Research Institute for Future Media Computing
未来媒体技术与研究所
Institute of Computer Vision
计算机视觉研究所

多媒体系统导论——图形和图像的数据表现

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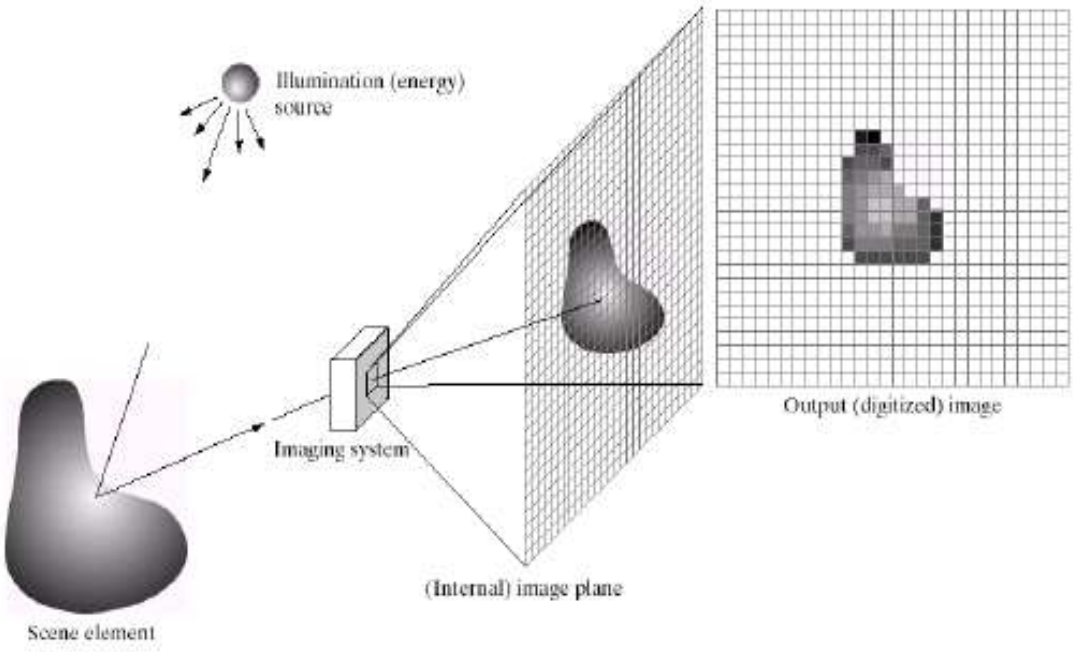
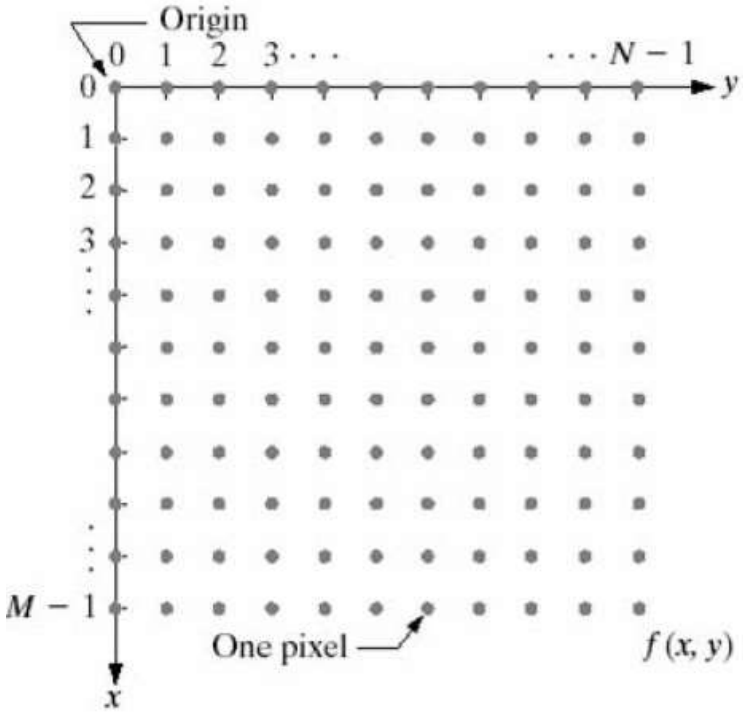
Outline of Lecture 02

- Fundamentals of image data representation
  - Standard image
- Gray-level image
  - Bitmap and bitplane（位平面）
- Color image
  - 24-bit color image and 8-bit color image
  - Histogram and color lookup tables
- Some popular image file format
- Some calculations
  - How to calculate the size of image?
  - How to transform 24 bit color image to 8 bit color image?
  - How to calculate histogram?
  - How does dithering work?

Fundamentals of Image Data Representation

Images





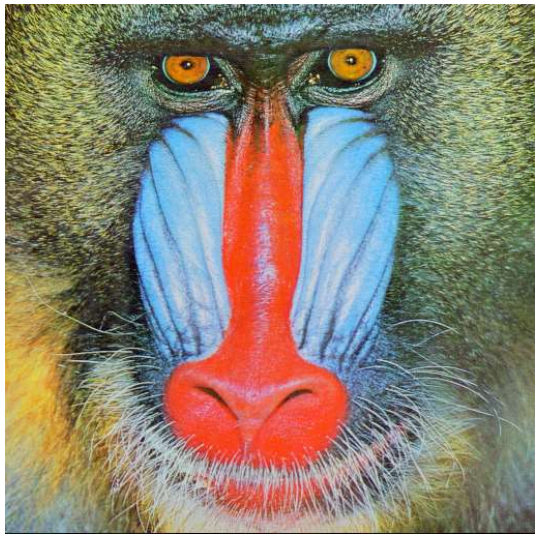
Fundamentals of Image Data Representation

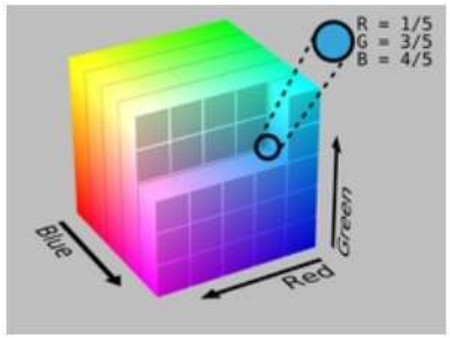
- Images consist of pixels
  - Pixel: picture element
  - The smallest discrete component of an image on the screen
- Image resolution
  - The number of pixels in a digital image
- Standard images
  - Illustrate algorithms and compare the performance
  - Lena: for gray-level image generally
  - Baboon（狒狒）: for color image generally

Standard Images

- Lena:
  - Image Resolution is 256 * 256
- Baboon:
  - Image Resolution is 512* 512

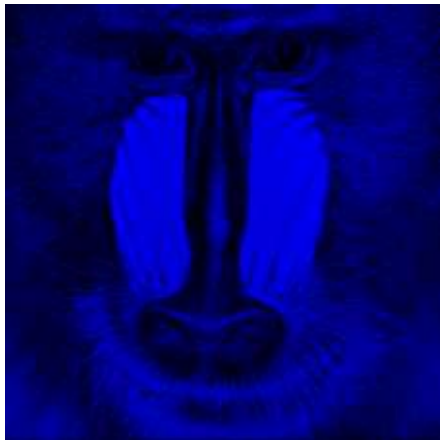
Fundamentals of Image Data Representation





R

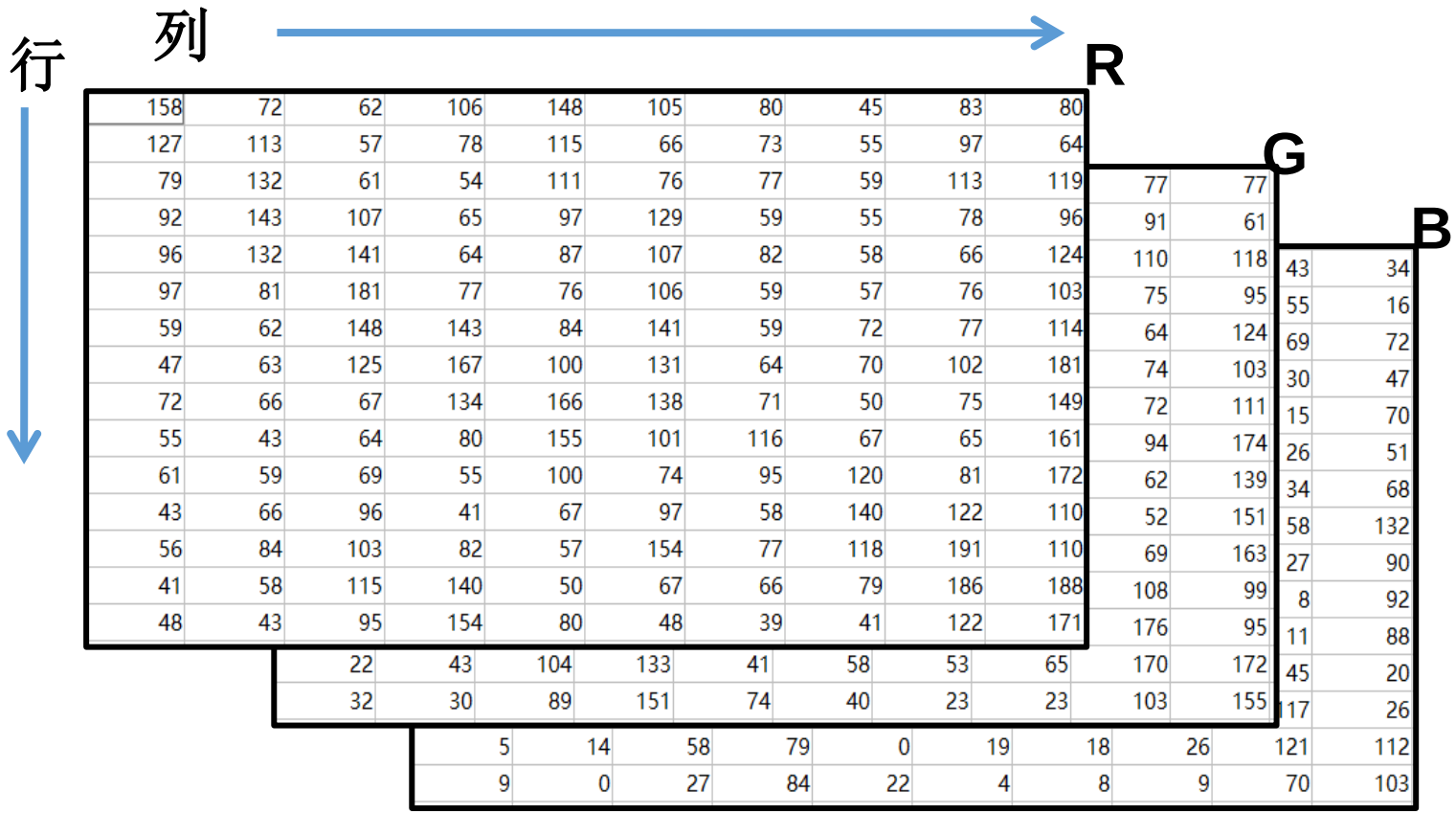
G



B

Fundamentals of Image Data Representation

- Matlab，imread(filename) 读取 uint8格式的图像(取值范围0 -255)
- See demo1RGB



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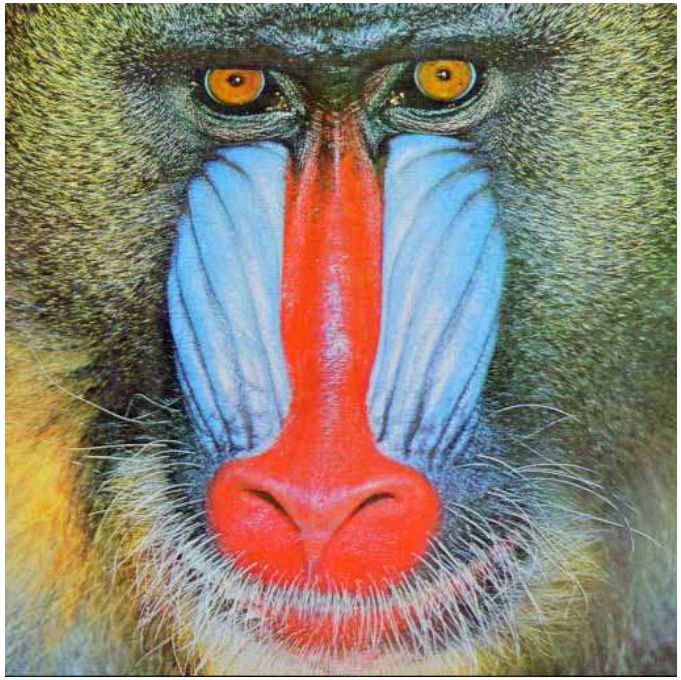
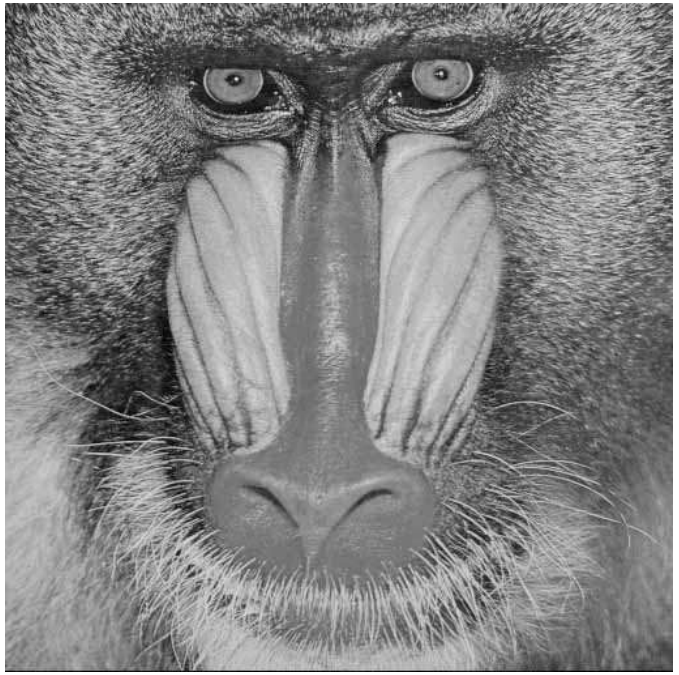
Gray-Level Image（灰度图像）

- Image is represented using luminance（亮度） information only
- 8-bit gray-level image
  - Each pixel has a gray value between 0 and 255
  - Matlab code ： rgb2gray(I)

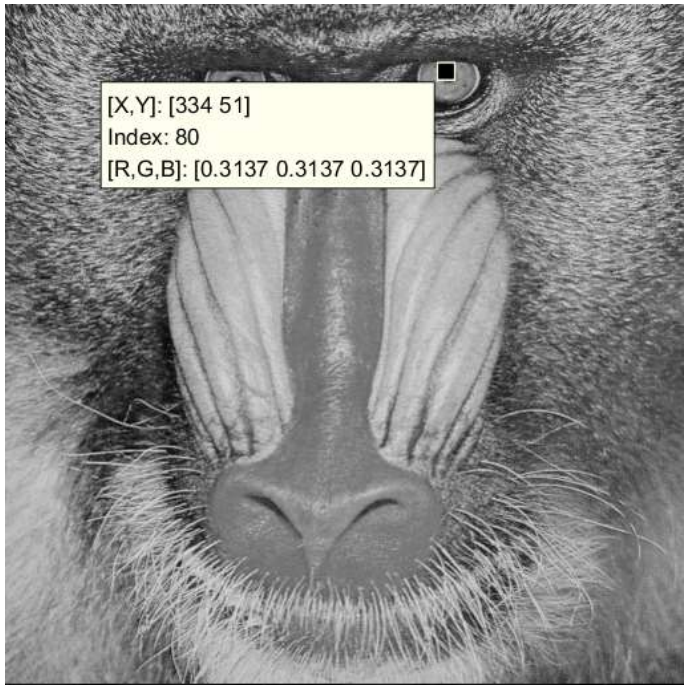
24-bit color Image



Gray Image



Gray-Level Image（灰度图像）



- 512x512的24位彩色图像转成8位灰度图像后，未压缩时数据量关系？

a. 灰度图像和彩色图像大小一样

b. 灰度图像是彩色图像数据量大小的一半

c. 灰度图像是彩色图像数据量大小的三分之一

Binary Image（二值图像）

- Each pixel is stored as a single bit 0/1.
- Also referred as 1-bit image
- Use for the pictures containing simple graphics or text

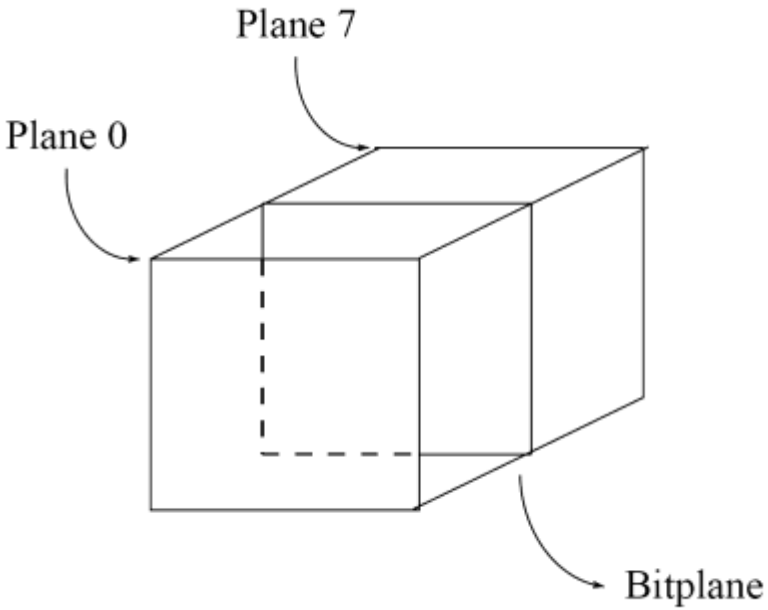
Bitmap of Gray-level Image

- The two-dimensional array of pixel values that represent the images/graphics

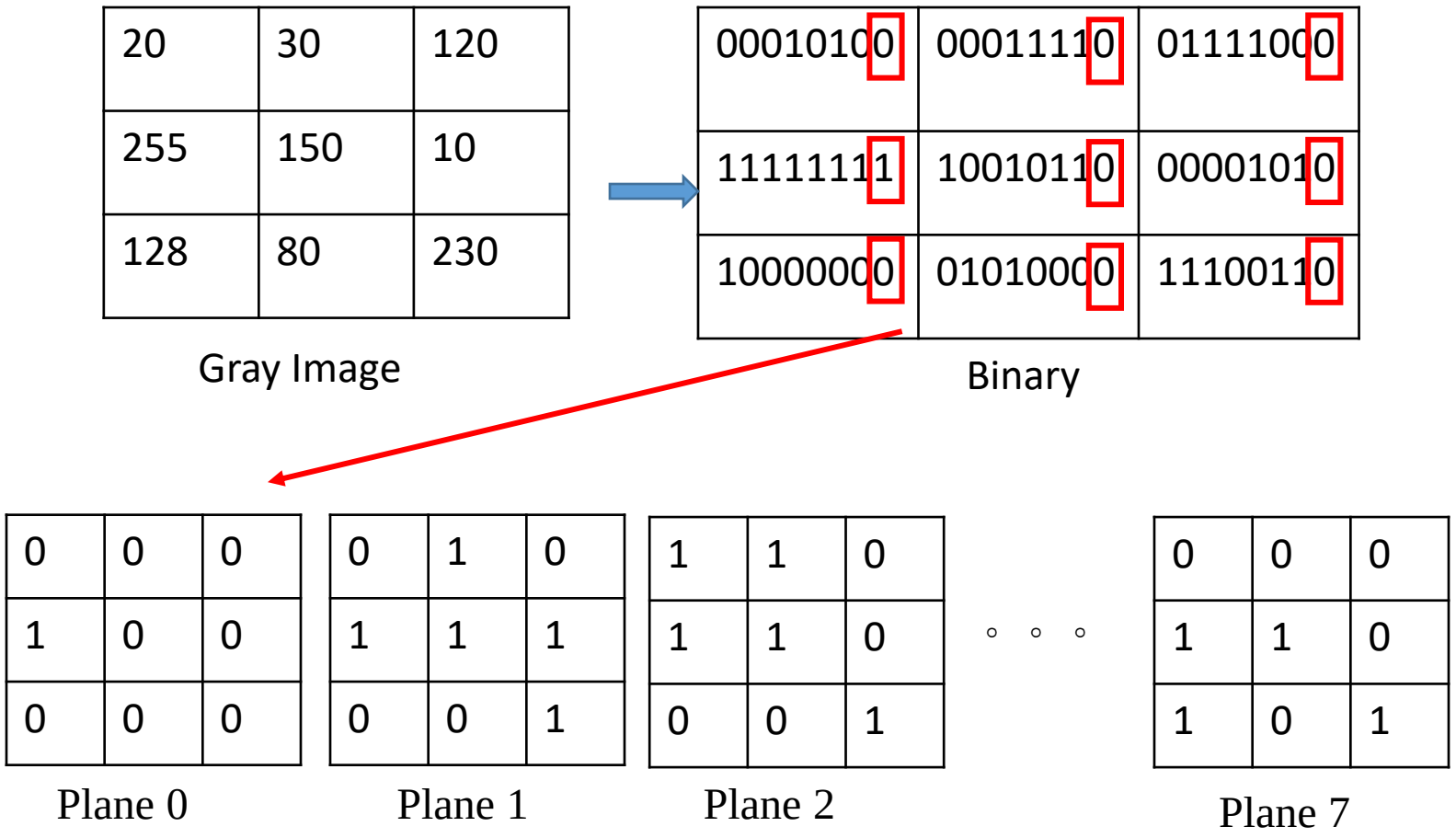
```
bit_map =

   254   210   180   144
   112    78    40     0
```

Bitplane（位平面） of 8-bit image

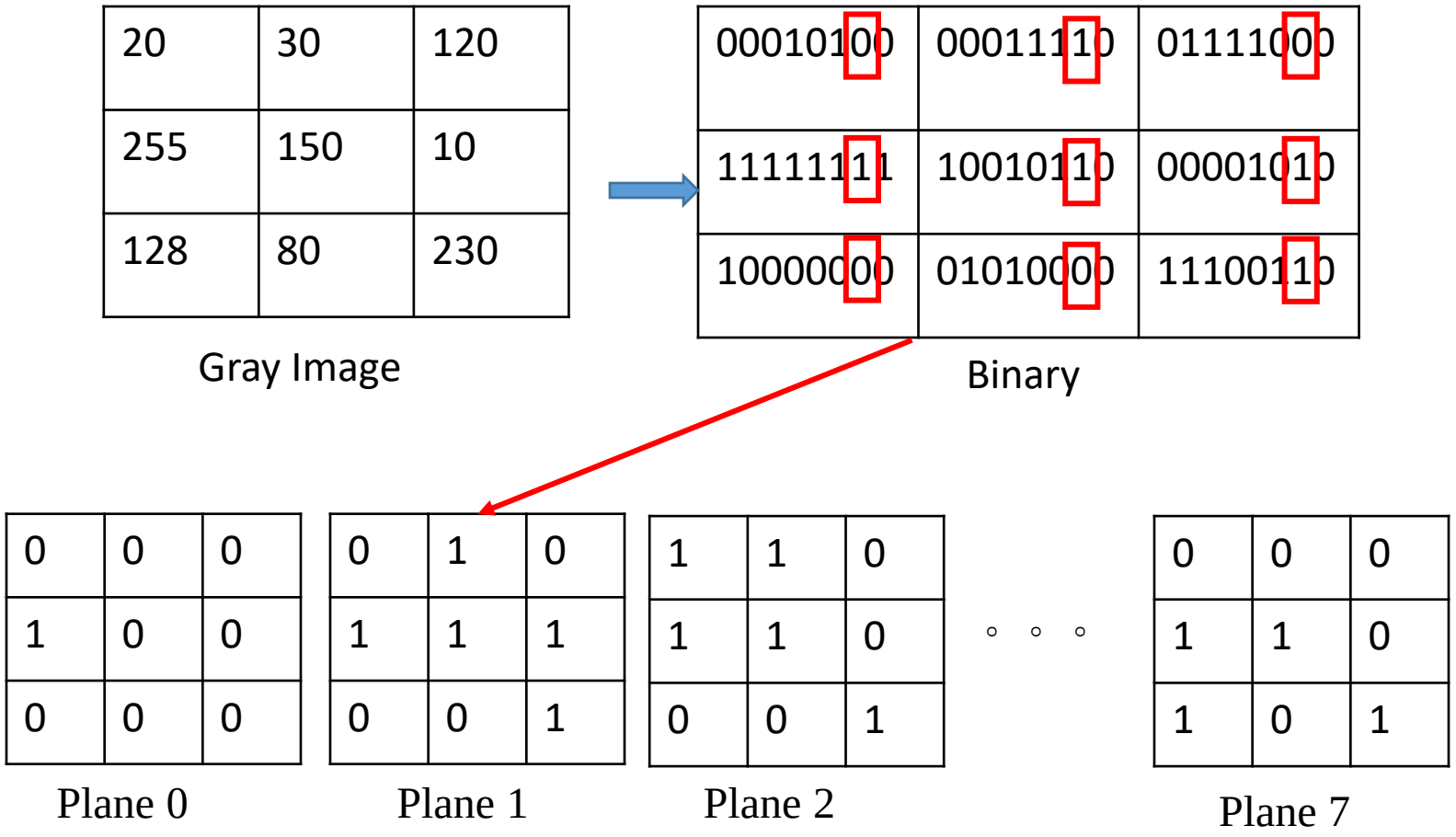
- Bitplanes
  - Consider the 8-bit image as a set of 1-bit bitplanes
  - Each plane consists of a 1-bit representation of the image



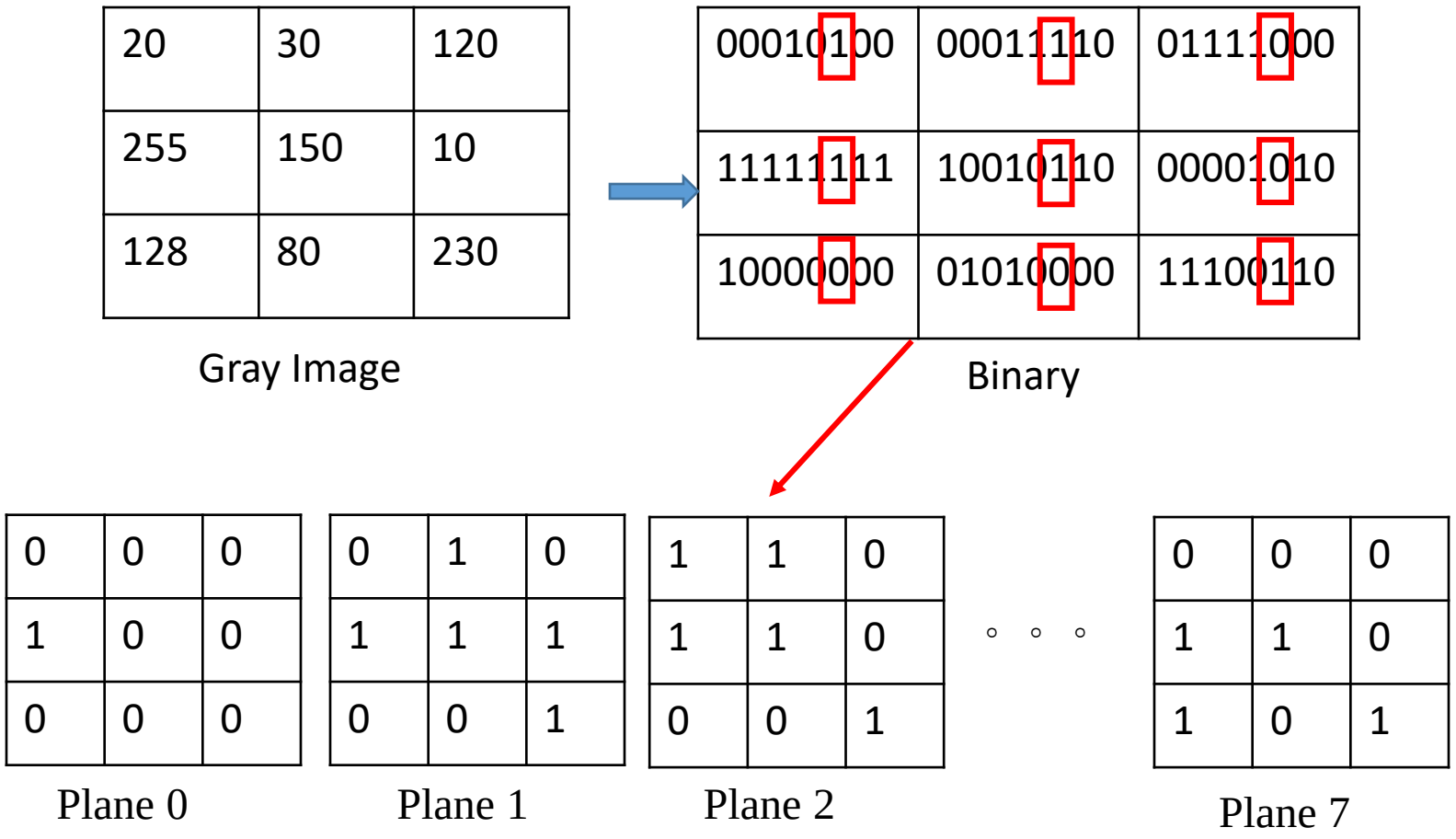
Bitplane（位平面） of 8-bit image



Bitplane（位平面） of 8-bit image



Bitplane（位平面） of 8-bit image



Demo of gray image

- Demo2
  - see demo2rgb2gray
  - Show color image, gray image, bit image
  - Convert color to gray and bit images
- Demo3
  - See demo3bitplane
  - Show bitplane

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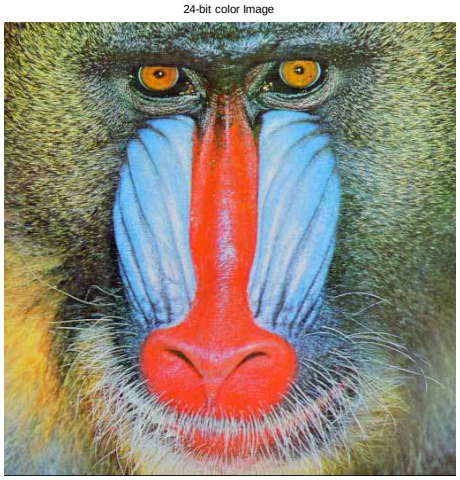
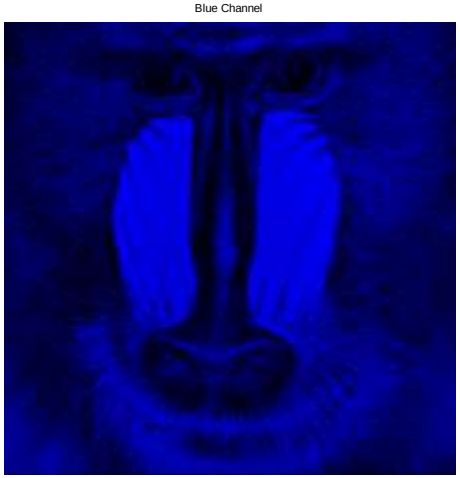
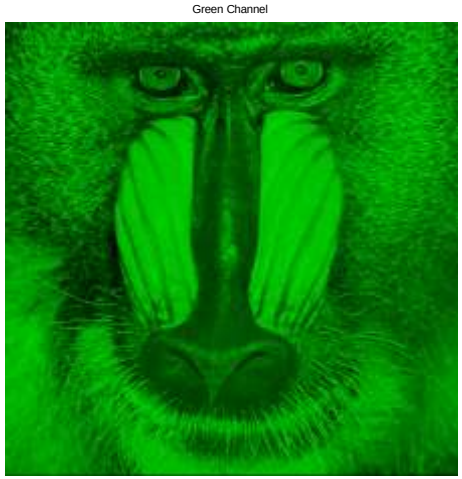
24-bit Color Image of RGB Model

- R
  - 8-bit
- G
  - 8-bit
- B
  - 8-bit







24-bit Color Image(真彩色)

- Each pixel is represented by three Bytes, usually RGB
  - Supports 256*256*256, totally 16.8-million possible combined color
  - Storage: for image resolution of 640*480, needs 900KB (640*480*3/1024)
- Some 24-bit color images are stored as 32-bit image
  - Extra byte of data for special-effect information

Color Lookup Tables (颜色查找表)

- Many systems can make use of 8 bits of color in producing a screen image（伪彩色）.
- Such image files use the concept of a lookup table（查找表）to store color information.
- Use index（索引） or code value（编码值） instead of 24-bit color information for each pixel
- Color lookup the table works well for small combinations

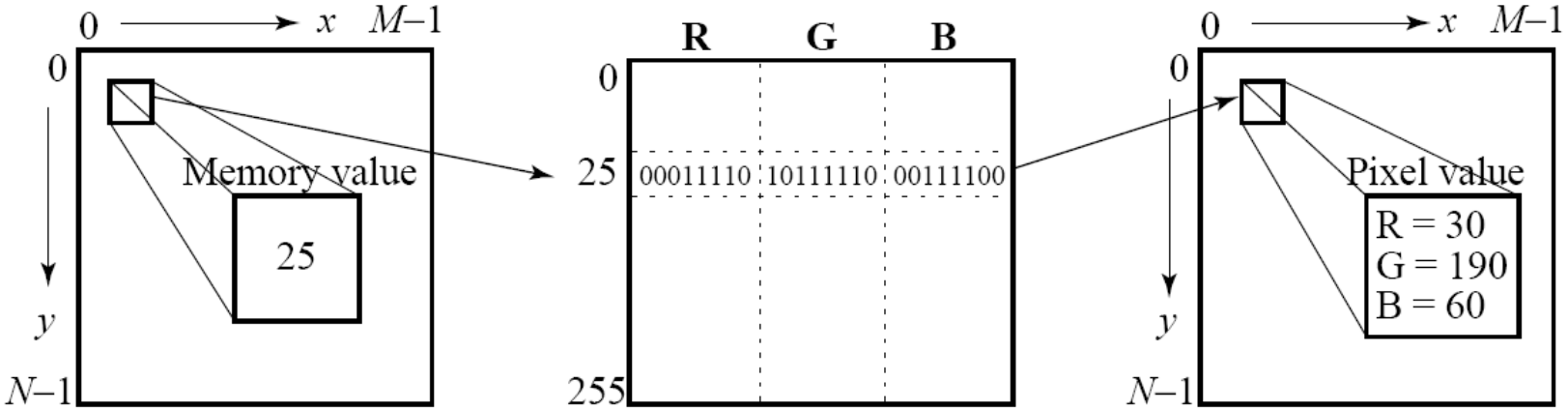
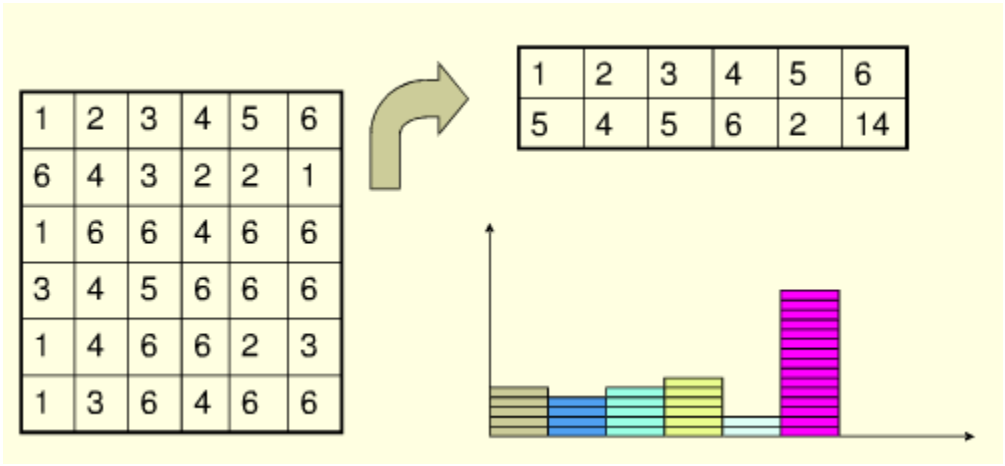
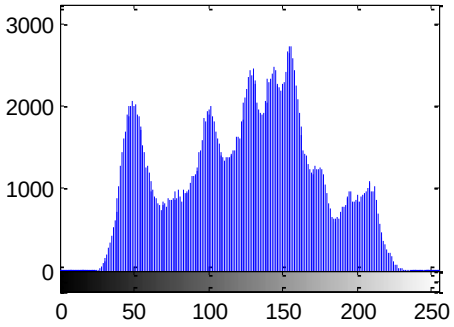


Image Histogram（直方图）

- A histogram is an accurate representation of the distribution of numerical data
- See demo4Hist





Probability $p_r(r_k) = \frac{n_k}{n}$

n_k is the number of pixels that have a value r_k

n is the total number of pixels of the image

8-bit Color Image

- Divide the RGB cube into equal slides in each dimension
  - R: 3-bit; G: 3-bit; B: 2-bit;
  - Edge artifacts （边缘伪影）
  - See demo5RGBto8
- Based image histogram, select 256 most popular colors

24-bit颜色图

8-bit颜色图

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Some Popular Image File Formats

- BMP
  - BitMap
  - Mainly use RGB color model
- Gif
  - Graphics Interchange Format
  - Important formats because of its historical connection to the WWW and HTML
- PDF
  - Portable Document Format
  - Include compression
- JPEG
  - Joint Photographic Experts Group
  - Currently the most important common file format

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How to Calculate the Size of Image

- 8 bit Gray image
  - Image resolution: 640*480
- Bytes
  - 640*480*8 = 2457600b= 2457600 /1024 Kb = 2400Kb
  - 640*480 = 307200B = 307200/1024 KB= 300KB

- 24 bit color image
- Bytes
  - 640*480*24 = 7372800b = 7372800/1024 Kb = 7200Kb
  - 640*480*3 = 921600B =921600/1024KB = 900KB

How to Transform 24-bit to 8-bit?

- Divide the RGB cube into equal slides in each dimension
  - R: 3-bit (0-7); G: 3-bit (0-7); B: 2-bit (0-3);
  - See demo5RGBto8

24-bit颜色图

8-bit颜色图

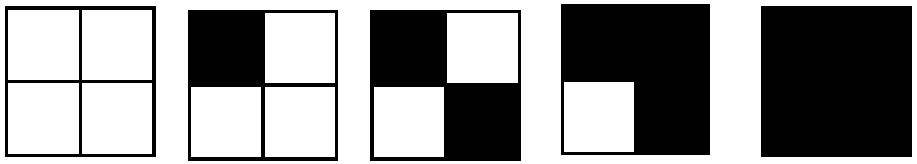
How to Calculate Histogram?

- Histogram
  - representation of the distribution of numerical data
- Help hist, imhist in Matlab
  - N = hist(Y) bins the elements of Y into 10 equally spaced containers and returns the number of elements in each container. Y is a vector.
  - imhist displays a histogram for the intensity image
- See demo4Hist

How Does Dithering (抖动) Work?

- 用只有黑墨的打印机，怎么打印出一个灰度图像?

- Basic strategy of dithering work
  - Trade intensity resolution for spatial resolution
- Dithering
  - To calculate patterns（图案）of dots such that values from 0 to 255 correspond to patterns that are more and more filled at darker pixel values, for printing on a 1-bit printer



Dithering Example

- Halftone printing （网板打印）
  - Replace a pixel value by a larger pattern, say 2×2 or 4×4
  - Rule: If the intensity is > the dither matrix entry then print an on dot at that entry location: replace each pixel by an $n \times n$ matrix of dots
- Dithering matrix

$$\begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$

In the printing color space, 0 represents white, 255 represents black. We can first re-map image values in 0…255 into the new range 0..4 by (integer) dividing by 256/5. Then, e.g., if the pixel value is 0 we print nothing, in a 2 × 2 area of printer output. But if the pixel value is 4 we print all four dots.

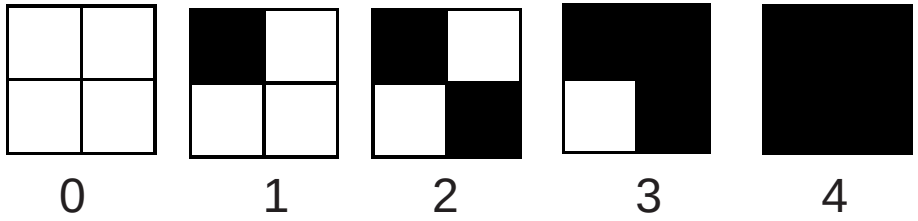
Dithering Example

$$\begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

0	1	2
3	4	0
1	2	3
4	0	1

0	0	1	0	1	0
0	0	0	0	0	1
1	1	1	1	0	0
0	1	1	1	0	0
1	0	1	0	1	1
0	0	0	1	0	1
1	1	0	0	1	0
1	1	0	0	0	0

Dithering Example



$$\begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

0	1	2
3	4	0
1	2	3
4	0	1

0	0	1	0	1	0
0	0	0	0	0	1
1	1	1	1	0	0
0	1	1	1	0	0
1	0	1	0	1	1
0	0	0	1	0	1
1	1	0	0	1	0
1	1	0	0	0	0

- Note that for a dithered image, since replacing each pixel by a 4×4 array of dots, makes an image 16 times as large.

Dithering Example

- Ordered dither (有序抖动)
  - turning on the printer output bit for a pixel if the intensity level is greater than the particular matrix element just at that pixel position

$$\begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$

0	1	2	3	4	5	6	7
6	7	8	9	10	11	9	10
12	13	14	15	16	0	1	2
1	2	3	4	5	6	3	4
7	8	9	10	11	12	7	8
13	14	15	16	0	1	10	11
2	3	4	5	6	7	2	12
8	9	10	11	12	13	14	15

0	0	0	0	1	0	0	0
0	1	0	1	0	1	0	1
1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0
1	0	1	0	1	1	1	0
1	1	1	1	0	0	0	1
0	0	1	0	1	0	1	1
0	1	0	1	0	1	1	1

Algorithm

- An algorithm for ordered dither, with $n \times n$ dither matrix, is as follows:
- See demo6dither

BEGIN

for x = 0 to x_{max} // columns

for y = 0 to y_{max} // rows

$i = x \bmod n$

$j = y \bmod n$

// $I(x, y)$ is the input, $O(x, y)$ is the output,

// D is the dither matrix. if $I(x, y) > D(i, j)$

$O(x, y)$ = 1;

else

$O(x, y)$ = 0;

END

Results

(a) (b) (c)

Fig. 3.4: Dithering of grayscale images.

(a): 8-bit grey image "lenagray.bmp". (b): Dithered version of the image. (c): Detail of dithered version.