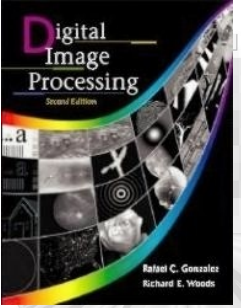

Processamento de Imagens Digitais

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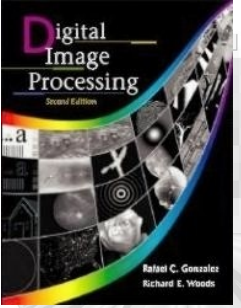
Fundamentos do Processamento de Imagens

Prof. Dr. Lucas Ferrari de



Fundamentos de Imagens Digitais

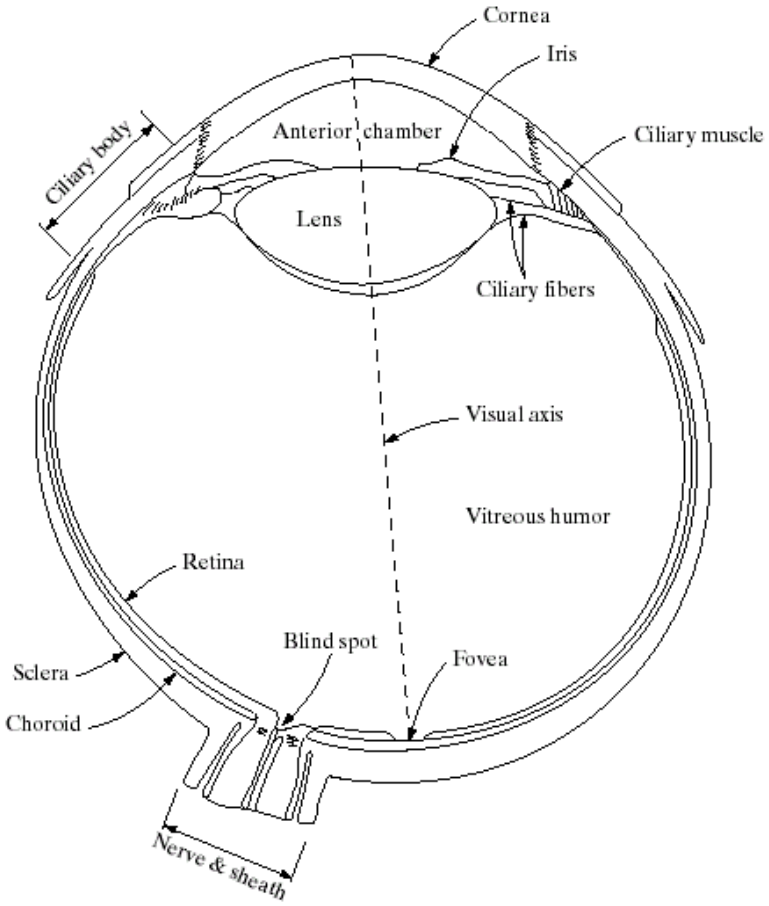
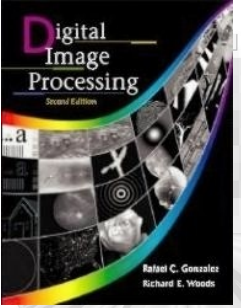


FIGURE 2.1 Simplified diagram of a cross section of the human eye.



Fundamentos de Imagens Digitais

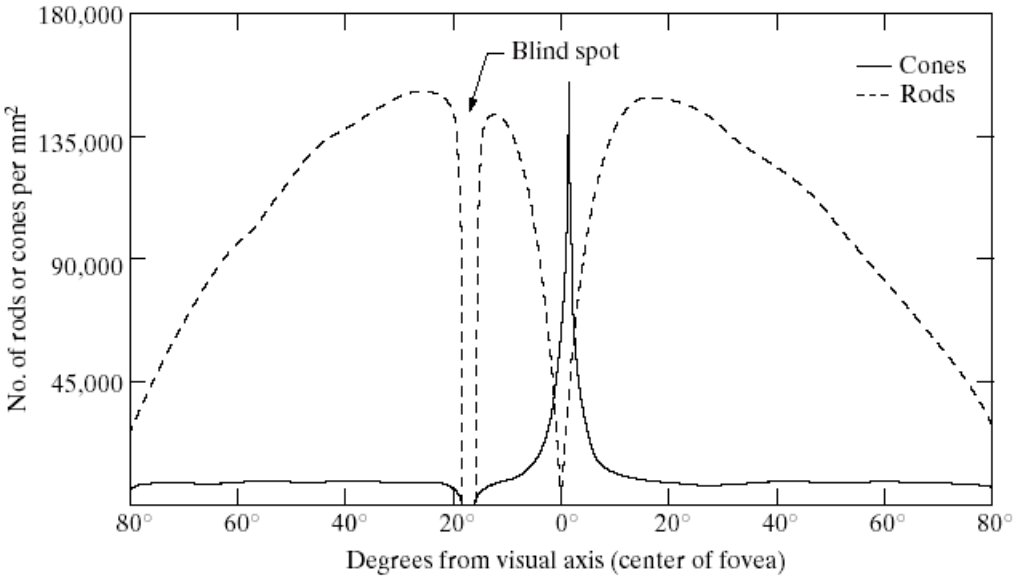


FIGURE 2.2 Distribution of rods and cones in the retina.

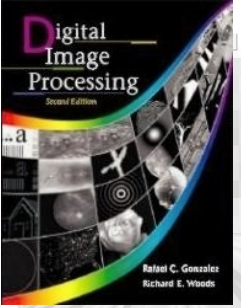


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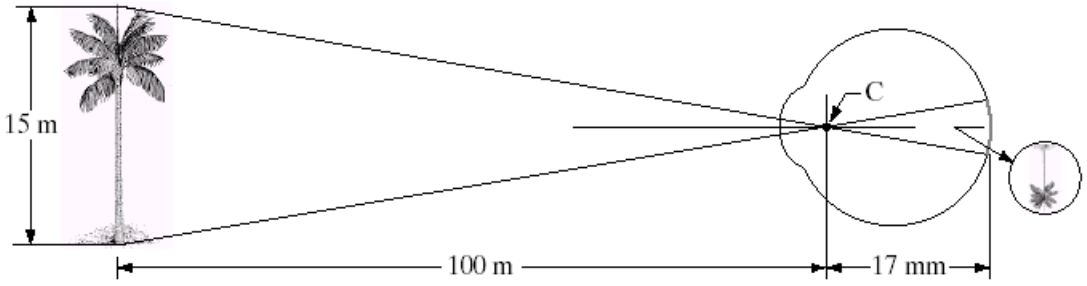
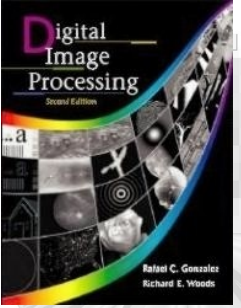
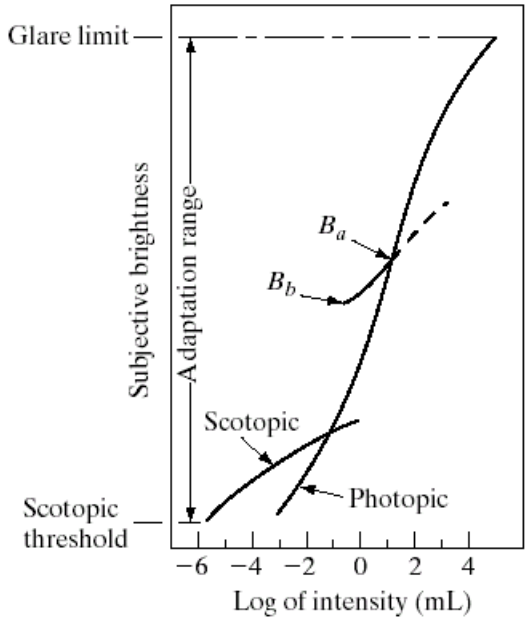
FIGURE 2.3
Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

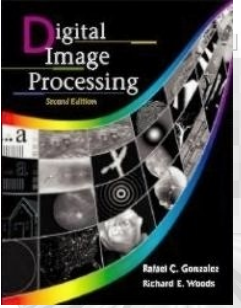




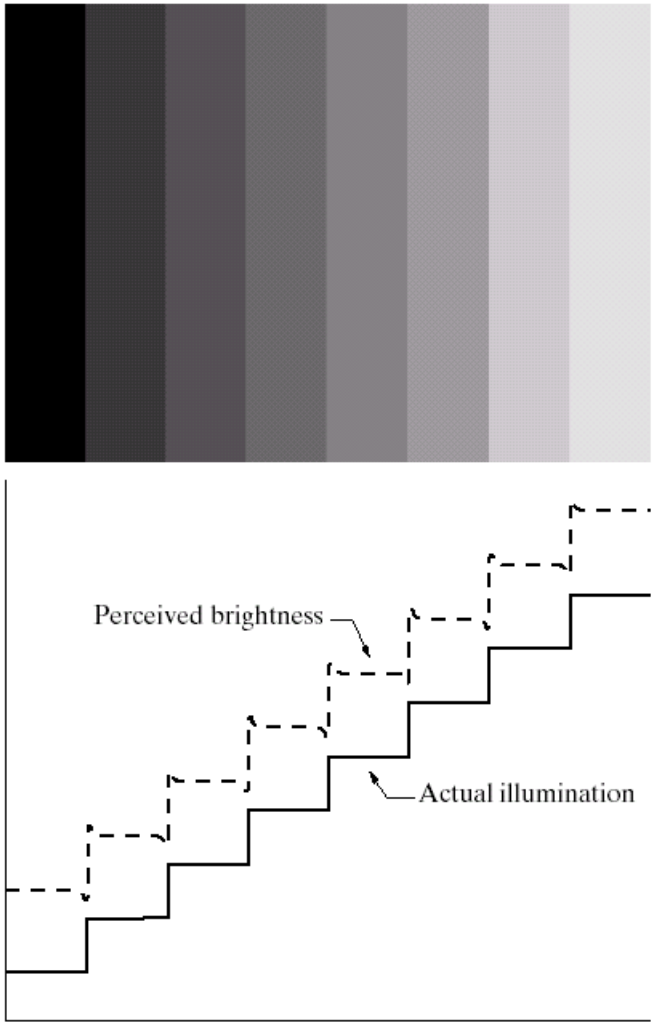
Fundamentos de Imagens Digitais

FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level.



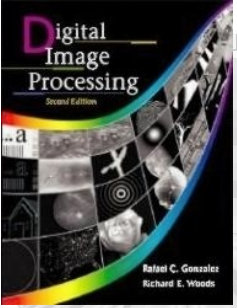


Fundamentos de Imagens Digitais



a
b

FIGURE 2.7
(a) An example showing that perceived brightness is not a simple function of intensity. The relative vertical positions between the two profiles in (b) have no special significance; they were chosen for clarity.



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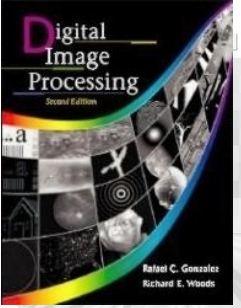
a b c

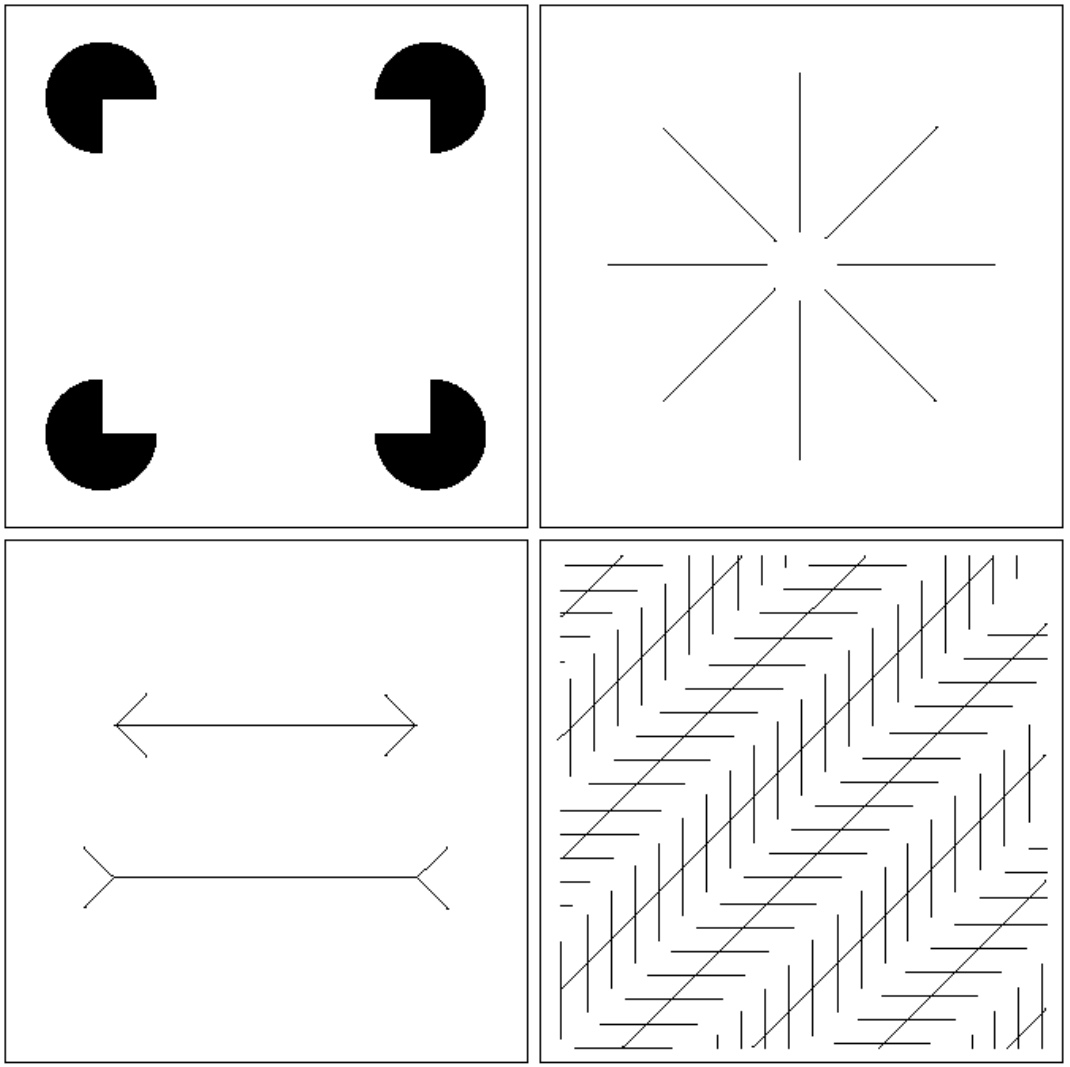
FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

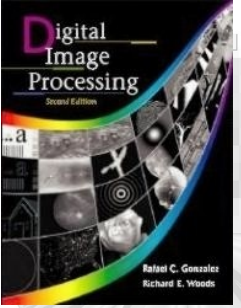


Fundamentos de Imagens Digitais

a b
c d

FIGURE 2.9 Some well-known optical illusions.





Fundamentos de Imagens Digitais

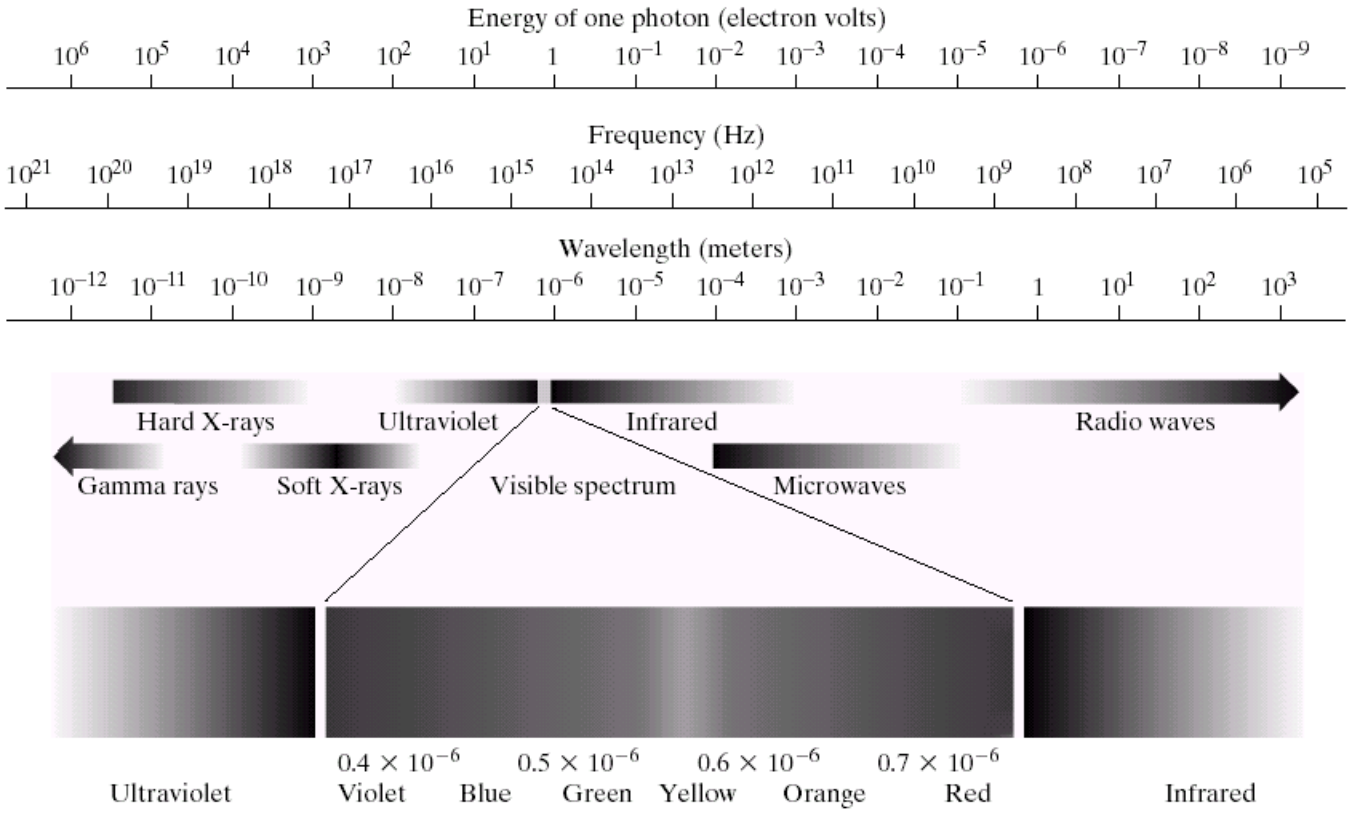
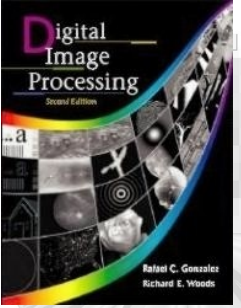


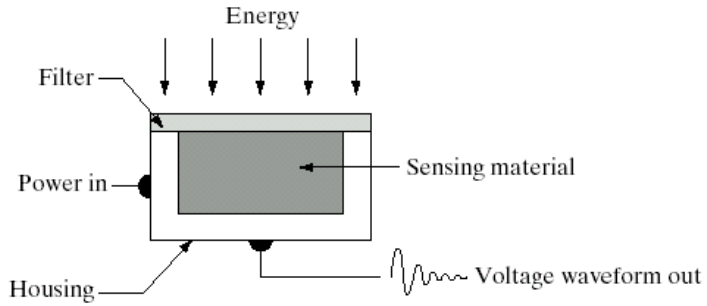
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

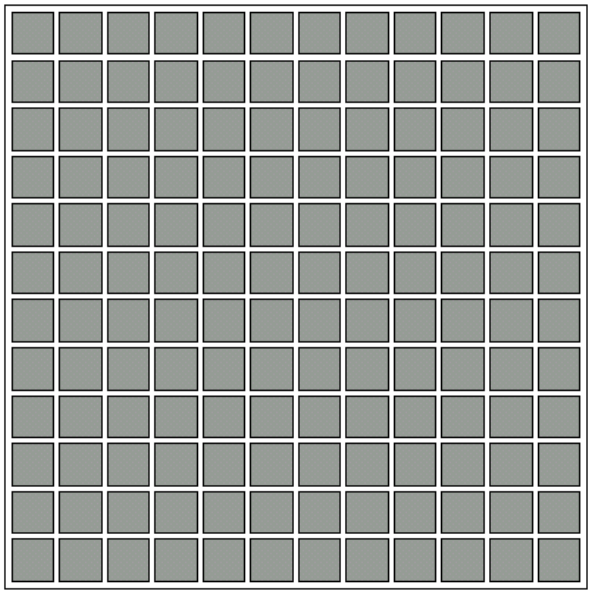


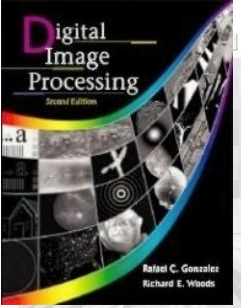
Fundamentos de Imagens Digitais

a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.







Fundamentos de Imagens Digitais

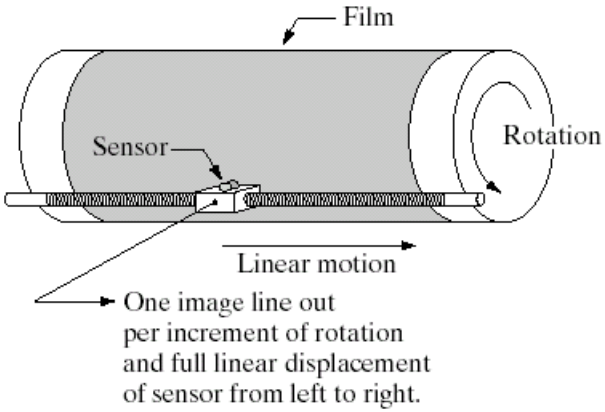
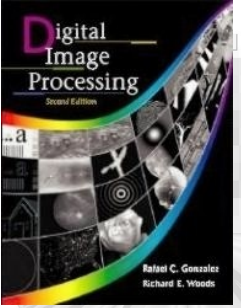
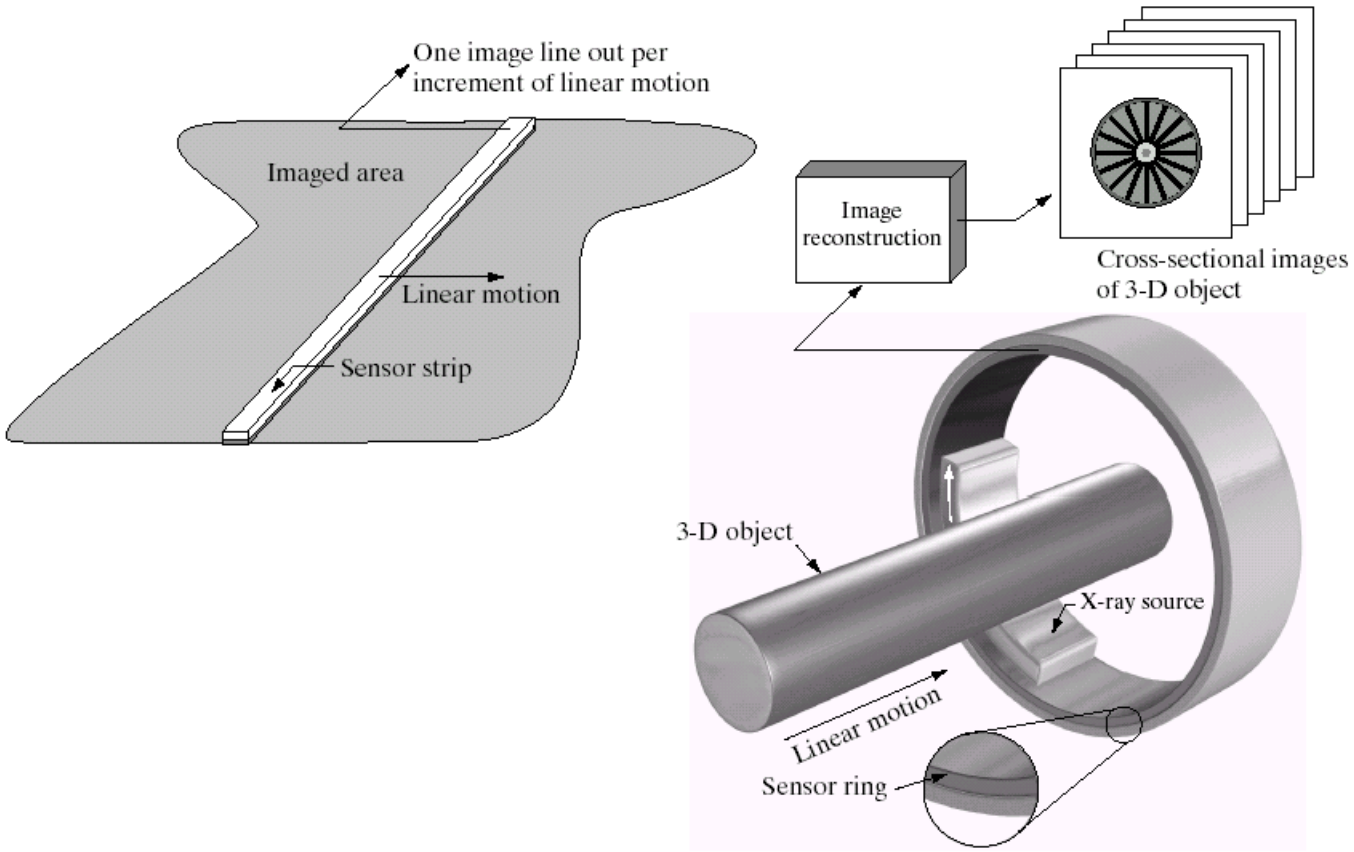


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

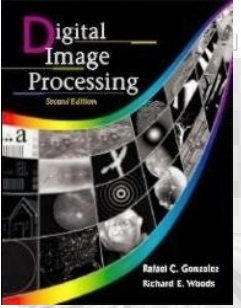


Fundamentos de Imagens Digitais

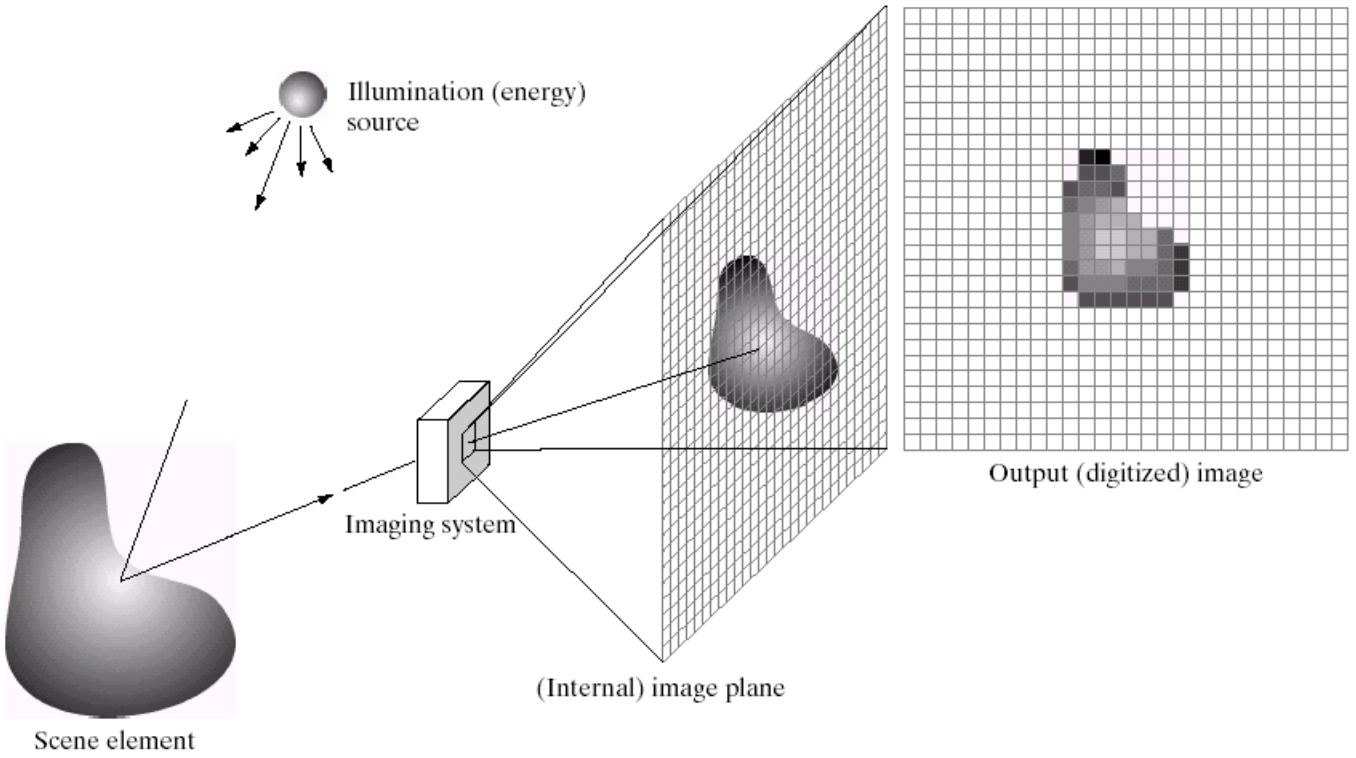


a b

FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

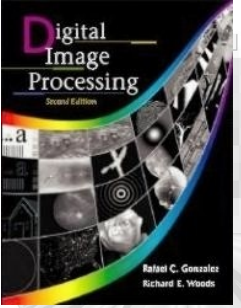


Fundamentos de Imagens Digitais

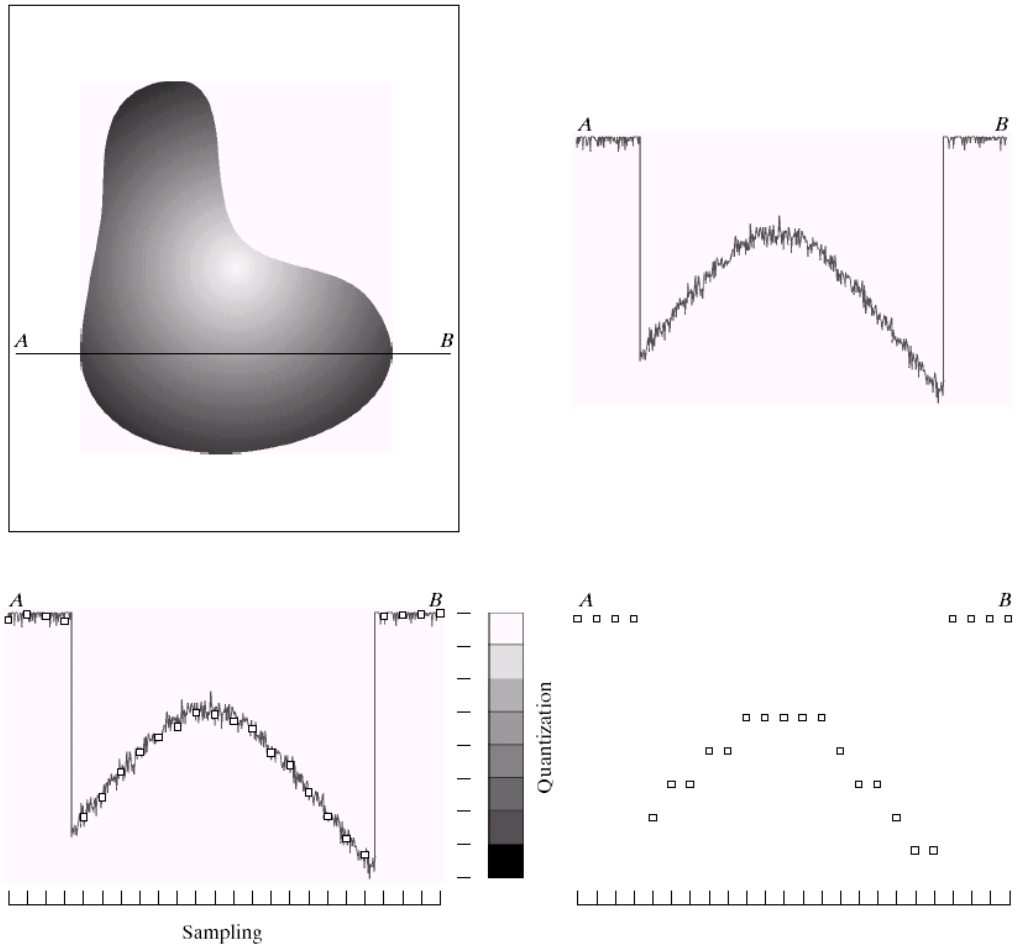


a b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

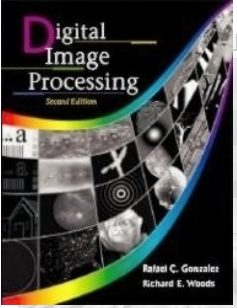


Fundamentos de Imagens Digitais



a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.



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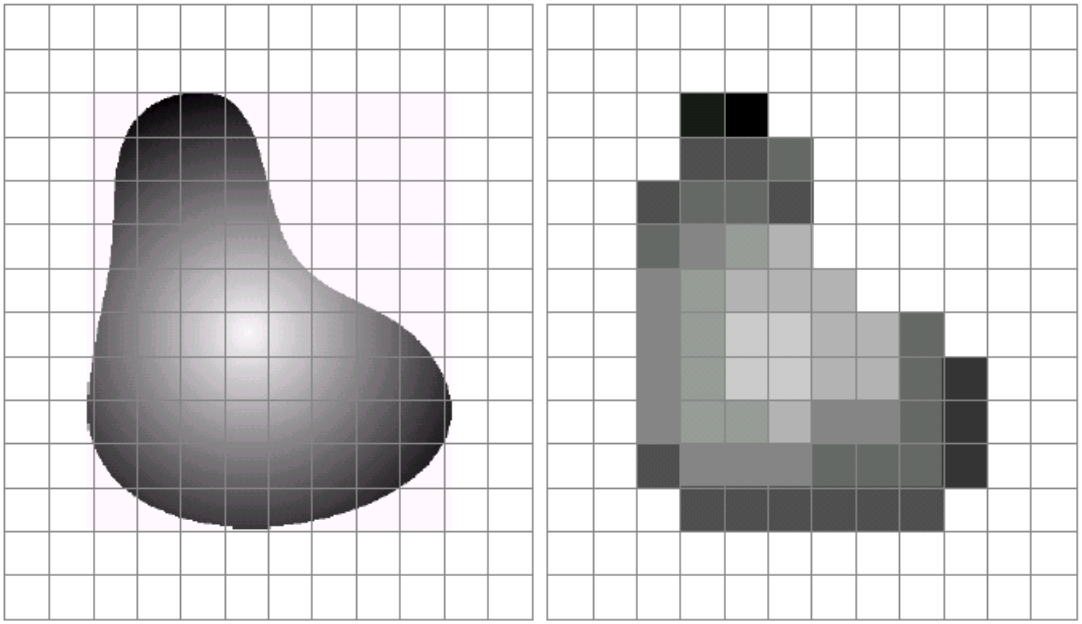
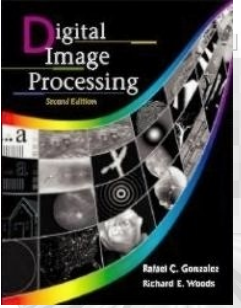


a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.



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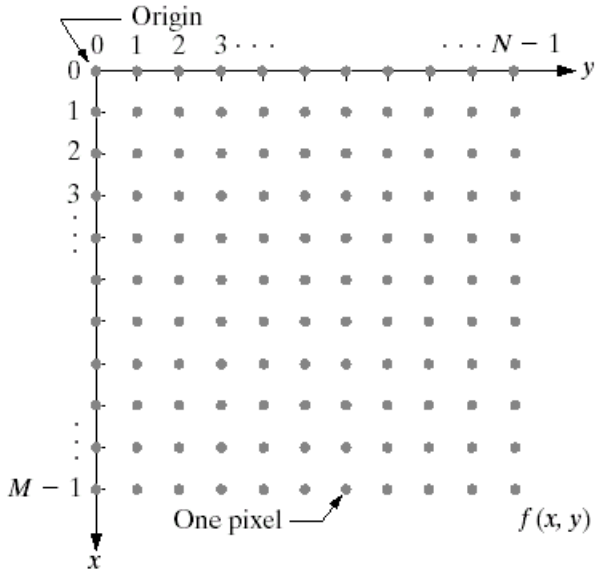
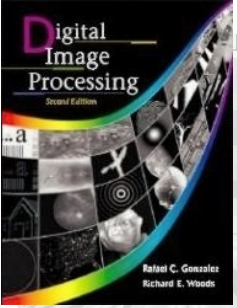


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

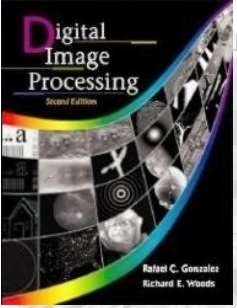


Fundamentos de Imagens Digitais

TABLE 2.1
Number of storage bits for various values of N and k.

N/k	1 ($L = 2$)	2 ($L = 4$)	3 ($L = 8$)	4 ($L = 16$)	5 ($L = 32$)	6 ($L = 64$)	7 ($L = 128$)	8 ($L = 256$)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

→ 8MB



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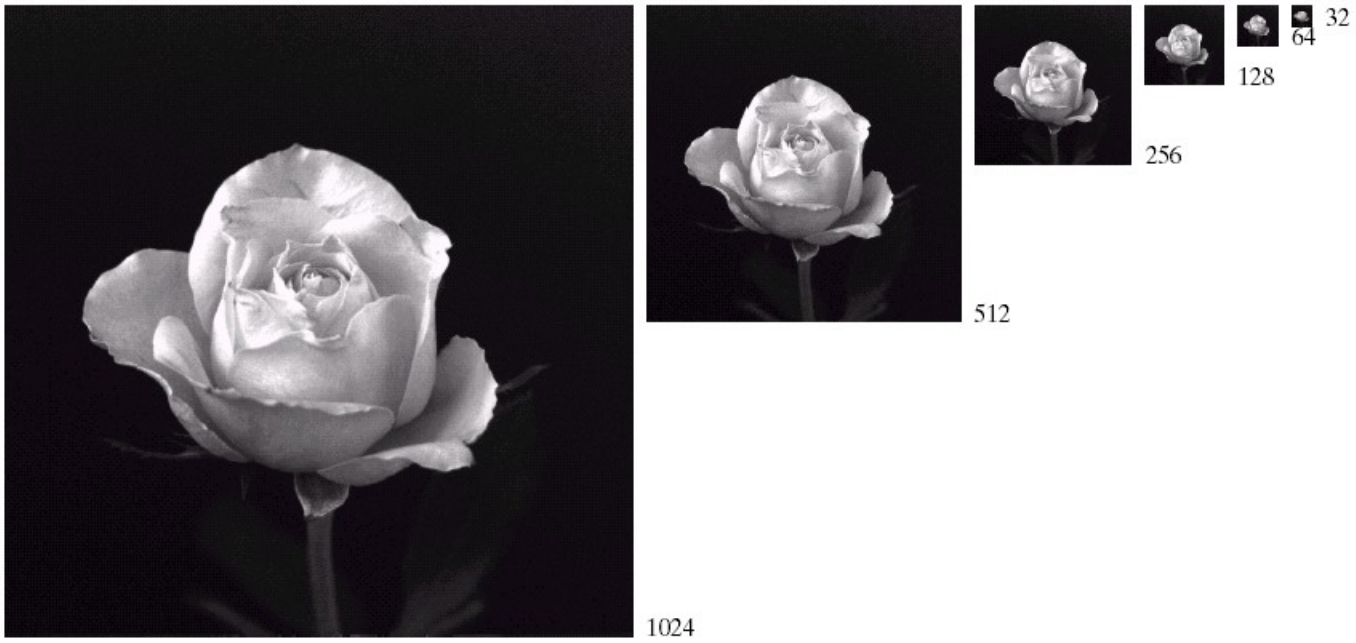
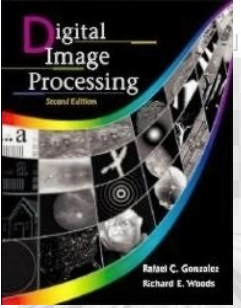
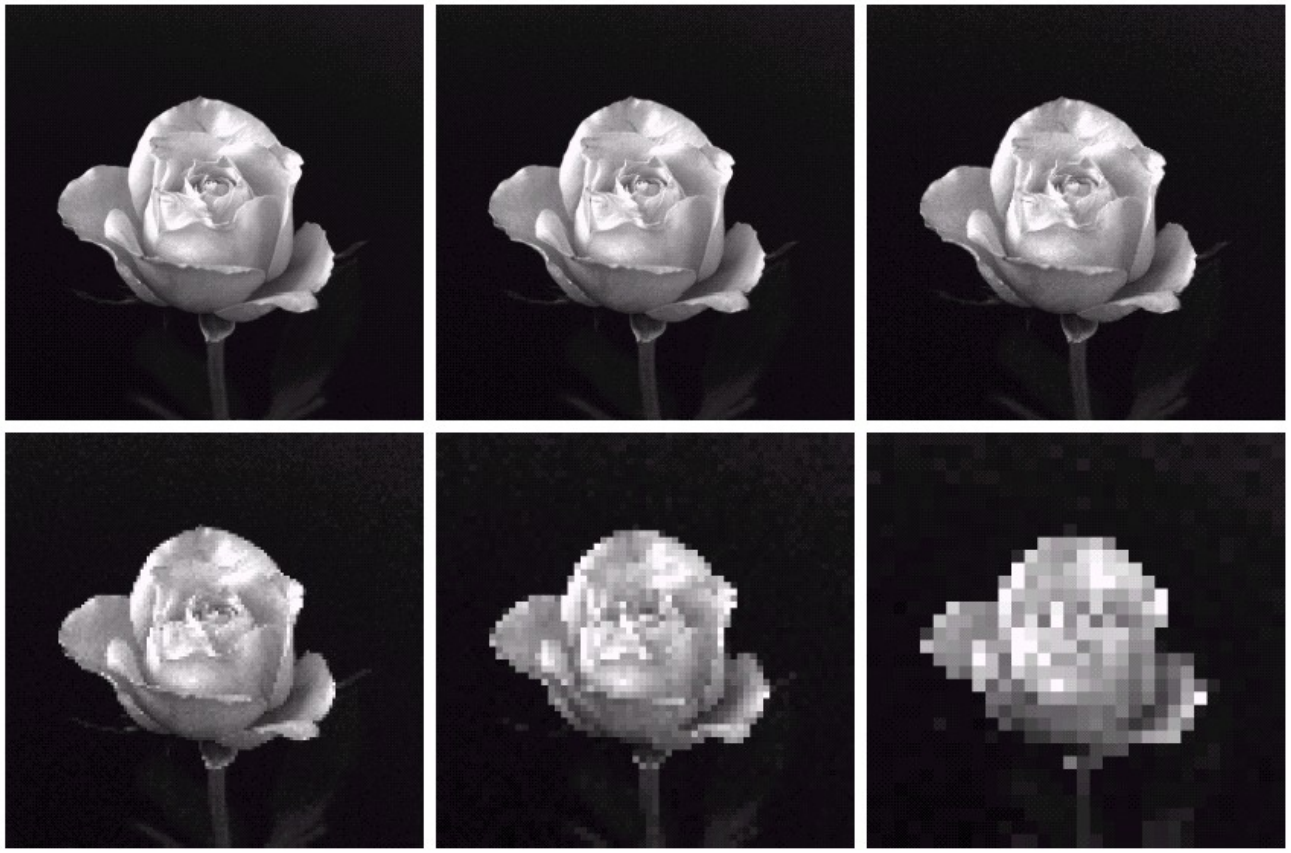


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

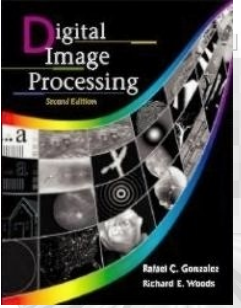


Fundamentos de Imagens Digitais

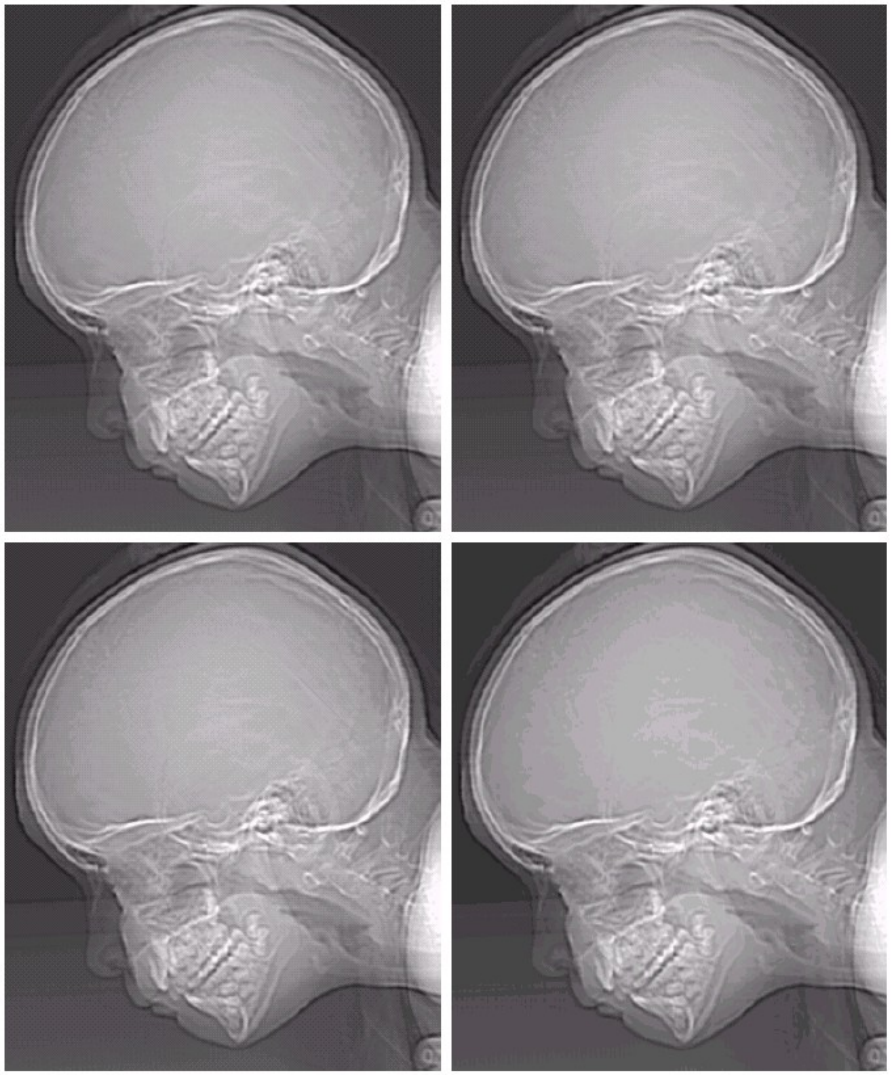


a b c
d e f

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



Fundamentos de Imagens Digitais



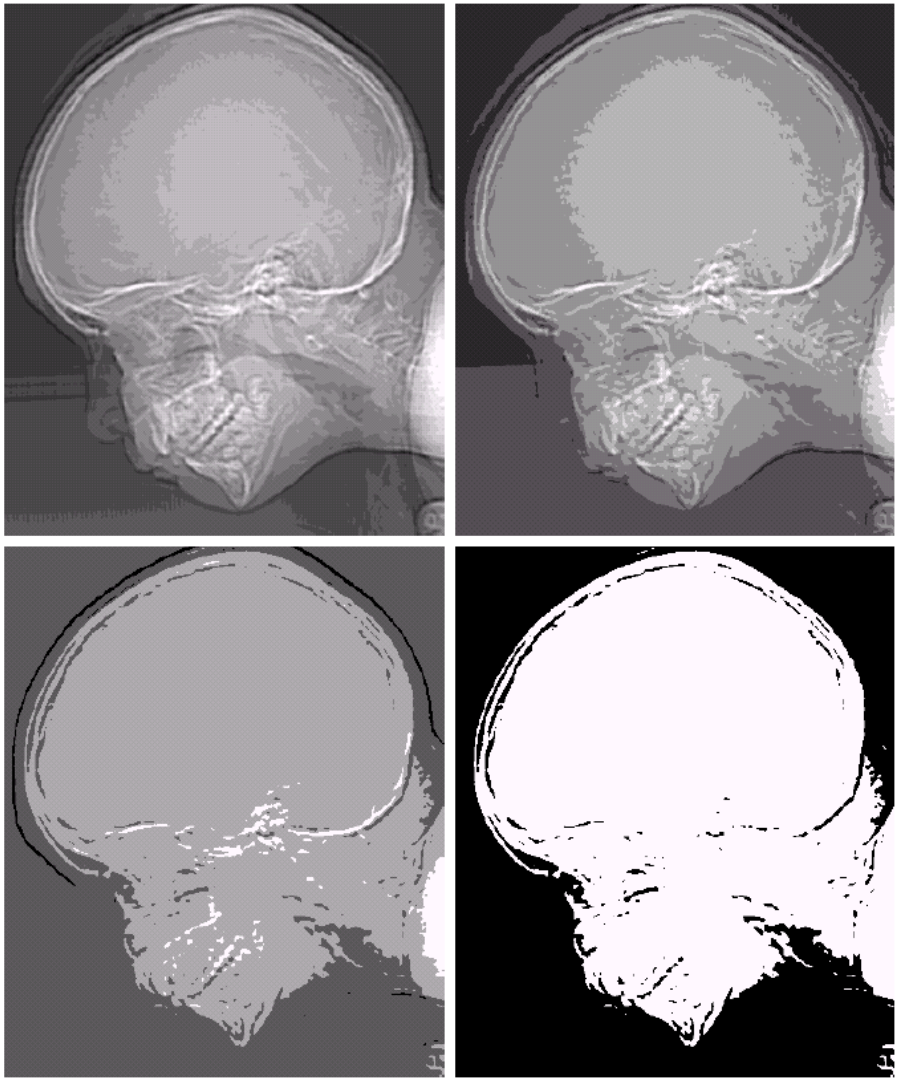
a b
c d

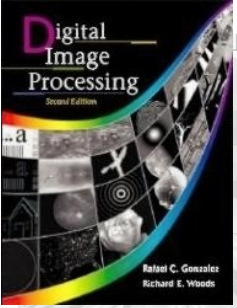
FIGURE 2.21
(a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

Fundamentos de Imagens Digitais

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.)





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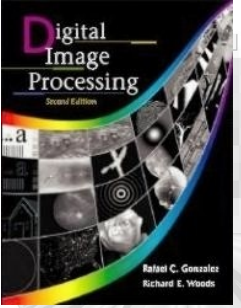
a b c

FIGURE 2.22 (a) Image with a low level of detail. (b) Image with a medium level of detail. (c) Image with a relatively large amount of detail. (Image (b) courtesy of the Massachusetts Institute of Technology.)



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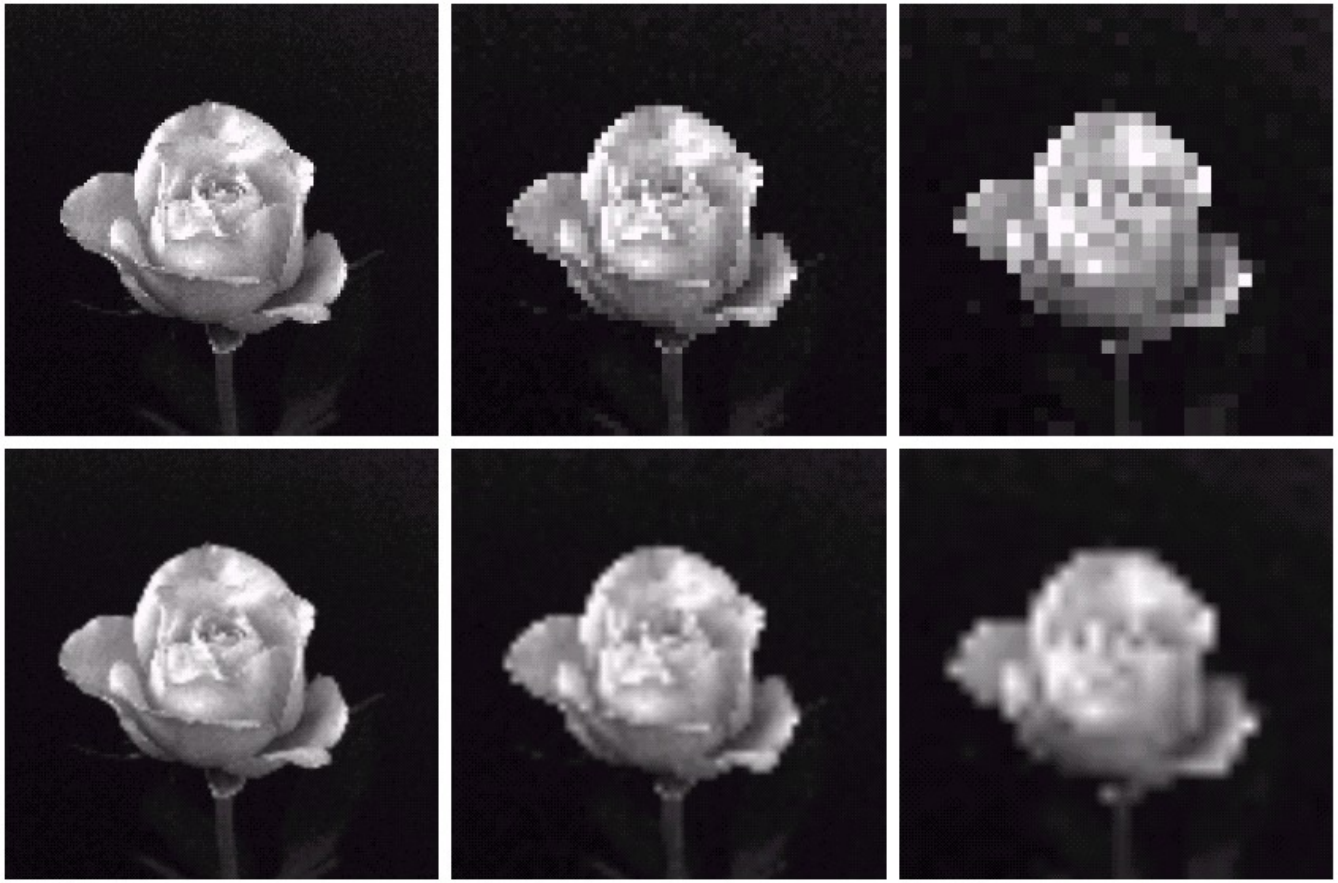
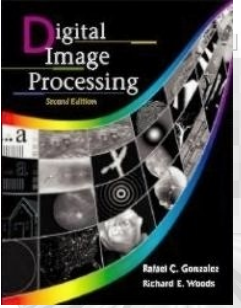
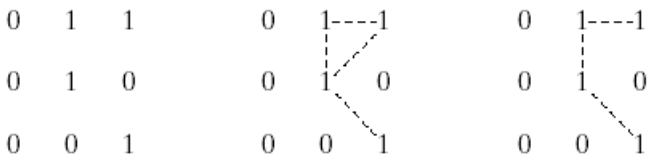


a b c
d e f

FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

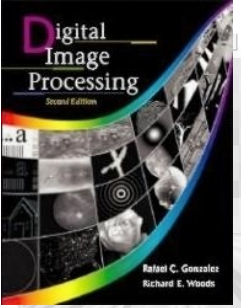


Fundamentos de Imagens Digitais



a b c

FIGURE 2.26 (a) Arrangement of pixels; (b) pixels that are 8-adjacent (shown dashed) to the center pixel; (c) *m*-adjacency.



Fundamentos de Imagens Digitais

Medidas de Distância:

- Dados os pontos *p*, *q* e *z* com coordenadas *(x,y)*, *(s,t)* e *(u,v)*, D é uma função de distância se:

(1) $D(p,q) \geq 0$

(2) $D(p,q) = 0$, se e somente se $p=q$

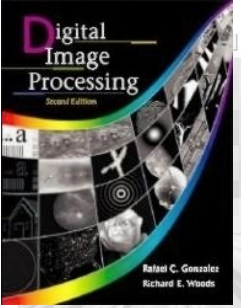
(3) $D(p,q) = D(q,p)$

(4) $D(p,z) \leq D(p,q)+D(q,z)$

Distância Euclidiana: $D_e(p,q)=[(x-s)^2+(y-t)^2]^{1/2}$

Distância City-Block: $D_4(p,q)=|x-s|+|y-t|$

Distância Xadrez: $D_8(p,q)=\max(|x-s|,|y-t|)$

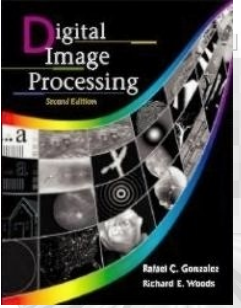


Fundamentos de Imagens Digitais

- Distância City-Block:
  - Os pixels com distâncias com algum valor ***r*** formam um losango centrado em (x,y).

Exemplo: $D_4 \leq 2$

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

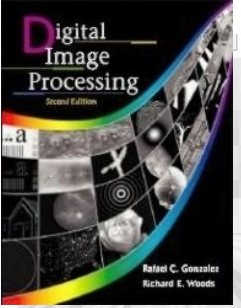


Fundamentos de Imagens Digitais

- Distância Xadrez:
  - Os pixels com distâncias com algum valor *r* formam um quadrado centrado em (x,y).

Exemplo: $D_8 \leq 2$

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2



Fundamentos de Imagens Digitais

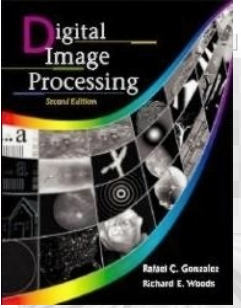
- Operações Aritméticas:
  - Amplamente utilizadas na área de processamento de imagens;
  - São denotadas entre dois pixels p e q como:

Adição: p + q

Subtração:p – q

Multiplicação: p*q (também pq e p x q)

Divisão: p/q (também p÷q)



Fundamentos de Imagens Digitais

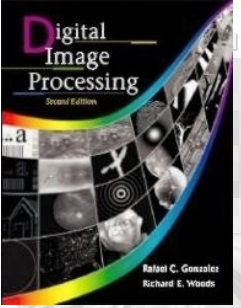
- Operações Aritméticas:

Adição: redução de ruído (média);

Subtração: remover informação estática de fundo (imagens em movimento);

Multiplicação e Divisão: correção de sombras nos níveis de cinza causadas pela iluminação não uniforme;

Um pixel por vez e o resultado pode ser armazenado em uma das imagens na posição (x,y), pois não será mais necessário utilizar o valor anterior.



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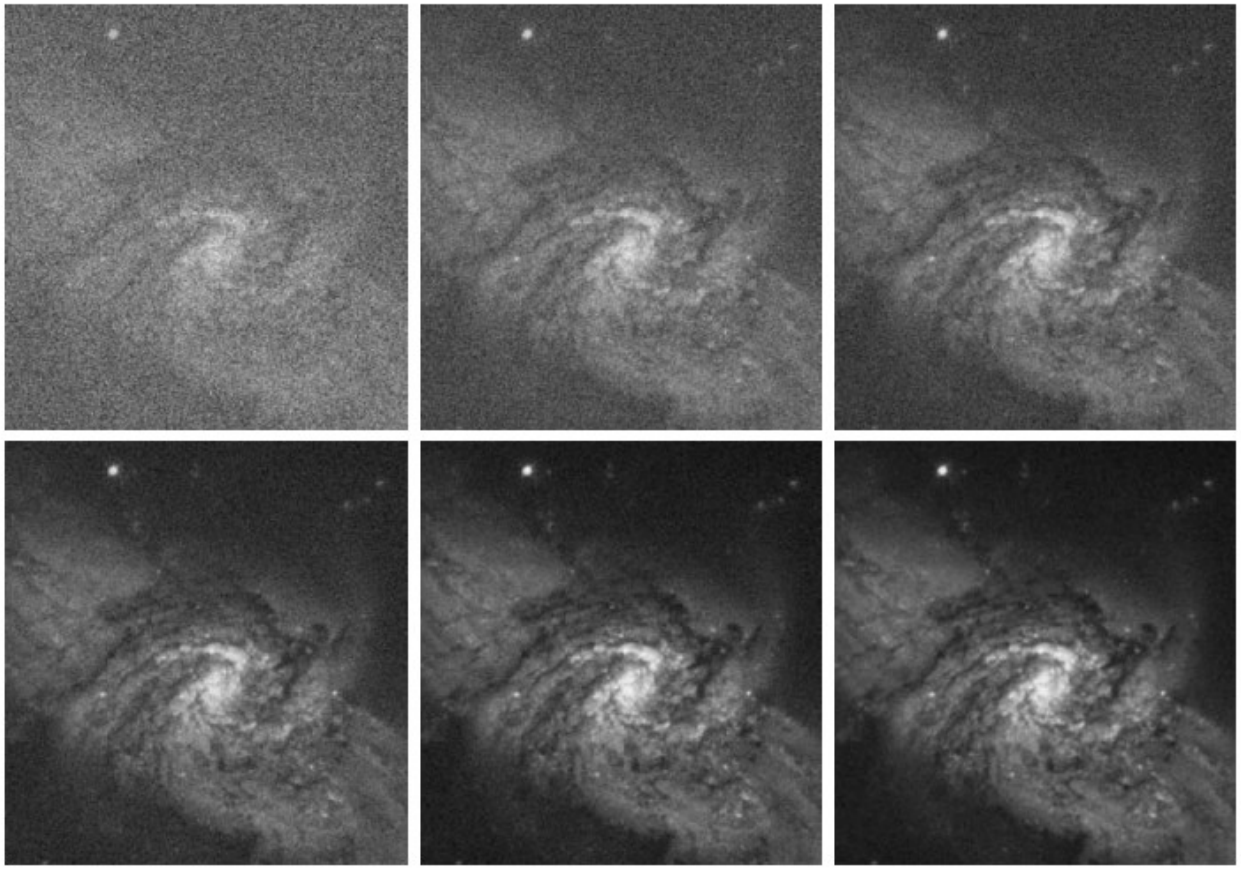
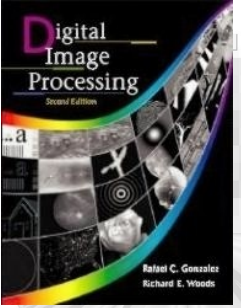
Fundamentos de Imagens Digitais

Adição:



a b c
d e f

FIGURE 2.26 (a) Image of Galaxy Pair NGC 3314 corrupted by additive Gaussian noise. (b)–(f) Results of averaging 5, 10, 20, 50, and 100 noisy images, respectively. (Original image courtesy of NASA.)

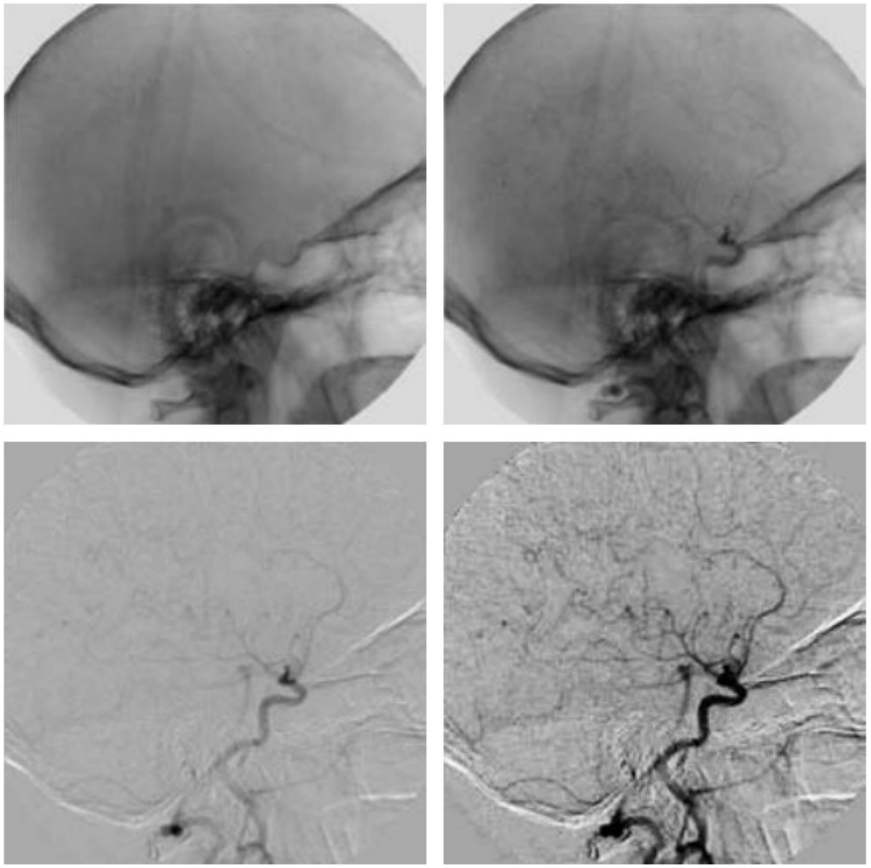


Fundamentos de Imagens Digitais

Subtração:

a b
c d

FIGURE 2.28 Digital subtraction angiography. (a) Mask image. (b) A live image. (c) Difference between (a) and (b). (d) Enhanced difference image. (Figures (a) and (b) courtesy of The Image Sciences Institute, University Medical Center, Utrecht, The Netherlands.)

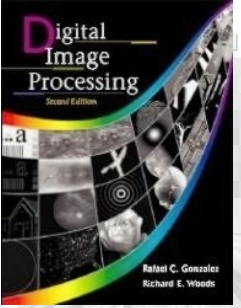


Fundamentos de Imagens Digitais

Subtração:

Subtração

Imagem deslocada em 2 pixels para direita e para cima

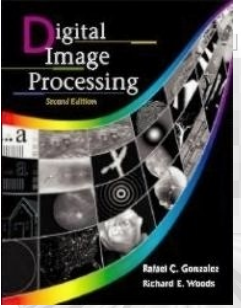


Fundamentos de Imagens Digitais

Multiplicação:

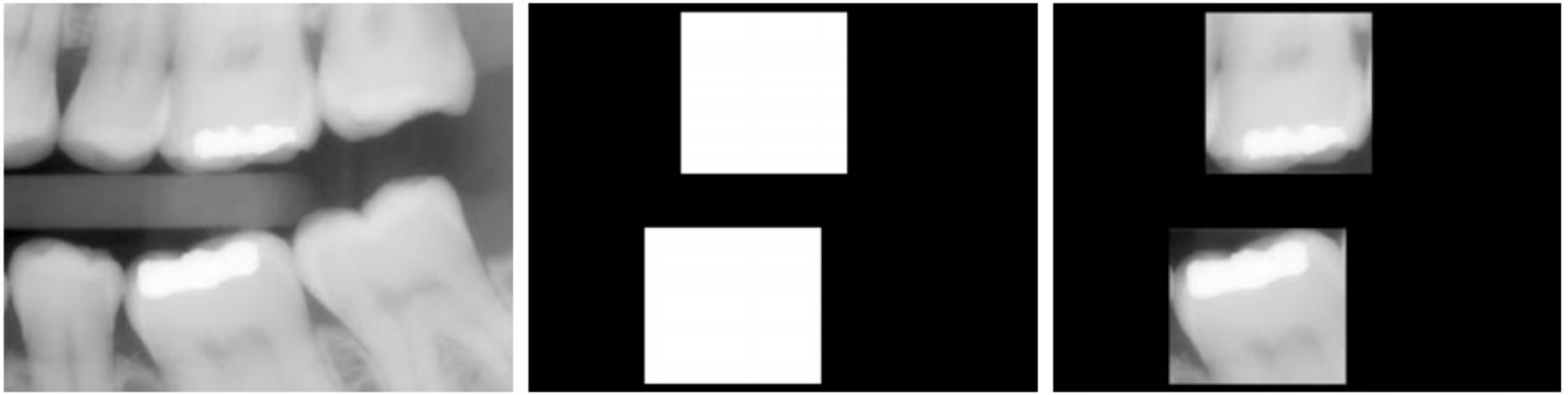
a b c

FIGURE 2.29 Shading correction. (a) Shaded SEM image of a tungsten filament and support, magnified approximately 130 times. (b) The shading pattern. (c) Product of (a) by the reciprocal of (b). (Original image courtesy of Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)



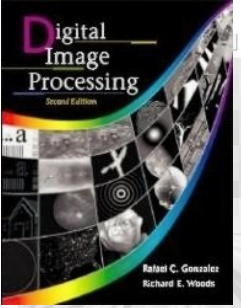
Fundamentos de Imagens Digitais

Multiplicação:



a b c

FIGURE 2.30 (a) Digital dental X-ray image. (b) ROI mask for isolating teeth with fillings (white corresponds to 1 and black corresponds to 0). (c) Product of (a) and (b).



Fundamentos de Imagens Digitais

Operações Lógicas:

Somente em imagens binárias;

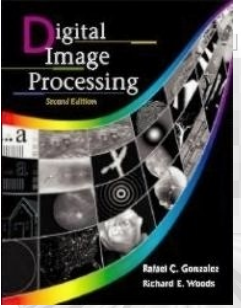
Utilizadas para tarefas como mascaramento, análise de forma e detecção de características.

Notações:

E: p E q (também, p • q)

OU: p OU q (também, p+q)

COMPLEMENTO: NÃO q (também, $\bar{q}$)



Fundamentos de Imagens Digitais

FIGURE 2.33 Illustration of logical operations involving foreground (white) pixels. Black represents binary 0s and white binary 1s. The dashed lines are shown for reference only. They are not part of the result.