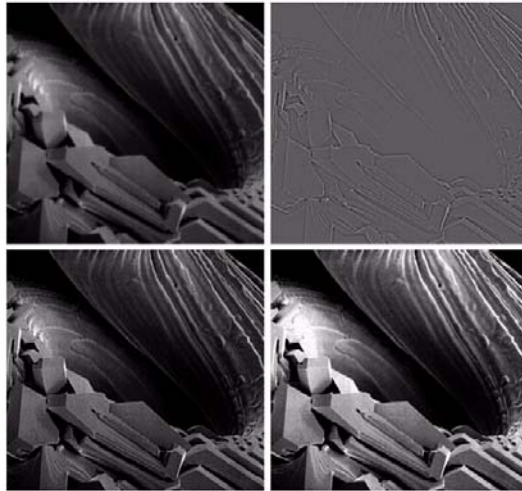
**dvmm**  
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## Sharpening filter: high-boost with Laplacian



a b  
c d

**FIGURE 3.43**  
 (a) Same as Fig. 3.41(c), but darker.  
 (b) 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  $A = 1.7$ .

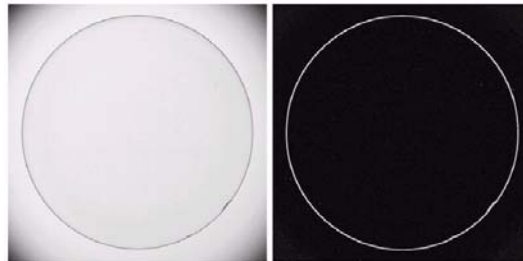


## Derivative operations: Sobel



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.)



## Combination of different operations

Original

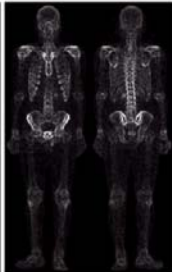


Laplacian



Sharpened with Laplacian

- Good at enhancing detailed structures



Sobel

- Good at enhancing edges

a b  
c d

**FIGURE 3.46**  
(a) Image of whole body bone scan.  
(b) Laplacian of (a). (c) Sharpened image obtained by adding (a) and (b). (d) Sobel of (a).

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## Principal rules + trial and error

Smoothed Sobel



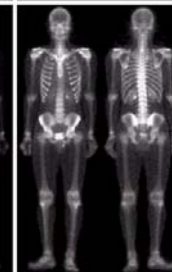
Smooth Sobel x Laplacian Sharpened



c f  
g h

**FIGURE 3.46**  
(Continued)  
(c) Sobel image smoothed with a  $5 \times 5$  averaging filter. (f) Mask image formed by the product of (c) and (a). (g) Sharpened image obtained by the sum of (a) and (f). (h) Final result obtained by applying a power-law transformation to (g). Compare (g) and (h) with (a). (Original image courtesy of G.E. Medical Systems.)

Sum of Mask & image



Power Law

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