180206081104P2009H

图像处理与分析

第二讲: 数字图像的基本概念

第一讲：简要回顾 (I)

- 图像处理的基本概念
  - 图像和视频包含的基本信息
  - 可见光谱，光子能量的普朗克定律
  - 图像处理的主要目的与不同层次
  - 图像处理与计算机视觉的关系
  - 图像处理在不同领域的应用和简要历史
  - 图像处理系统的基本构成

- 人类视觉的基本机理

- 编程软件MATLAB和Python简介

第一讲：简要回顾 (II)

- 课程组织和相关信息
  - 重要相关专业杂志和国际会议
  - 重要网上资源和同类课程信息
- 图像格式的基本概念和常用类型 (TIFF, JPEG)
- 图像获取的基本概念
  - 典型采集场景
  - 典型成像设备 CCD vs CMOS
- 图像采样与量化
  - 像素的位深度 (bit depth)
  - 空间采样，灰度采样

数字图像采集典型场景示例

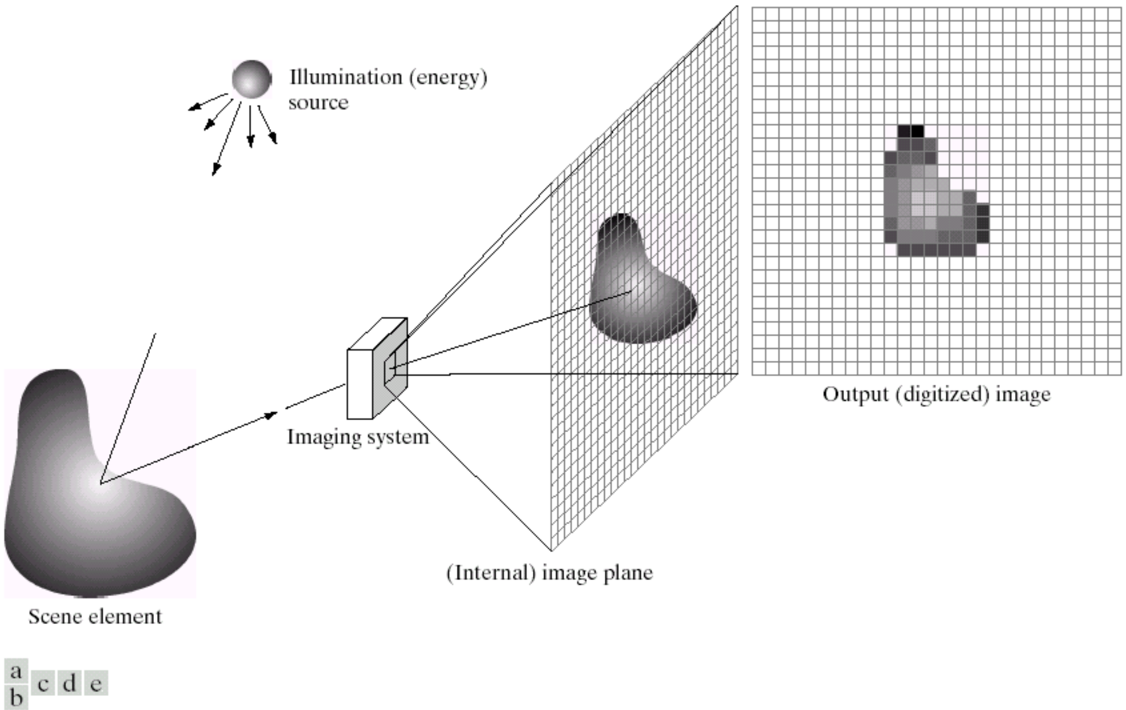


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

一个简单的成像模型 (I)

将二维图像记为 $f(x,y)$

$$0 \le f(x,y) < \infty$$

将入射到物体的光照分布函数记为 $i(x,y)$

$$0 \le i(x,y) < \infty$$

将物体的表面反射函数为 $r(x,y)$

$$0 \le r(x,y) \le 1$$

一个简单的成像模型 (II)

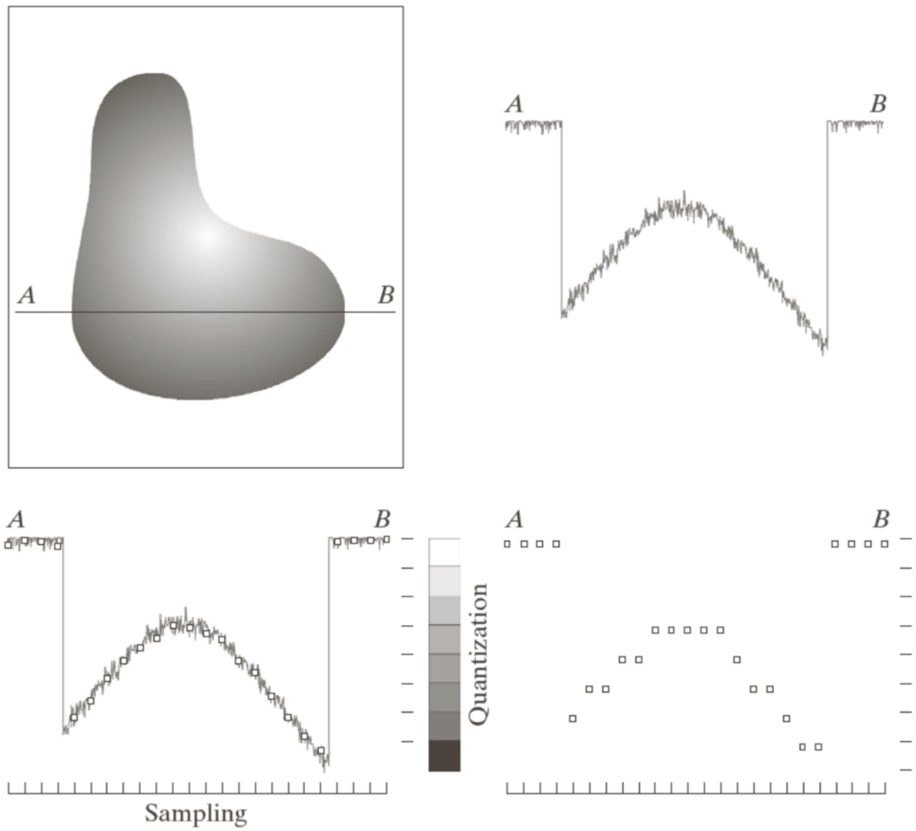
$$f(x,y)=i(x,y)r(x,y)$$

如果将物体的表面反射的转换函数记为

$$0 \le c(x,y) \le 1$$

$$f(x,y)=i(x,y)r(x,y)c(x,y)$$

采样与量化 (I)



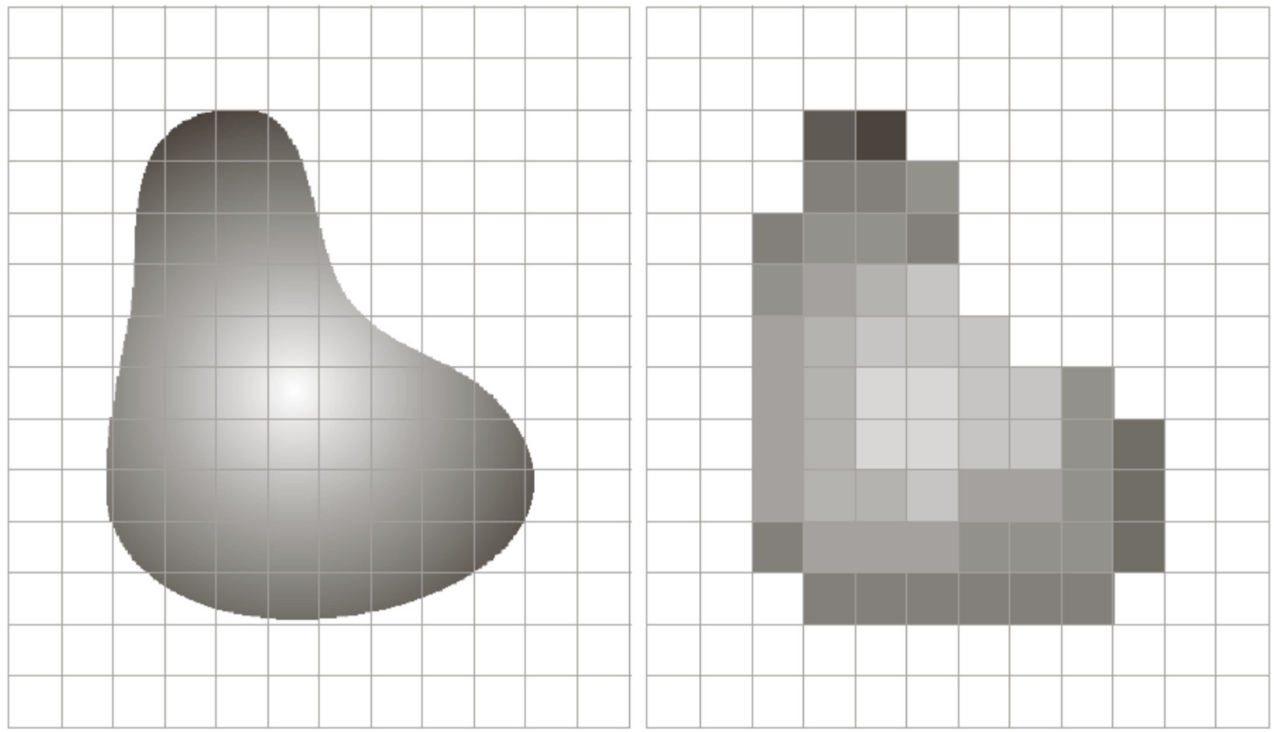
a b
c d

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.

采样与量化 (II)

- 空间采样与量化由物理像素(光学系统+图像采集芯片）决定。

- 灰度采样与量化由模拟-数字转换决定。



a b

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

图像的空间分辨率

a b
c d

FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

图像的空间分辨率

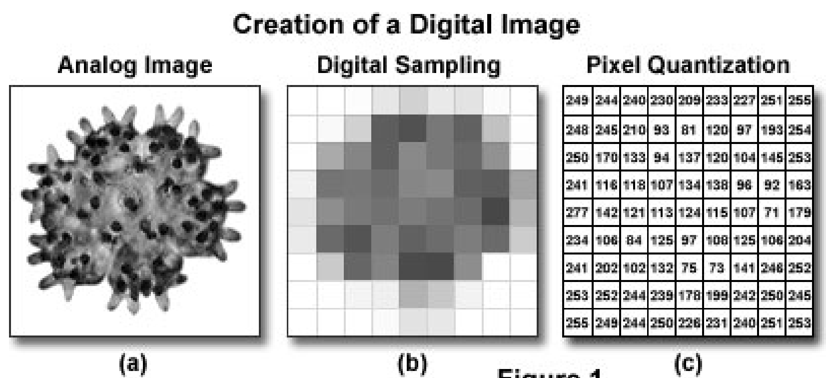


Figure 1

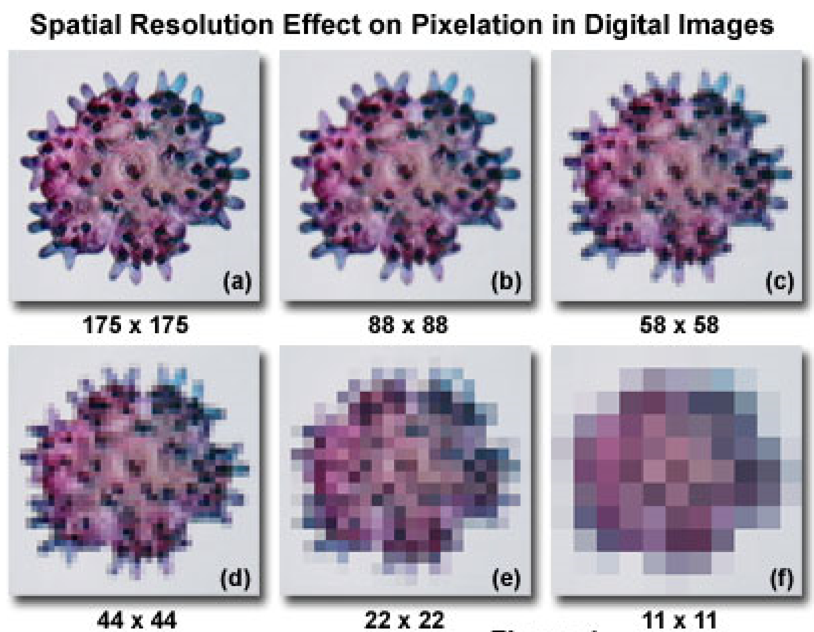
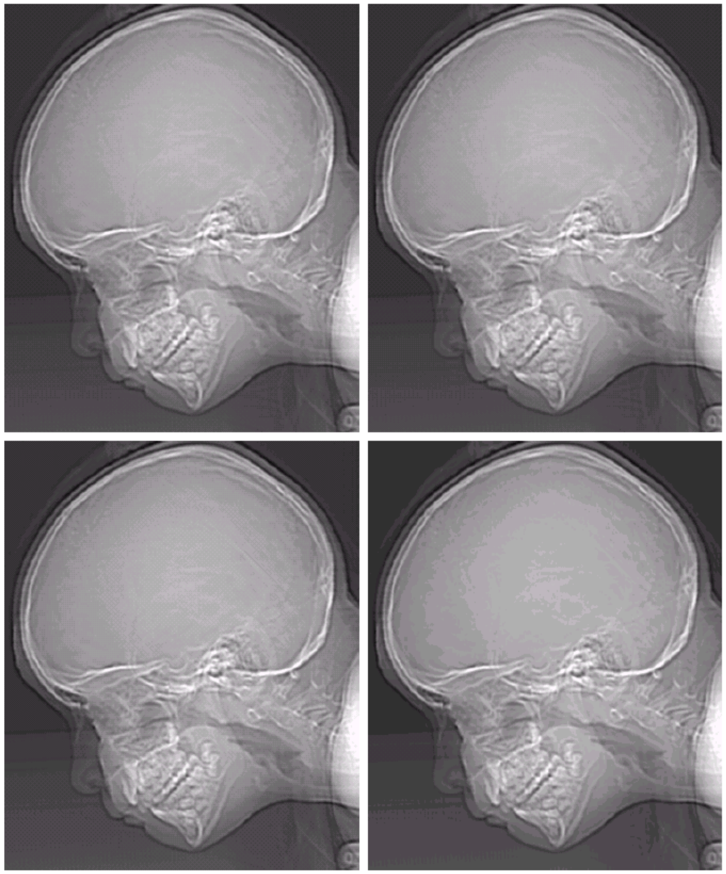


Figure 4

图像的灰度分辨率

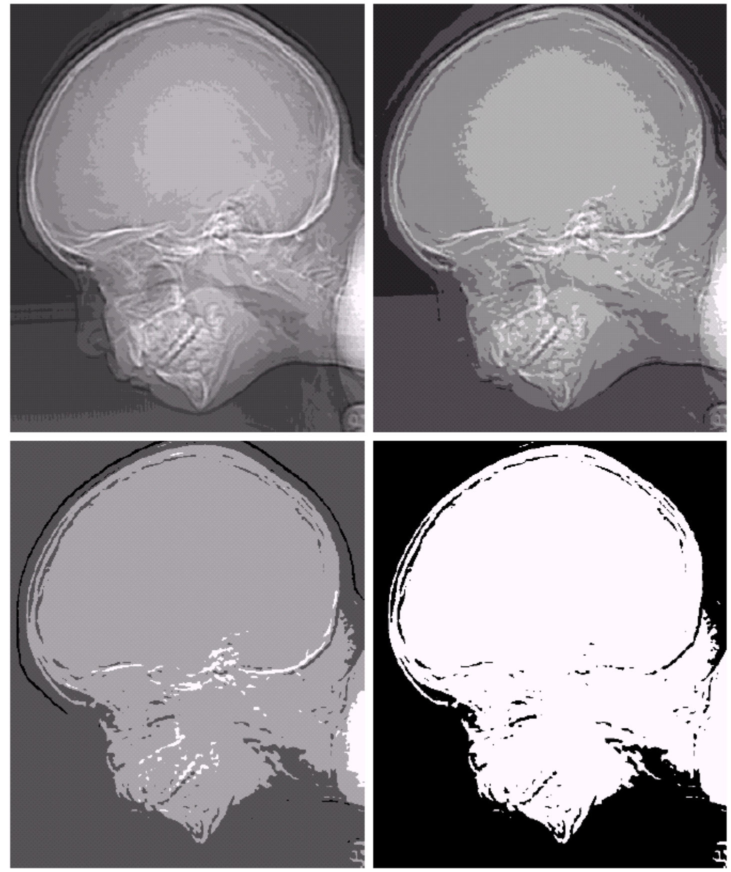


a b
c d

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.

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.)

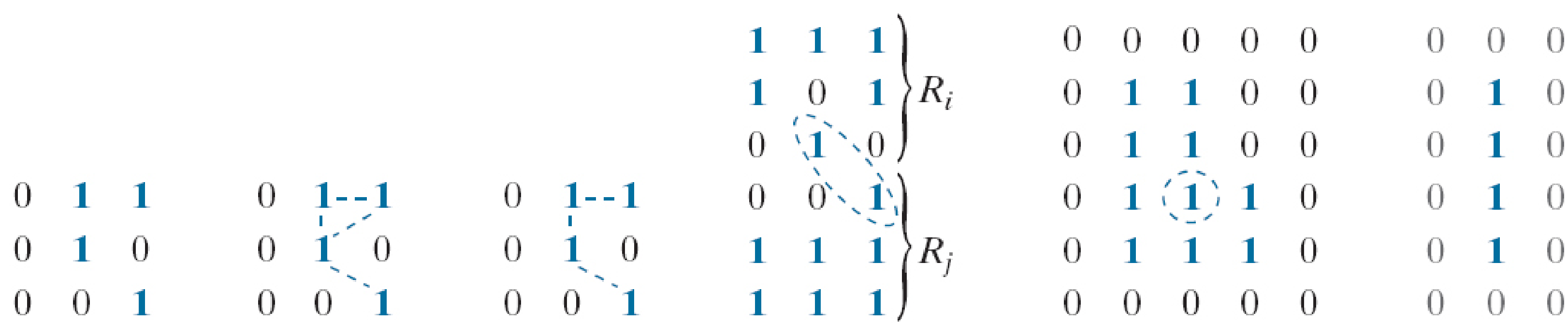


内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

像素间的基本关系(I)

(a) An arrangement of pixels. (b) Pixels that are 8-adjacent (adjacency is shown by dashed lines). (c) **m**-adjacency. (d) Two regions (of 1's) that are 8-adjacent. (e) The circled point is on the boundary of the 1-valued pixels only if 8-adjacency between the region and background is used. (f) The inner boundary of the 1-valued region does not form a closed path, but its outer boundary does.



a b c d e f

像素间的基本关系(II)

- 4-邻域

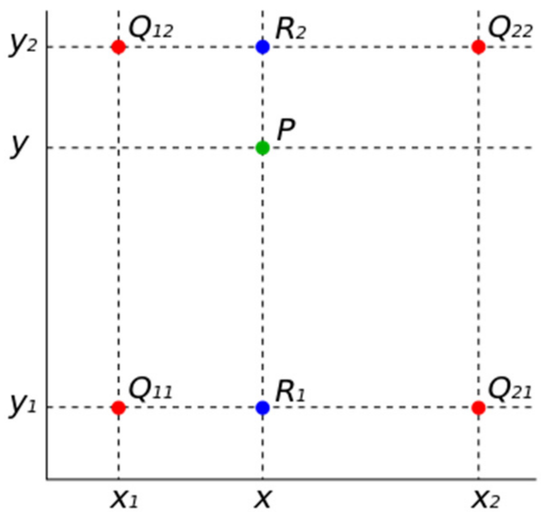
$$p=(x,y)\rightarrow N_4(p)=(x-1,y),(x+1,y),(x,y-1),(x,y+1)$$

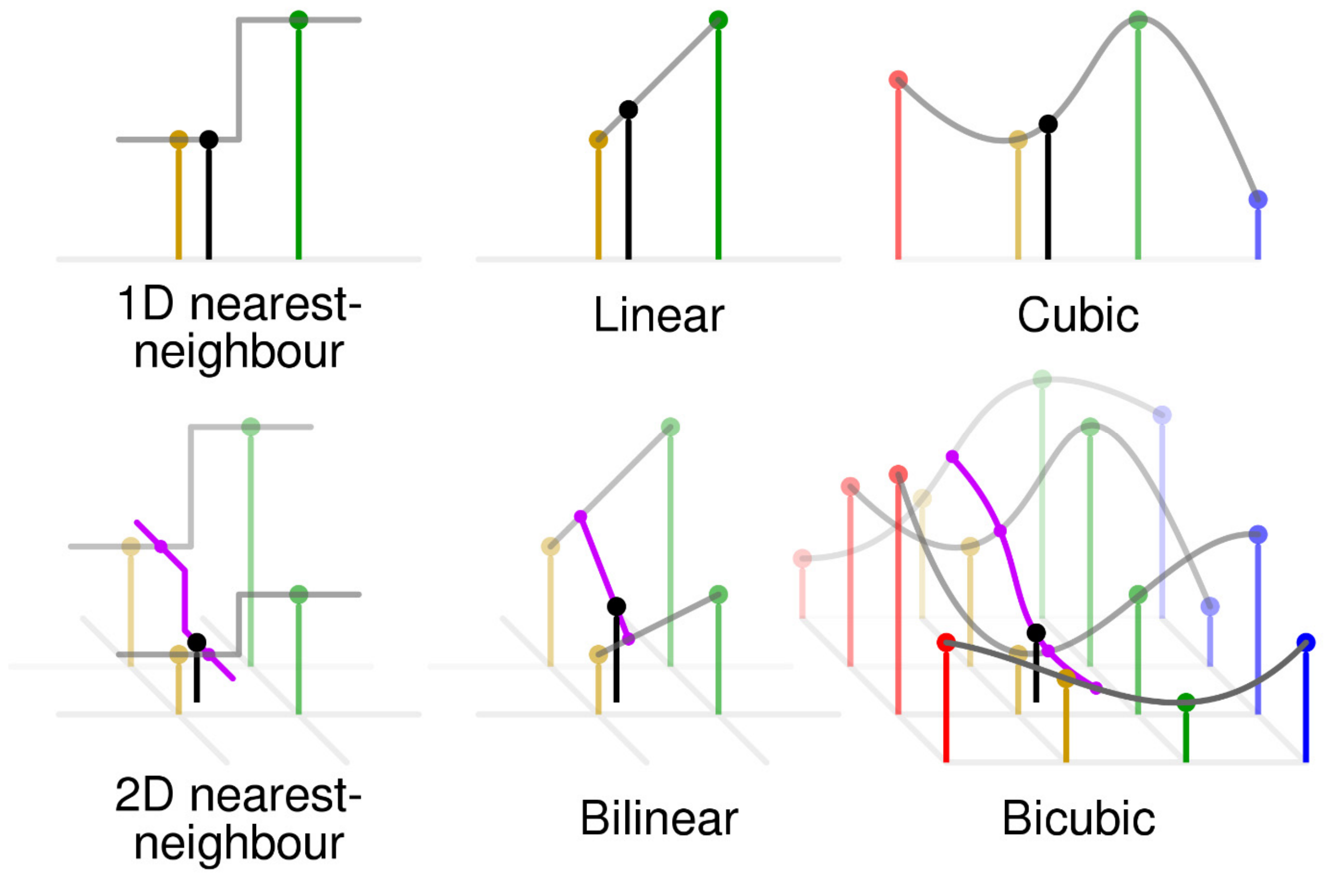
$$p=(x,y)\rightarrow N_d(p)=(x-1,y-1),(x+1,y-1),(x-1,y+1),(x+1,y+1)$$

- 8-邻域

$$p=(x,y)\rightarrow N_8(p)=N_4(p)\cup N_d(p)$$

图像插值





https://en.wikipedia.org/wiki/Bilinear_interpolation

内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

像素间的基本运算

$$s(x,y)=f(x,y)+g(x,y)$$

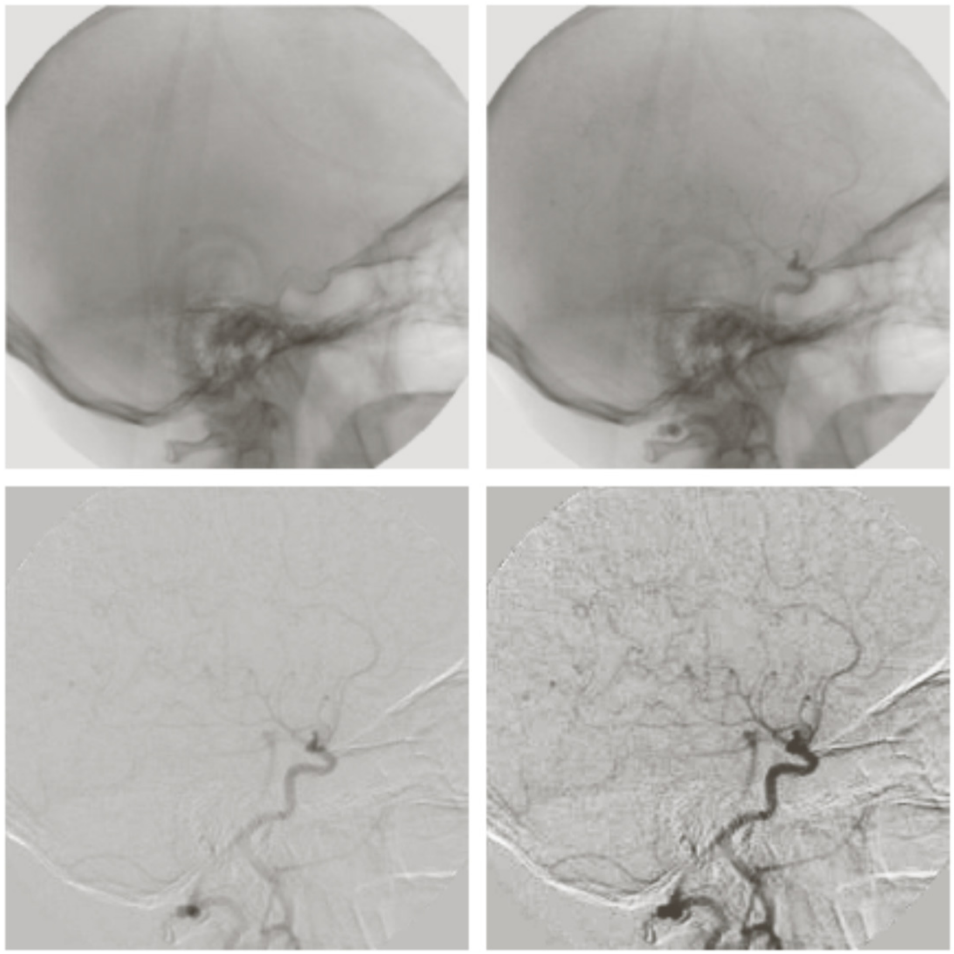
$$d(x,y)=f(x,y)-g(x,y)$$

$$p(x,y)=f(x,y)*g(x,y)$$

$$v(x,y)=f(x,y)\div g(x,y)$$

$$f(x,y)=\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \qquad g(x,y)=\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

图像的简单算数运算 (I)



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.)

图像的简单算数运算 (II)

a b c

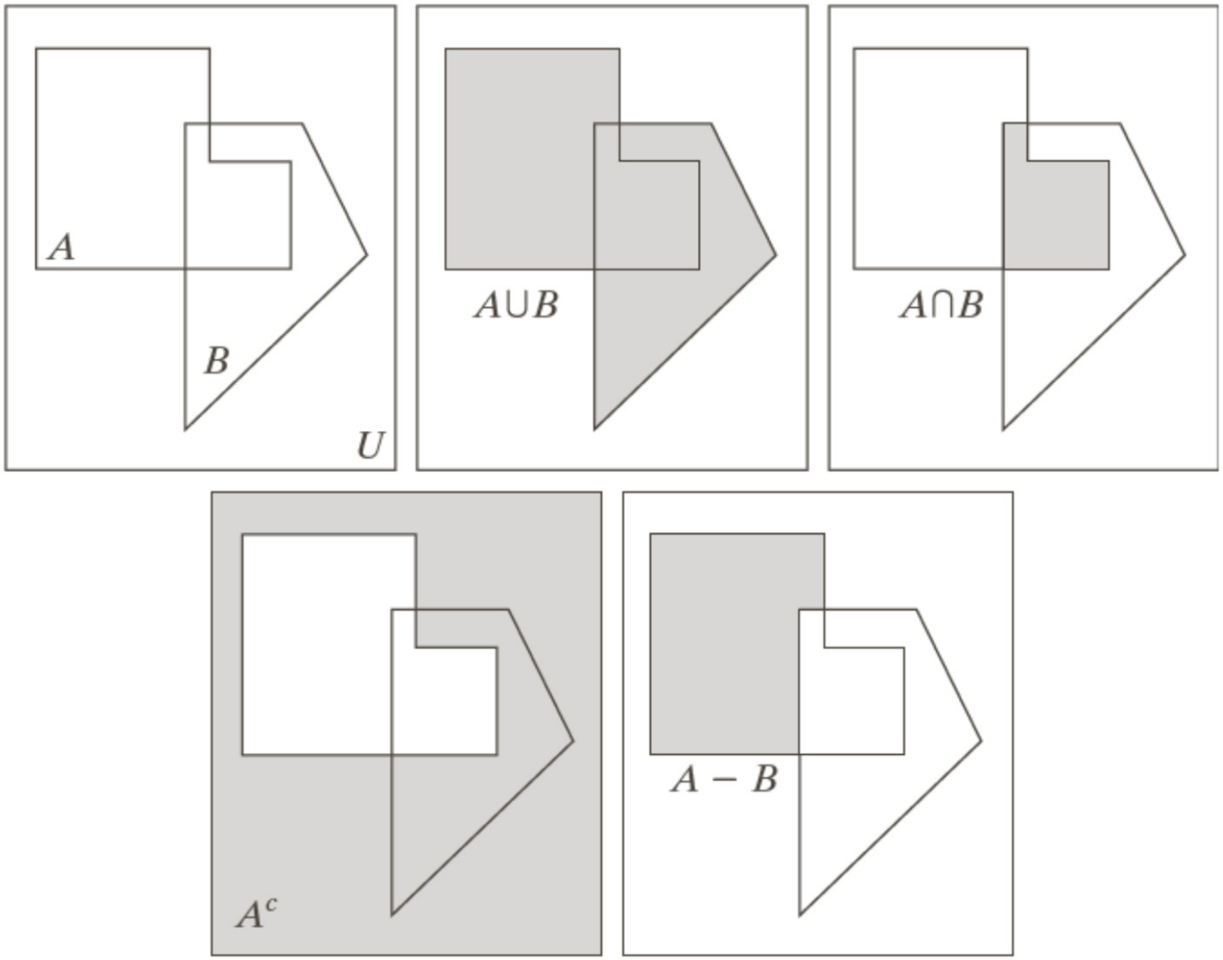
FIGURE 2.29 Shading correction. (a) Shaded SEM image of a tungsten filament and support, magnified approximately 130 times. (b) The shading pattern. (c) Product of (a) by the reciprocal of (b). (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

像素集基本集合运算

Some important set operations and relationships.

Description	Expressions
Operations between the sample space and null sets	$\Omega^c = \varnothing;\ \varnothing^c = \Omega;\ \Omega \cup \varnothing = \Omega;\ \Omega \cap \varnothing = \varnothing$
Union and intersection with the null and sample space sets	$A \cup \varnothing = A;\ A \cap \varnothing = \varnothing;\ A \cup \Omega = \Omega;\ A \cap \Omega = A$
Union and intersection of a set with itself	$A \cup A = A;\ A \cap A = A$
Union and intersection of a set with its complement	$A \cup A^c = \Omega;\ A \cap A^c = \varnothing$
Commutative laws	$A \cup B = B \cup A$ $A \cap B = B \cap A$
Associative laws	$(A \cup B) \cup C = A \cup (B \cup C)$ $(A \cap B) \cap C = A \cap (B \cap C)$
Distributive laws	$(A \cup B) \cap C = (A \cap C) \cup (B \cap C)$ $(A \cap B) \cup C = (A \cup C) \cap (B \cup C)$
DeMorgan's laws	$(A \cup B)^c = A^c \cap B^c$ $(A \cap B)^c = A^c \cup B^c$

图像的集合与逻辑运算示例 (I)



a b c
d e

FIGURE 2.31
(a) Two sets of coordinates, A and B, in 2-D space. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B. In (b)–(e) the shaded areas represent the member of the set operation indicated.

像素集基本逻辑运算

Truth table defining the logical operators

$$\text{AND}(\wedge), \text{OR}(\vee), \text{and} \quad \text{NOT}(\sim).$$

a	b	a AND b	a OR b	NOT(a)
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0

图像的集合与逻辑运算示例 (II)

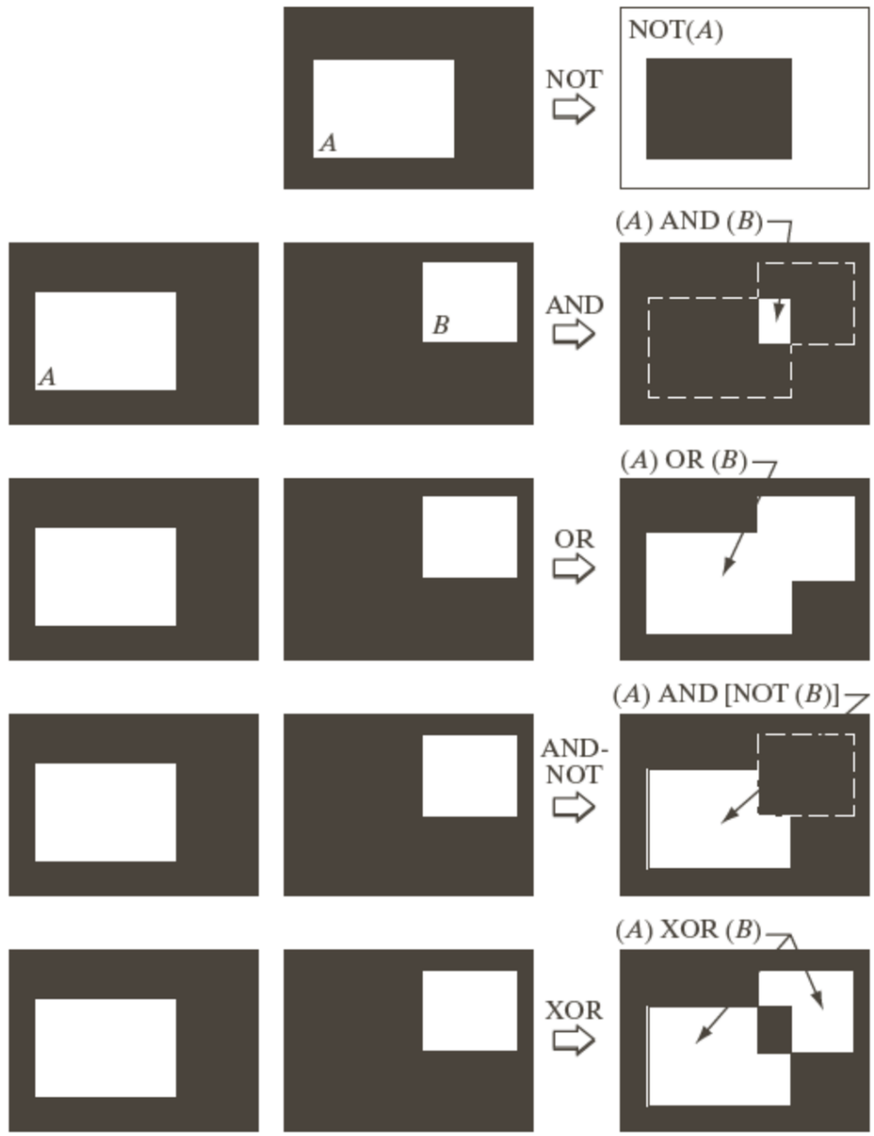
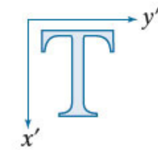
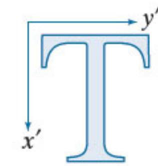
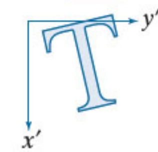
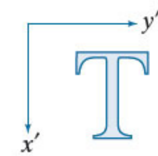
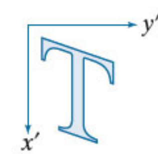
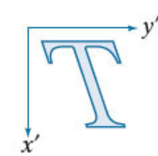


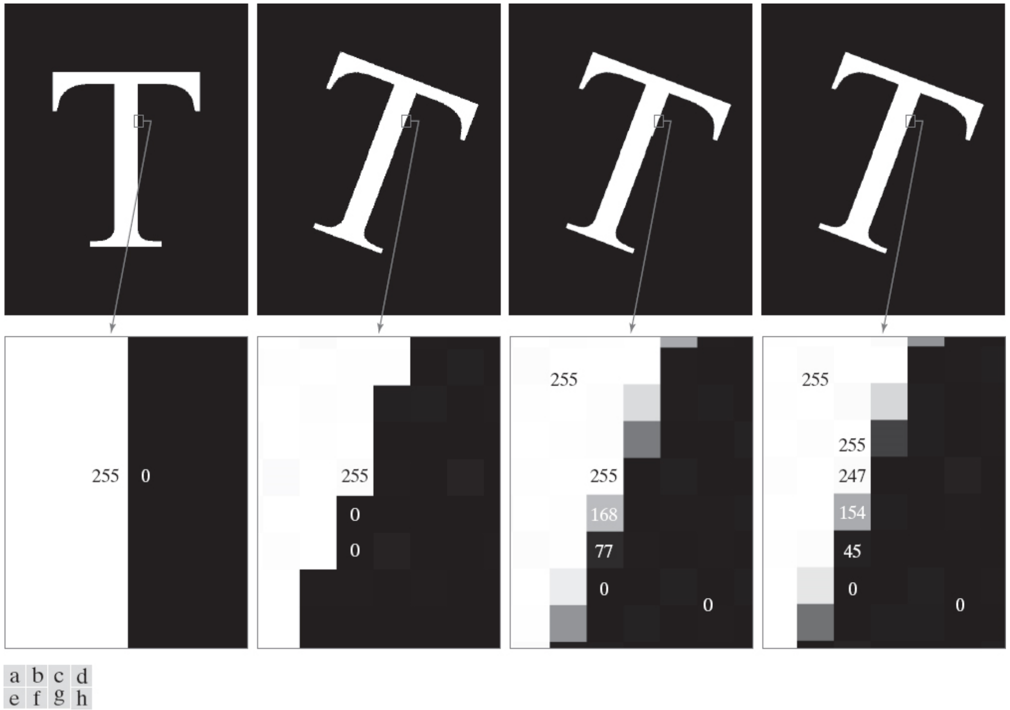
FIGURE 2.33 Illustration of logical operations involving foreground (white) pixels. Black represents binary 0s and white binary 1s. The dashed lines are shown for reference only. They are not part of the result.

图像的变几何换 (I)

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \mathbf{A} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (2\text{-}45)$$

Transformation Name	Affine Matrix, A	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x$ $y' = y$	
Scaling/Reflection (For reflection, set one scaling factor to −1 and the other to 0)	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = c_x x$ $y' = c_y y$	
Rotation (about the origin)	$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x\cos\theta - y\sin\theta$ $y' = x\sin\theta + y\cos\theta$	
Translation	$\begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x + t_x$ $y' = y + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & s_v & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x + s_v y$ $y' = y$	
Shear (horizontal)	$\begin{bmatrix} 1 & 0 & 0 \\ s_h & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x$ $y' = s_h x + y$	

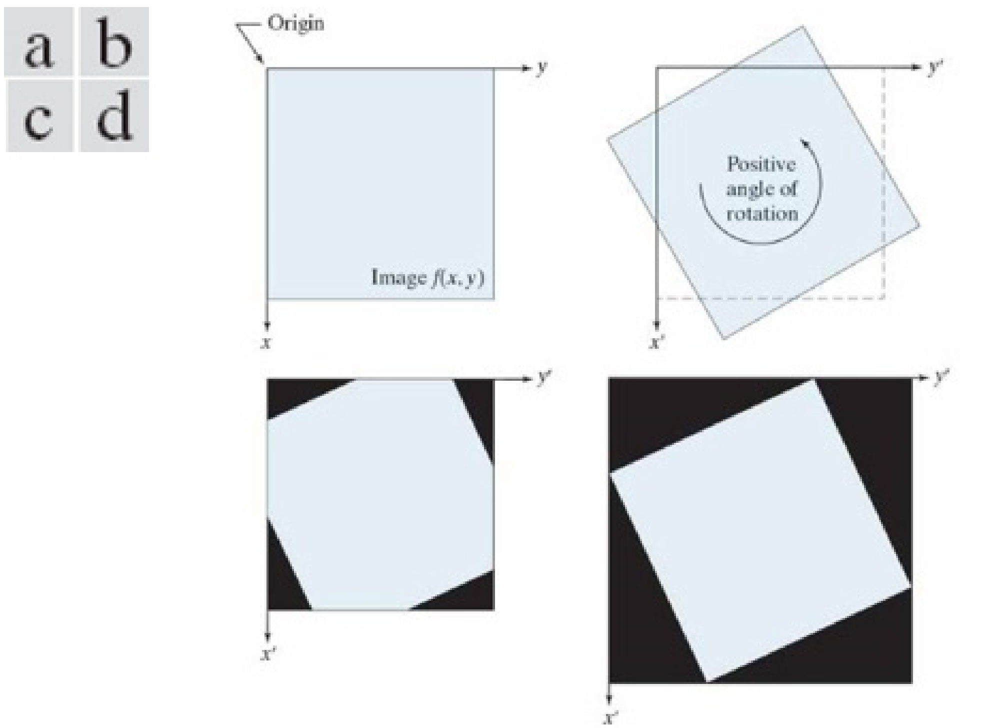
图像的几何变换 (II)



(a) Orignal image of letter T. (b) Image rotated −21 degree using nearest-neighbor interpolation for intensity assignments. (c) Image rotated −21 degree using bilinear interpolation. (d) Image rotated −21 degree using bicubic interpolation. (e)-(h) Zoomed sections (each square is one pixel, and the numbers shown are intensity values).

图像的集合变换 (III)

(a) A digital image. (b) Rotated image (note the counterclockwise direction for a positive angle of rotation). (c) Rotated image cropped to fit the same area as the original image. (d) Image enlarged to accommodate the entire rotated image.



线性算子的基本概念

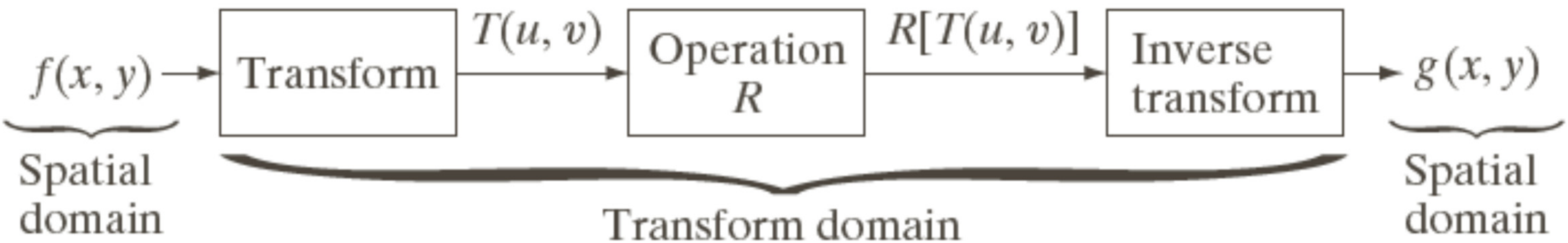


FIGURE 2.39 General approach for operating in the linear transform domain.

$$R\left[f(x,y)\right]=g(x,y)$$

$$R\left[a_1 f_1(x,y)+a_2 f_2(x,y)\right]=a_1 R\left[f_1(x,y)\right]+a_2 R\left[f_2(x,y)\right]$$
$$=a_1 g_1(x,y)+a_2 g_2(x,y)$$

内容提纲

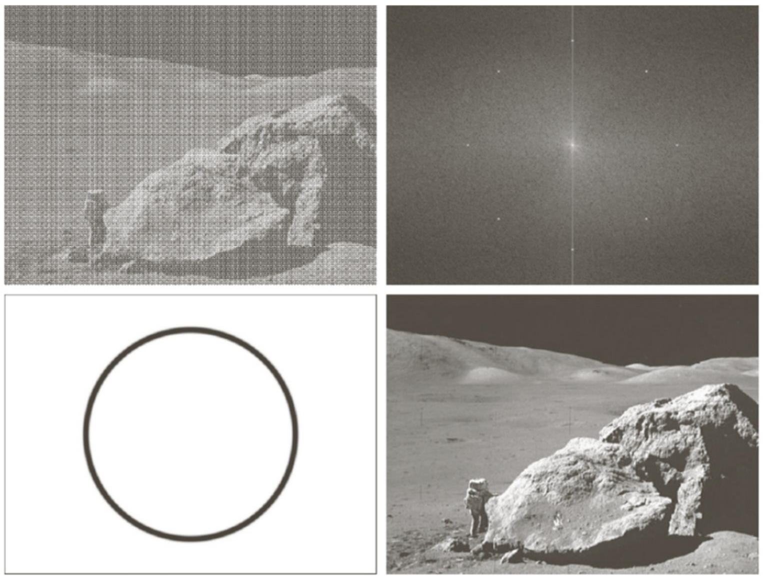
- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

图像处理的重要性 (I)

- 改善图示信息以便人们进行解释

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.)

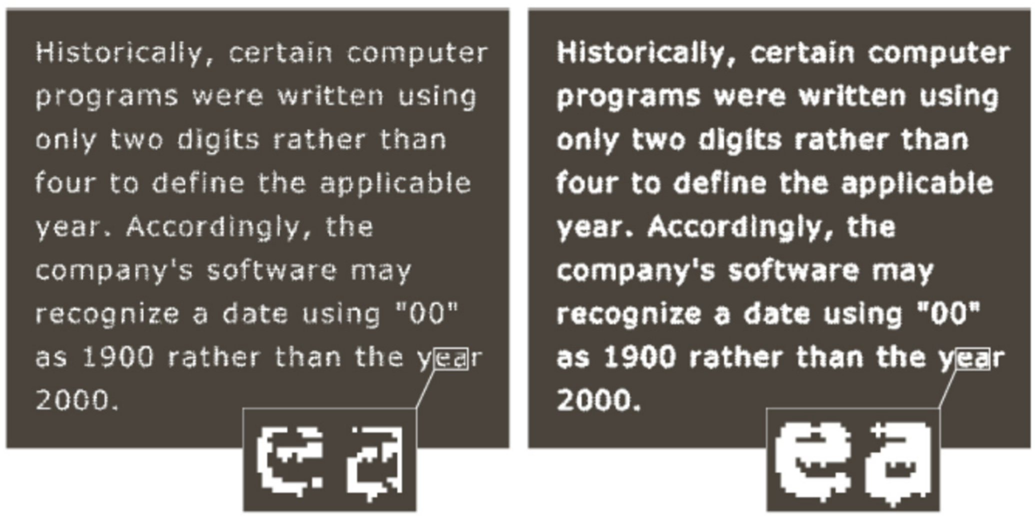


a b c

FIGURE 5.30 Results of constrained least squares filtering. Compare (a), (b), and (c) with the Wiener filtering results in Figs. 5.29(c), (f), and (i), respectively.

图像处理的重要性 (II)

- 为存储，传输和表示而对于图像进行处理，以便于机器自动理解。

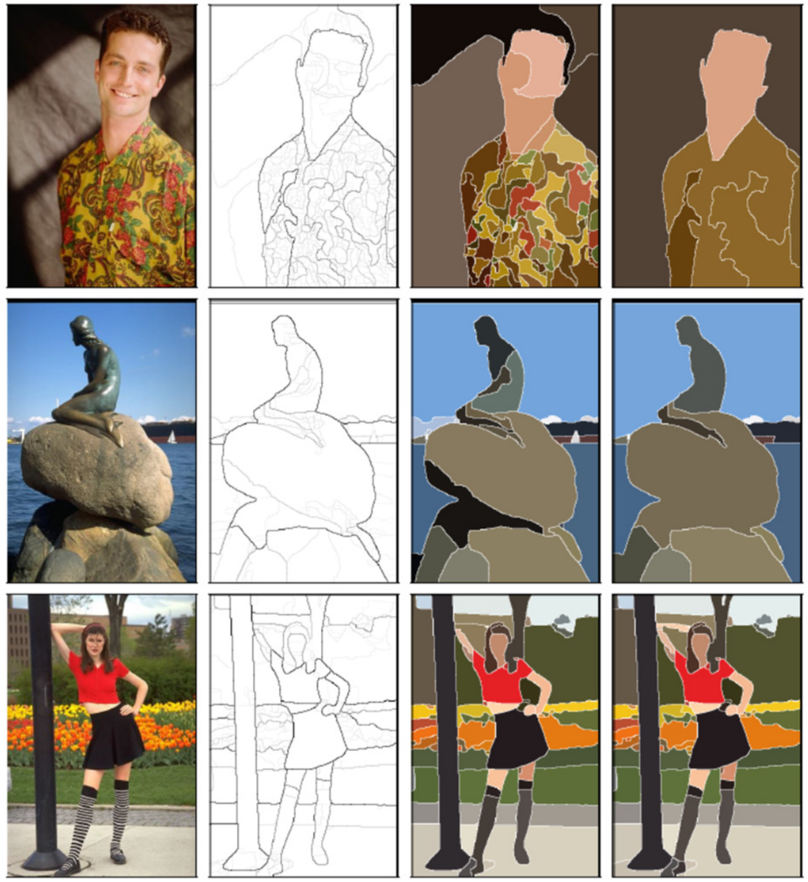


0	1	0
1	1	1
0	1	0

a c
b

FIGURE 9.7 (a) Sample text of poor resolution with broken characters (see magnified view). (b) Structuring element. (c) Dilation of (a) by (b). Broken segments were joined.

图像处理的重要性 (III)



图像 → **图像处理** → 特征

Arbelaez et al, PAMI, 2010

图像处理的不同功能层次

- 低级处理
  - 图像降噪，对比度增强，图像锐化
  - 输入输出均为图像
- 中级处理
  - 图像属性提取
  - 输入为图像，输出为图像属性
- 高级处理 (计算机视觉，人工智能)
  - 图像理解

数字图像处理的基本步骤

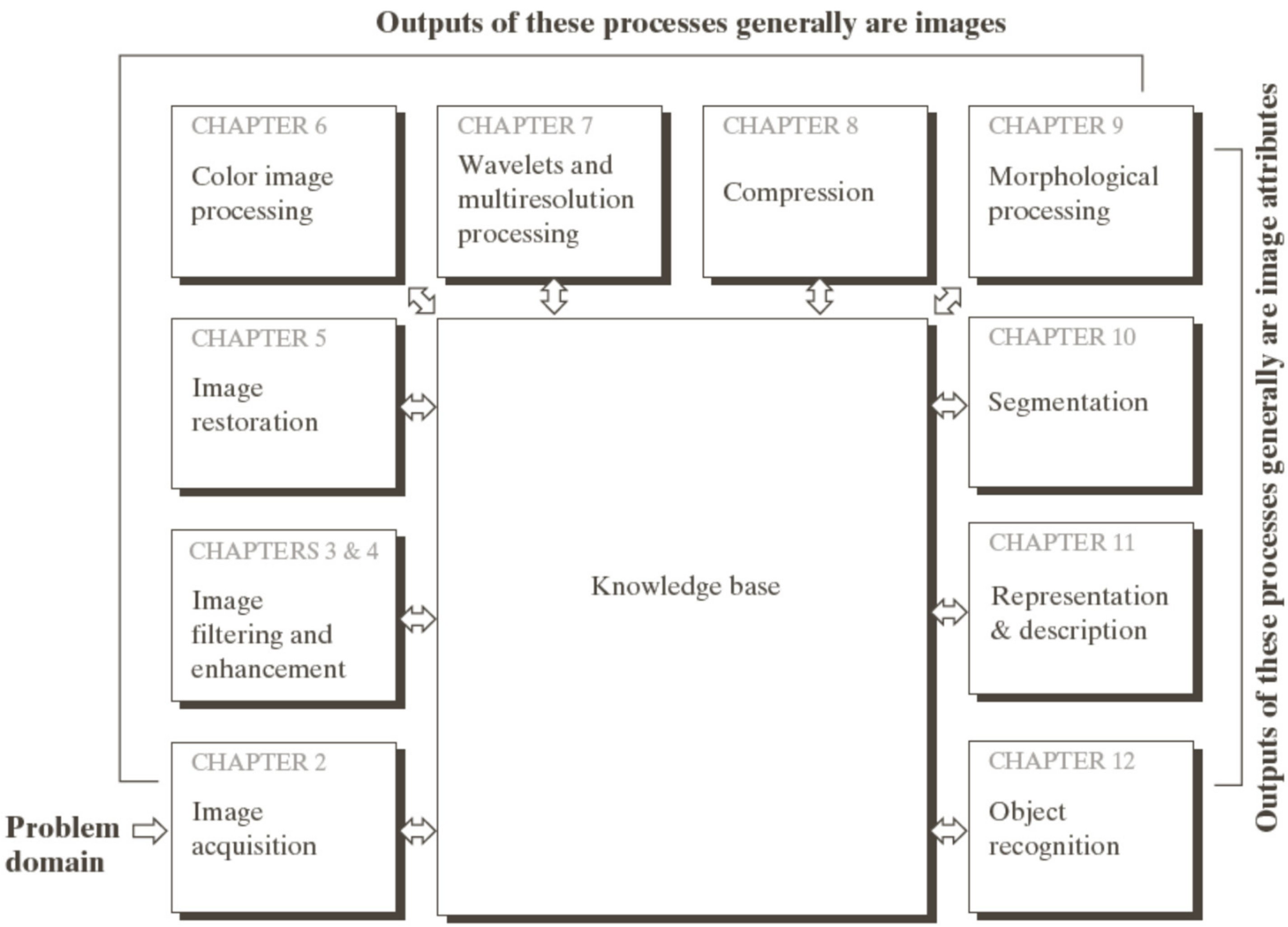


FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

本课程涉及的内容

- 图像滤波
- 图像增强
- 图像复原与重建
- 图像形态学处理
- 图像多尺度处理
- 图像分割与边缘检测

图像滤波与边缘检测

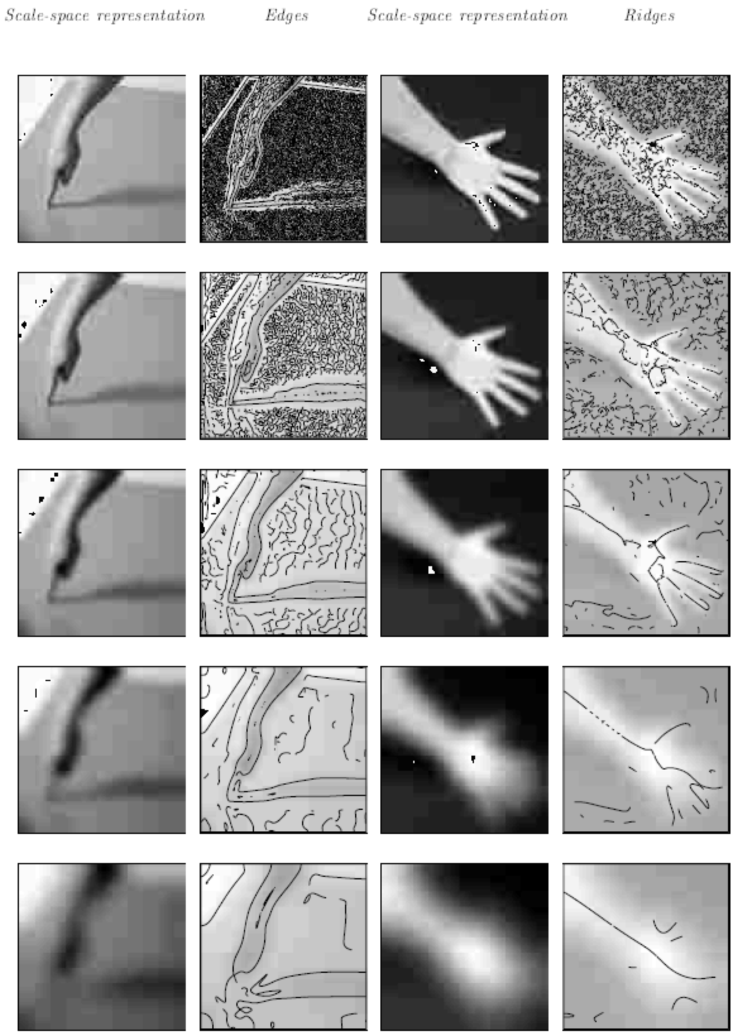
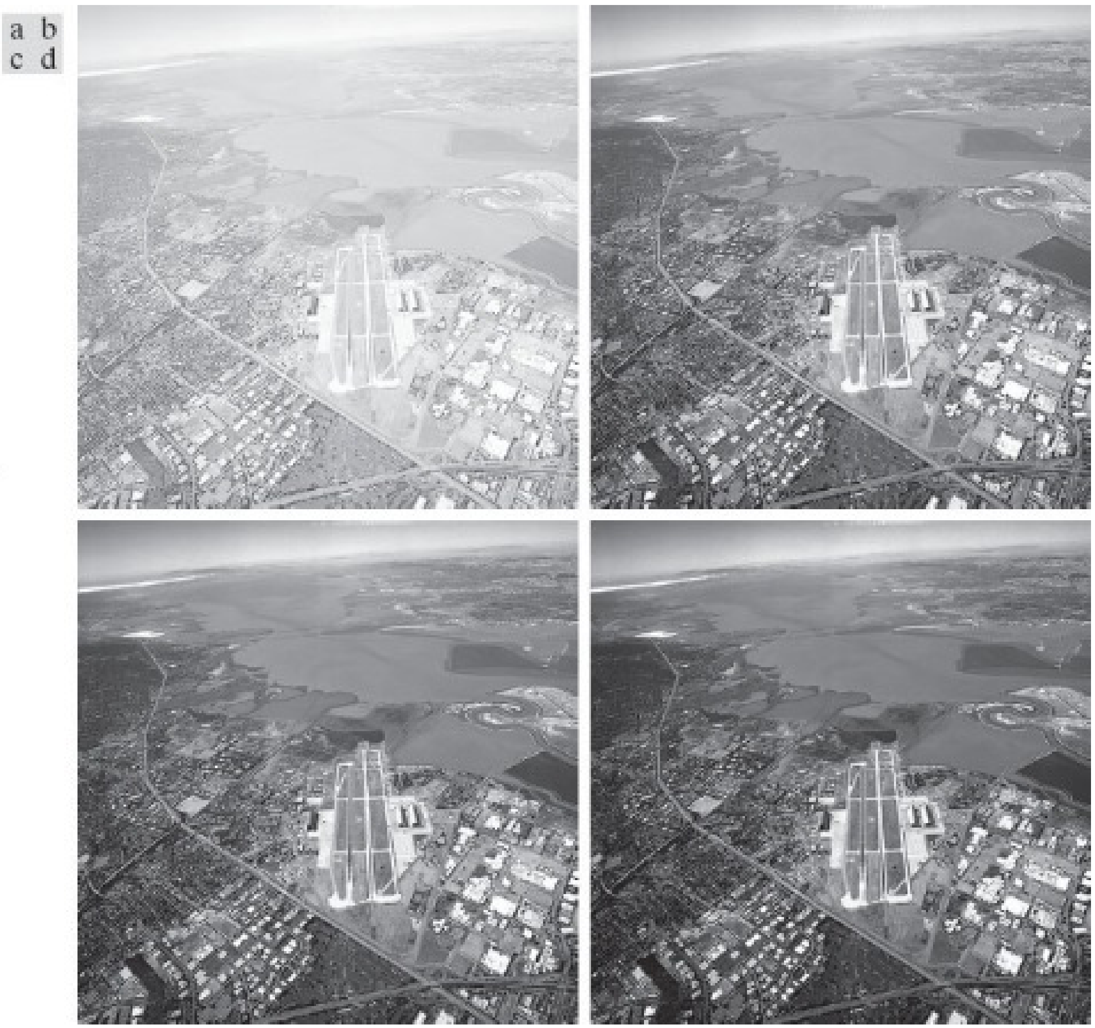
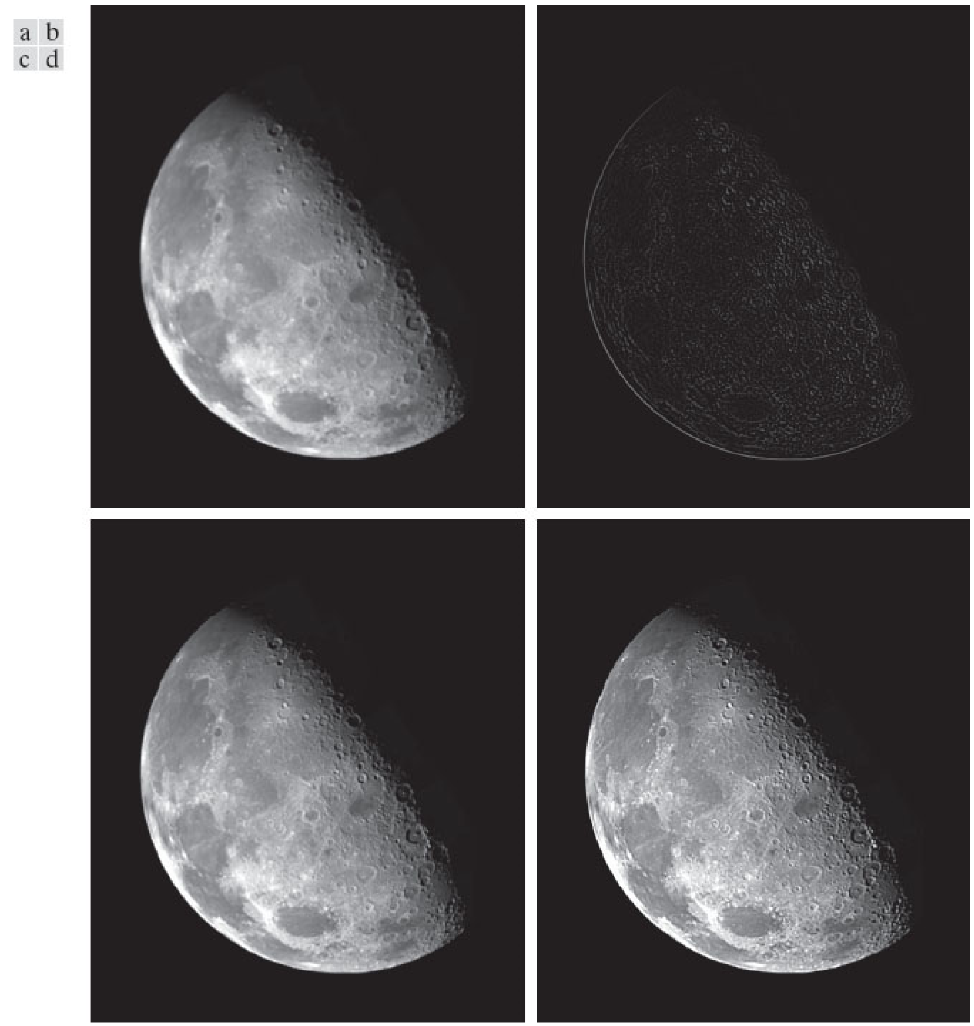


*Figure 1.4: Edges and ridges computed at different scales in scale-space (scale levels $t = 1.0$, 4.0, 16.0, 64.0 and 256.0 from top to bottom) using a differential geometric edge detector and ridge detector, respectively. (Image size: 256*256 pixels.)*

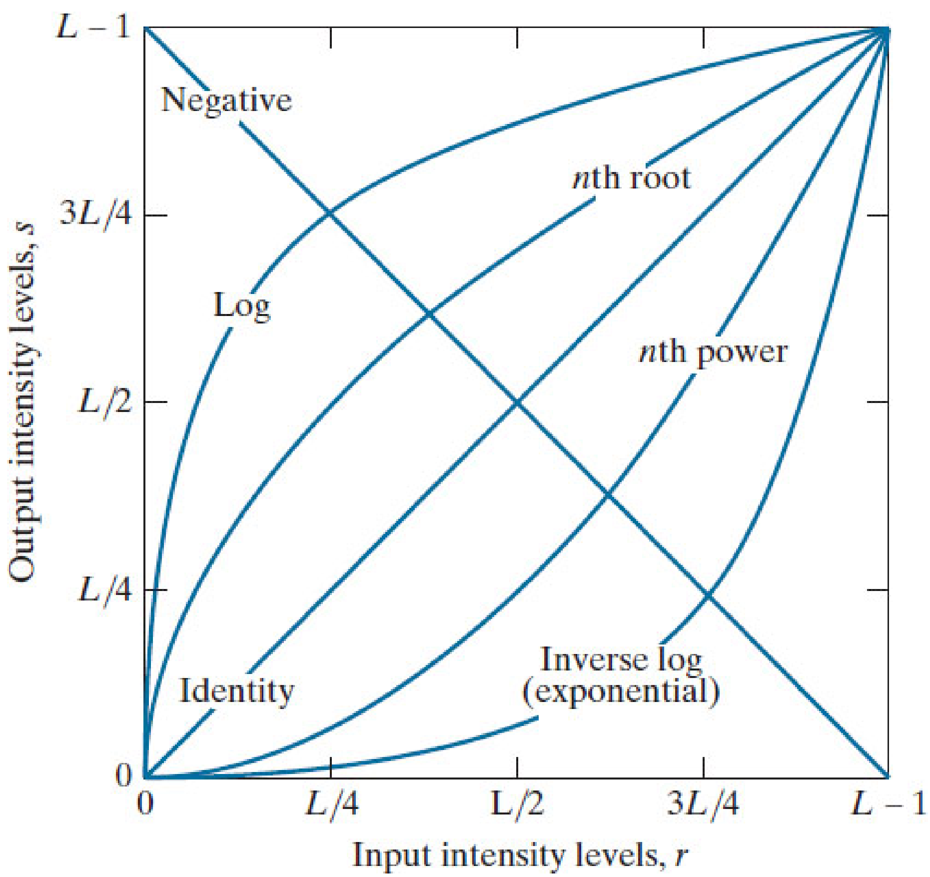
Lindeberg (1999) [`` Principles for automatic scale selection'',] in: B. Jahne (et al., eds.), Handbook on Computer Vision and Applications, volume 2, pp 239--274, Academic Press.

图像增强





灰度校正



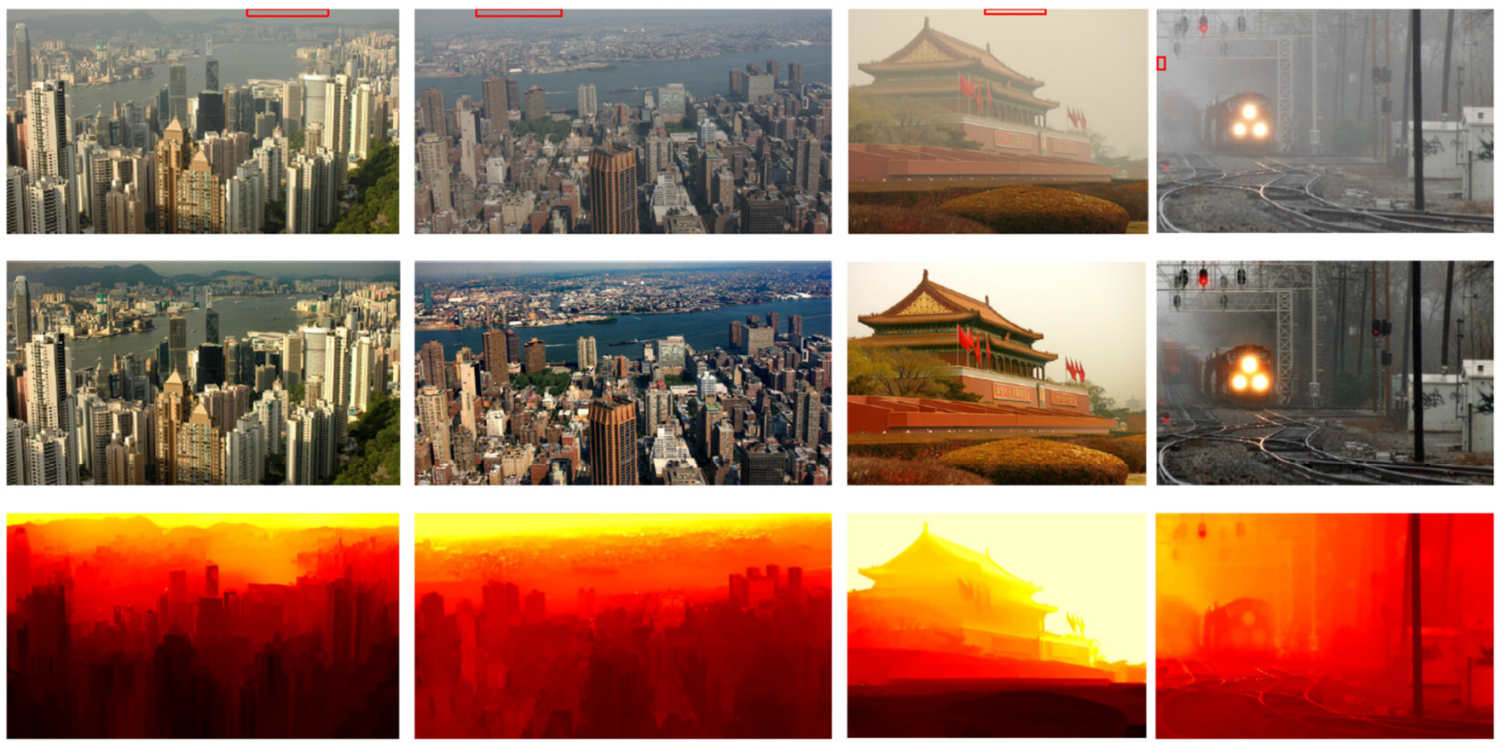
L – 1
3L/4
L/2
L/4
0
0
L/4
L/2
3L/4
L – 1
Output intensity levels, s
Input intensity levels, r
Negative
Log
nth root
Identity
nth power
Inverse log
(exponential)

图像复原与重建

a b c

图像去雾

(a) (b) (c)



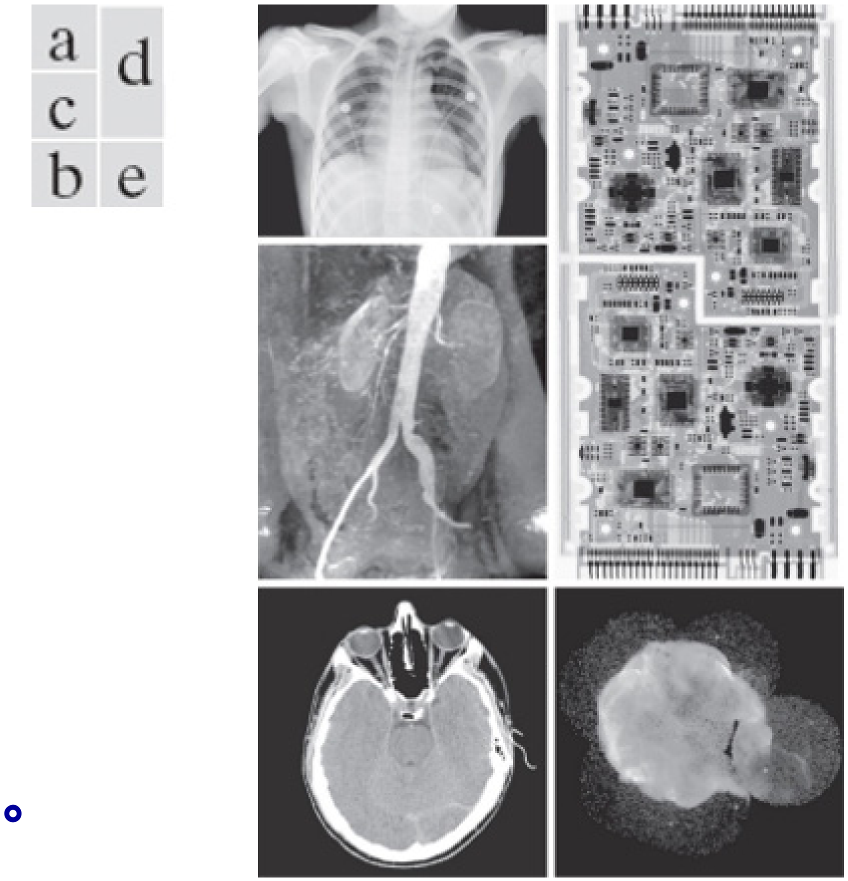
Single Image Haze Removal using Dark Channel Prior, **Kaiming He**, Jian Sun, and Xiaoou Tang, Computer Vision and Pattern Recognition (**CVPR**), 2009

内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

图像处理的应用领域

- 自然与社会场景图像处理
- 工业图像处理
- 医学图像处理
- 生物图像处理
- 遥感图像处理
- 天文图像处理
- 不同领域发展了多种面向应用的技术。
- 不同领域的技术往往可以相互借鉴。



内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

按照光子能量排列的电磁波谱

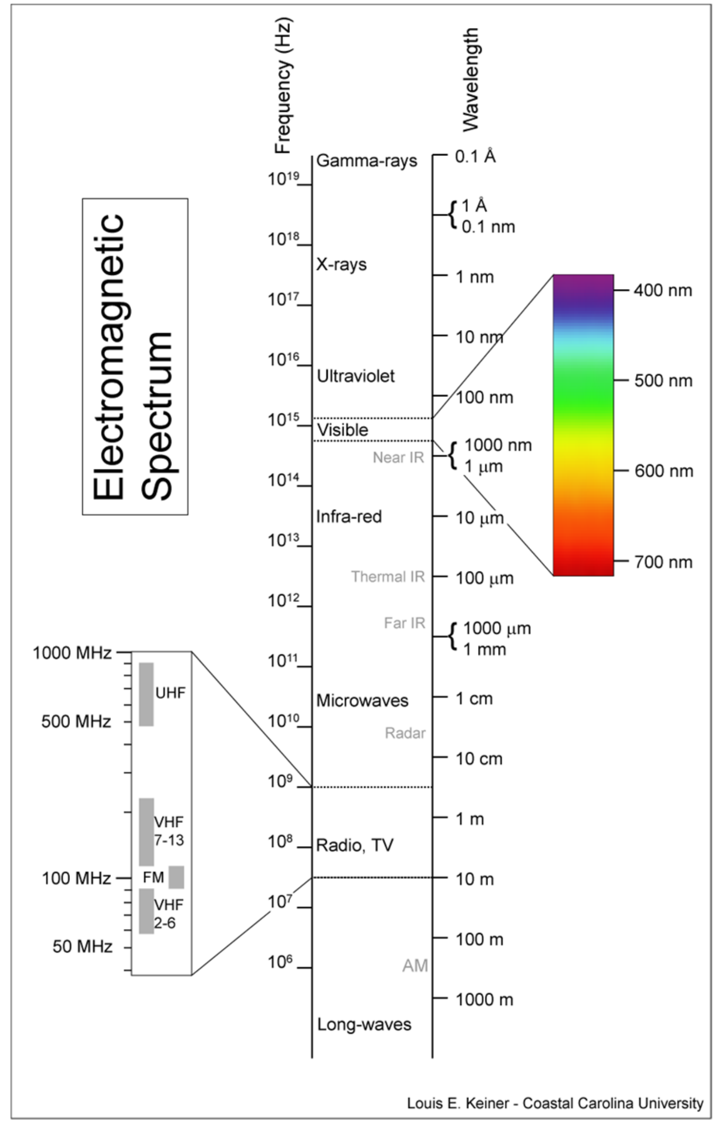
- 光子能量的普朗克定律：

$$E = h\nu = h\frac{c}{\lambda}$$

h: 普朗克常数; 6.626×10^{-34}J·s
ν: 光频率;
λ: 光波长
c: 光速

光子能量 =
3.973 ×10^{-19}J at 500nm

- 光波长越短光子能量越高。



色彩的基本概念 (I)

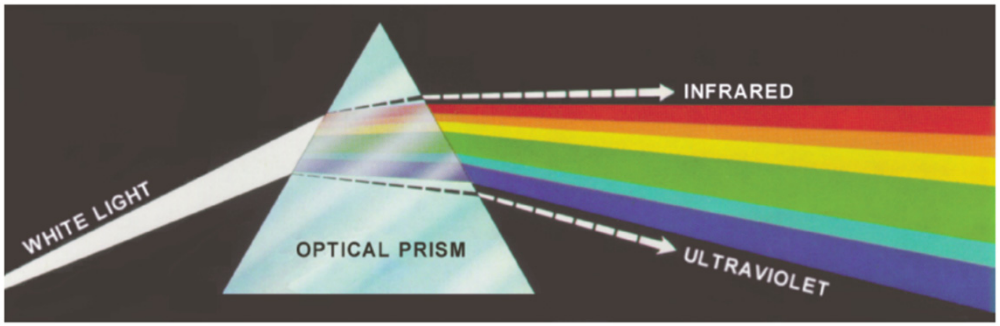


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

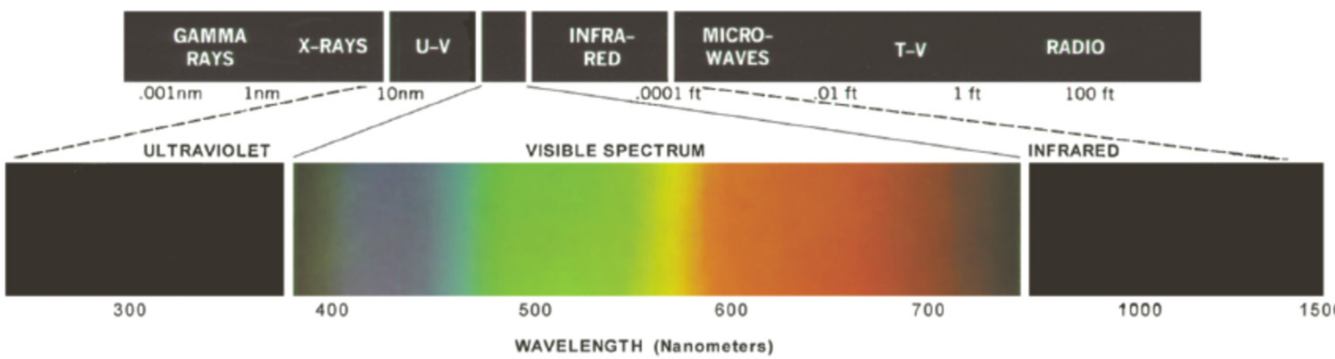


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

色彩的基本概念 (II)

- 人类的锥状感光细胞中65%对于红色敏感，33%对于绿色敏感，只有2%对于蓝色敏感。

- 国际照明委员会定义
  蓝 = 435.8 nm
  绿 = 546.1 nm
  红 = 700　nm

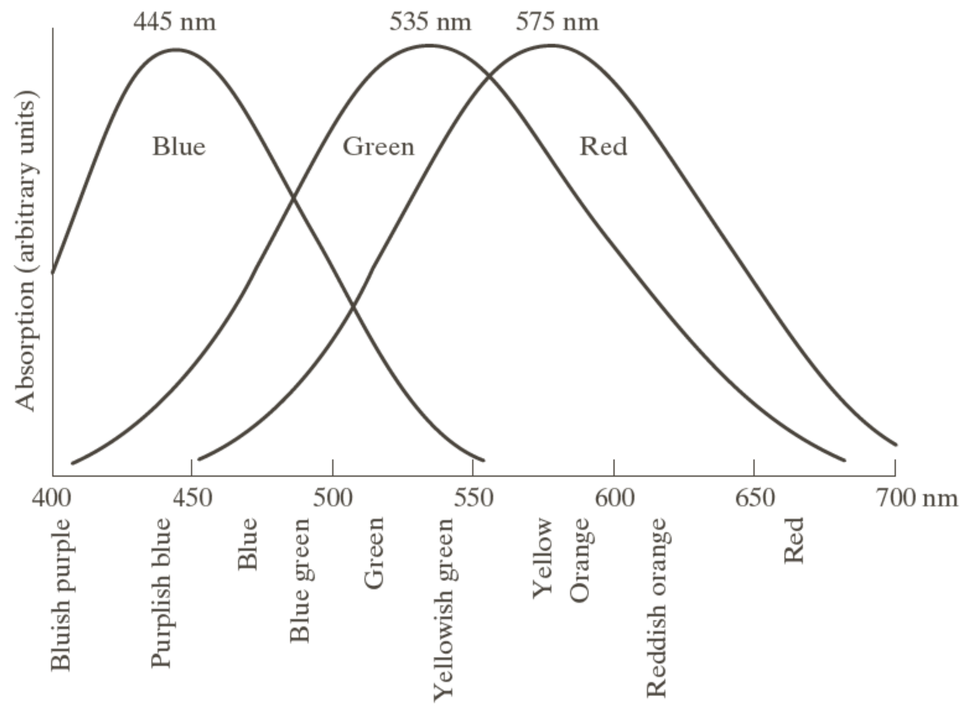


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

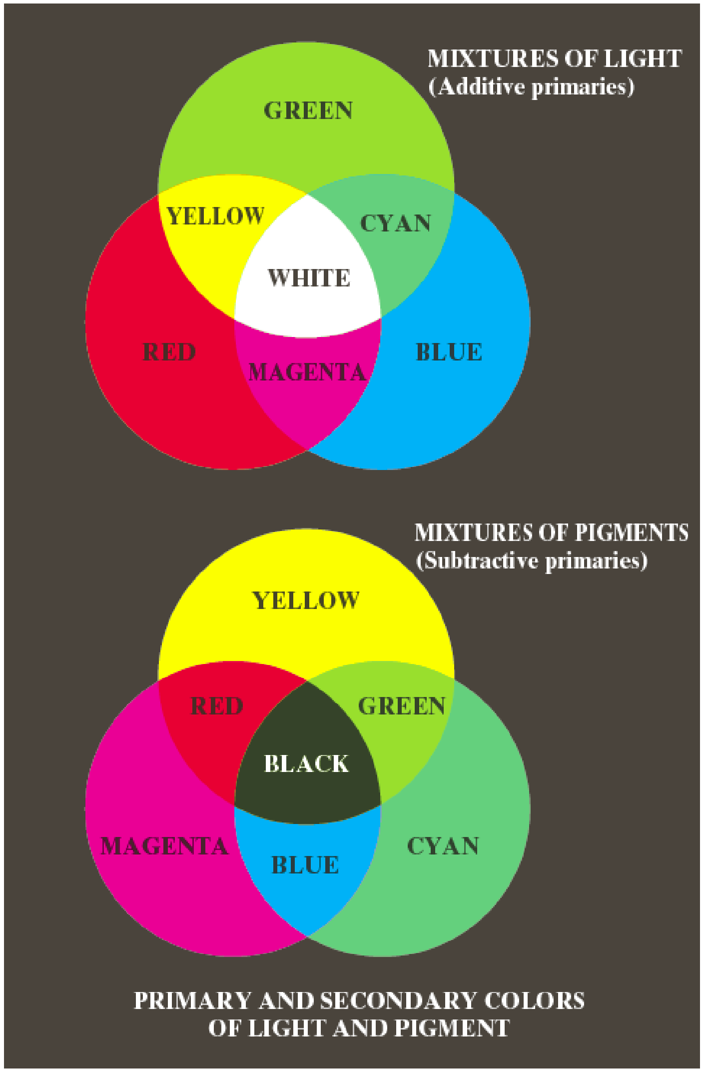
不同颜色的组合

- 光的(加性)原色与二次色
- 颜料的(减性)原色与二次色
- 三色值系数

  $x = X/(X+Y+Z)$

  $y = Y/(X+Y+Z)$

  $z = Z/(X+Y+Z)$



a
b

FIGURE 6.4 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

https://www.printplace.com/blog/reasons-for-cmyk-printing/

彩色模型(I): RGB模型-加性模型

- $(2^8)^3 = 16,777,216$

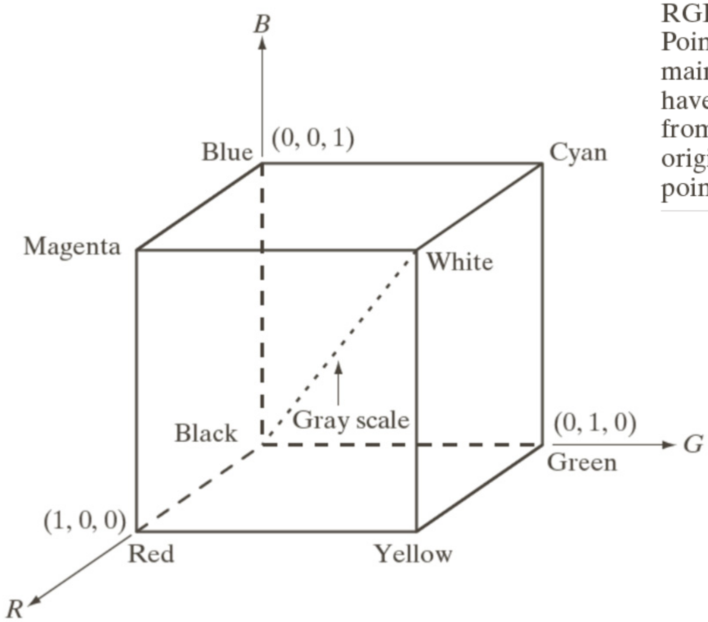


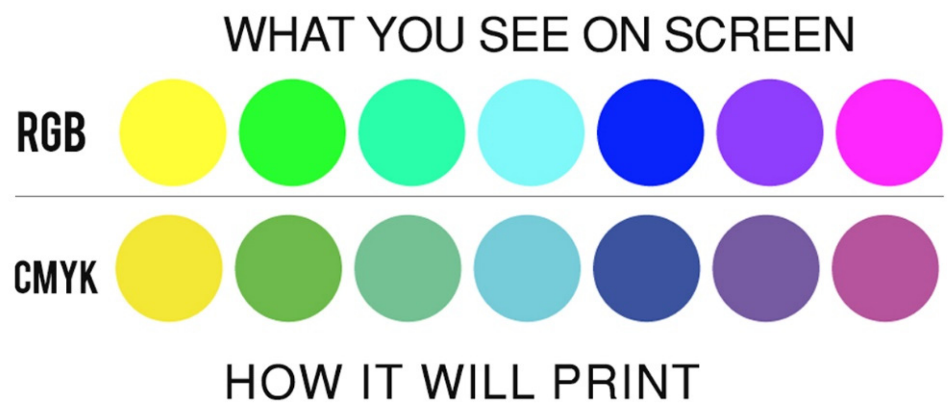
FIGURE 6.7 Schematic of the RGB color cube. Points along the main diagonal have gray values, from black at the origin to white at point (1, 1, 1).

FIGURE 6.8 RGB 24-bit color cube.

彩色模型(II): CMYK模型-减性模型

- CMYK 模型更适合打印和印刷。
- 相对于RGB, CMYK更容易实现浅色。

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



https://www.printplace.com/blog/reasons-for-cmyk-printing/

CMY和CMYK之间的转换

$$C = (C - K)/(1 - K) \tag{6-10}$$

$$M = (M - K)/(1 - K) \tag{6-11}$$

$$Y = (Y - K)/(1 - K) \tag{6-12}$$

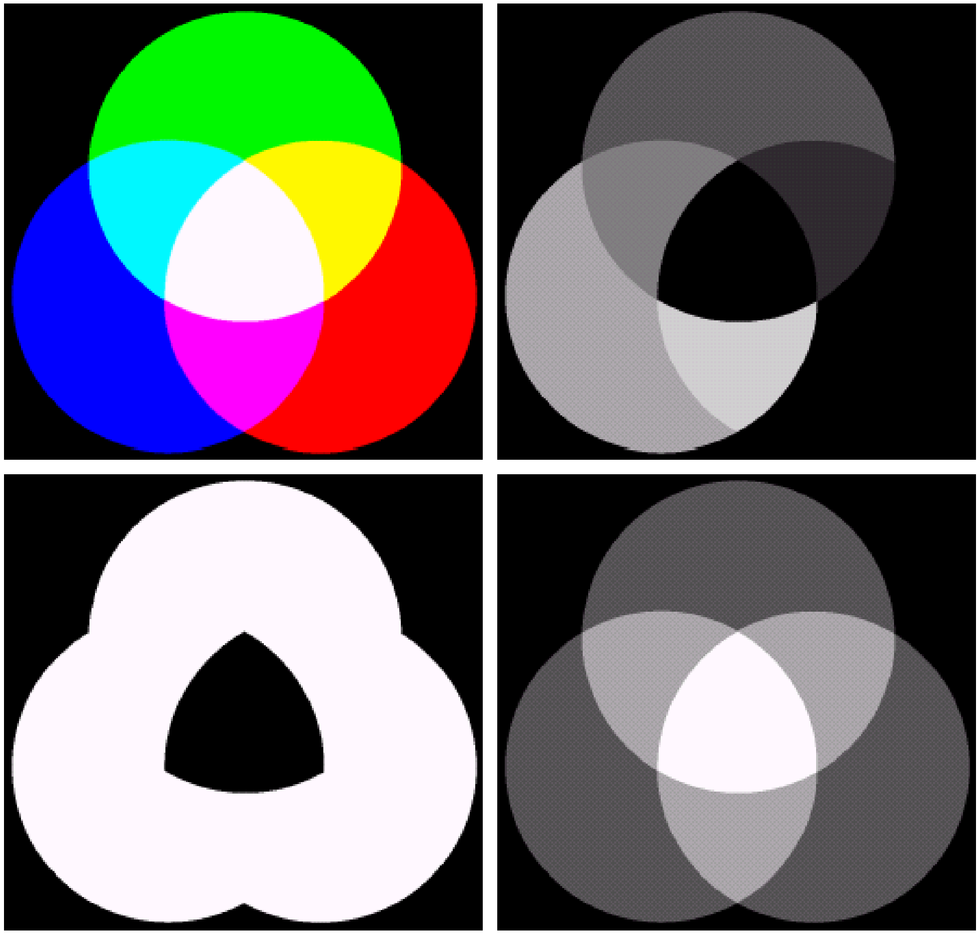
$$C = C * (1 - K) + K \tag{6-13}$$

$$M = M * (1 - K) + K \tag{6-14}$$

$$Y = Y * (1 - Y) + K \tag{6-15}$$

HSI/HSL/HSV彩色模型

- H: 色调
  - 纯度
- S: 饱和度
  - 白色的稀释度
- I: 强度 (intensity)
- L: 亮度 (lightness)
- V: 亮度 (value)



a b
c d

FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

RGB 转为HSI

Converting Colors from RGB to HSI

Given an image in RGB color format, the H component of each RGB pixel is obtained using the equation

$$H = \begin{cases} \theta & \text{if } B \le G \\ 360 - \theta & \text{if } B > G \end{cases} \tag{6-16}$$

with†

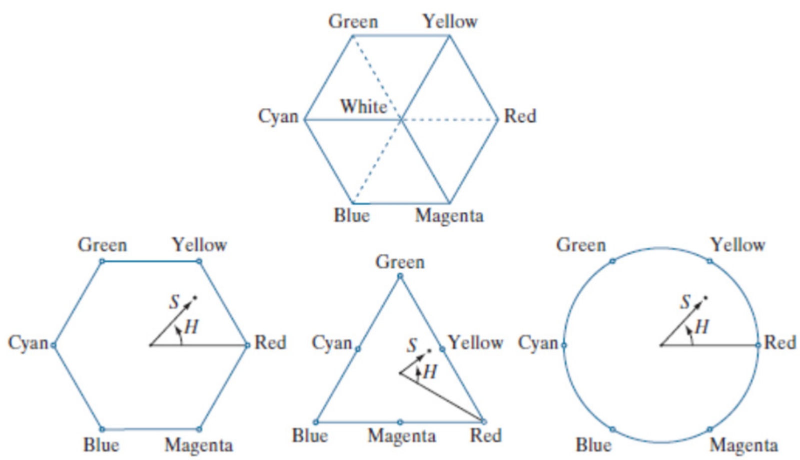
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2 + (R-B)(G-B)\right]^{1/2}} \right\} \tag{6-17}$$

The saturation component is given by

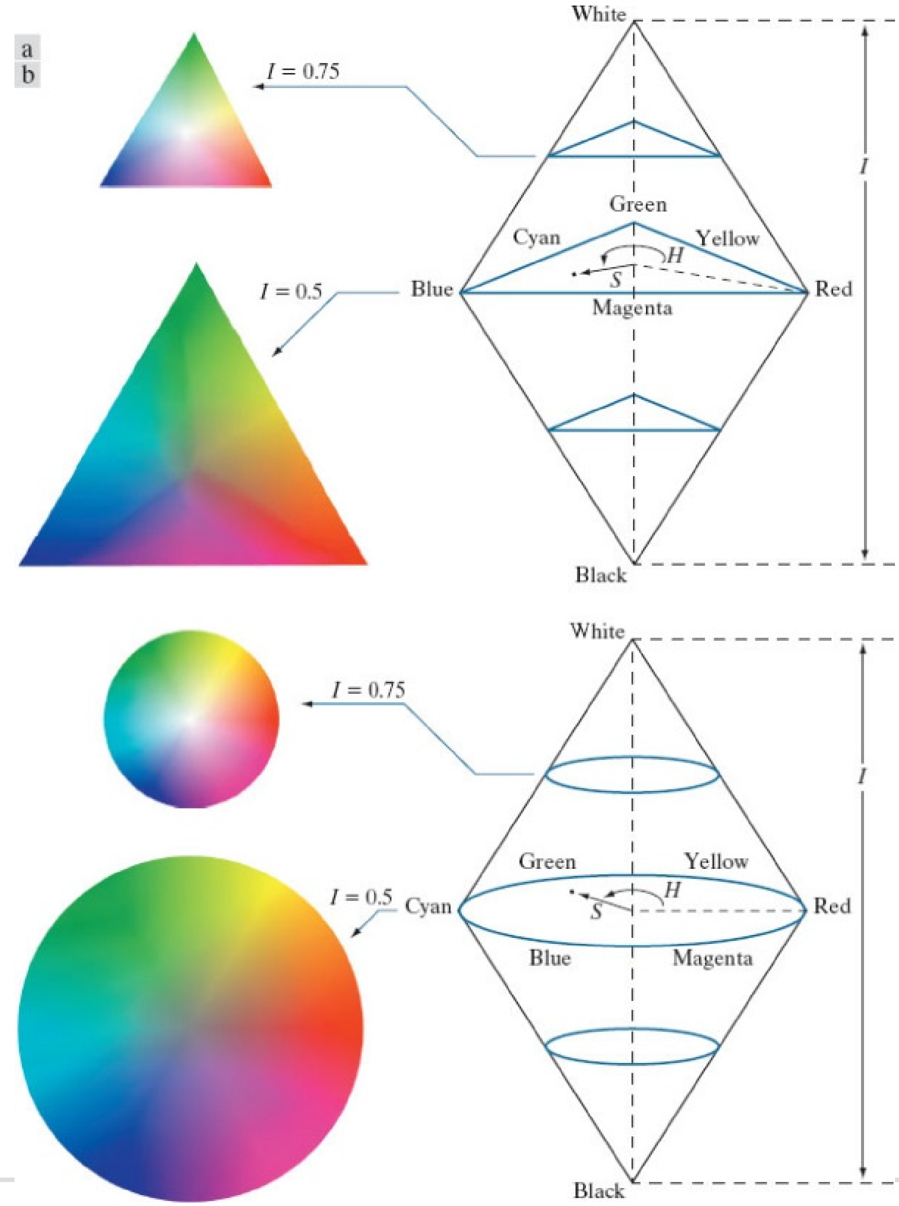
$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right] \tag{6-18}$$

$$I = \frac{1}{3}(R+G+B) \tag{6-19}$$

RGB 转为HSI

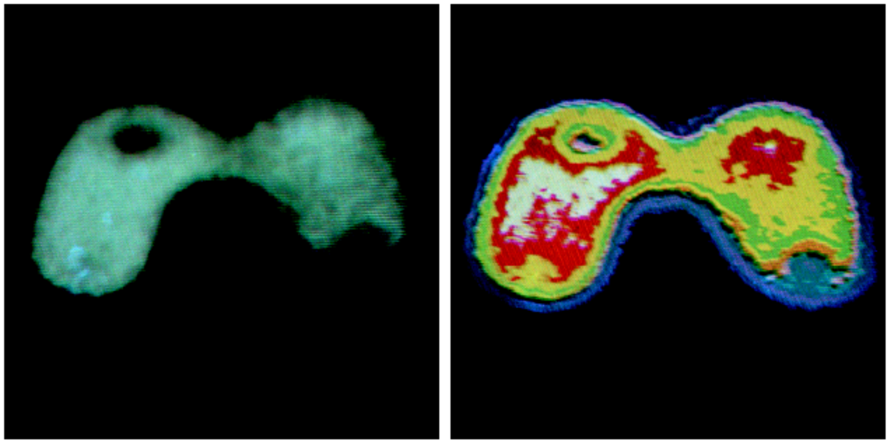


Green
Yellow
Cyan
White
Red
Blue
Magenta
Green
Yellow
Cyan
S
H
Red
Blue
Magenta
Green
Cyan
S
H
Yellow
Blue
Magenta
Red
Green
Yellow
Cyan
S
H
Red
Blue
Magenta



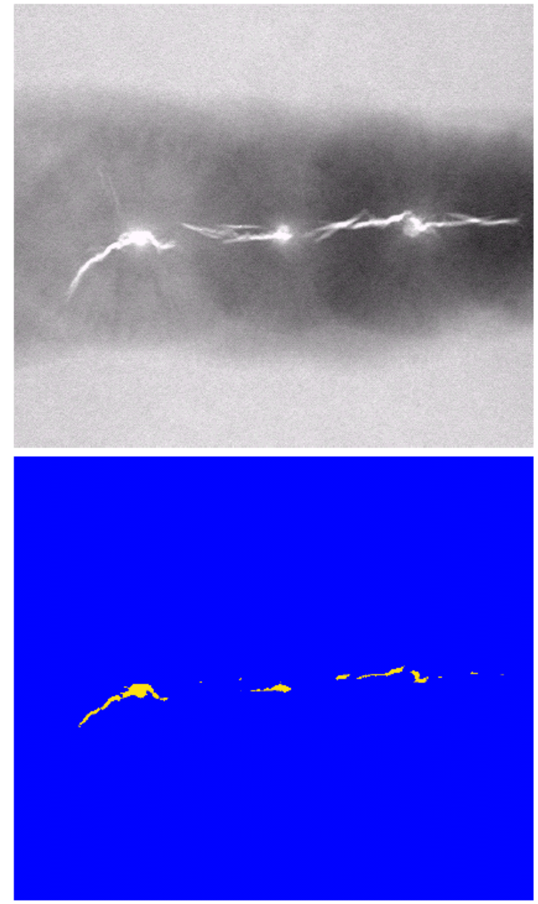
a
b
I = 0.75
I = 0.5
White
Green
Cyan
Yellow
H
S
Blue
Red
Magenta
I
Black
I = 0.75
I = 0.5
White
Green
Yellow
H
S
Cyan
Red
Blue
Magenta
I
Black

灰度图像转换为伪彩色图像 (I)



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.)



a
b

FIGURE 6.21 (a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)

灰度图像转换为伪彩色图像 (II)

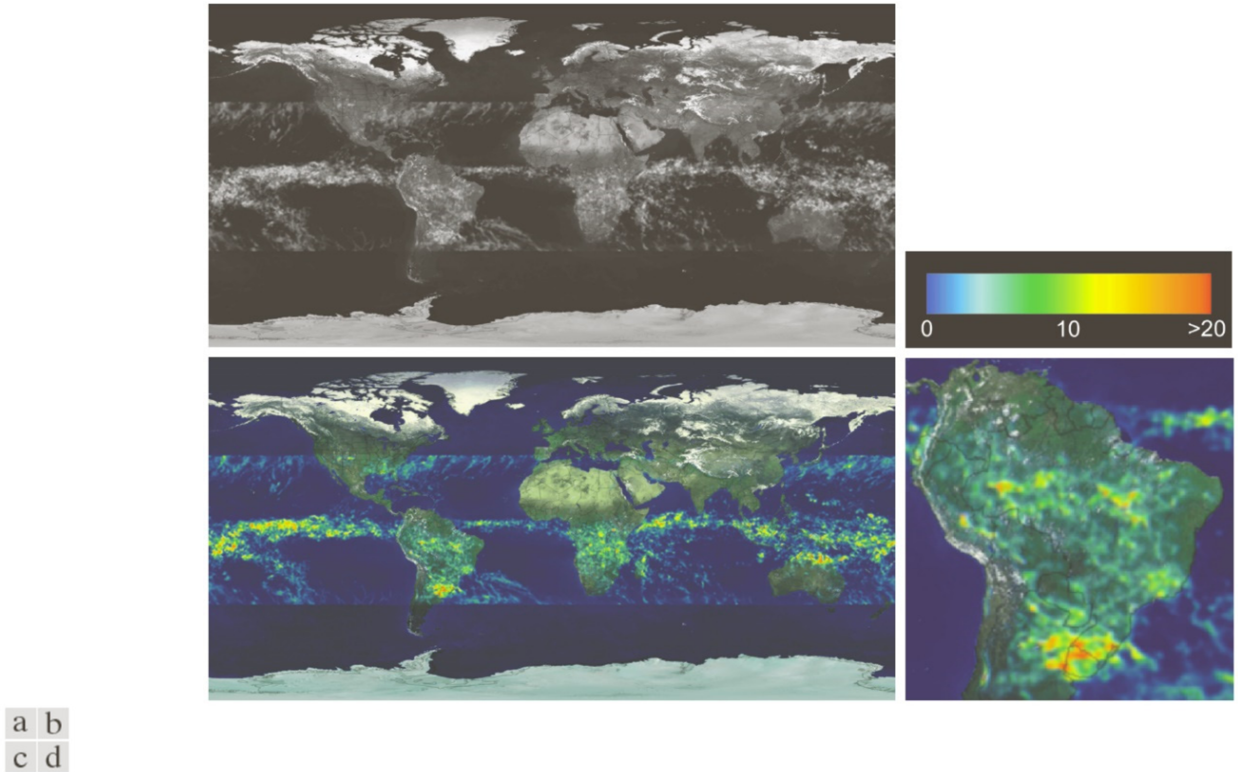


FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South American region. (Courtesy of NASA.)

伪彩色多通道图像

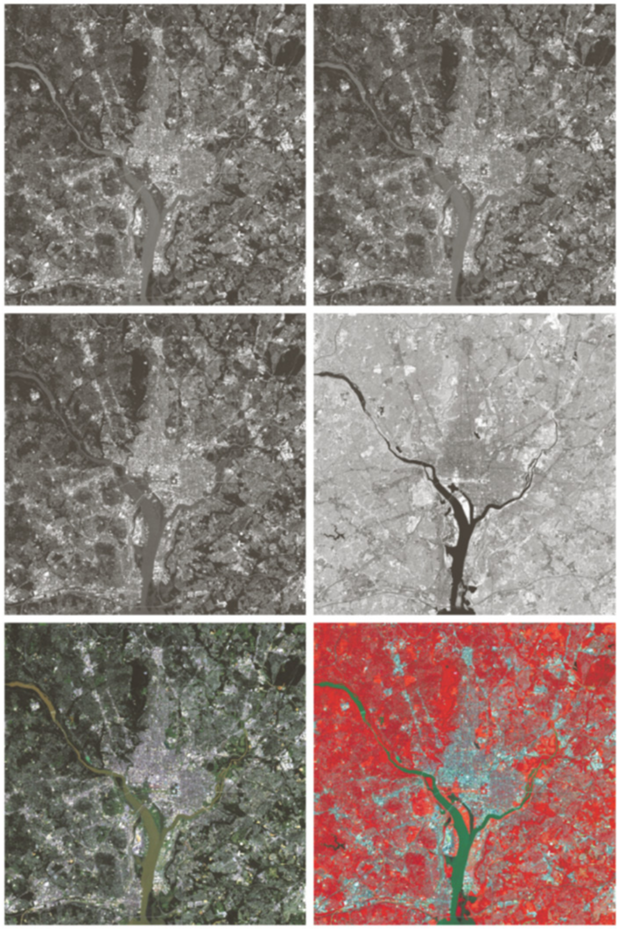
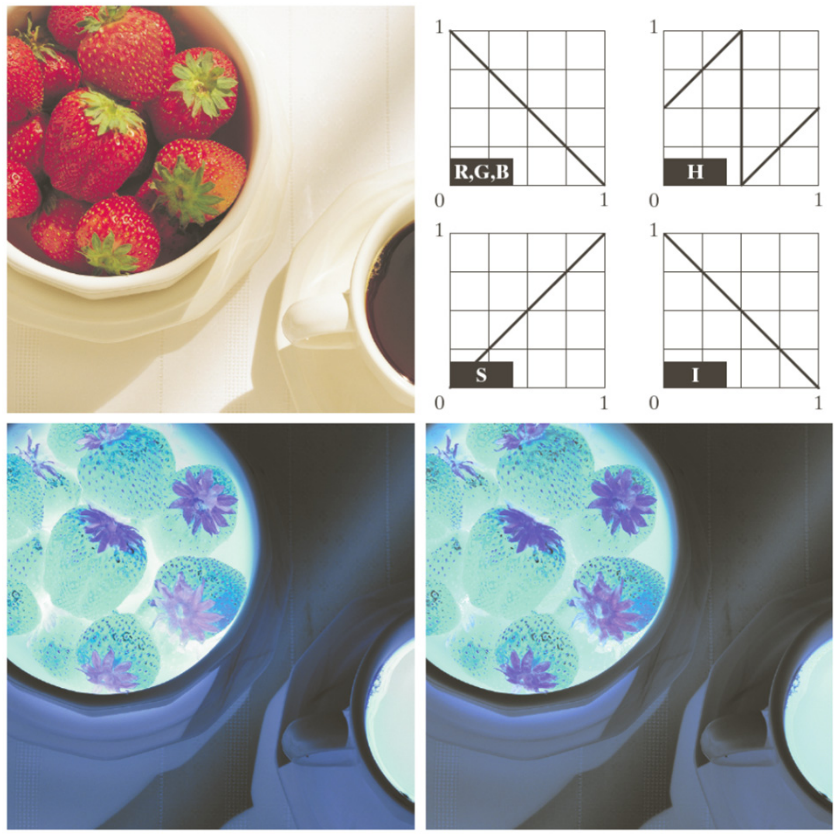


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

a	b
c	d
e	f

彩色图像变换



a b
c d

FIGURE 6.33 Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

彩色图像色调校正

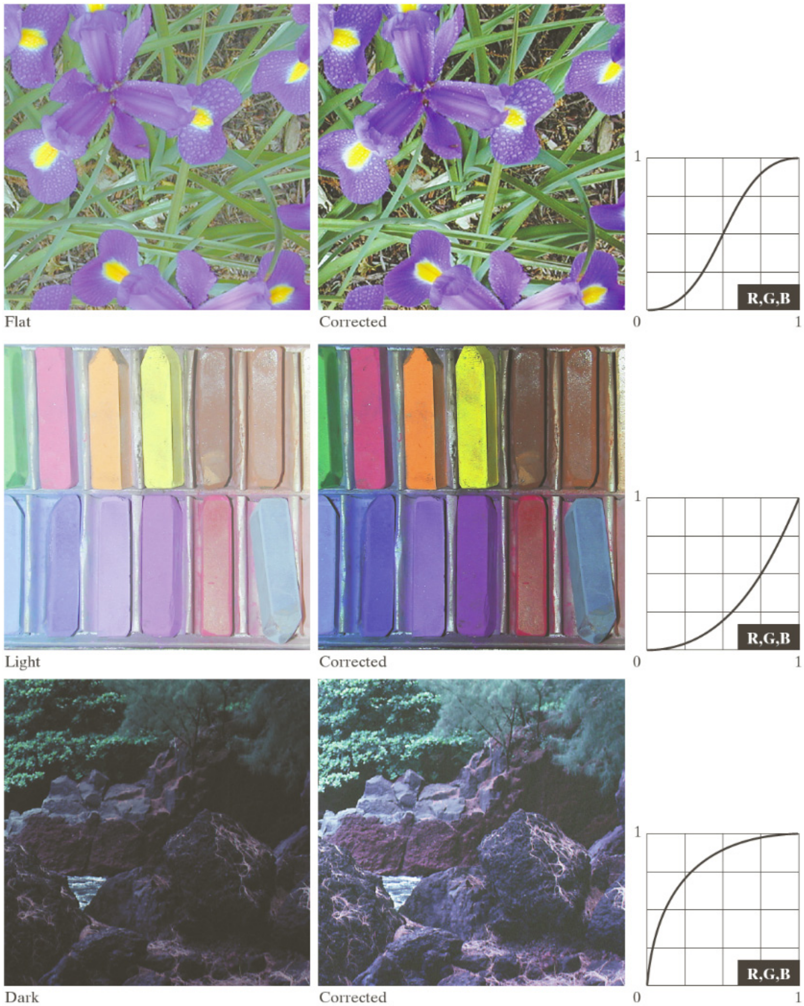


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

彩色图像处理示例 (I)

a b
c d

FIGURE 6.38 (a) RGB image. (b) Red component image. (c) Green component. (d) Blue component.

彩色图像处理示例 (II)

a b c

FIGURE 6.39 HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

彩色图像处理示例 (III)

a b c

FIGURE 6.40 Image smoothing with a 5 × 5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

彩色图像处理示例 (IV)

a b c

FIGURE 6.41 Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the HSI intensity component and converting to RGB. (c) Difference between the two results.

内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

基本图像处理运算简介：Adobe Photoshop (I)

- 主要用于光栅(raster)图像(像素图像)编辑，图形设计和数字美术。
- 主要使用图像层 (layering) 来实现设计与编辑的功能。
- 于1988年由Thomas & John Knoll兄弟首创，1989年出售给Adobe，目前已成为事实上的工业标准。
- Adobe Photoshop 1.0 于1990年2月19日开始发售。
- 主要格式是 .PSD (photoshop document). 支持30,000×30,000像素的图像，文件最大2GB。

基本图像处理运算简介：Adobe Photoshop (II)

- 大文件格式 .PSB (Photoshop Big) 支持300,000×300,000像素图像，文件大小上限为 4 Exabyte (4百万TB）。

- 支持多种彩色模型 （RGB, CMYK, CIELAB, Duotone, LAB)

- 主要功能
  - 像素编辑
  - 图像校正
  - 图像滤波
  - 三维设计
  - 简单视频编辑

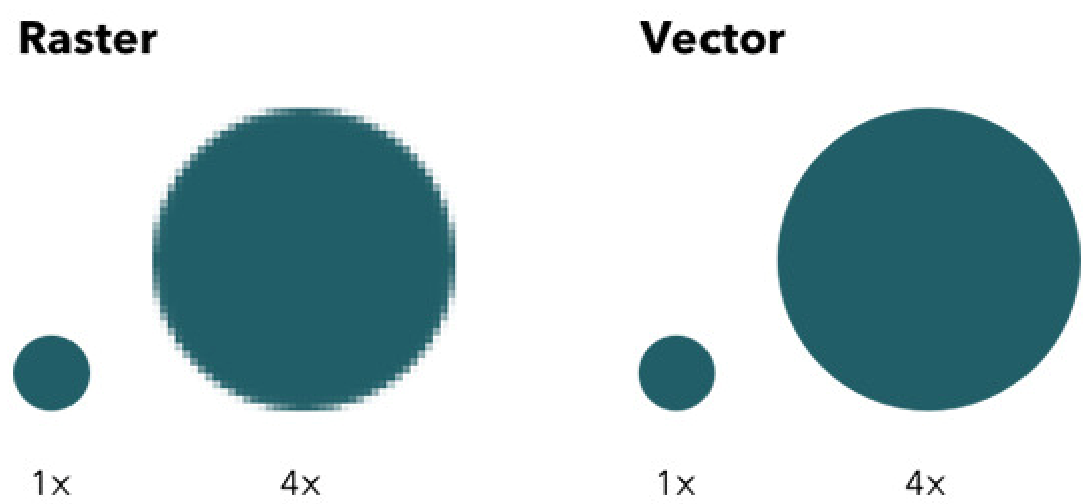
基本图像处理运算简介：Adobe Photoshop (III)

- 易用性较好但编程功能有限。

- 常用功能
  - 图像格式转换
  - 图像文件大小调整
  - 图像亮度，对比度，色彩调整
  - 基本图像处理 （滤镜功能）
  - 排版图设计
  - 图像打印

基本图像处理运算简介：Adobe Illustrator

- 用于矢量图设计，包括高端科技出版图形设计与排版。出版业常采用。
- 可通过便利的图形缩放，颜色修改等等。
- 可使用EPS图形格式。
- 复杂几何造型功能有限。
- 于1987年1月开始发售。



基本图像处理运算简介：OpenCV (I)

- 早期主要由Intel支持，第一版于2000年6月CVPR首发。
- 主要编程语言是C++，提供已优化代码。
- 正式版1.0于2006年发布。
- OpenCV2 于2009年10月发布。
- 2012年8月成立OpenCV.org。

基本图像处理运算简介：OpenCV (II)

- 提供基本图像处理功能

- 目前包括超过2500 个优化计算机视觉算法。

- 主要功能
  - 物体识别
  - 跟踪
  - 物体几何重建

- 支持Python, Java 和MATLAB接口。

- 支持深度学习框架 TensorFlow, Torch/PyTorch.

基本图像处理运算简介：MATLAB 图像处理运算箱

- 基本输入输出，格式转换，显示，主要针对单幅图像
- 图像的几何变换
- 线性滤波
- 图像形态学处理
- 图像增强
- 图像分割
- 图像去模糊
- 彩色图像处理
- 大图像处理

基本图像处理运算简介：MATLAB 计算机视觉运算箱

- 基本输入输出，格式转换，显示，主要针对视频文件
- 提供与OpenCV的接口
- 图像配准和立体视觉
- 物体识别
- 运动估计与跟踪
- 图像的几何变换
- 图像滤波和增强
- 图像的统计学和形态学处理
- 代码生成

基本图像处理运算简介：PIL/Pillow

- PIL- Python Imaging Library
  http://www.pythonware.com/products/pil/
  - 基本图像操作
  - 图像增强，滤波

- 最早起始于1995年

- 最后一个稳定版是 PIL1.1.7, 发布于2009年11月

- Pillow在PIL基础上开发，提供对于Python 3.x 版的支持。

第一次编程作业

内容提纲

- 空间分辨率与灰度分辨率
- 像素间的基本关系
- 图像处理的基本数学运算
- 图像处理的基本功能
- 图像处理的应用领域
- 彩色图像
- 代表性图像处理软件
- 图像的噪声模型

数字图像采集典型场景示例

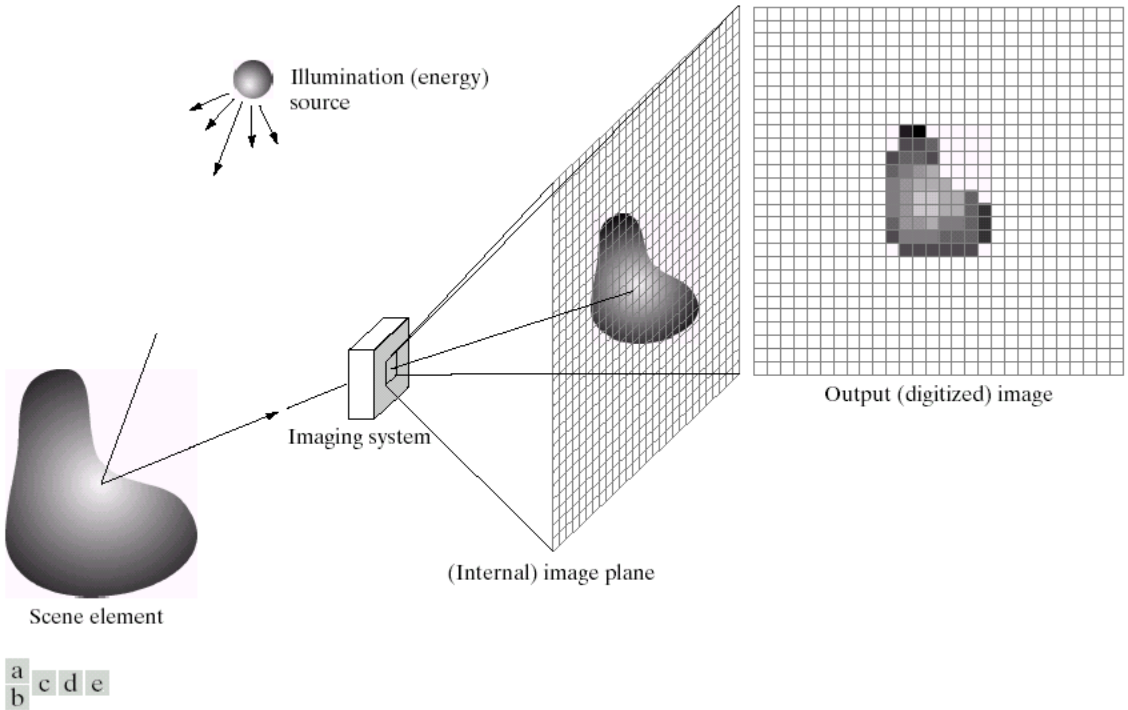


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

图像的噪声模型 (I)

- 加性噪声 additive noise

$$i(\cdot) = g(\cdot) + n(\cdot)$$

- 乘性噪声 multiplicative noise

$$i(\cdot) = g(\cdot)n(\cdot)$$

$$\log i = \log g + \log n$$

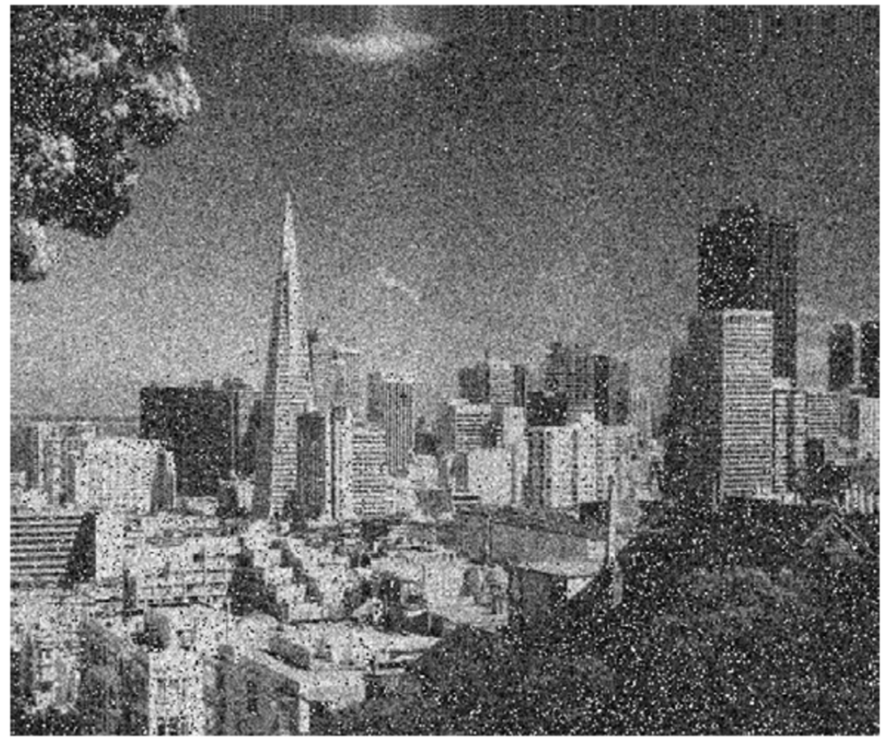
- 一个图像可能同时受到多种噪声的影响

高斯噪声 (I)

SD=10

- 常见的噪声来源：背景噪声 (dark noise), 放大器噪声 (amplifier noise)

高斯噪声 (II)



SD=30

椒盐(salt and pepper) 噪声

- 常见的噪声来源：传输噪声 (transmission noise)

$$P(n=0)=1-\alpha$$

$$P(n=MAX)=\alpha/2$$

$$P(n=MIN)=\alpha/2$$

Poisson噪声

$$P(n=k)=\frac{e^{-\lambda}\lambda^{k}}{k!}$$

$$E(n)=\lambda$$

$$\sigma^{2}(n)=\lambda$$

$$\Rightarrow \quad noise \sim \sqrt{pixel\_intensity}$$

Questions?

A Microscope as a Linear System

- A light microscope can be considered as a linear system.

- A linear system satisfies the following two conditions
  - Homogeneity
  - Additivity

- Homogeneity

$$\boxed{\begin{gathered} x(t) \rightarrow y(t) \\ \Downarrow \\ k \cdot x(t) \rightarrow k \cdot y(t) \end{gathered}}$$

- Additivity

$$\boxed{\begin{gathered} x_1(t) \rightarrow y_1(t) \\ x_2(t) \rightarrow y_2(t) \\ \Downarrow \\ x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t) \end{gathered}}$$

How to Characterize a Linear System

- A linear system can be characterized by
  - Impulse response
  - Frequency response

- Impulse response of a microscope: point spread function

$$I(x,y)=O(x,y)\otimes psf(x,y)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}O(u,v)\cdot psf(x-u,y-v)\,dudv$$

- Frequency response of a microscope: optical transfer function

$$F\{I(x,y)\}=F\{O(x,y)\}\cdot F\{psf(x,y)\}=F\{O(x,y)\}\cdot OTF(\cdot)$$

Airy Disk

- Airy (after George Biddell Airy) disk is the diffraction pattern of a point feature under a circular aperture.

- It has the following form

$$y = \left[\frac{2J_1(x)}{x} \right]^2$$

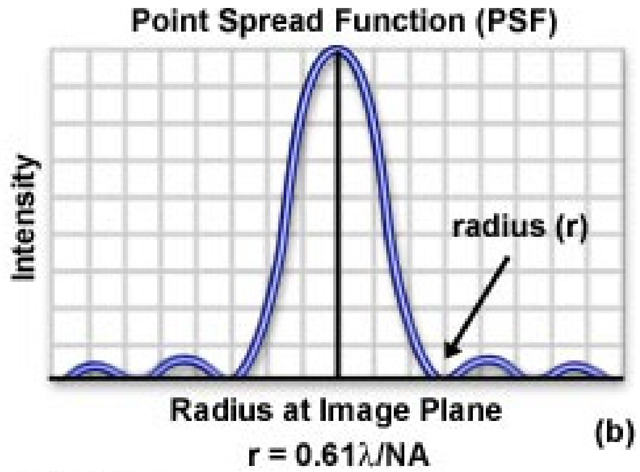


Figure 1

$J_1(x)$ is a Bessel function of the first kind.

- Detailed derivation is given in

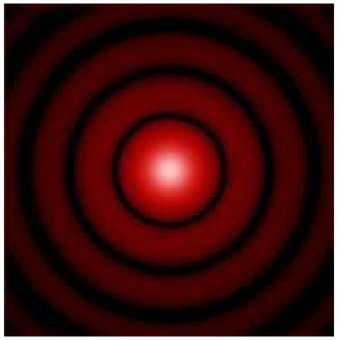
  Born & Wolf, Principles of Optics, 7th ed., pp. 439-441.

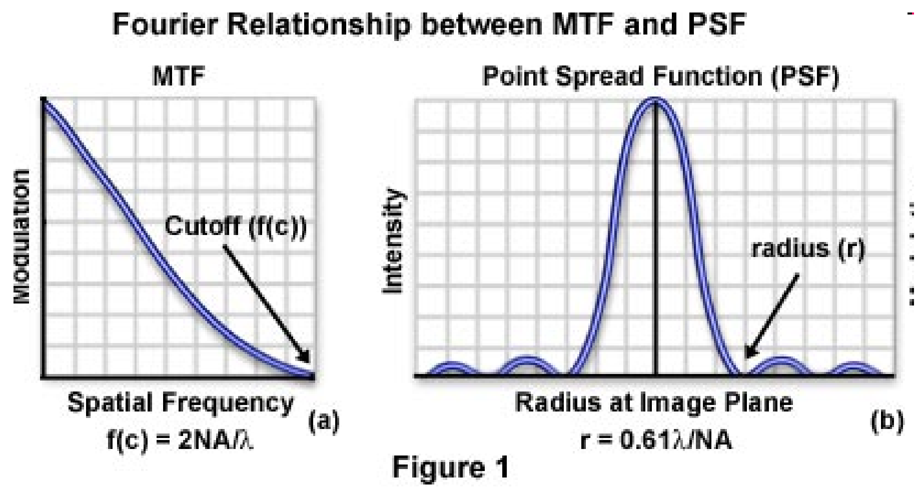
Microscope Image Formation (I)

- Microscope image formation can be modeled as a convolution with the PSF.

$$I(x,y) = O(x,y) \otimes psf(x,y)$$

$$F\{I(x,y)\} = F\{O(x,y)\} \cdot F\{psf(x,y)\}$$





http://micro.magnet.fsu.edu/primer/java/mtf/airydisksize/index.html

Microscope Image Formation (II)

- The impulse response of the microscope is called its point spread function (PSF).
- The transfer function of a microscope is called its optical transfer function (OTF).
- The PSF has the shape of an Airy Disk.

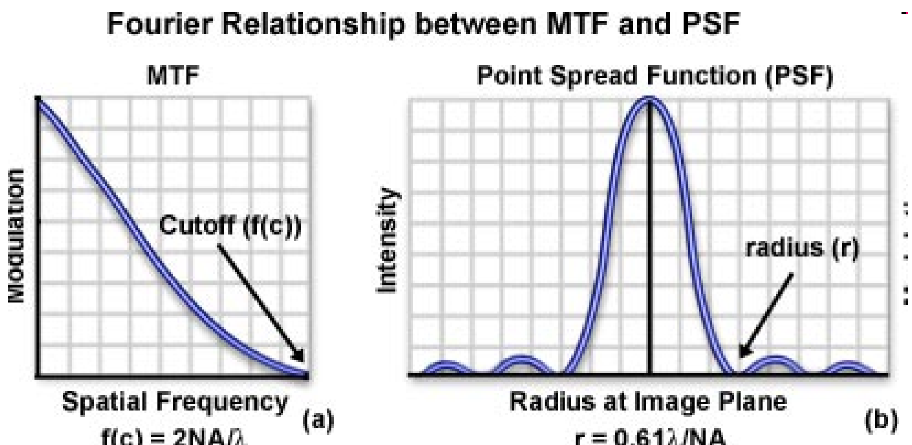
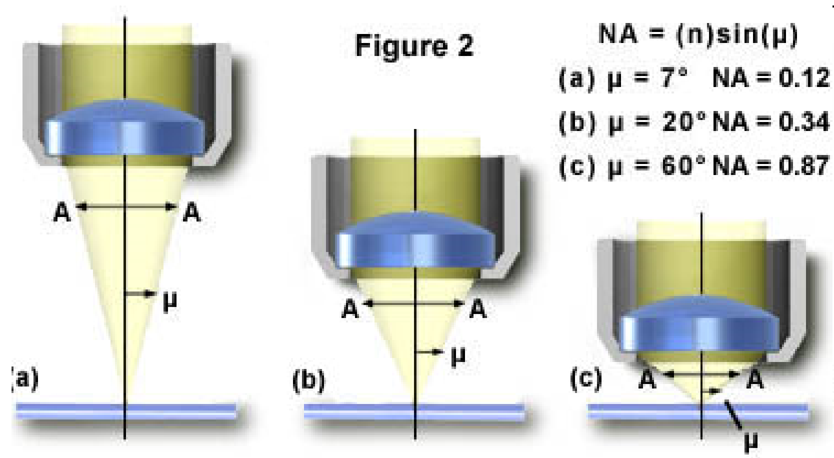


Figure 1

Numerical Aperture

- Numerical aperture (NA) determines microscope resolution and light collection power.



$$NA = n \cdot \sin \mu$$

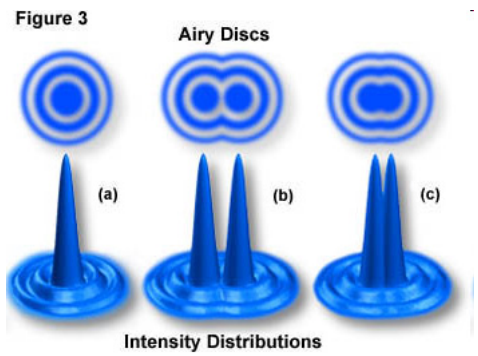
n: refractive index of the medium between the lens and the specimen

μ: half of the angular aperture

Different Definition of Light Microscopy Resolution Limit (Demo)

- Rayleigh limit

$$D = \frac{0.61\lambda}{NA}$$



- Sparrow limit

$$D = \frac{0.47\lambda}{NA}$$

http://www.microscopy.fsu.edu/primer/java/imageformation/rayleighdisks/index.html

Summary: High Resolution Microscopy

- Size of cellular features are typically on the scale of a micron or smaller.

- To resolve such features require
  - Shorter wavelength (electron microscopy)
  - High numerical aperture (resolution)
  - High magnification (spatial sampling)

$$D = \frac{0.61\lambda}{NA}$$

ICIP 2023 簡介

https://2023.ieeeicip.org/

ICCV2023簡介

https://iccv2023.thecvf.com/