

# Prelucrarea Imaginilor

SEA - 2020

Laurențiu Frangu, Laurențiu Baicu

# Administrative

- 28 C, 28 L
- Credite: 5
- Notare: laborator (40%), examinare (tez + oral) (60%)
- La examinare: permis orice document

# Bibliografie

- L. Frangu – Recunoa terea formelor i prelucrarea imaginilor, Ed. Academica, Gala i, 2001.
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# Cuprins

1. Introducere, sisteme de achiziție și prelucrare a imaginilor
2. Preprocesare și îmbunătățire
3. Segmentarea și transformări morfologice
4. Extragerea trăsăturilor și măsurarea pe imagine
5. Recunoașterea formelor
6. Aplicații

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Image processing for:

Human use  
(Outcome is an enhanced image)

Computer use  
(Outcome is a set of descriptors and measures of the objects)

Noise cancellation
Filtering
Edge enhancement
Histogram equalization
Image mixing, resizing, etc.

Preprocessing

Noise cancellation
Filtering
Edge enhancement
Histogram equalization

2<sup>nd</sup> Processing stage

Fourier transform
Histogram evaluation
Segmentation
Erosion, dilation
Thinning, skeleton

Feature extraction

Labeling
Descriptors computation
Measures
Shape analysis
Texture analysis

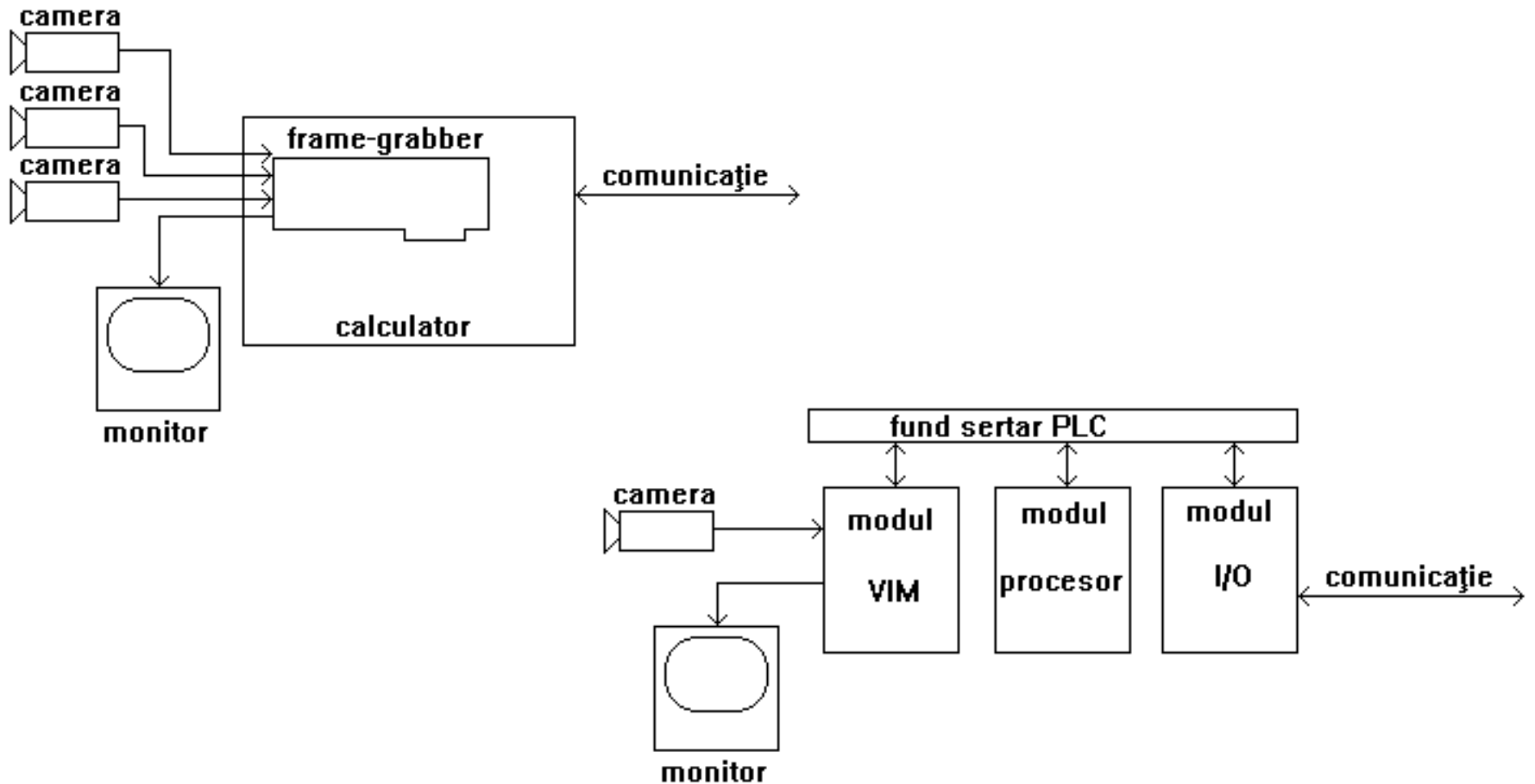
# Introducere

- Sisteme de achiziție a imaginii
- Semnal 2D digital (spațiul este variabilă în ambele dimensiuni)
- Semnal 3D = secvență de imagini (video)
- Eantionare și cuantizare
- Cuantizarea nu este esențială
- Eantionarea este esențială
  - Teorema eantionării (sampling theorem)
  - Modelul în timp (ecuații în diferențe)
  - Modele frecvențiale (FFT, transformata Z)
  - Prelucrarea este digitală

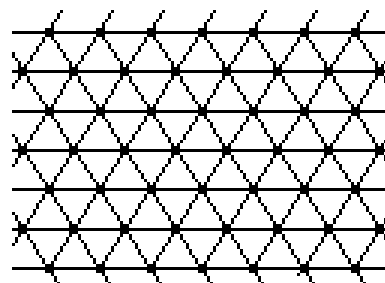
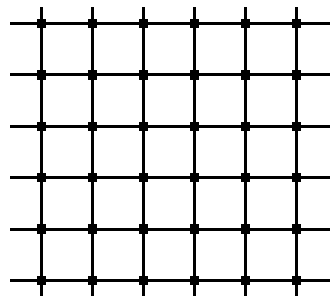
# Introducere

- Achiziția imaginii
- Sursa imaginii
  - video camer , telefon smart
  - aparat foto
  - scanner
- Conținutul de culoare
- Semnal analogic/digital (predominant)
- Rețeaua de eșantionare
- Formatul de transfer al datelor
- Formatul fi ierelor

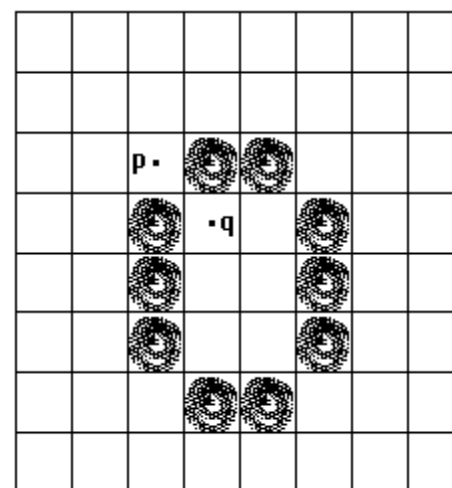
# Introducere



# Introducere

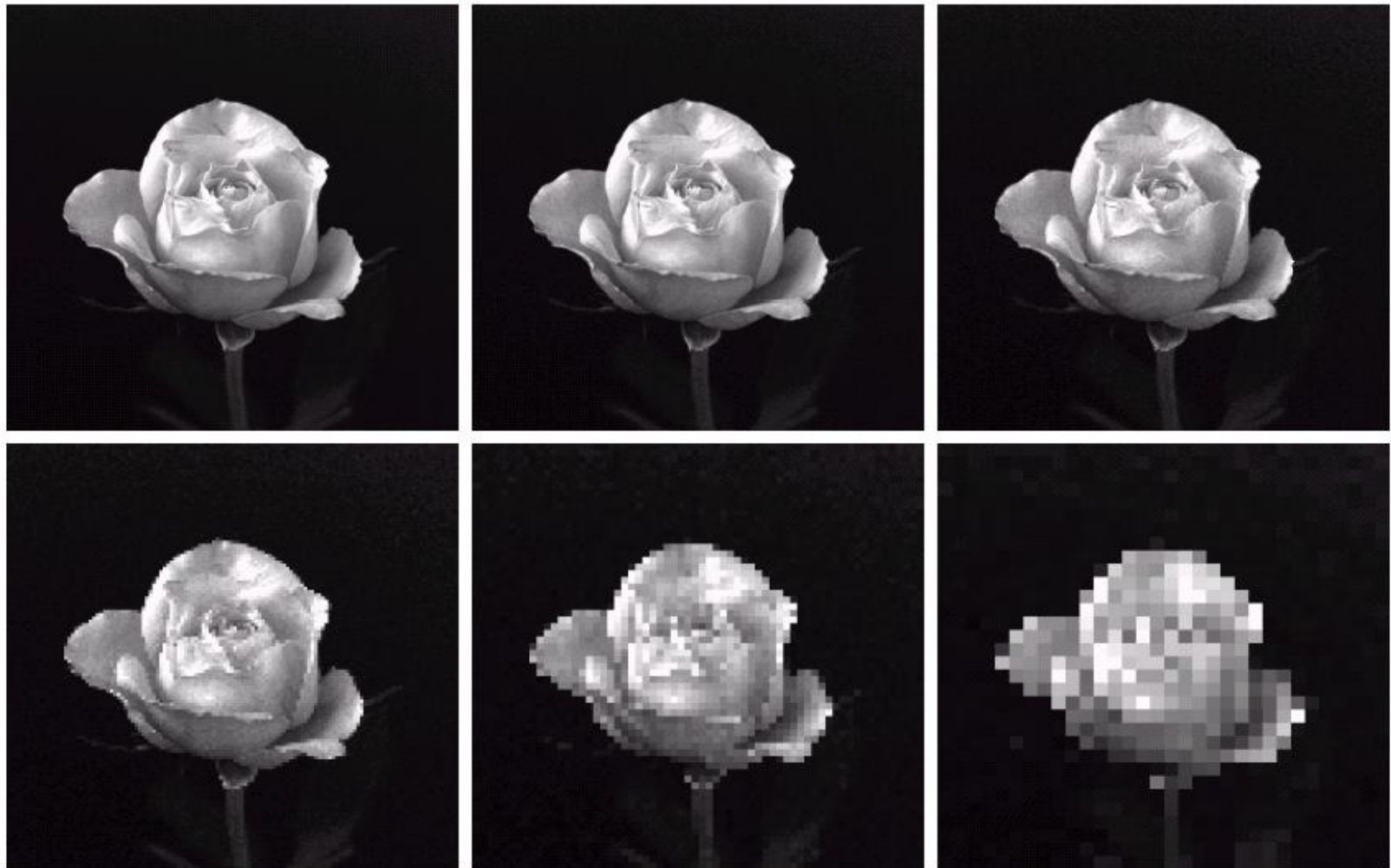


$\dot{v}_4$	$\dot{v}_3$	$\dot{v}_2$
$\dot{v}_5$	$\dot{p}$	$\dot{v}_1$
$\dot{v}_6$	$\dot{v}_7$	$\dot{v}_8$



# Introducere

- Formatul fișierului
- Bitmap și similar (bmp, mmp, tga, png)
  - 1 bit/pixel
  - 4 bits/pixel
  - 8 bits/pixel
  - 24 bits/pixel
- Comprimat (jpg, tif)
- Orientat obiect sau vectorial (numai pentru imagini sintetice)



a	b	c
d	e	f

**FIGURE 2.20** (a)  $1024 \times 1024$ , 8-bit image. (b)  $512 \times 512$  image resampled into  $1024 \times 1024$  pixels by row and column duplication. (c) through (f)  $256 \times 256$ ,  $128 \times 128$ ,  $64 \times 64$ , and  $32 \times 32$  images resampled into  $1024 \times 1024$  pixels.



a	b
c	d

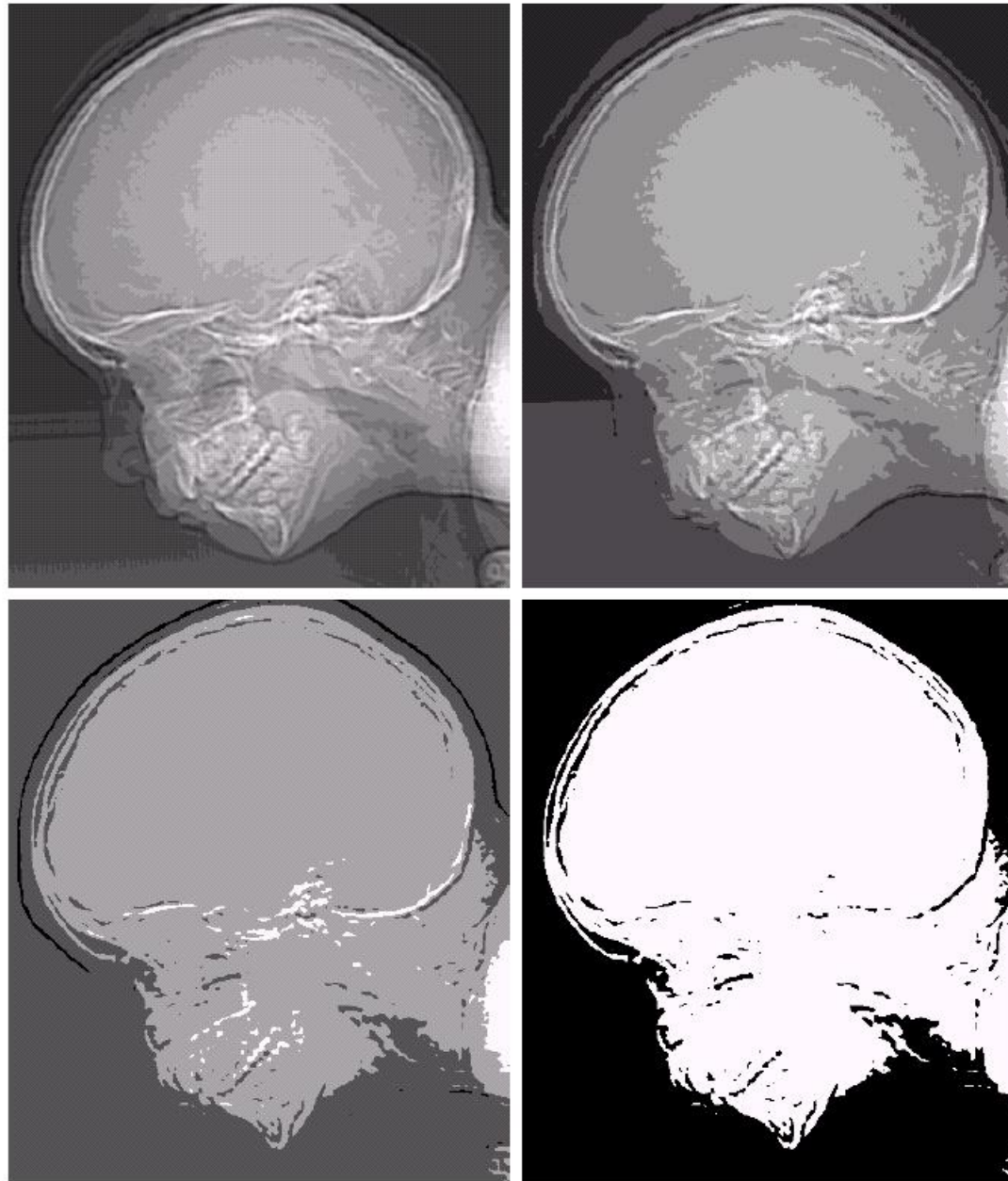
**FIGURE 2.21**  
 (a)  $452 \times 374$ ,  
 256-level image.  
 (b)–(d) Image  
 displayed in 128,  
 64, and 32 gray  
 levels, while  
 keeping the  
 spatial resolution  
 constant.

e	f
g	h

**FIGURE 2.21**

*(Continued)*

(e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



# Cuprins

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# Preprocesare

## Filtrare

- Imagini organizate ca harta pixelilor
- Filtrarea necesită o mască (matricea ponderilor)
- Filtrare prin convoluție imagine-mască
- Prelucrare necauzală, 2D
- Posibile filtre liniare/nonliniare

# Preprocesare

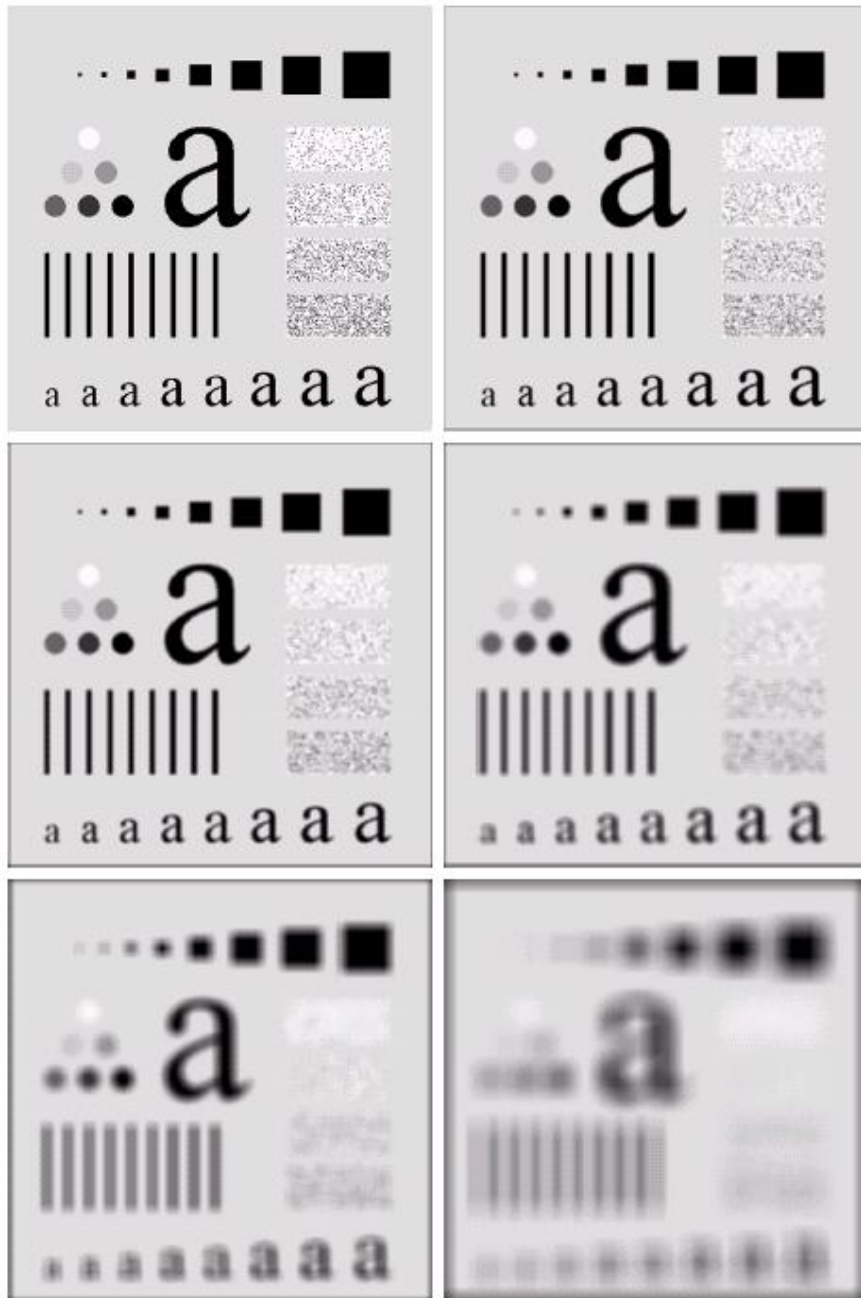
## Filtrare trece-jos

- Operator liniar
- Suma ponderilor este 1, nu are loc depășire
- Reduce zgomotul de frecvență mare
- Atenuează muchiile, detaliile fine

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

$$H = \frac{1}{10} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

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



## Filtrare trece-jos

# Preprocesare

## Filtrare trece-sus

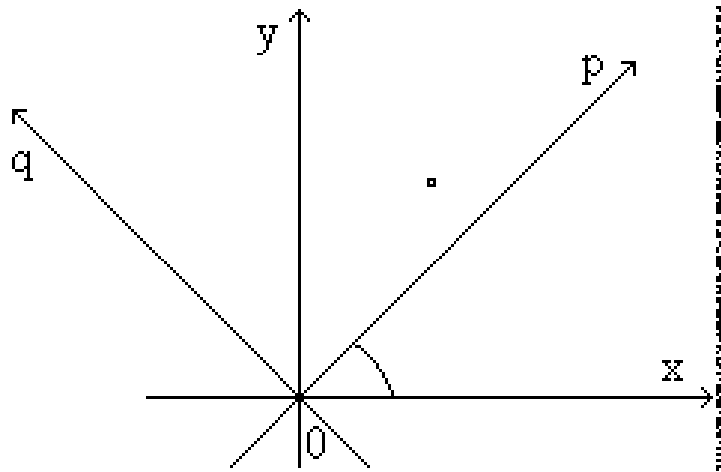
- Operator de derivare, liniar
- Depășirea este posibil
- Reduce zgomotul de frecvență mare
- Accentuează muchiile, detaliile fine
- Accentuează zgomotul

$$H = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix} = \begin{bmatrix} -1 & -2 & -1 \\ -2 & 13 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

# Preprocesare

## Operatori invariianți la rotație

- Proprietăți care nu depind de orientare



$$p = x \cos r + y \sin r$$
$$q = -x \sin r + y \cos r$$

# Preprocesare

## Operatori invariianți la rotație

$$\Delta F(x, y) = \frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial y^2} \quad \text{Laplace}$$

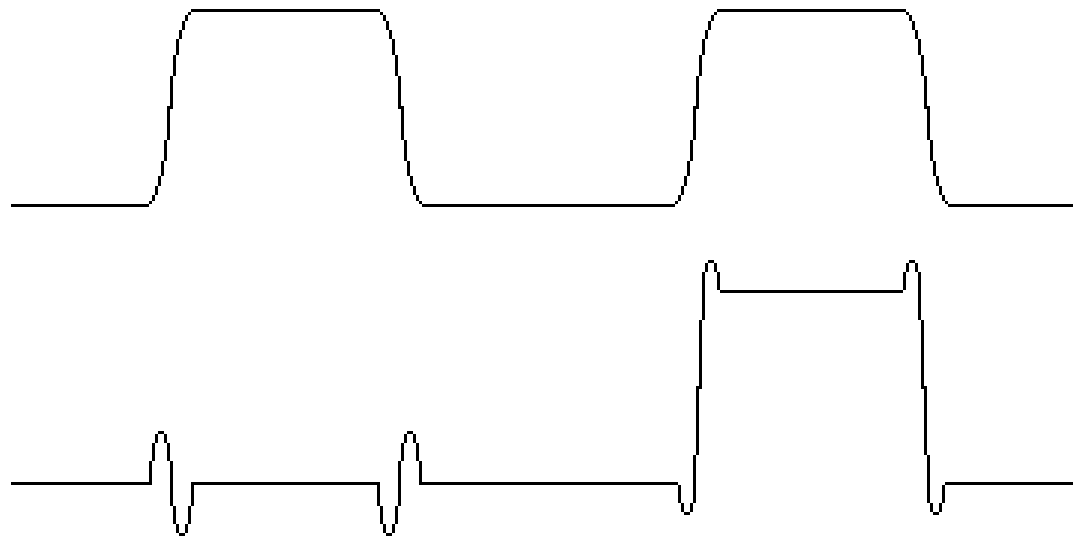
$$\frac{\partial}{\partial p} = \cos r \frac{\partial}{\partial x} + \sin r \frac{\partial}{\partial y}$$

$$\frac{\partial}{\partial q} = -\sin r \frac{\partial}{\partial x} + \cos r \frac{\partial}{\partial y}$$

$$\Delta F(p, q) = \frac{\partial}{\partial p} \left( \frac{\partial F}{\partial p} \right) + \frac{\partial}{\partial q} \left( \frac{\partial F}{\partial q} \right) = \dots = \Delta F(x, y)$$

# Preprocesare

## Operatori invariianți la rotație



Laplace = derivata de ordin 2

# Preprocesare

## Operatori invariianți la rotație

$$\frac{\partial F}{\partial x} = \frac{F(x) - F(x-1)}{x - (x-1)} = F(x) - F(x-1)$$

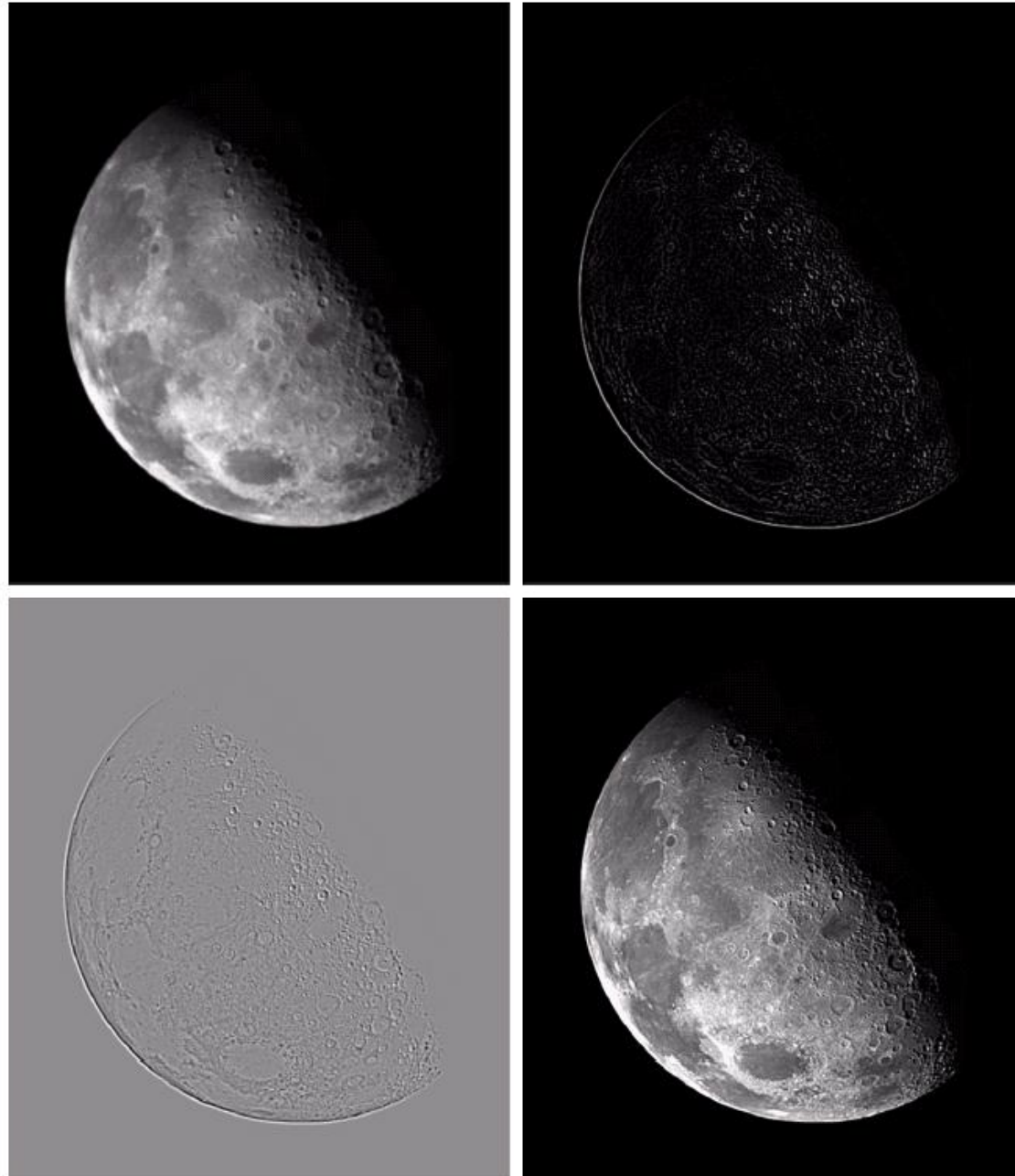
$$\frac{\partial^2 F}{\partial x^2} = F(x+1) - 2F(x) + F(x-1)$$

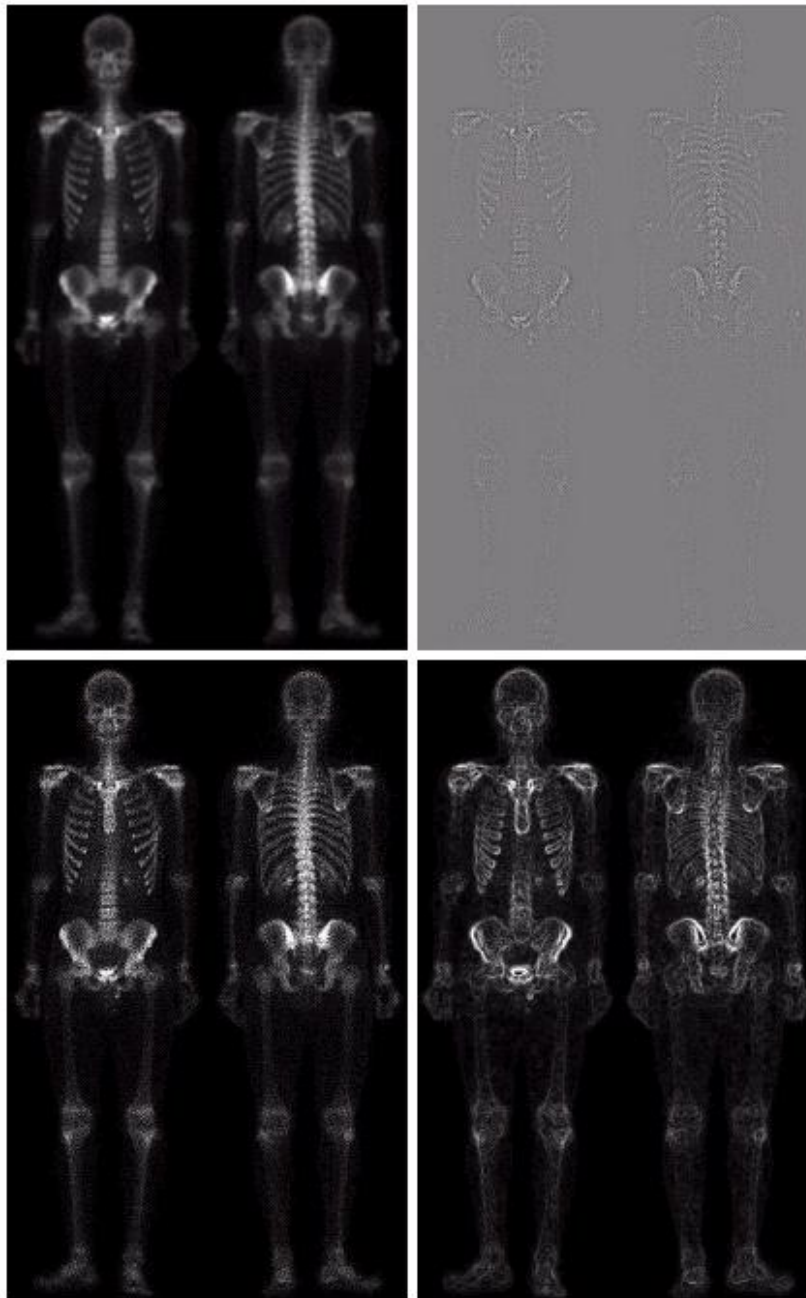
$$H = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} - z \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 0 & -z & 0 \\ -z & 1+4z & -z \\ 0 & -z & 0 \end{bmatrix}$$

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.)





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).

# Preprocesare

## Operatori invariianți la rotație

$$|grad(F)| = \sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2}$$

$$m = \frac{\partial F}{\partial y} / \frac{\partial F}{\partial x}$$

Gradient = derivata de ordin 1

# Preprocesare

## Operatori dependenți de orientare

- Prewit
- Sobel (pentru muchii verticale sau orizontale)

$$H = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

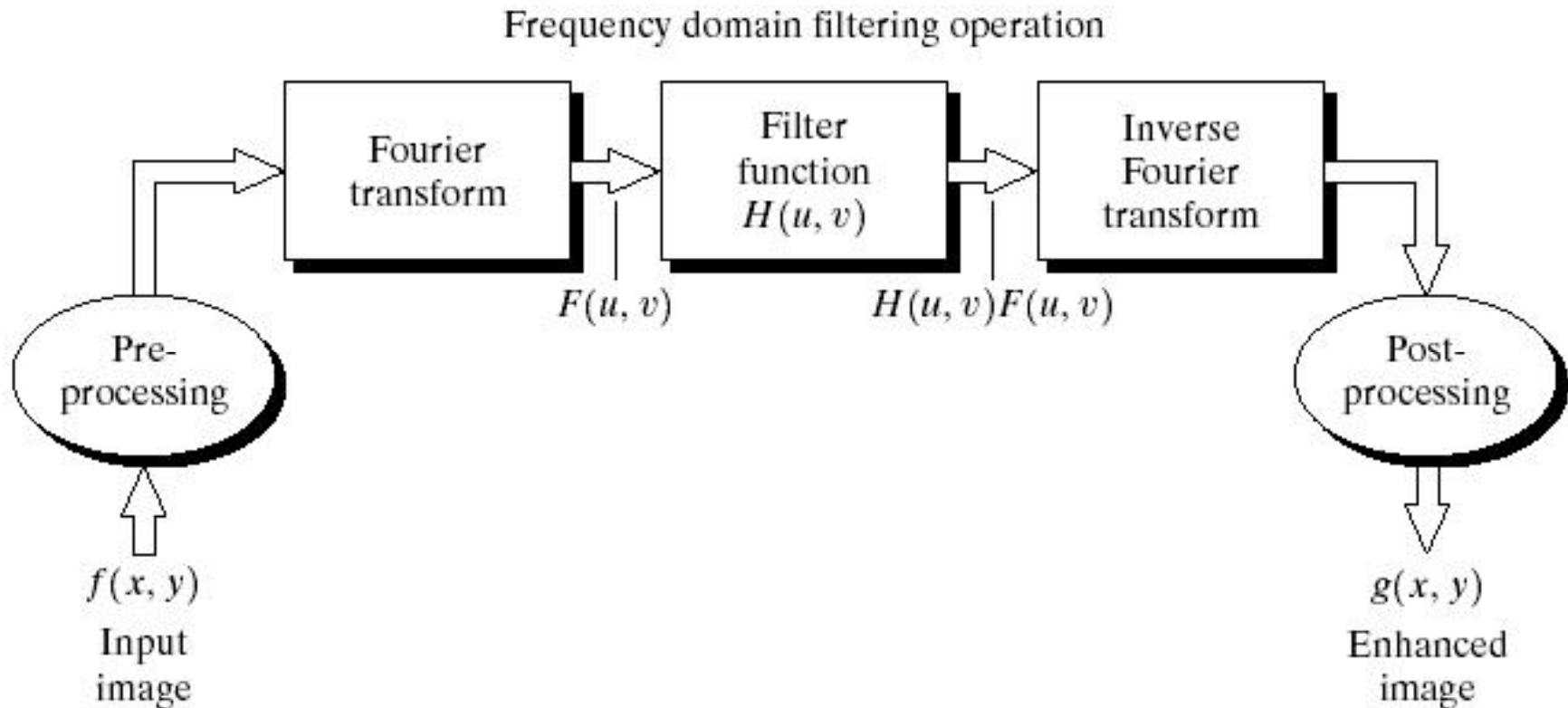
$$H = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

# Preprocesare

## Filtrare în domeniul frecvență

- Operatori de filtrare aplicați transformatei Fourier
- Imaginea recuperată prin transformarea Fourier invers
- Posibilitatea de a reduce sau accentua selectiv intervale spectrale
- Ușor de eliminat zgomotul periodic

# Preprocesare



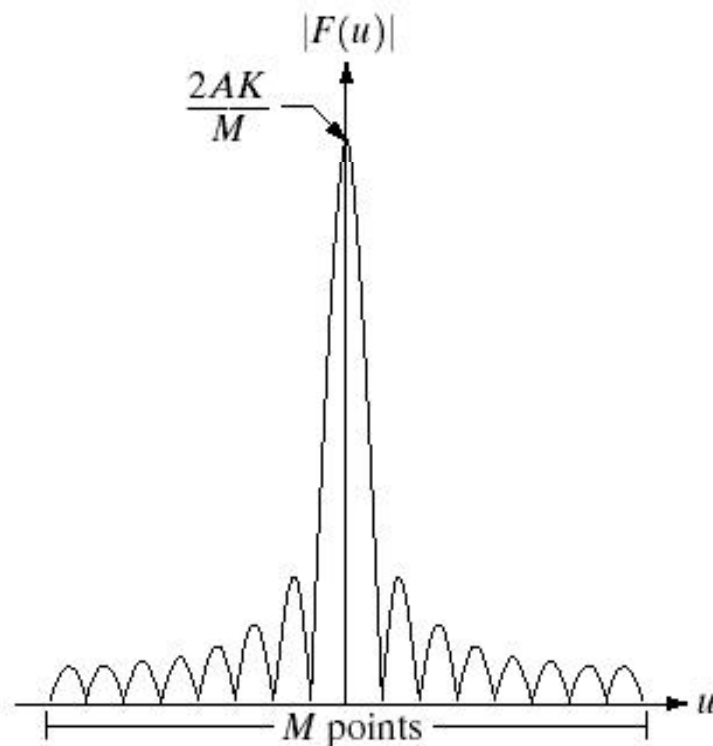
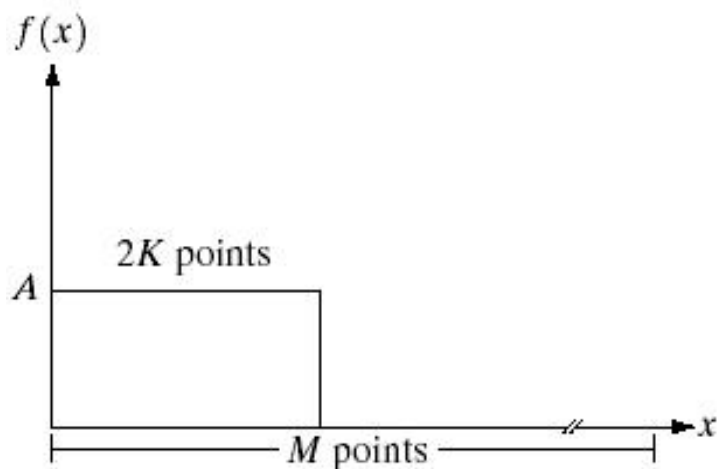
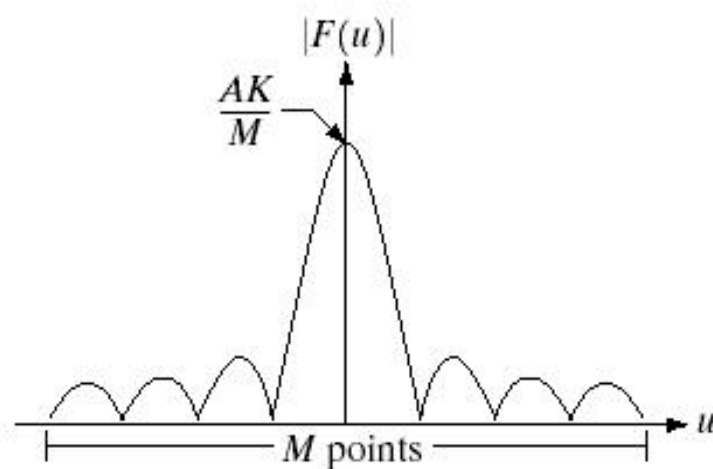
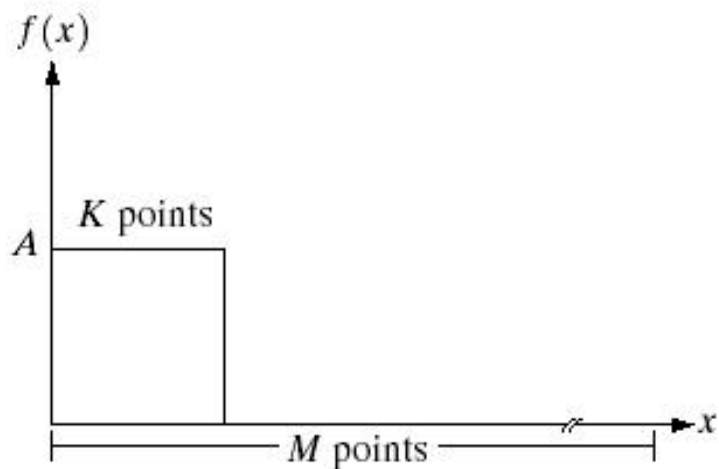
**FIGURE 4.5** Basic steps for filtering in the frequency domain.

# Preprocesare

The Fourier transform of a discrete function  $f(x)$  of one variable, where  $x = 0, 1, \dots, M - 1$ :

$$F(u) = \frac{1}{M} \cdot \sum_{x=0}^{M-1} f(x) \cdot e^{-j2\pi ux / M}$$

$$u = 0, 1, \dots, M-1$$



a	b
c	d

**FIGURE 4.2** (a) A discrete function of  $M$  points, and (b) its Fourier spectrum. (c) A discrete function with twice the number of nonzero points, and (d) its Fourier spectrum.

# Preprocesare

The discrete Fourier transform of a function  $f(x,y)$  (image) of size  $M \times N$ , where  $x = 0, 1, \dots, M-1$ , and  $y = 0, 1, \dots, N-1$ :

$$F(u, v) = \frac{1}{MN} \cdot \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \cdot e^{-j2\pi (ux/M + vy/N)}$$

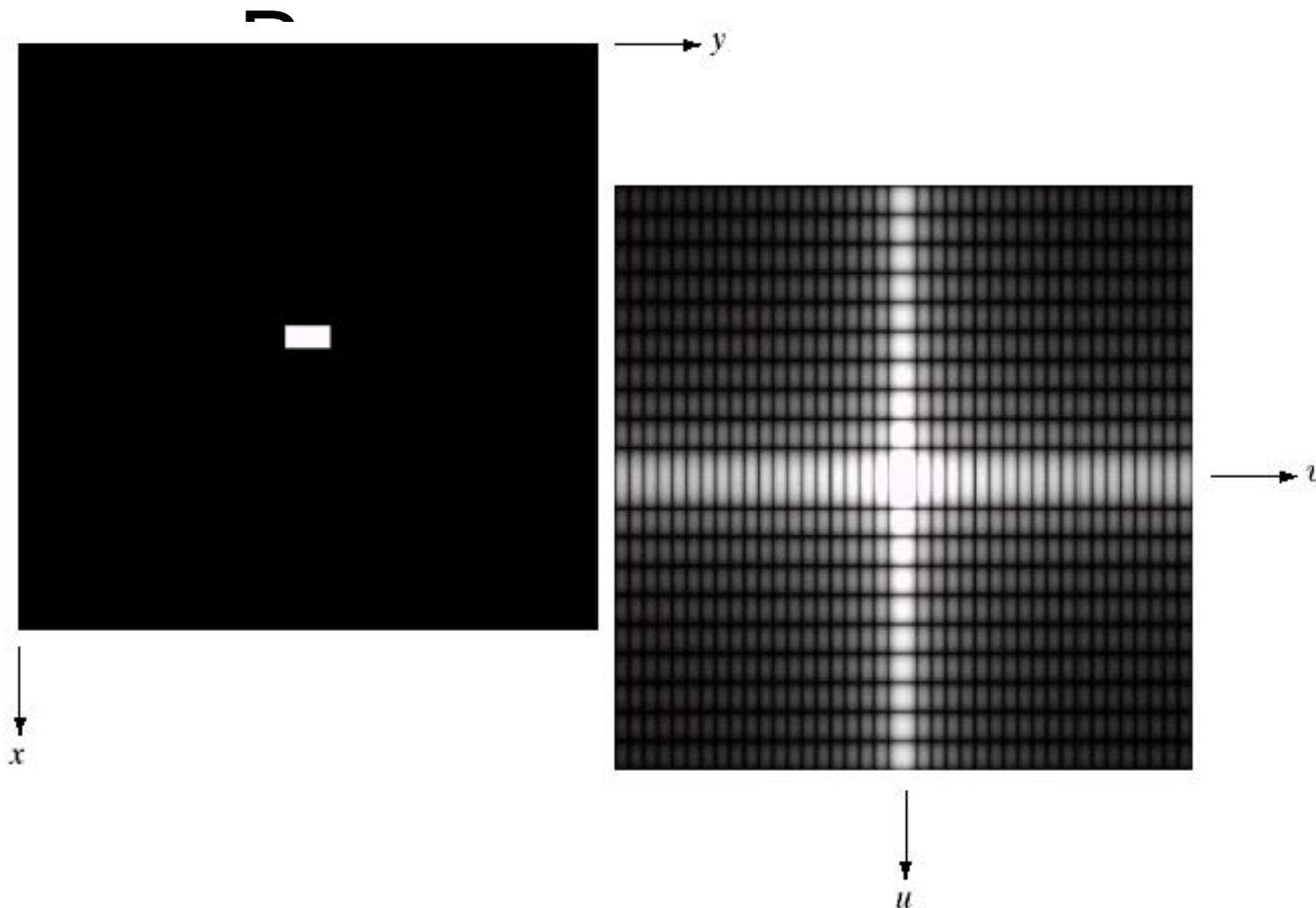
$$u = 0, 1, \dots, M-1, \text{ and } v = 0, 1, \dots, N-1$$

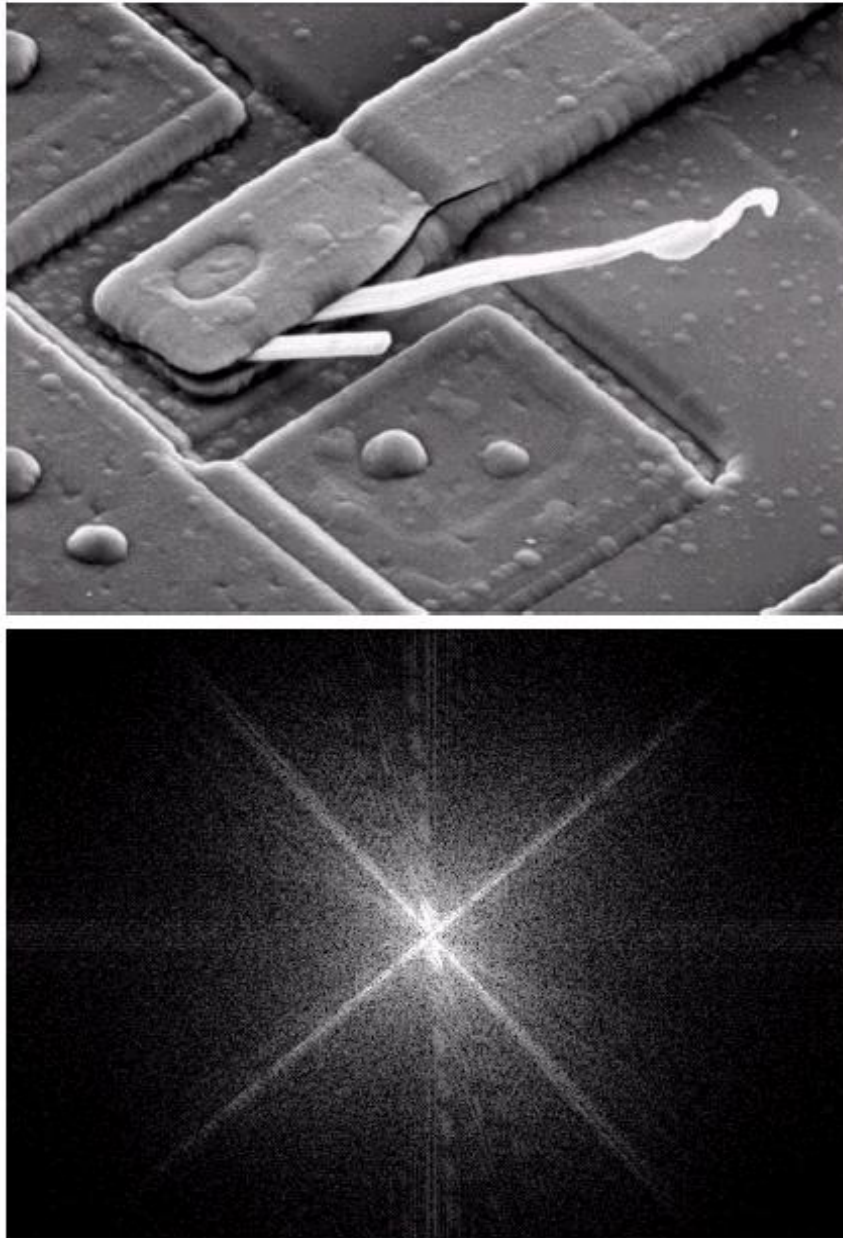
a b

### FIGURE 4.3

(a) Image of a  $20 \times 40$  white rectangle on a black background of size  $512 \times 512$  pixels.

(b) Centered Fourier spectrum shown after application of the log transformation given in Eq. (3.2-2). Compare with Fig. 4.2.

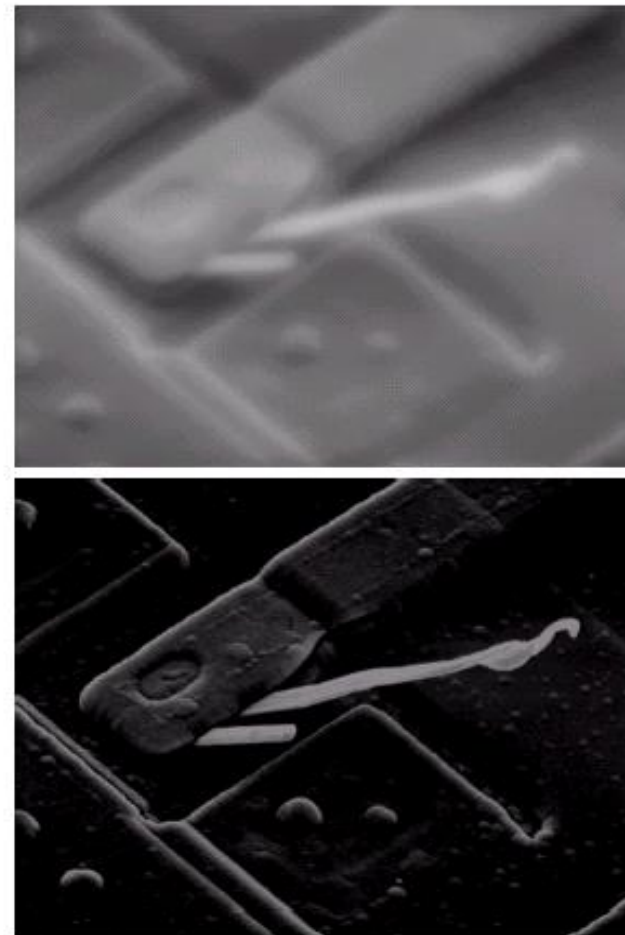
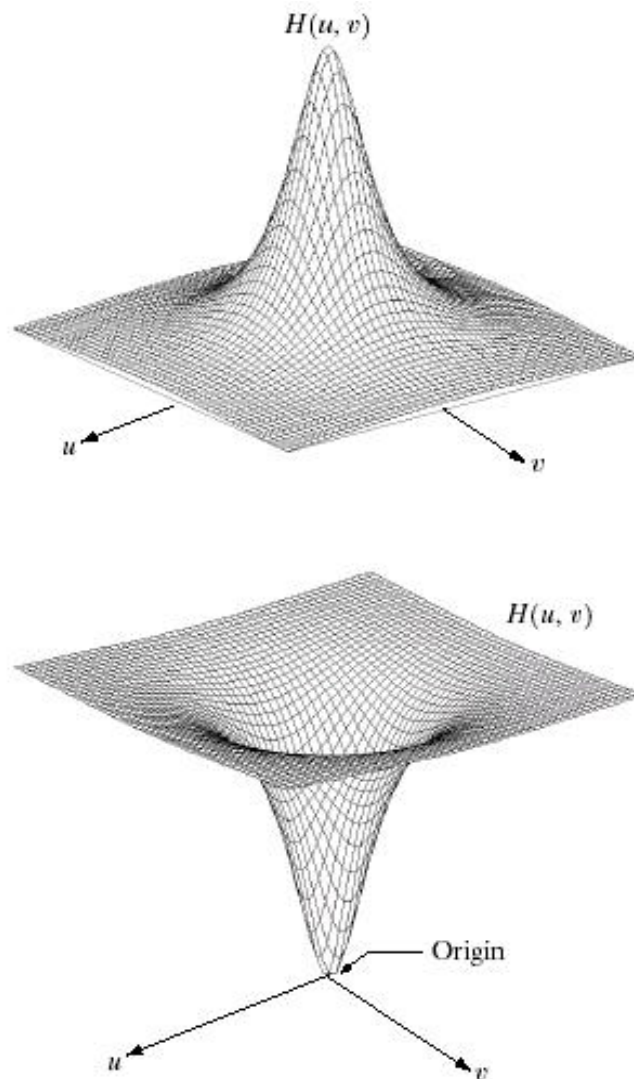




a  
b

#### FIGURE 4.4

(a) SEM image of a damaged integrated circuit.  
(b) Fourier spectrum of (a).  
(Original image courtesy of Dr. J. M. Hudak, Brockhouse Institute for Materials Research, McMaster University, Hamilton, Ontario, Canada.)



a	b
c	d

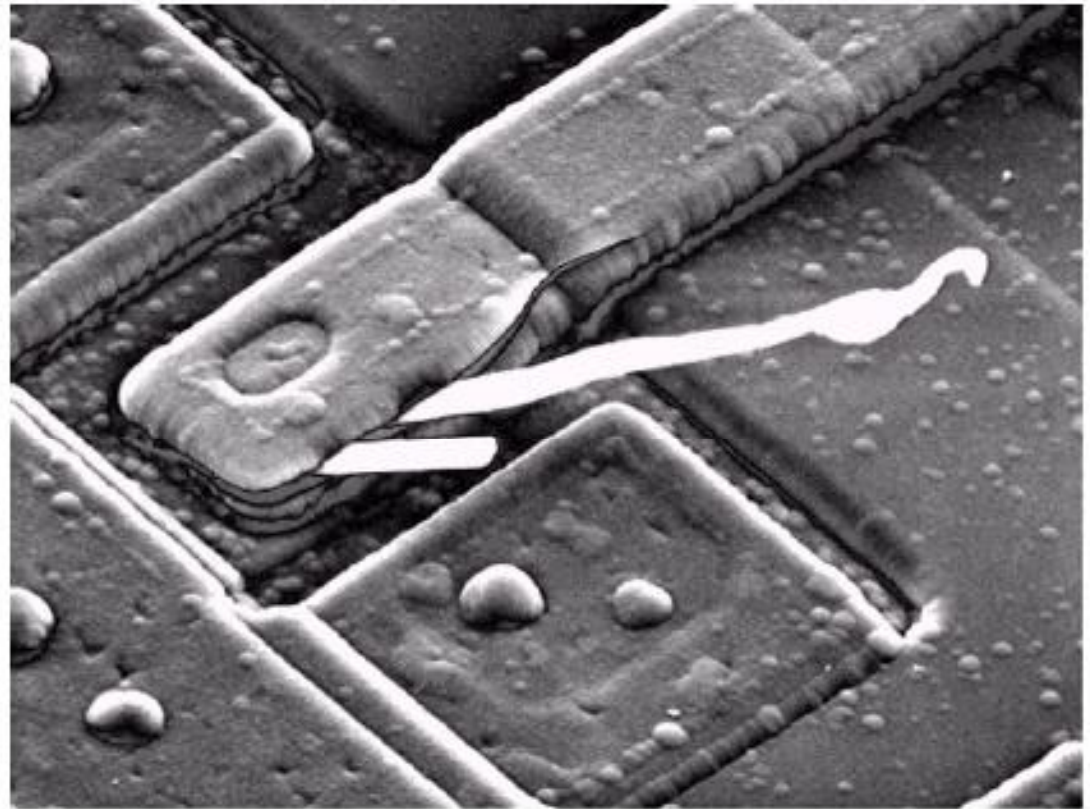
**FIGURE 4.7** (a) A two-dimensional lowpass filter function. (b) Result of lowpass filtering the image in Fig. 4.4(a). (c) A two-dimensional highpass filter function. (d) Result of highpass filtering the image in Fig. 4.4(a).

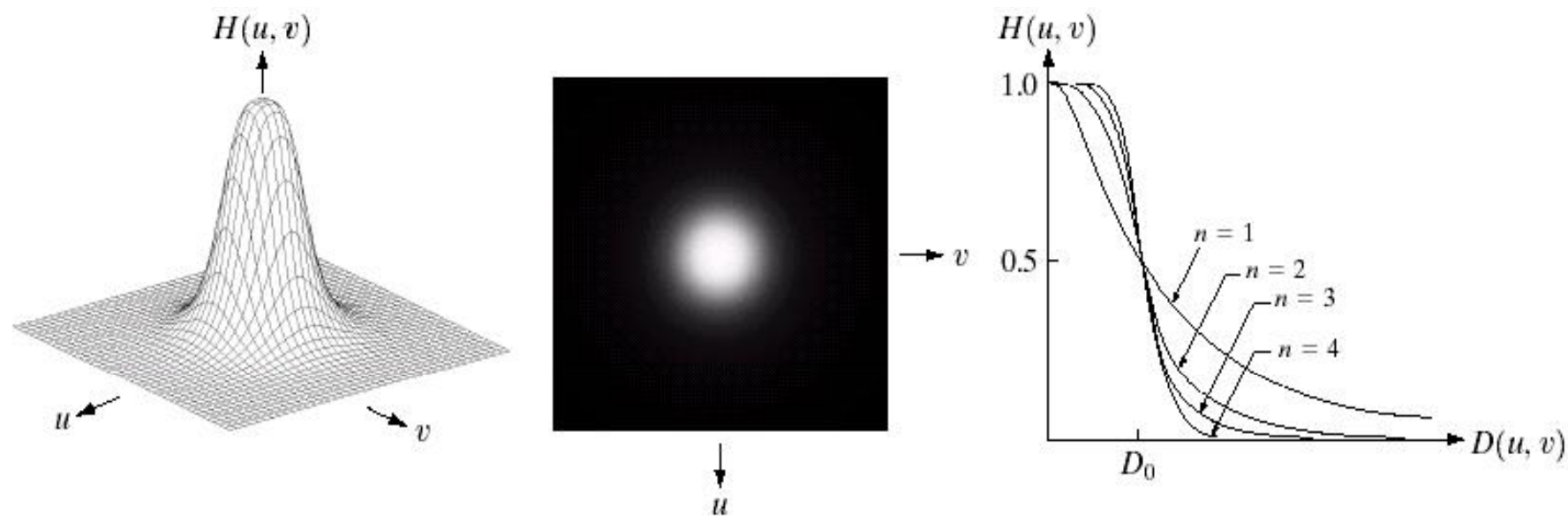
# Preprocesare

## **FIGURE 4.8**

Result of highpass filtering the image in Fig. 4.4(a) with the filter in Fig. 4.7(c), modified by adding a constant of one-half the filter height to the filter function. Compare with Fig. 4.4(a).

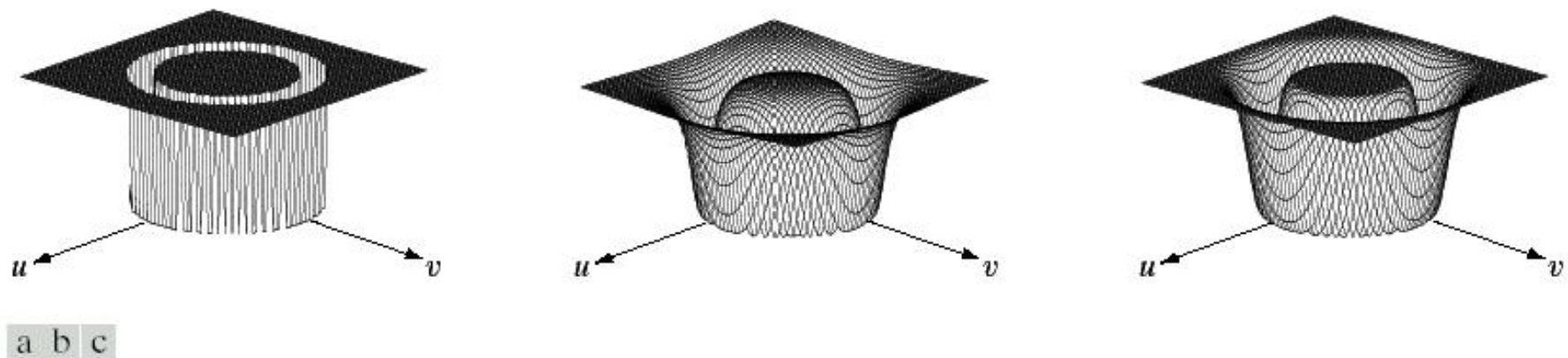
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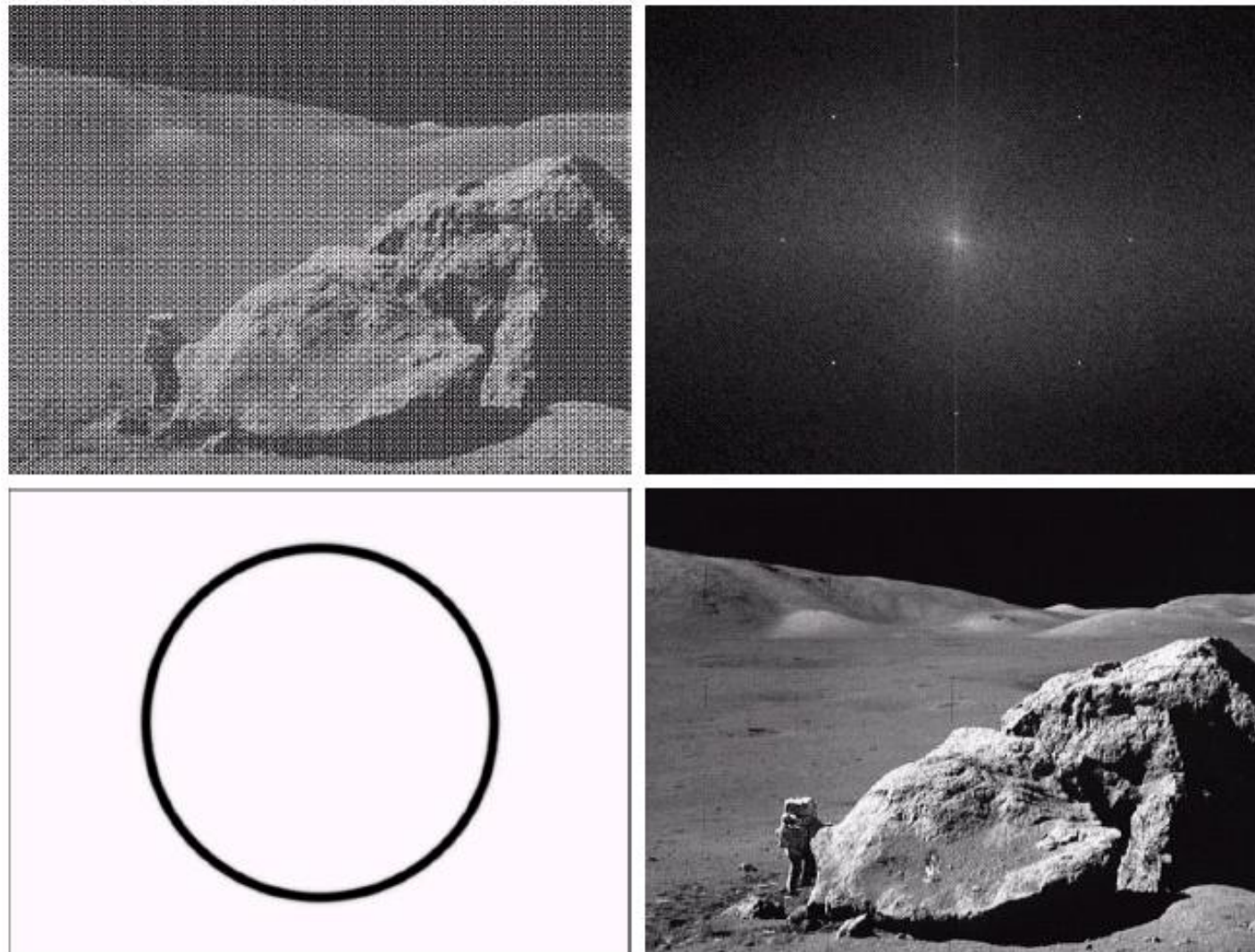
a b c

**FIGURE 4.14** (a) Perspective plot of a Butterworth lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross sections of orders 1 through 4.



**FIGURE 5.15** From left to right, perspective plots of ideal, Butterworth (of order 1), and Gaussian bandreject filters.

## Eliminarea zgomotului periodic



a	b
c	d

**FIGURE 5.16**

(a) Image corrupted by sinusoidal noise. (b) Spectrum of (a). (c) Butterworth bandreject filter (white represents 1). (d) Result of filtering. (Original image courtesy of NASA.)

a b

**FIGURE 5.20**

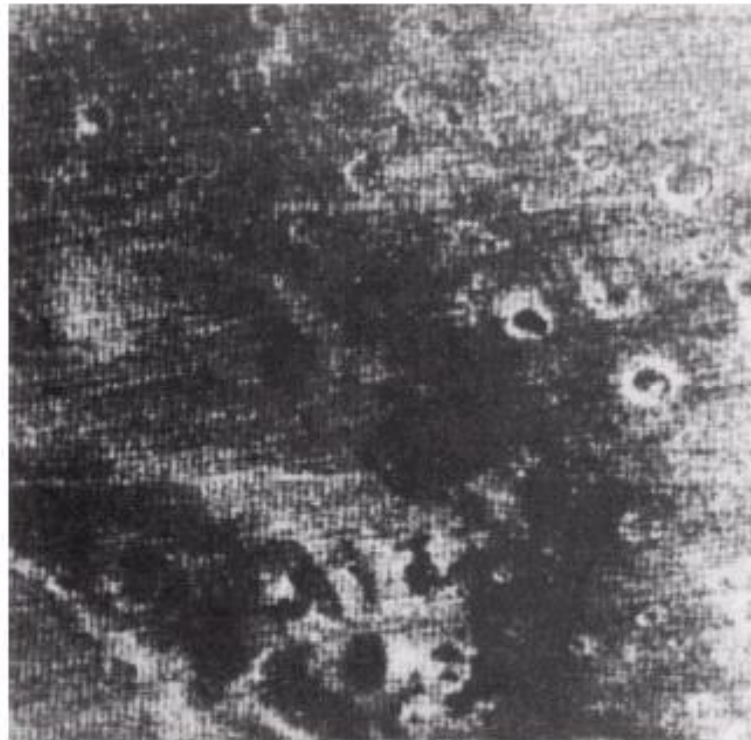
(a) Image of the  
Martian terrain  
taken by

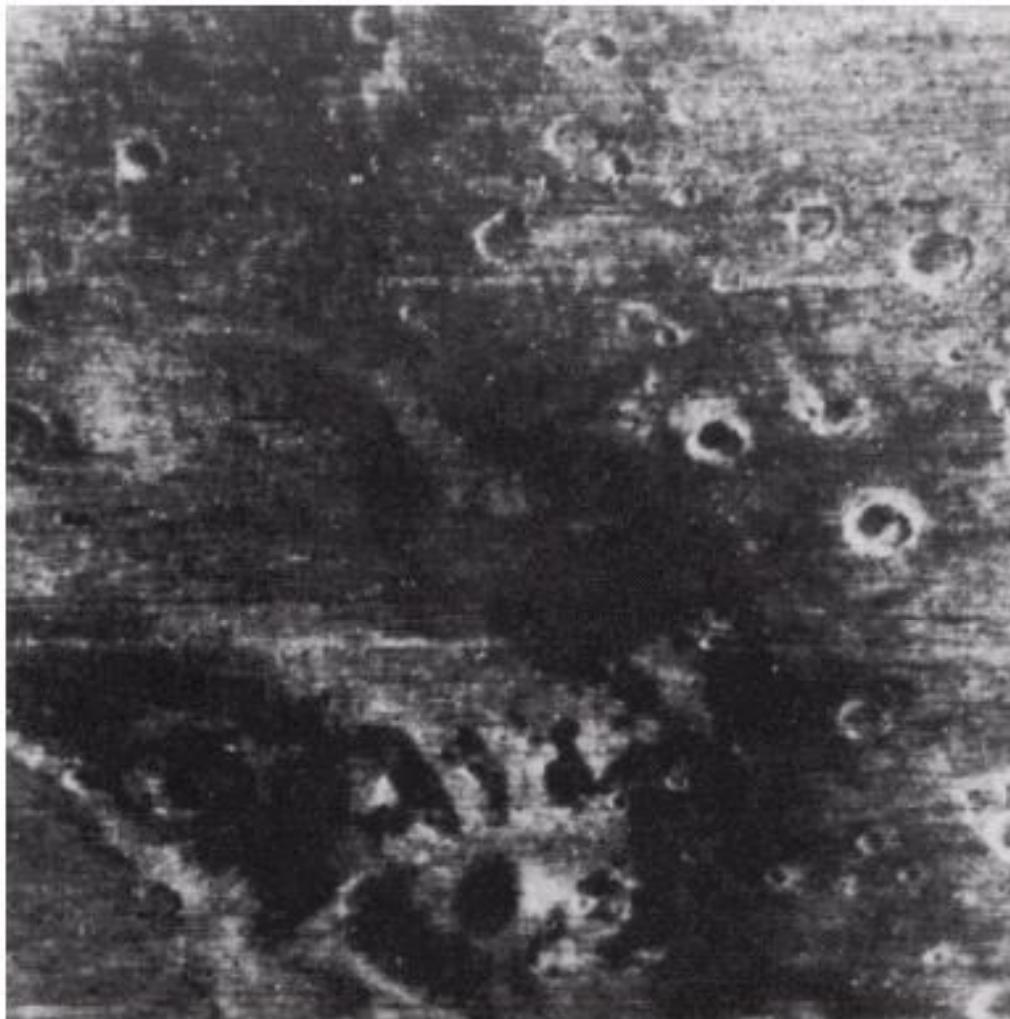
*Mariner 6.*

(b) Fourier  
spectrum showing  
periodic  
interference.

(Courtesy of  
NASA.)

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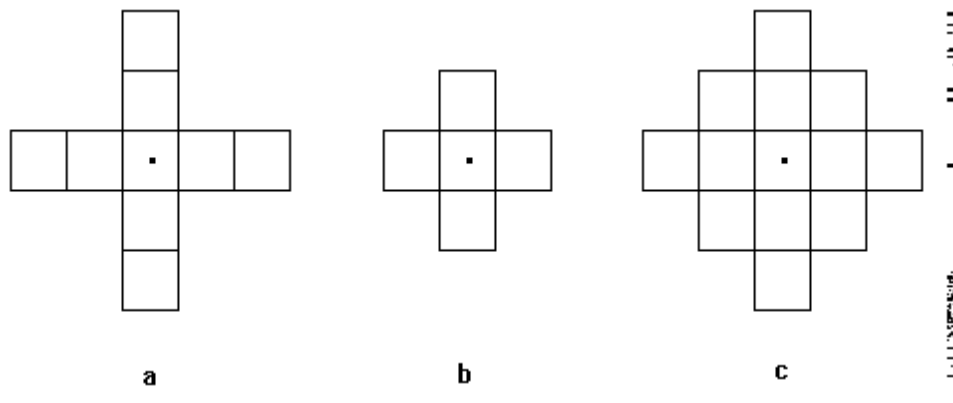
**FIGURE 5.23** Processed image. (Courtesy of NASA.)

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# Preprocesare

## Filtrare median

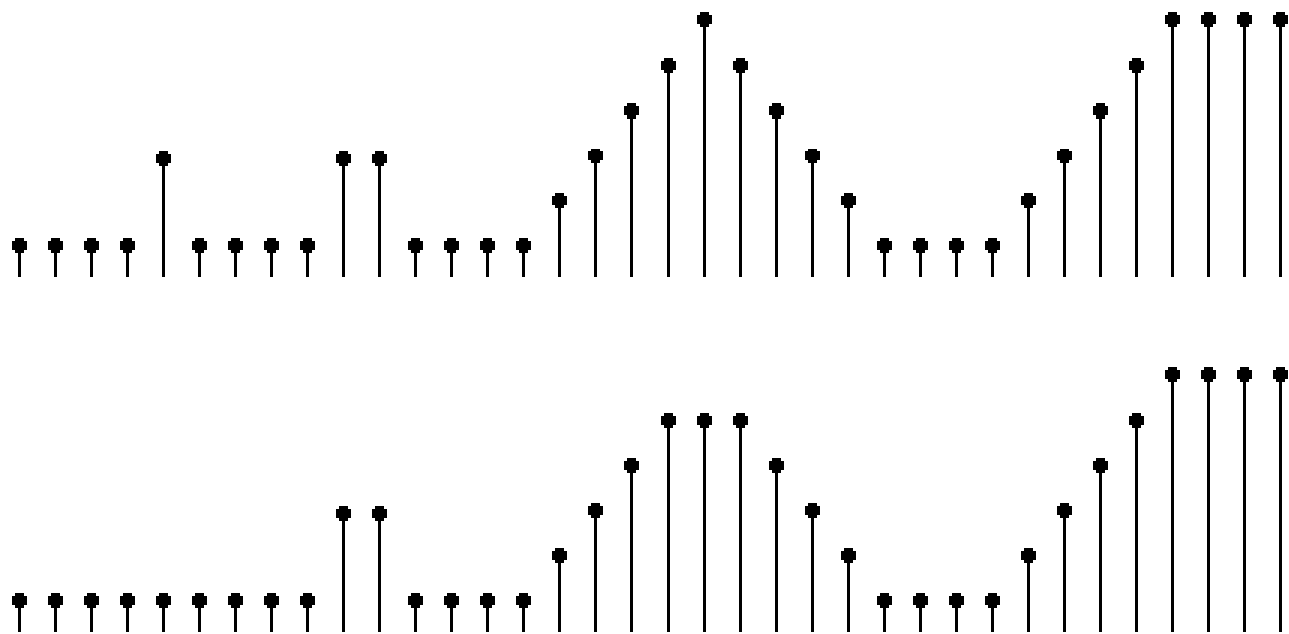
- Neliniar
- Reține valoarea mediană dintr-o secvență
- Elimin zgomotul de tip impuls
- 1D sau 2D

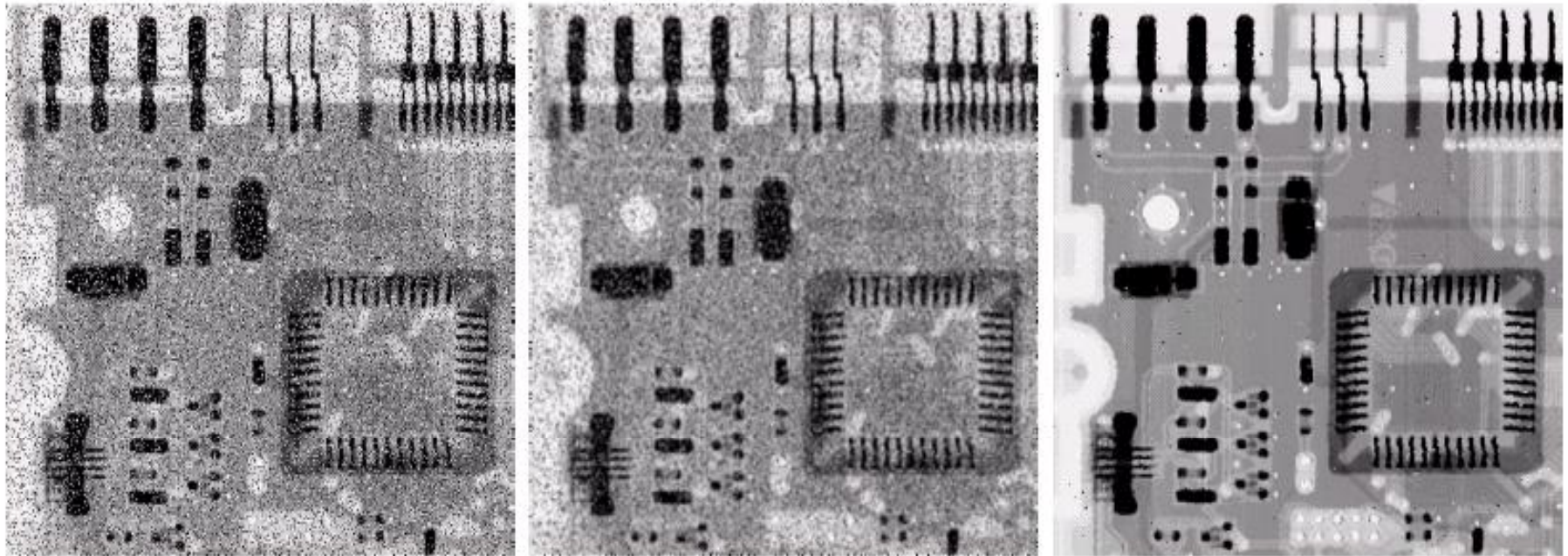


# Preprocesare

## Filtrare median

- 1D, mască de lungime 3





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.)

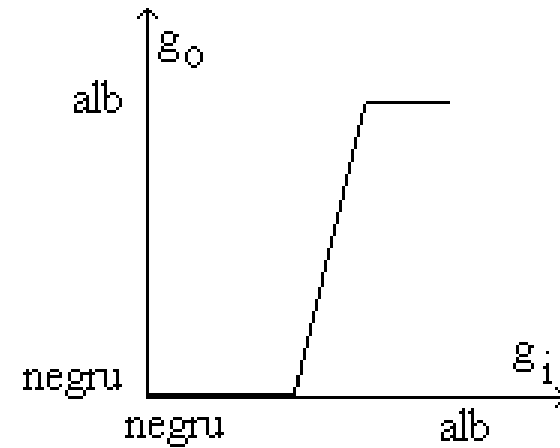
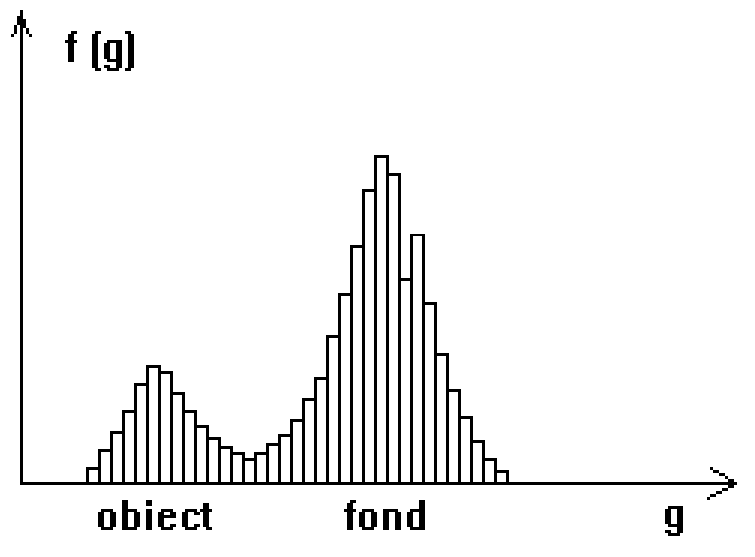
# Preprocesare

## Modificarea histogramei

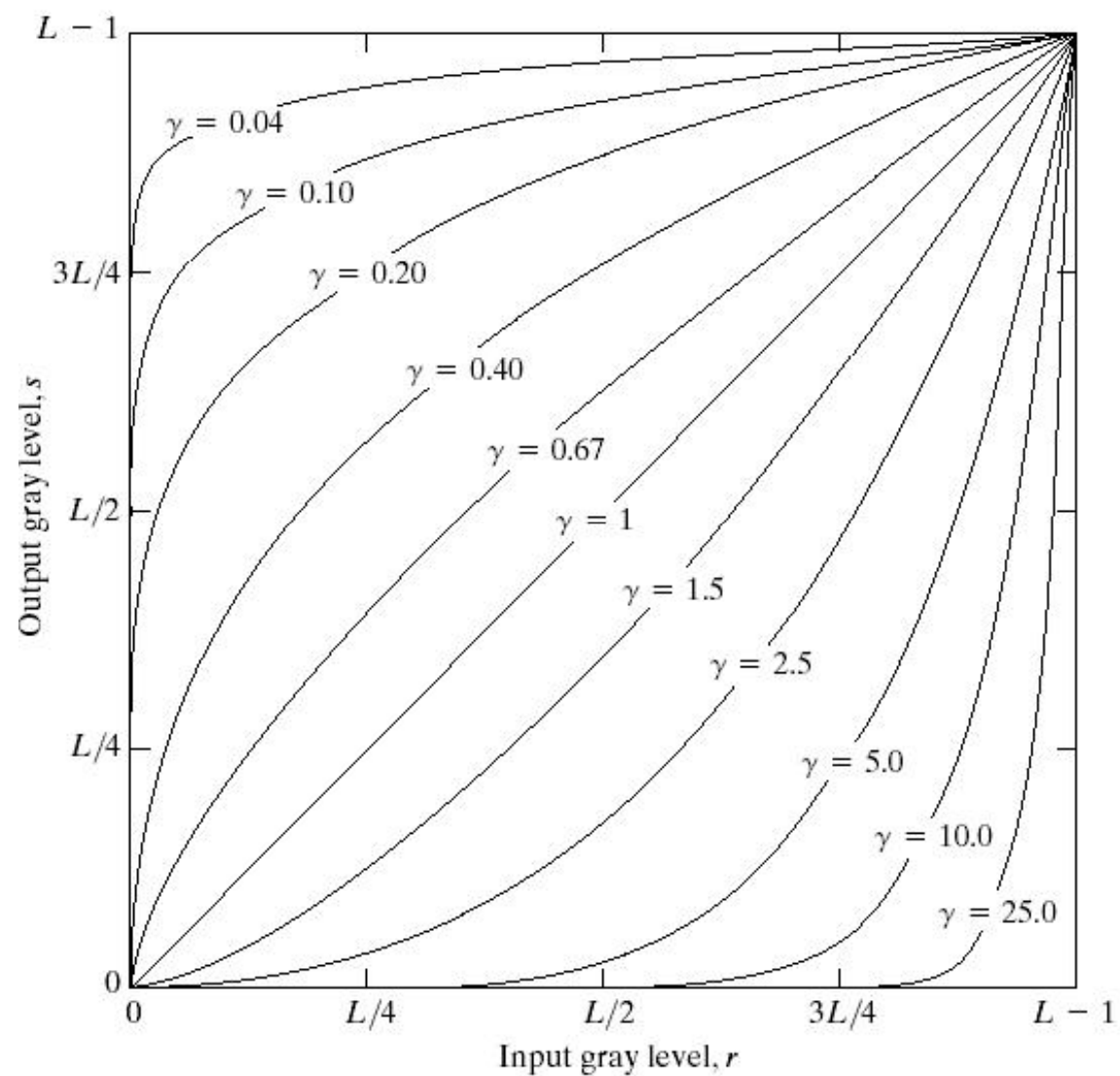
- Pentru utilizarea eficientă a scării de gri
- Accentuează zonele luminoase sau întunecate
- Forma S, forma gama, etc.
- Util pentru operatorul uman (medicină, meteo etc.)

# Preprocesare

## Modificarea histogramei



$$g_o = (g_{alb} - g_{negru}) \frac{g_i - g_{\min}}{g_{\max} - g_{\min}} + g_{negru}$$

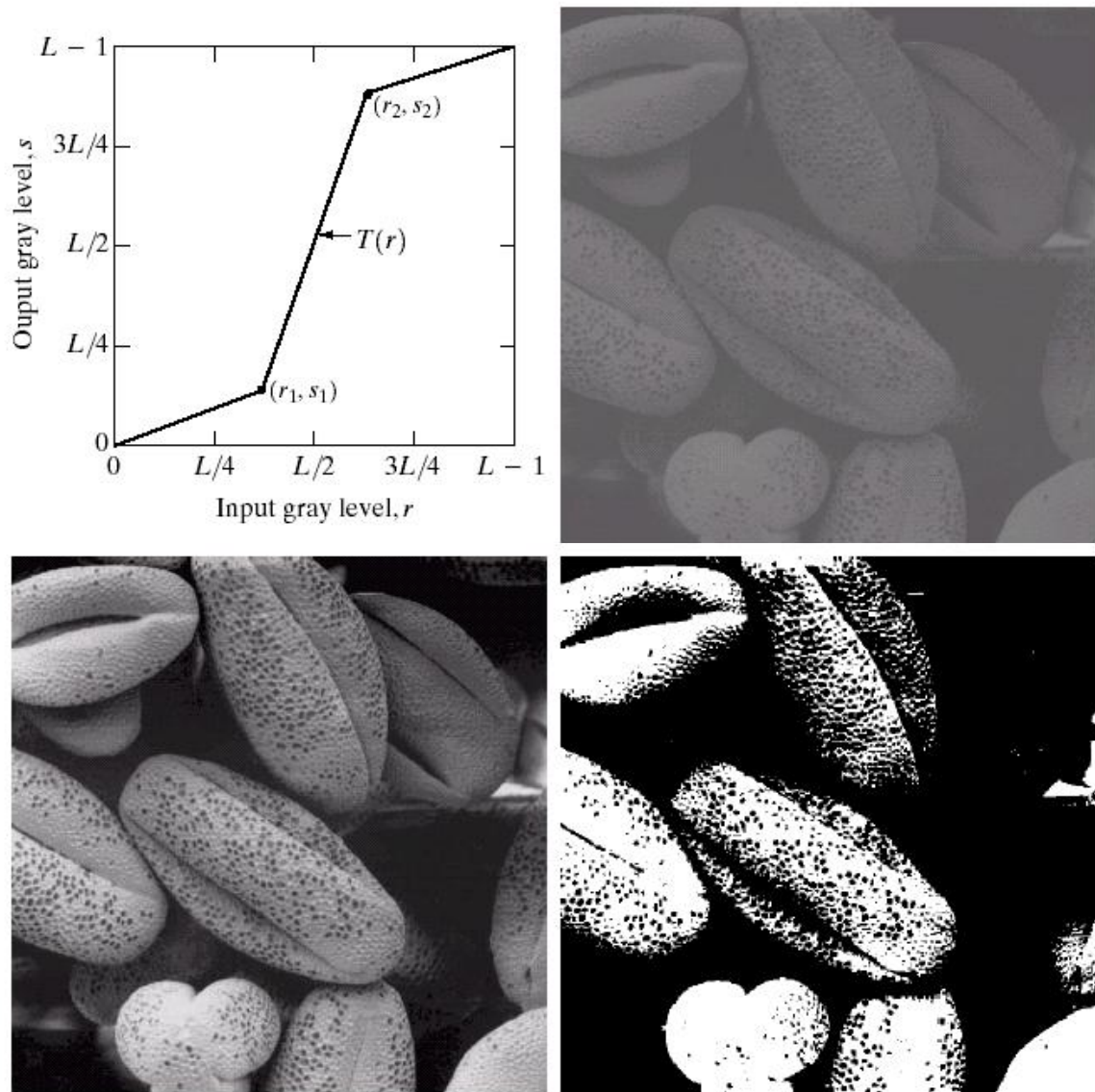


**FIGURE 3.6** Plots of the equation  $s = cr^\gamma$  for various values of  $\gamma$  ( $c = 1$  in all cases).

a	b
c	d

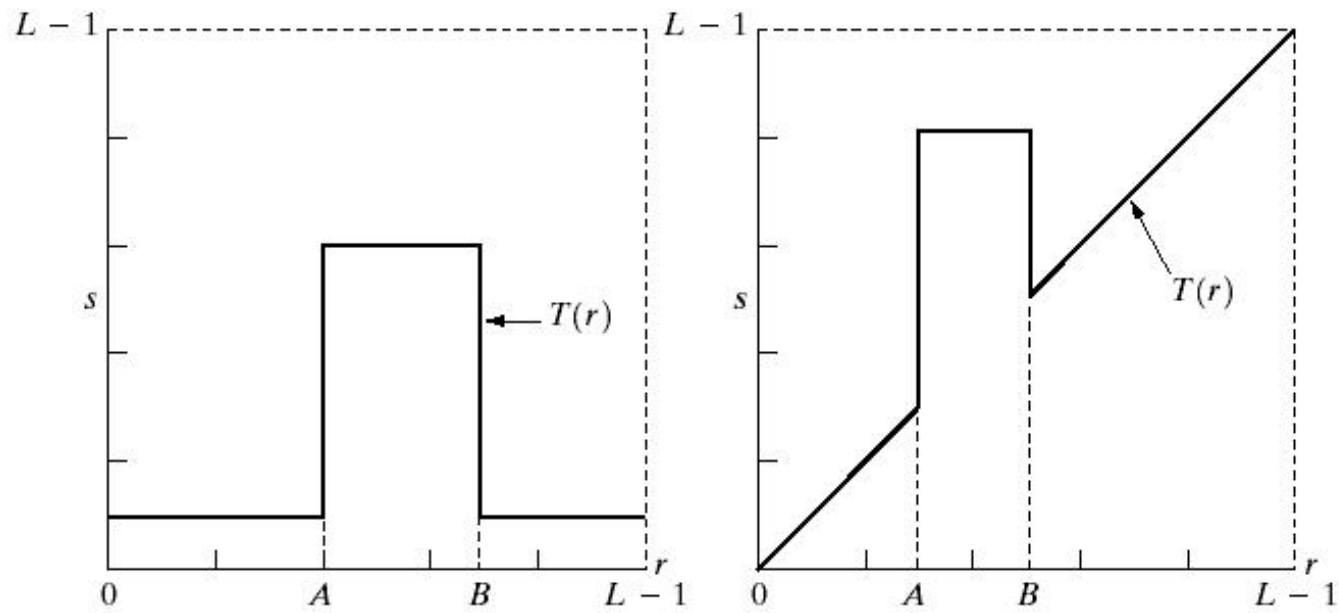
**FIGURE 3.9**  
 (a) Aerial image.  
 (b)–(d) Results of  
 applying the  
 transformation in  
 Eq. (3.2-3) with  
 $c = 1$  and  
 $\gamma = 3.0, 4.0,$  and  
 $5.0$ , respectively.  
 (Original image  
 courtesy of  
 NASA.)





a	b
c	d

**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.)



a	b
c	d

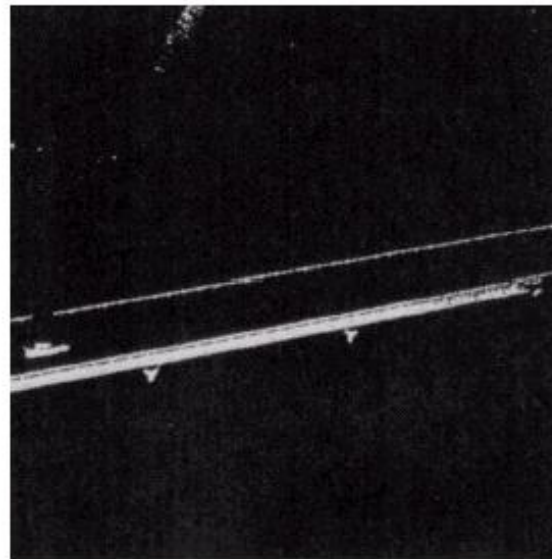
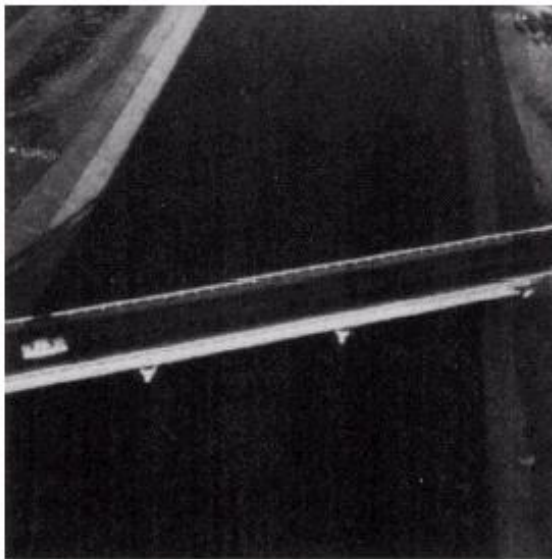
**FIGURE 3.11**

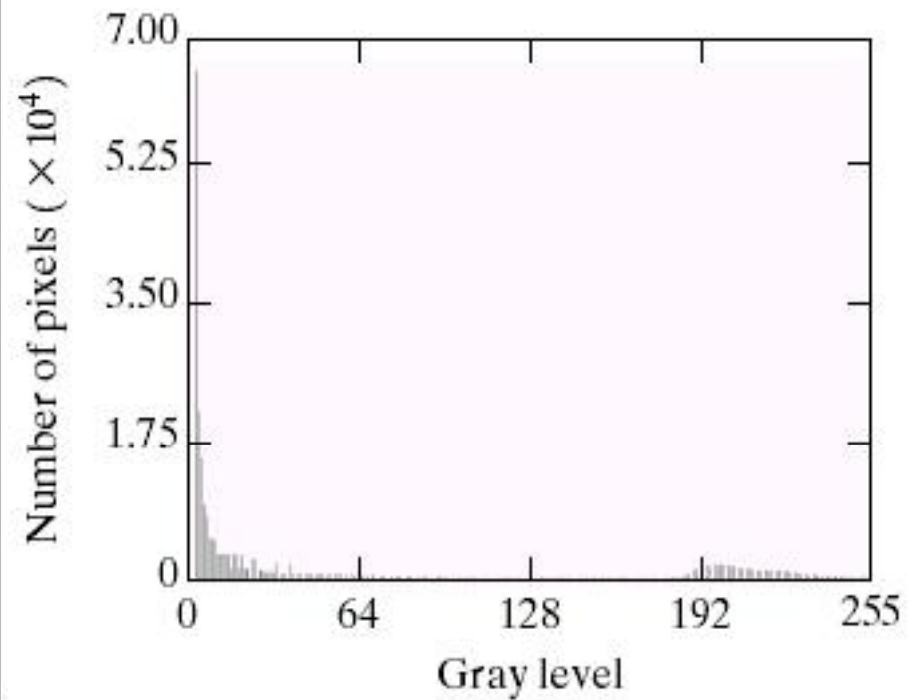
(a) This transformation highlights range  $[A, B]$  of gray levels and reduces all others to a constant level.

(b) This transformation highlights range  $[A, B]$  but preserves all other levels.

(c) An image.

(d) Result of using the transformation in (a).





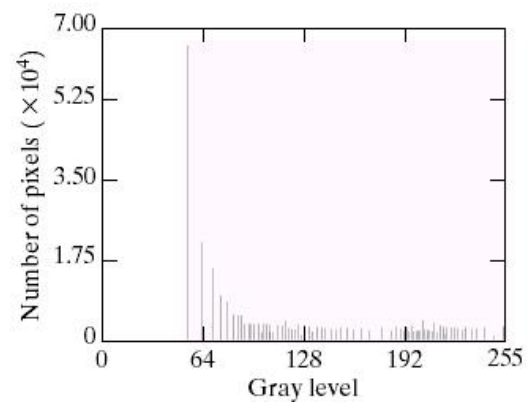
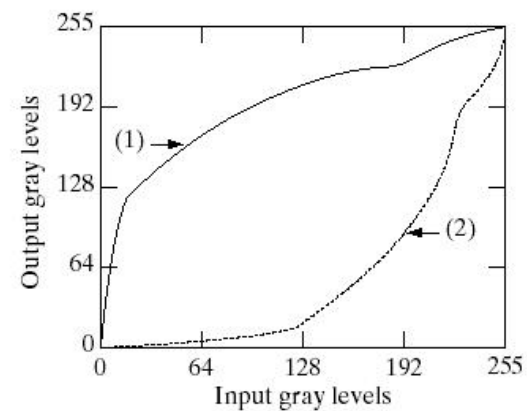
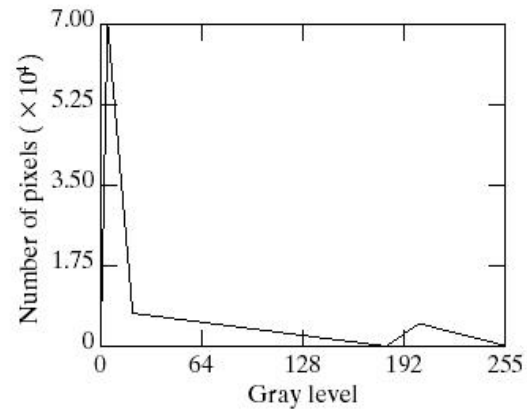
a b

**FIGURE 3.20** (a) Image of the Mars moon Phobos taken by NASA's *Mars Global Surveyor*. (b) Histogram. (Original image courtesy of NASA.)

a c  
b  
d

**FIGURE 3.22**

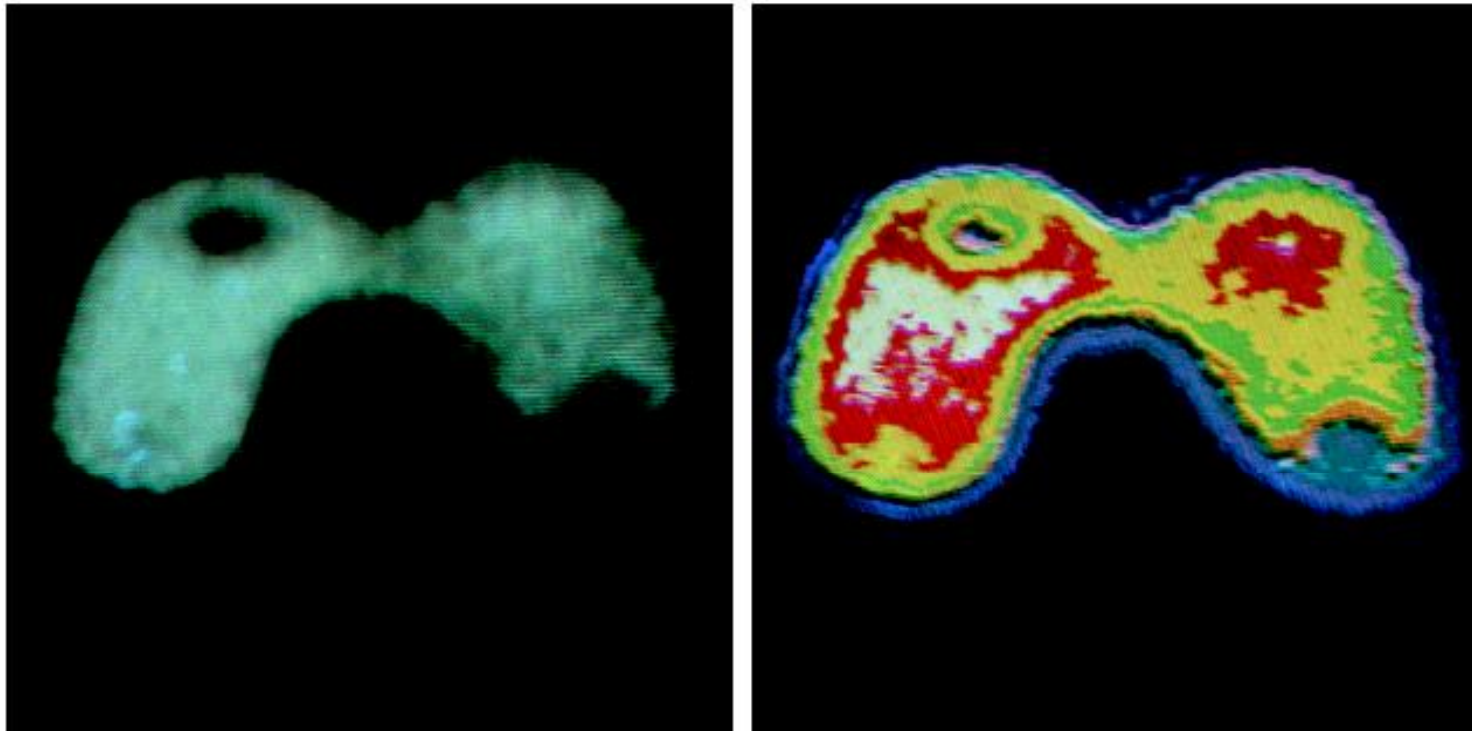
(a) Specified histogram.  
(b) Curve (1) is from Eq. (3.3-14), using the histogram in (a); curve (2) was obtained using the iterative procedure in Eq. (3.3-17).  
(c) Enhanced image using mappings from curve (2).  
(d) Histogram of (c).



# Preprocesare

## Pseudocolor

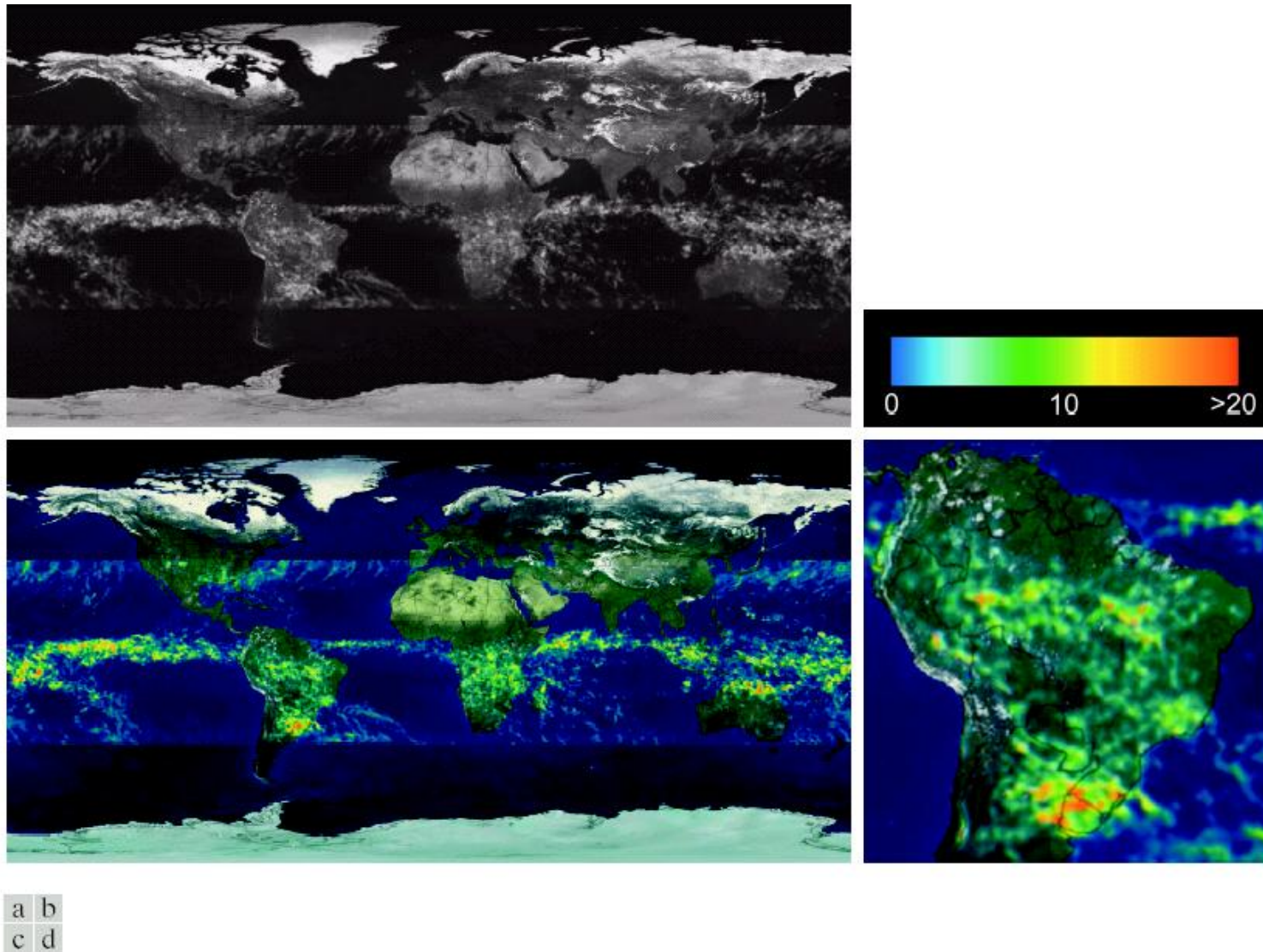
- Pentru imagini monocrome, cu contrast scăzut
- Util pentru operatorul uman (medicină, meteo etc.)
- Omul are sensibilitate vizuală mai mare la informația de crominanță decât la cea de luminanță



a b

**FIGURE 6.20** (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

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**FIGURE 6.22** (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South America region. (Courtesy of NASA.)

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