Chapter2 Fundamentals of Image and Vision

- 2.1 Human Eye and Brightness Vision
- 2.2 Image Fundaments
- 2.3 Sampling and Quantization
- 2.4 Relationships between Pixels
- 2.5 Arithmetic and logic Operations

2.1 Human Eye and Brightness Vision

2.1.1 Structure of the Human Eye

- Shape: nearly a sphere, diameter=20mm
- Components: cornea(角膜), sclera(巩膜), choroid(脉络膜), retina(视网膜), lens, fovea(中央凹), blind spot(盲点), nerve (神经)and sheath(鞘).

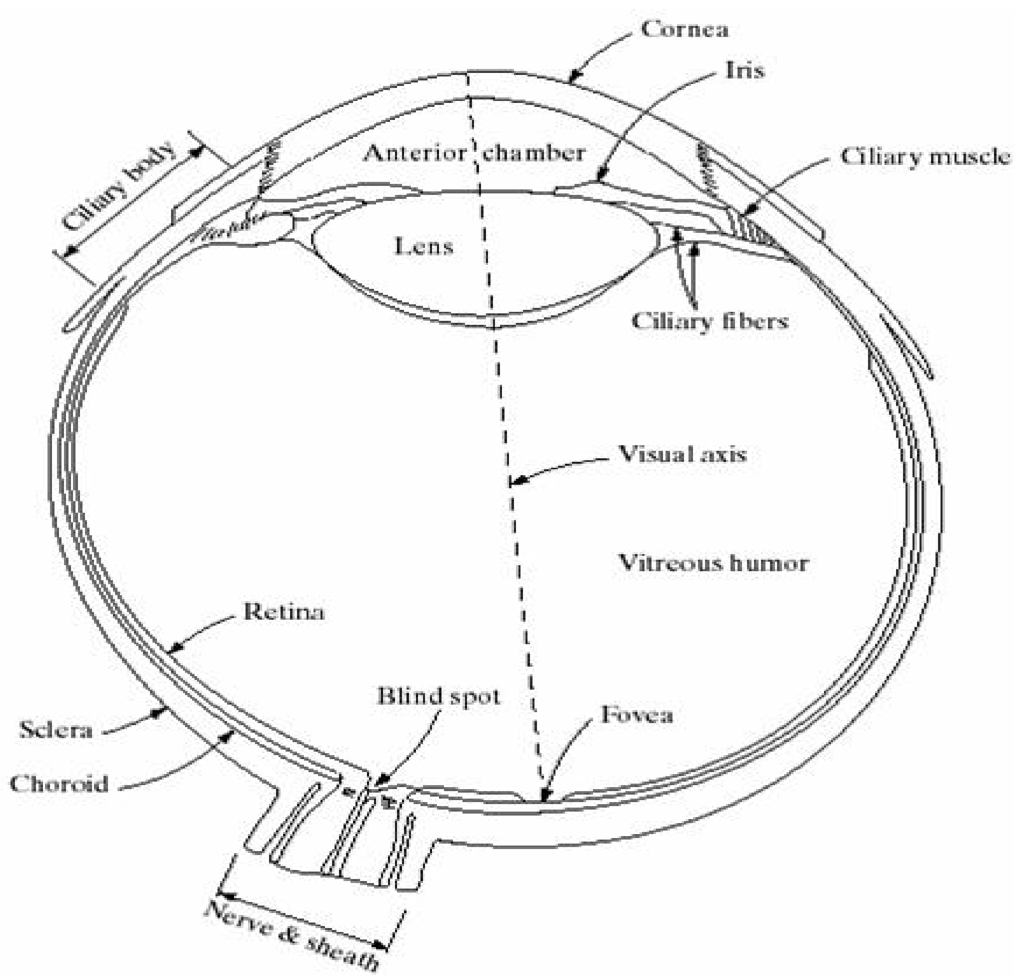


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

2.1 Human Eye and Brightness Vision

2.1.1 Structure of the Human Eye

	cones	rods
number	6~7 million	75~175 million
Sensitivity	color	shape
vision	Photopic (Bright-light)	Scotopic(dim-light)

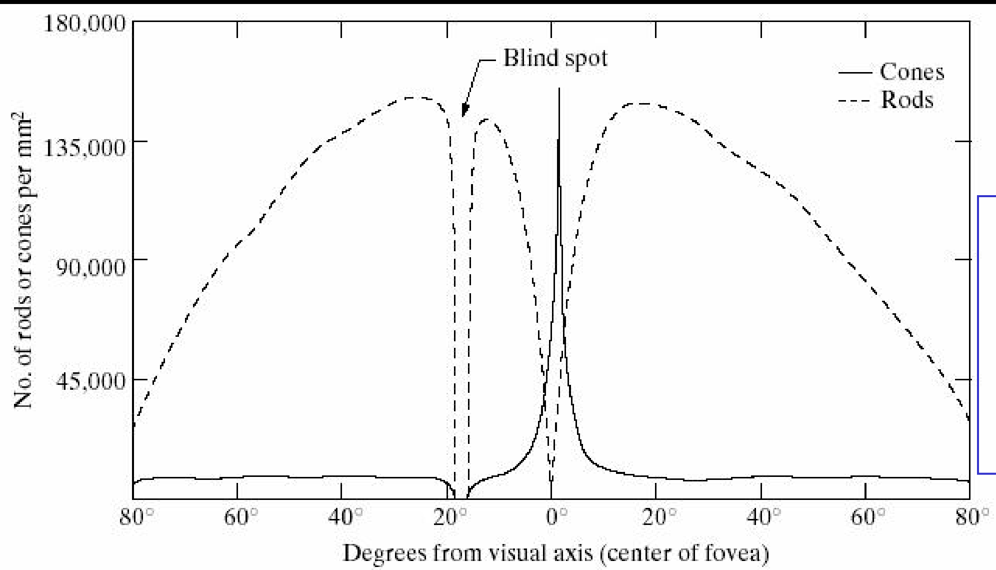


FIGURE 2.2 Distribution of rods and cones in the retina.

Fovea area: 1.5mm*1.5mm

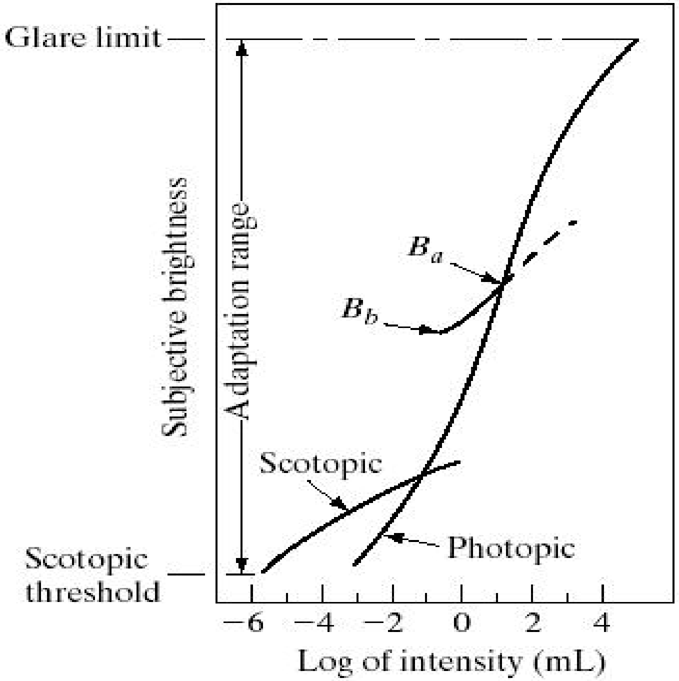
Density of cones: 15000/mm²

Cones in fovea: 337 000

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

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



Phenomenon 1: Subjective Brightness

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 2: Simultaneous contrast

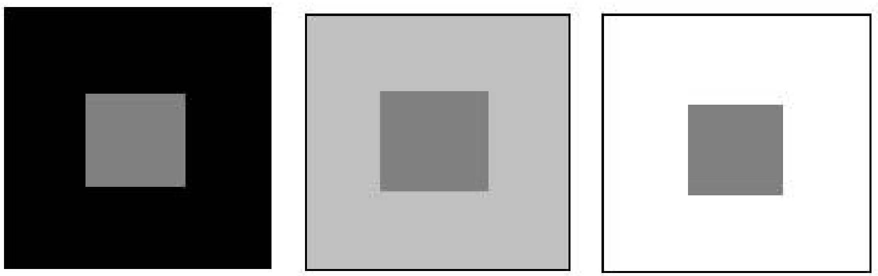


Figure 2.8

- Although all the center squares have the same intensity,they appear to the eye to become darker as the background gets lighter.

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

254

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

253

2.1 Human Eye and Brightness Vision

2.1.3 Log characteristic

Phenomenon 3: Weber Ratio

252

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

251

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

250

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

248

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

245

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

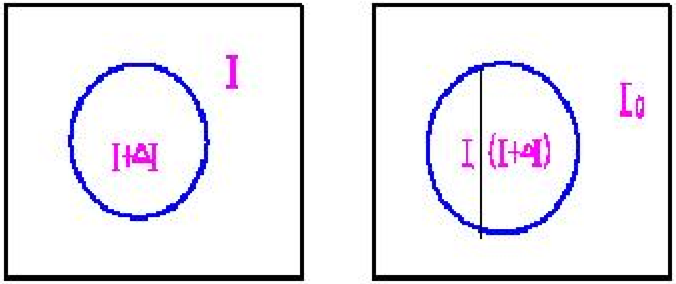
Phenomenon 3: Weber Ratio

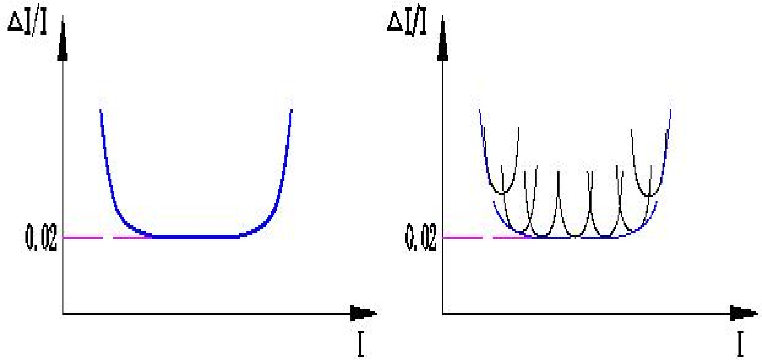
230

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio





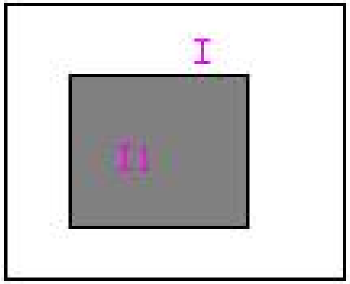
2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon 3: Weber Ratio

Explanation: $$d(\ln I) = dI / I$$

Definitions of Contrast:



$$C_p = (I_1 - I)/I = \Delta I / I$$

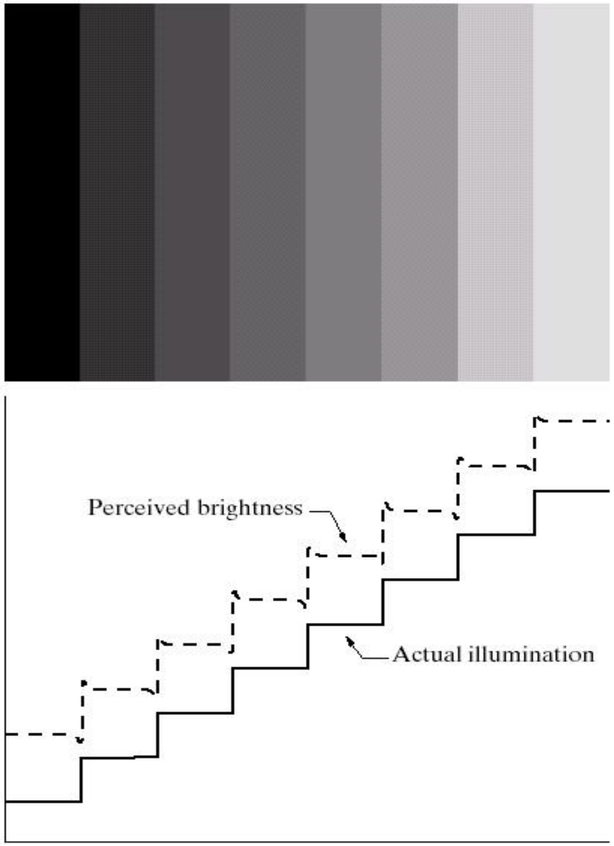
$$C_I = I_{\max} / I_{\min}$$

Weber Ratio=0.02=2%

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon4:
Mach band



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.

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Phenomenon5:
Optical illusions

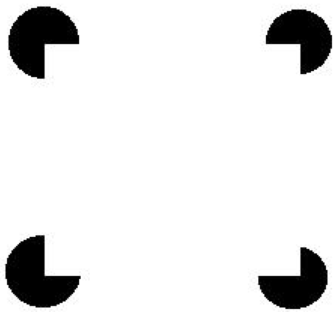


Figure 2.9-1

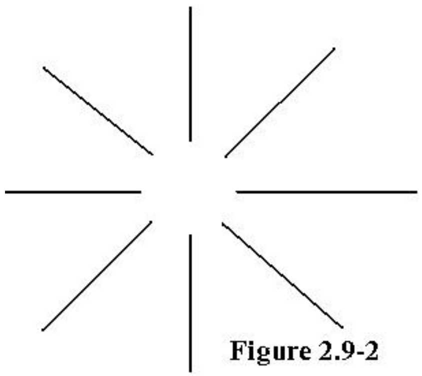
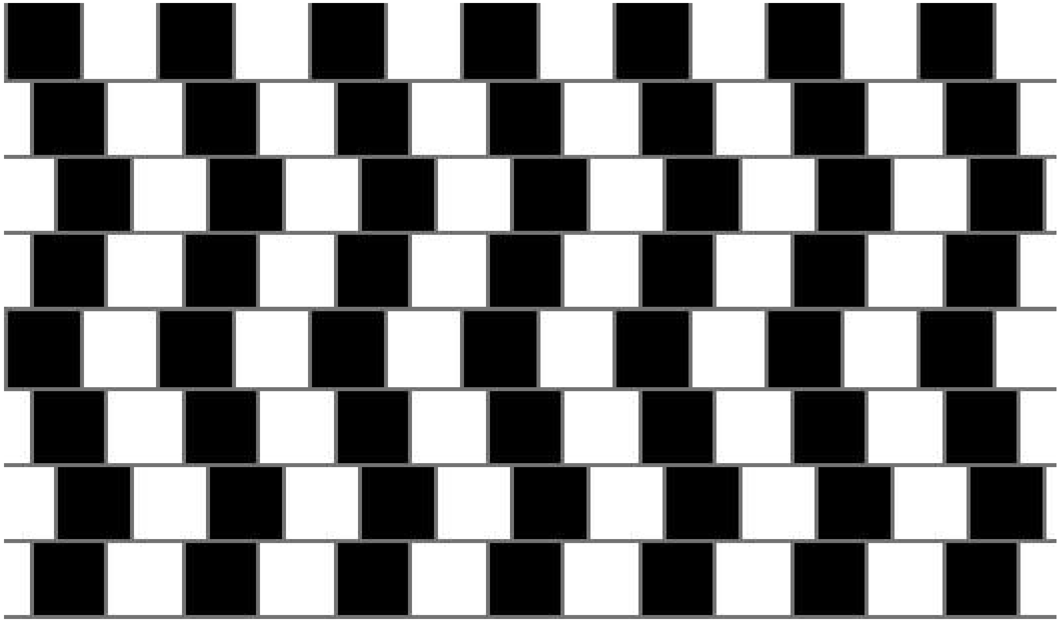


Figure 2.9-2



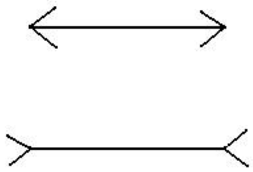
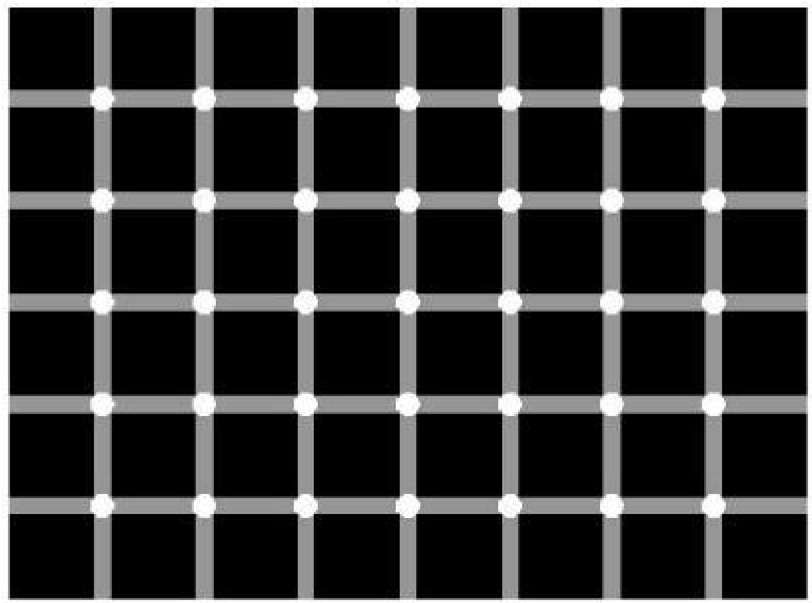


Figure 2.9-3

2.1 Human Eye and Brightness Vision

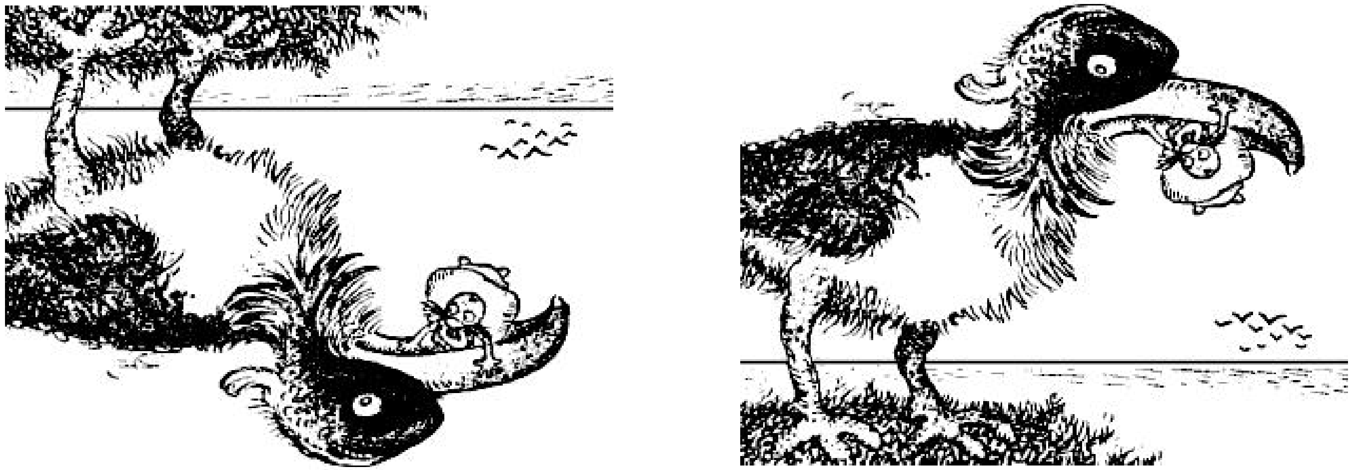
2.1.2 Vision Phenomena

Phenomenon5:
Optical illusions

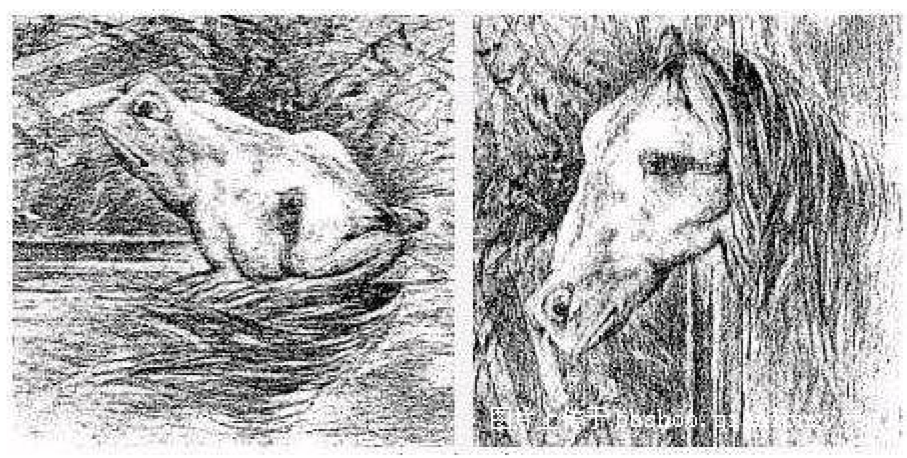


數數看有幾個黑點！ :o)


CHINAHDDN.COM
龍騰在綫娛樂網
看着黑点，然后头向后移



图像的二义性

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中华网论坛

1，盯着照片上女孩儿鼻子上的红点30秒钟
2，将你的目光移到墙面或较平的表面
3，快速眨动你的眼睛，你看见了什么？

2.1 Human Eye and Brightness Vision

2.1.2 Vision Phenomena

Conclusion:

- Log transformation is usually used in preprocessing step of DIP system , in order to improve the visual results.
- The subjective brightness is relatived
- The discriminability of human eye is limited

2.2 Image Fundaments

2.2.1 Image data presentation

Assume that an image f(x,y) is sampled so that the resulting digital image has M rows and N columns.We use integer values for those of the coordinates (x,y).

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \ddots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

2.2 Image Fundaments

2.2.1 Image data presentation

We often use a more traditional matrix notation to denote a digital image and its elements.

$$A = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

- Clearly, $a_{ij} = f(i, j)$

2.2 Image Fundaments

2.2.1 Image data presentation

two dimensional array	**A[M][N]**
Image size	**M*N**
Pixel at point (i,j)	A[i][j]

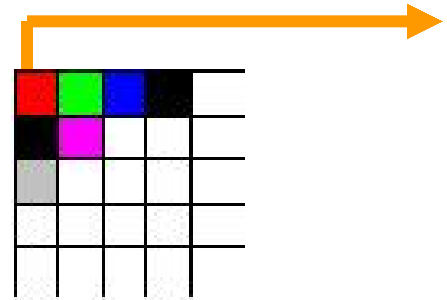
2.2 Image Fundaments

2.2.2 Image Types

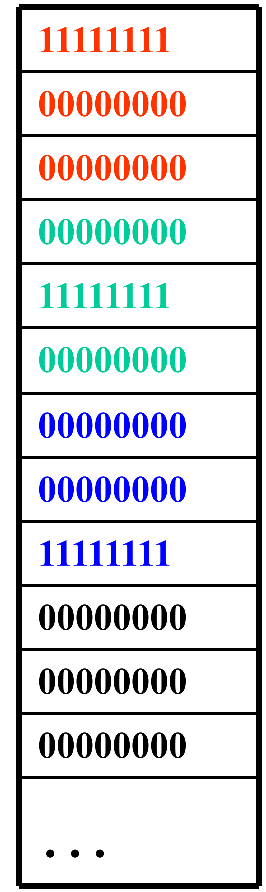
Type	Bits/pixel	color levels
Binary image	1	2
Gray Image	8	256
Color image	24	16777216
Multispectral Image	8*n	

2.2 Image Fundaments

2.2.2 Image Types



Frame Buffer



Binary Image

Gray Image

Color Image

2.2 Image Fundaments

2.2.3 Image Statisic Parmeters

Max value: $$ma\_value = \max(A(i,j))$$

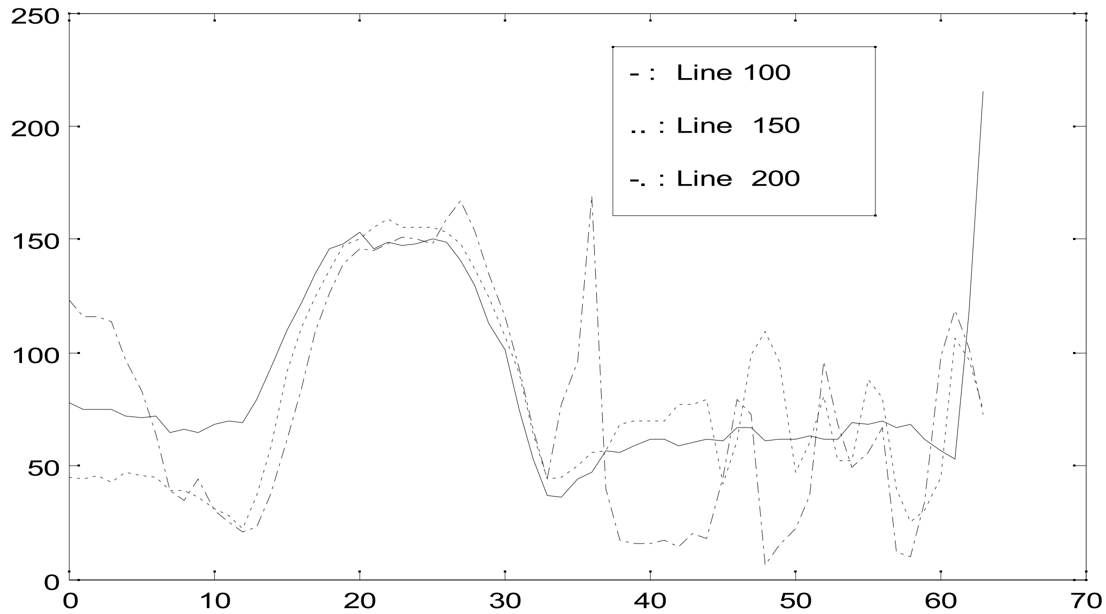
Min value: $$mi\_value = \min(A(i,j))$$

Mean value: $$me\_value = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} A(i,j)$$

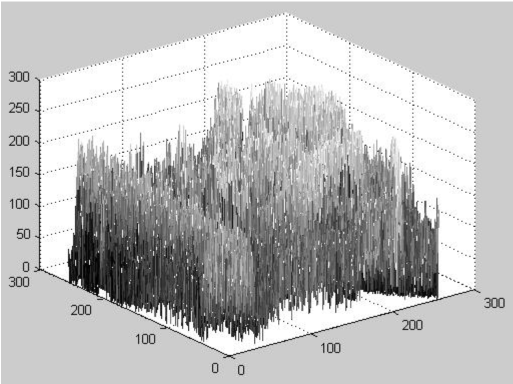
Variance: $$\sigma^2 = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (A(i,j) - me\_value)^2$$

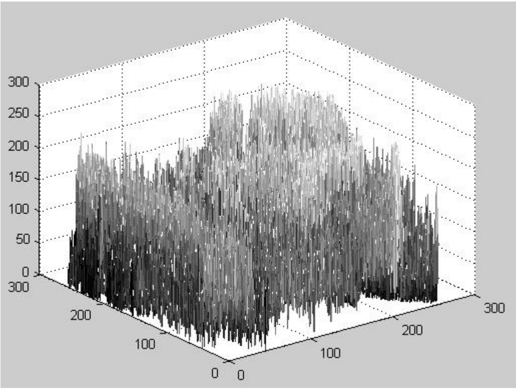
Where: $i = 0,1,\ldots M-1$ $\quad$ $j = 0,1,\ldots N-1$

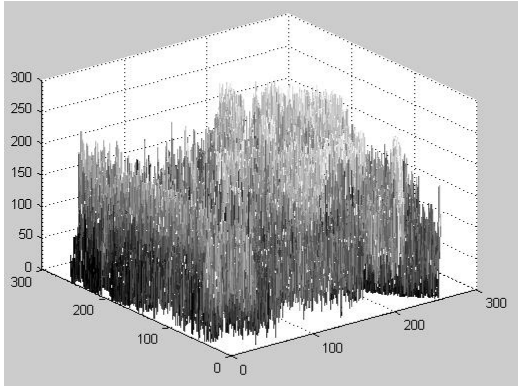
2.2 Image Fundaments



2.2 Image Fundaments







2.2 Image Fundaments

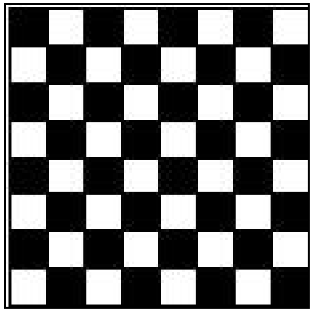
2.2.4 Image Dara File Formats

Name	type	application
raw data format	*.dat, *.raw	Dos, UNIX and Macintosh image
Bit-mapped format	*.bmp	Microsoft Windows format
Tagged file format	*.tif	Dos, UNIX and Macintosh image

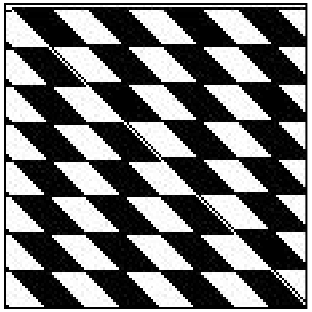
2.2 Image Fundaments

2.2.4 Image Dara File Formats

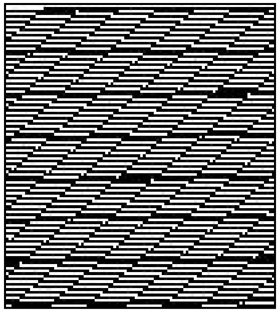
Raw data file: simple but no any attached information.
If you don’t know the width of image, then:



113



112



100

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Bit-mapped file:

File head	Bitmap head	Color map	data

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Bit-mapped file: file head

Offset	**Length**	**Name**	**Description**
0	2	bfType	“BM”
2	4	bfSize	Size of file
6	2	bfReserved1	0
8	2	bfReserved2	0
10	4	bfOffBits	Offset after file head

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Bit-mapped file: bitmap head

Offset	Length	Name	Description
14	4	biSize	Size of bitmap head, 40
18	4	biWidth	Width of Image
22	4	biHeight	Height of Image
26	2	biPlanes	Always “1”
28	2	biBitCount	Bits/pixel, 1,4,8 or 24
30	4	biCompression	Size of compressed file
34	4	bfSizeImag	Offset after file head

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Bit-mapped file: bitmap head

Offset	**Length**	**Name**	**Description**
38	4	biXPelsPerMeter	Resolution in horizon direction
42	4	biYPelsPerMeter	Resolution in vertical direction
46	4	biClrUsed	Color number used
50	4	biClrImportant	Important color's number
54	4*N	bmiColors	Color Mapping table

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Bit-mapped file: Color map

Offset	**Length**	**Name**	**Description**
0	1	rgbBlue	Value of blue
1	1	rgbGreen	Value of green
2	1	rgbRed	Value of red
3	1	rgbReserved	0

2.2 Image Fundaments

2.2.4 Image Dara File Formats

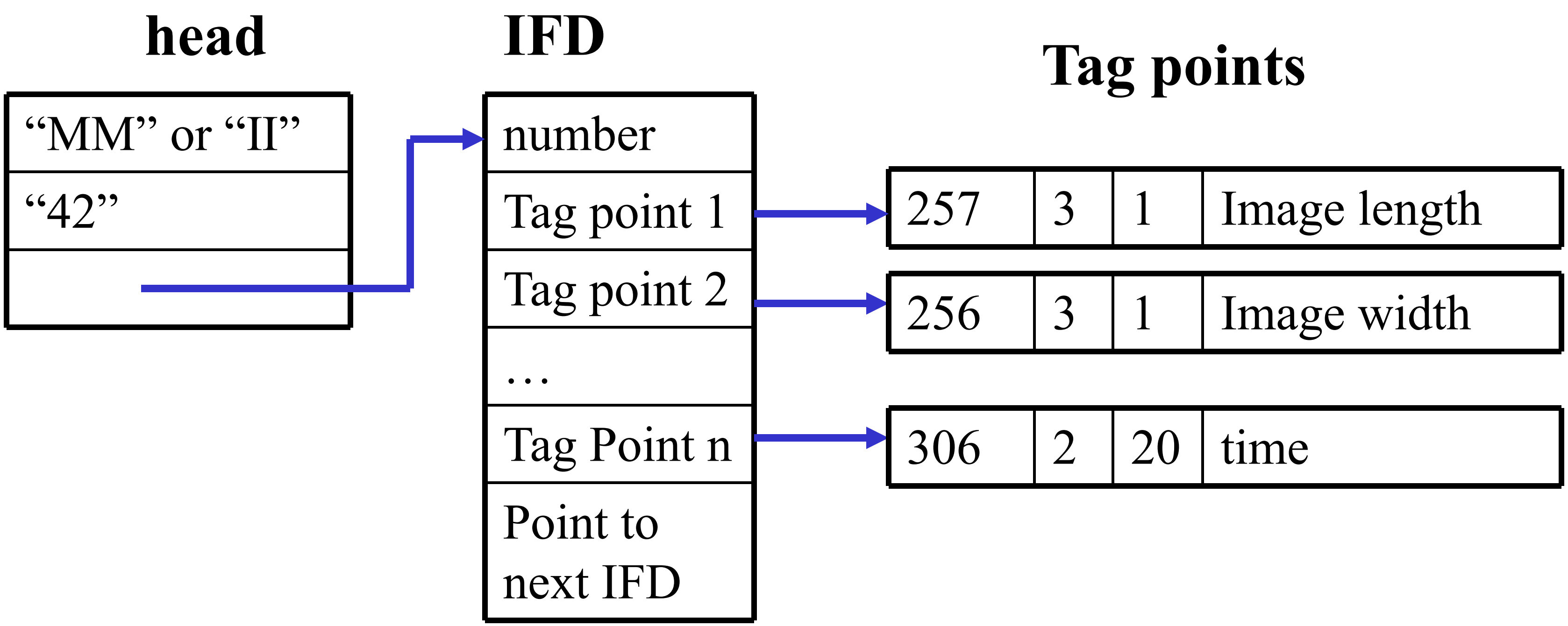
Bit-mapped file: example of Color map biBitCount=8

Number	**rgbBlue**	**rgbGreen**	**rgbRed**
0	0	0	0
1	1	1	1
. . .	. . .	. . .	. . .
255	255	255	255

2.2 Image Fundaments

2.2.4 Image Dara File Formats

Tagged file format



IFD: image file directory

42，是道格拉斯・亚当斯所作的小说《银河系漫游指南》中“生命、宇宙以及任何事情的终极答案”的答案

2.3 Sampling and Quantization

2.3.1 Spatial resolution

The number G of discrete gray levels and the size of image are typically integer power of 2. The range of values spanned by the gray levels is called the dynamic range of an image

$$G = 2^k \qquad M = 2^m \qquad N = 2^n$$

The number b of bits required to store a digital image is :

$$b = M \times N \times k$$

When $M=N$:

$$b = N^2 k$$

2.3 Sampling and Quantization

2.3.1 Spatial resolution

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.

2.3 Sampling and Quantization

2.3.2 Zooming and Shrinking Digital Images

Zooming requires two steps:

(1) the creation of new pixel locations

(2) the assignment of gray levels to those new locations.

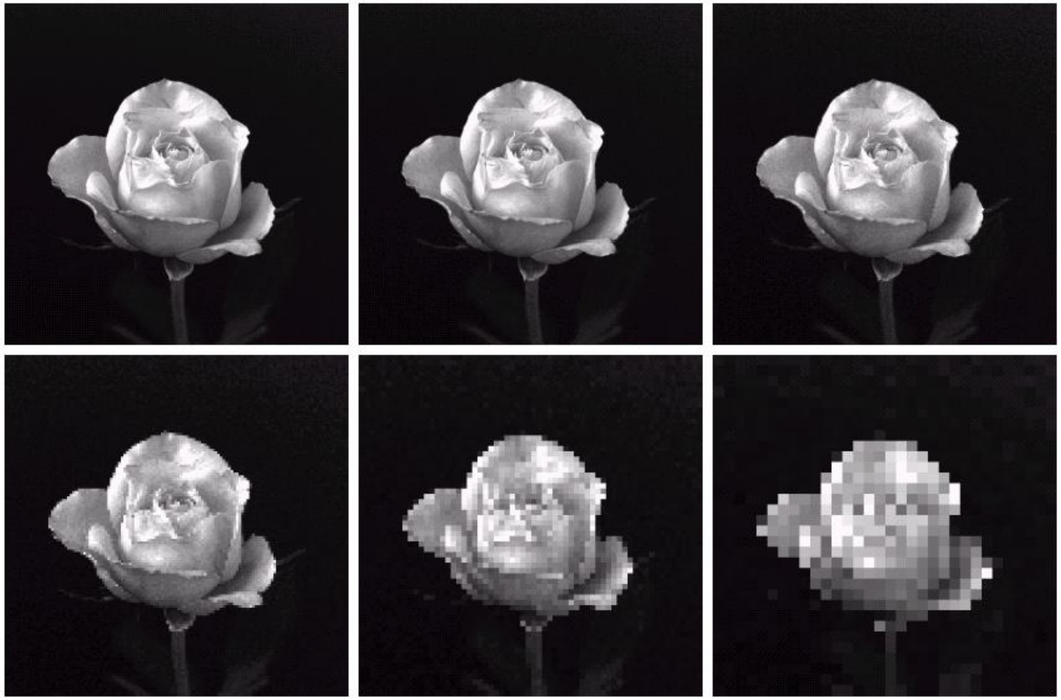
Methods:

(1) Nearest neighbor interpolation

(2) Bilinear interpolation

2.3 Sampling and Quantization

2.3. 2 Zooming and Shrinking Digital Images

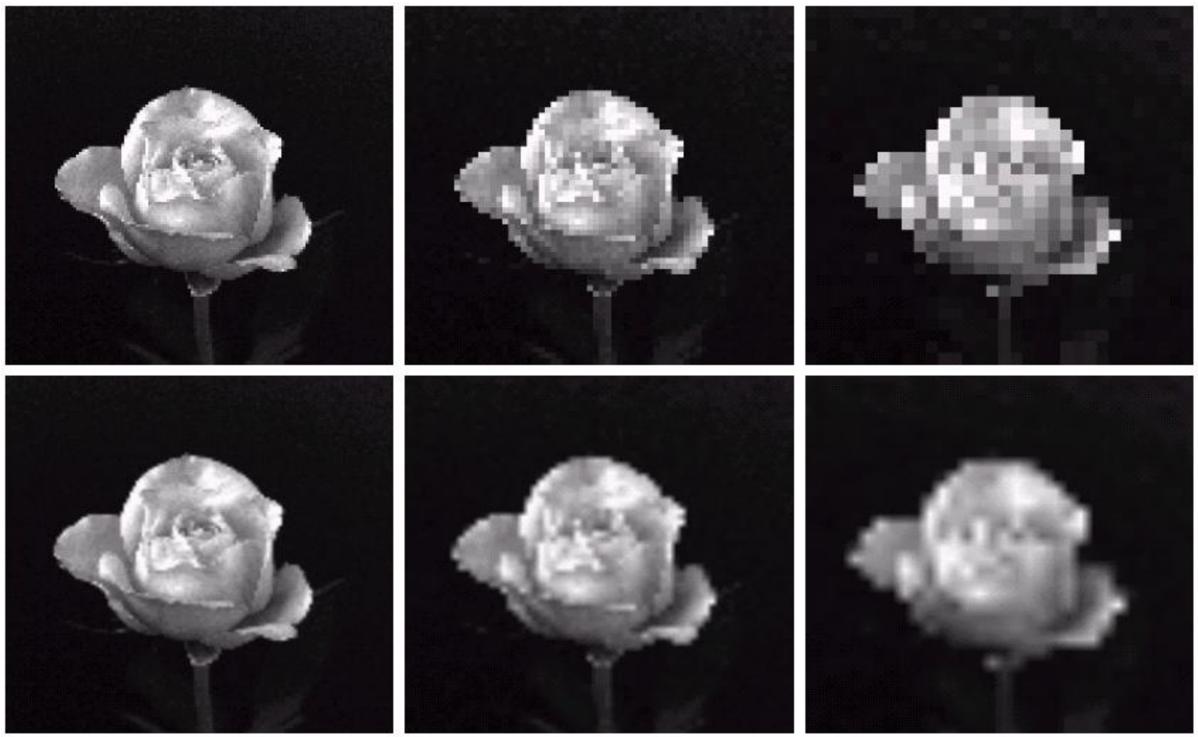


a b c
d e f

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.

2.3 Sampling and Quantization

2.3.3 Zooming and Shrinking Digital Images



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.

2.3 Sampling and Quantization

2.3.2 Gray level resolution

8bit 4bit 2bit 1bit

2.4 Relationship between Pixels

2.4.1 Neighborhood of a pixel

A pixel p at coordinates (x,y) has four horizontal and vertical neighbors whose coordinates are given by This set of pixels,called the 4-neighbors of p,is denoted by $N_4(p)$

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \ddots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

0	$(x-1,y)$	0
$(x,y-1)$	(x,y)	$(x,y+1)$
0	$(x+1,y)$	0

2.4 Relationship between Pixels

2.4.1 Neighborhood of a pixel

The four *diagonal* neighbors of p have coordinates. and are denoted by

$N_D(p)$

$(x-1, y-1)$	0	$(x-1, y-1)$
0	(x, y)	0
$(x+1, y-1)$	0	$(x+1, y+1)$

$N_D(p)$ together with $N_4(p)$,are called the *8-neighbors* of p,denoted by $N_8(p)$

2.4 Relationship between Pixels

2.4.2 Connectivity

To establish if two pixels are connected,it must be determined if they are neighbors and if their gray levels satisfy a specified criterion of similarity. If V is defined as the set of gray levels, then

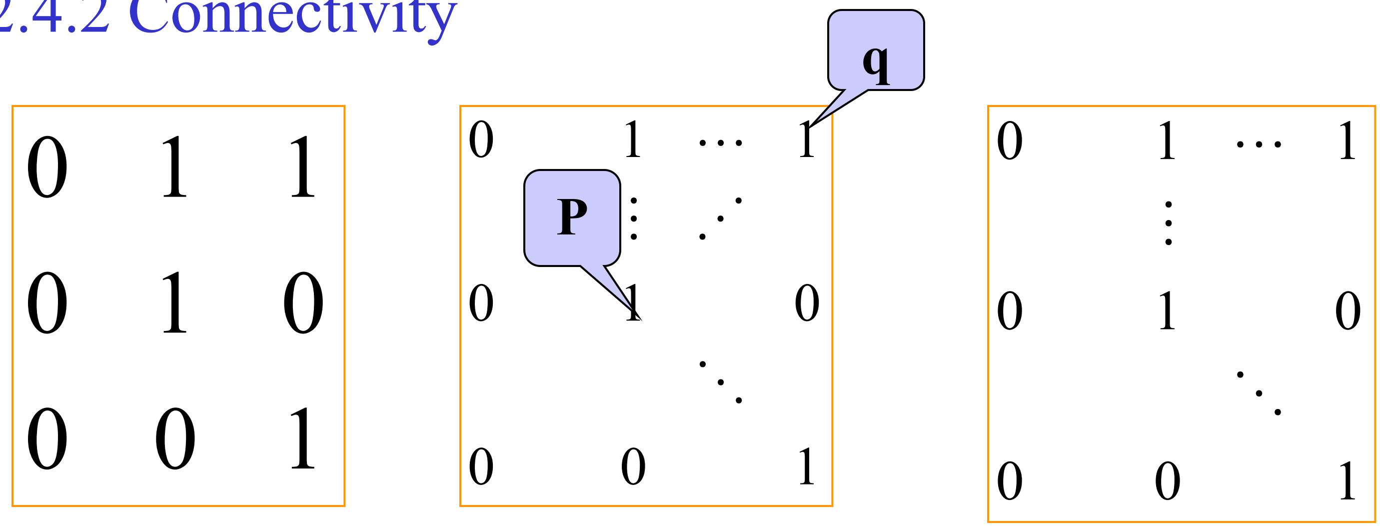
- *4-adjacency:* two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$
- *8-adjacency* : two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$
- *m-adjacency* : two pixels p and q with values from V are 4-adjacent if

  (i)q is in $N_4(p)$,or

  (ii) q is in $N_D(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V.

2.4 Relationship between Pixels

2.4.2 Connectivity



a *b* *c*

Figure 2.26 (a) Arrangement of pixels;(b) pixels that are 8-adjacent;(c)m-adjacent

2.4 Relationship between Pixels

2.4.3 Distance Measures

For pixels p,q and z ,with coordinates (x,y),(s,t),and(u,v),respectively, D is a *distance function or metric* if

(a) $D(p,q) \geq 0 \quad (D(p,q) = 0, if \;\; p = q)$

(b) $D(p,q) = D(q,p), and$

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

2.4 Relationship between Pixels

2.4.3 Distance Measures

- The Euclidean distance is

$$D_e(p,q) = [(x-s)^2 + (y-t)^2]^{\frac{1}{2}}$$

- And the city-block and chessboard distances are:

$$D_4(p,q) = |x-s| + |y-t|$$

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

- The D_m distance is defined as the shortest m-path between the points.

2.4 Relationship between Pixels

2.4.3 Distance Measures: example 1

City-block distance(D_4)

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

(a)

Chessboard distance (D_8)

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

(b)

图2.7.4　等距离轮廓实例

2.4 Relationship between Pixels

2.4.3 Distance Measures: example 2

$$\begin{array}{ccccc} & & 0 & & 1(q) \\ & & & \iddots & \\ 0 & & 1 & & \\ & \iddots & & & \\ 1(p) & & & & \end{array}$$

$$D_m(p,q)=2$$

$$\begin{array}{ccccc} & & 0 & & 1(q) \\ & & & \iddots & \\ 1 & \cdots & 1 & & \\ \vdots & & & & \\ 1(p) & & & & \end{array}$$

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

$$\begin{array}{ccccc} & & 1 & \cdots & 1(q) \\ & & \vdots & & \\ 0 & & 1 & & \\ & \iddots & & & \\ 1(p) & & & & \end{array}$$

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

$$\begin{array}{ccccc} & & 1 & \cdots & 1(q) \\ & & \vdots & & \\ 1 & \cdots & 1 & & \\ \vdots & & & & \\ 1(p) & & & & \end{array}$$

$$D_m(p,q)=4$$

2.5 Arithmetic and Logic Operation

2.5.1 Arithmetic operation

Arithmetic operations between two pixels *p* and *q* include:

Addition: $p+q$

Subtraction: $p-q$

Multiplication: $p*q$

Division: p/q

Digital watermarking

2.5 Arithmetic and Logic Operation

2.5.2 Logical operation:

AND OR NOT

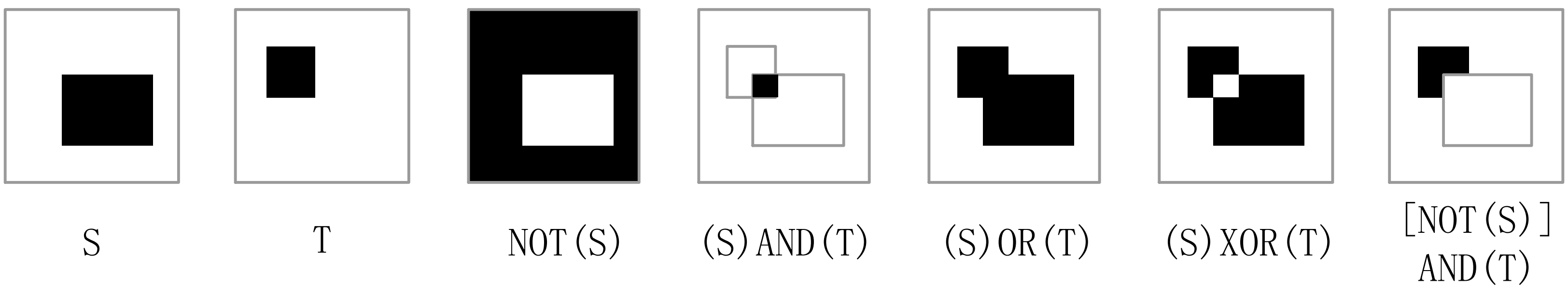


图2.8.1　二值图象的逻辑运算

summary

- Basic idea of the eye in perceiving pictorial information
- Fundamentals of images, include presentation, sampling and quantization, relationship between pixels, arithmetic and logic operations and so on.

The End

Homework

- 马赫带和同时对比度反映了什么共同问题?
- 列举几个视觉错觉的例子.
- 计算5×5邻域各像素到中心象素的的欧式距离,街区距离和棋盘距离。

编程

- 编写一个程序，打开灰度图像lena.bmp，读出以（200，200）为左上角的10*10区域的像素值。
- 编写一个程序，打开灰度图像lena.bmp，将前256行像素设为255，打印处理后的图像。
- 任意修改灰度的lena.bmp 的彩色映像表，写出你的修改方法，给出修改后图像打印显示（彩色打印）。