Network & Media Laboratory

Fundamentals of Multimedia

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Network & Media Laboratory

2. Graphics and Image Data Representation

Main content

- **Basic Data Types**
  - 1-Bit Images
  - 8-Bit Grey-Level Images
  - 24-Bit Color Images
  - 8-Bit Color Images
  - Color Lookup Table (LUTs)
- **Popular File Formats**
  - JPEG ,GIF, BMP, others

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1、Basic Graphics/Image Types

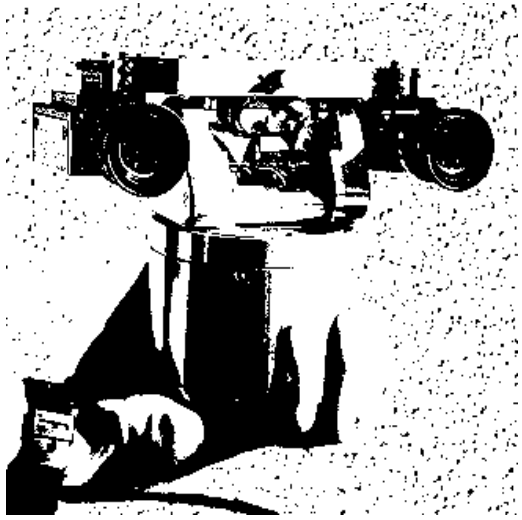
1-Bit Image; 8-Bit Grey-Level Image

24-Bit Color Image; 8-Bit Color Image

Color Lookup Tables

1.1 1-Bit Image: Case

Also called Binary Image or Monochrome Image



1-Bit Image Examples

1.1 1-Bit Image: Features

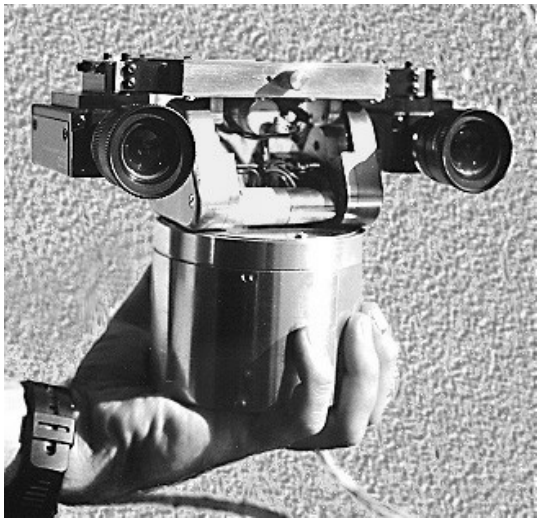
- Consist of on and off pixels (pixel--picture elements in digital images)
- Each pixel is stored as a single bit (0 or 1), 0--black, 1--white

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

1.1 1-Bit Image: Size and Usage

- **Storage**
  - Monochrome image with resolution: 640×480
  - 640×480/8 bytes
  - Storing space needed: 38.4KB
- **Usage**
  - Pictures containing only simple graphics and text

1.2 8-Bit Gray-level Image: Case



8-Bit Gray-Level Image Examples

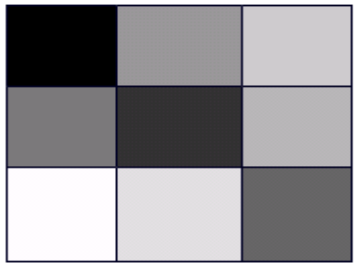
1.2 8-Bit Gray-level Image：Case

8-Bit Gray-Level Image VS 1-Bit Image

1.2 8-Bit Gray-level Image: Features

- Each pixel is represented by a single byte
  - A gray value between 0 and 255

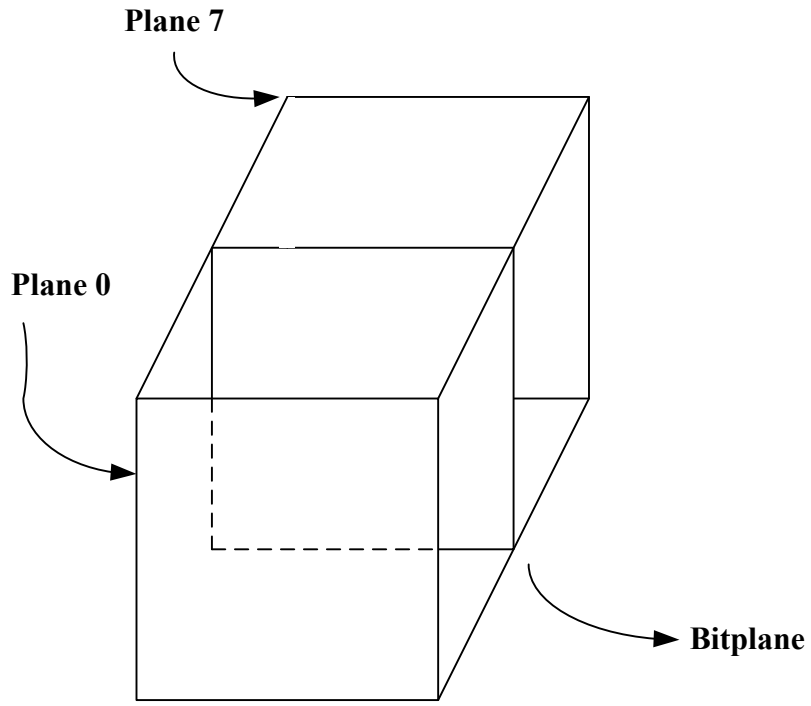
- The entire image can be thought of as a two-dimensional array of pixel values
  - Called bitmap



$$I = \begin{bmatrix} 0 & 150 & 200 \\ 120 & 50 & 180 \\ 250 & 220 & 100 \end{bmatrix}$$

1.2 8-Bit Gray-level Image: Features

- 8-Bit image as a set of 1-bit bitplanes
  - Each plane consists of a 1-bit representation of the image at one level
  - All the bitplanes make up a single byte that stores the value between 0 ~ 255

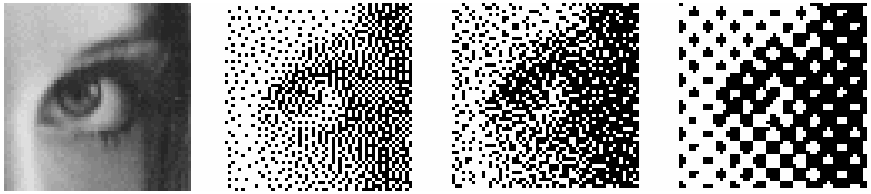


1.2 8-Bit Gray-level Image: Size

- **Resolution**
  - **High: 1600×1200**
  - **Low: 640×480**
  - **Aspect Ratio : 4:3**
- **The space needed by a 640×480 grey image**
  - **640×480=307,200 bytes**
- **Hardware storing Image Array**
  - **frame buffer /"Video" card**

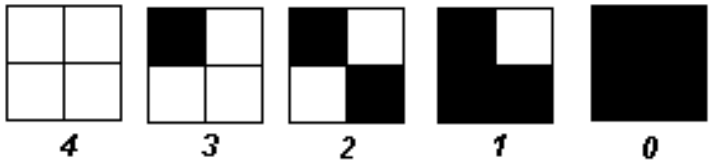
1.2 8-Bit Gray-level Image: Print

- Printing such image is complex
  - Use Dithering
  - Convert intensity resolution into spatial resolution
- 1bit-Output Printer --Using large matrix
  - 0~255 grey value – Corresponding a model
    - One pattern – one pixel
- Halftone printing



1.2 8-Bit Gray-level Image: print

- An N×N matrix represents N^2+1 levels of intensity
  - 2×2 pattern can represent five level:



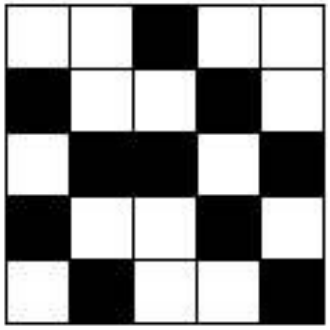
0	3
2	1

- The above method **increasing the size of the output image**
  - If one pixel uses 4×4 pattern, the size of an N×N image becomes 4N×4N, makes an image **16 times** as large!

1.2 8-Bit Gray-level Image: print

- **One better method: Avoid enlarging the output image**
  - **Store an integer matrix (Standard Pattern), each value from 0 to 255**
  - **Comparing the grey image matrix with pattern, print the dot when the value greater than the grey**

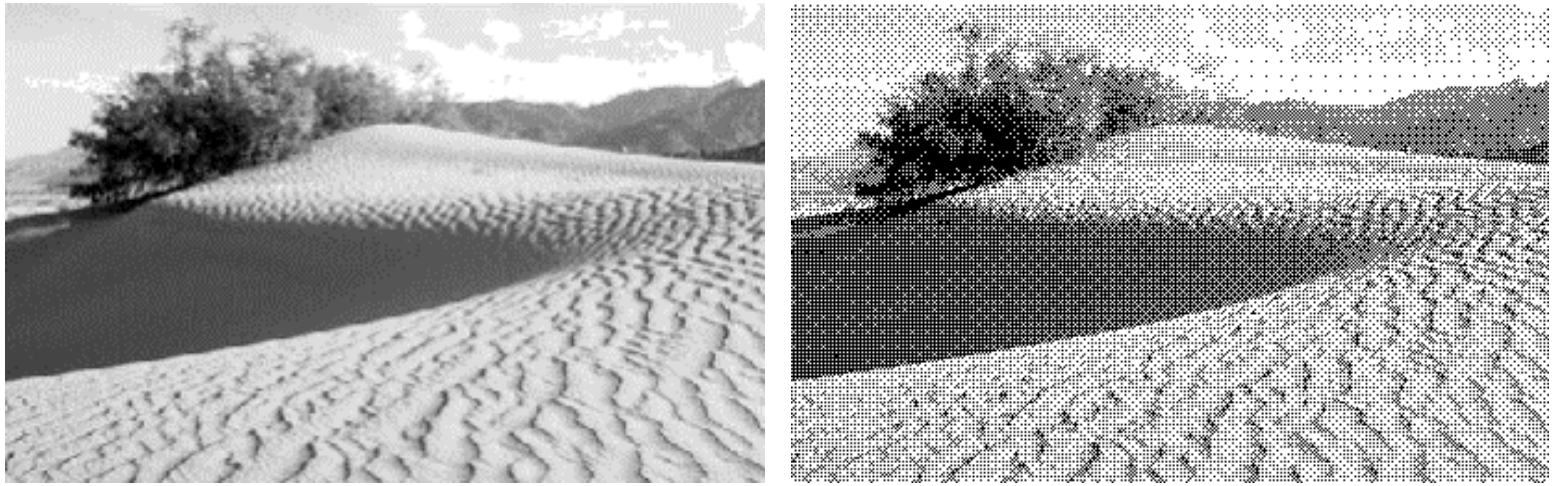
0	14	22	5	8
18	9	1	19	13
6	24	16	7	23
21	2	12	20	3
10	15	4	11	17



One 25-grey level case: left is standard
the right with grey=15

1.2 8-Bit Gray-level Image： Print

- Generate the output image using standard matrix



An example

1.3 24-Bit Color Image: Case

嫦娥

李商隐

云母屏风烛影深，
长河渐落晓星沉。
嫦娥应悔偷灵药，
碧海青天夜夜心！

ChangE flying to the Moon

1.3 24-Bit Color Image: Feature

- Each pixel using three bytes: representing RGB
  - Value from 0 to 255;
  - Supports 256×256×256 colors, 16,777,216
- Each pixel described by different grey values of RGB

$$R = \begin{bmatrix} 255 & 240 & 240 \\ 255 & 0 & 80 \\ 255 & 0 & 0 \end{bmatrix} \quad G = \begin{bmatrix} 0 & 160 & 80 \\ 255 & 255 & 160 \\ 0 & 255 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 80 & 160 \\ 0 & 0 & 240 \\ 255 & 255 & 255 \end{bmatrix}$$

1.3 24-Bit Color Image: Size

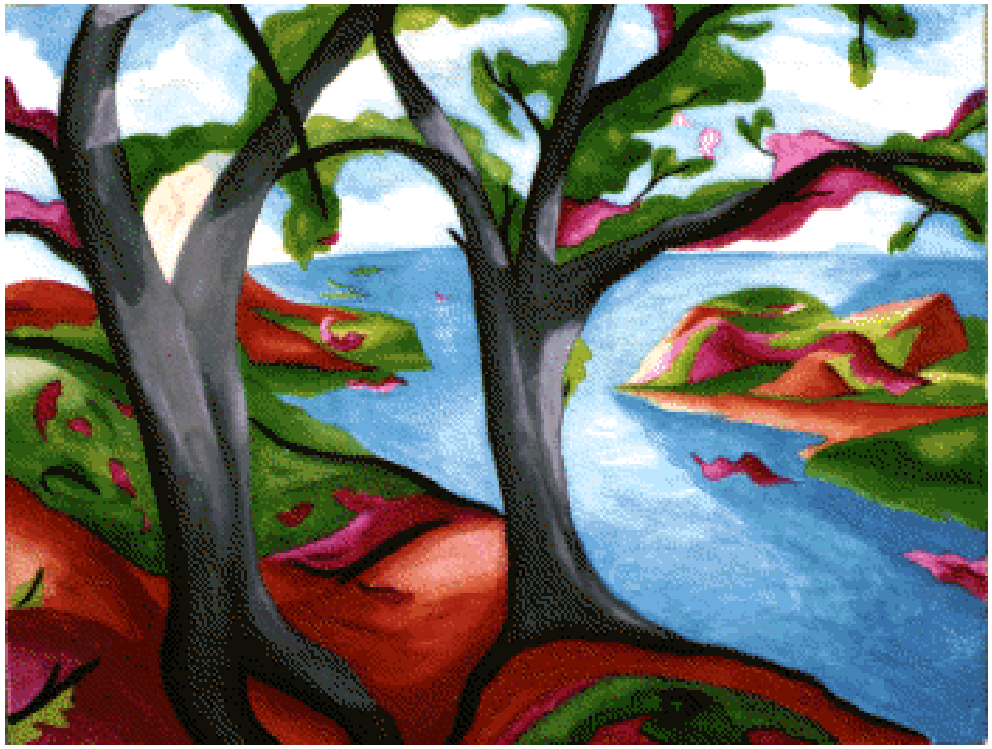
- 640×480 24-Bit Color image，921.6KB
  - 640×480×3 bytes

- Many 24-bit color image actually stored as 32-Bit image
  - Extra data of each pixel used to store αvalue，indicate the special effect information（such as, transparency flag）

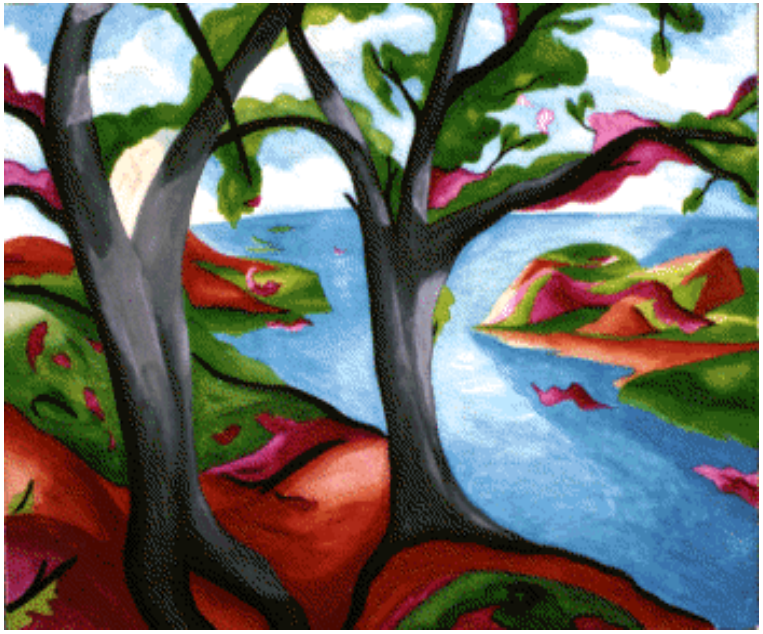
  - Semi-transparency image color = Source image color×（100% - transparency）+Background image color×transparency

1.4 8-Bit Color Image: Case

- Also called 256-colors image



1.4 8-Bit Color Image: Case



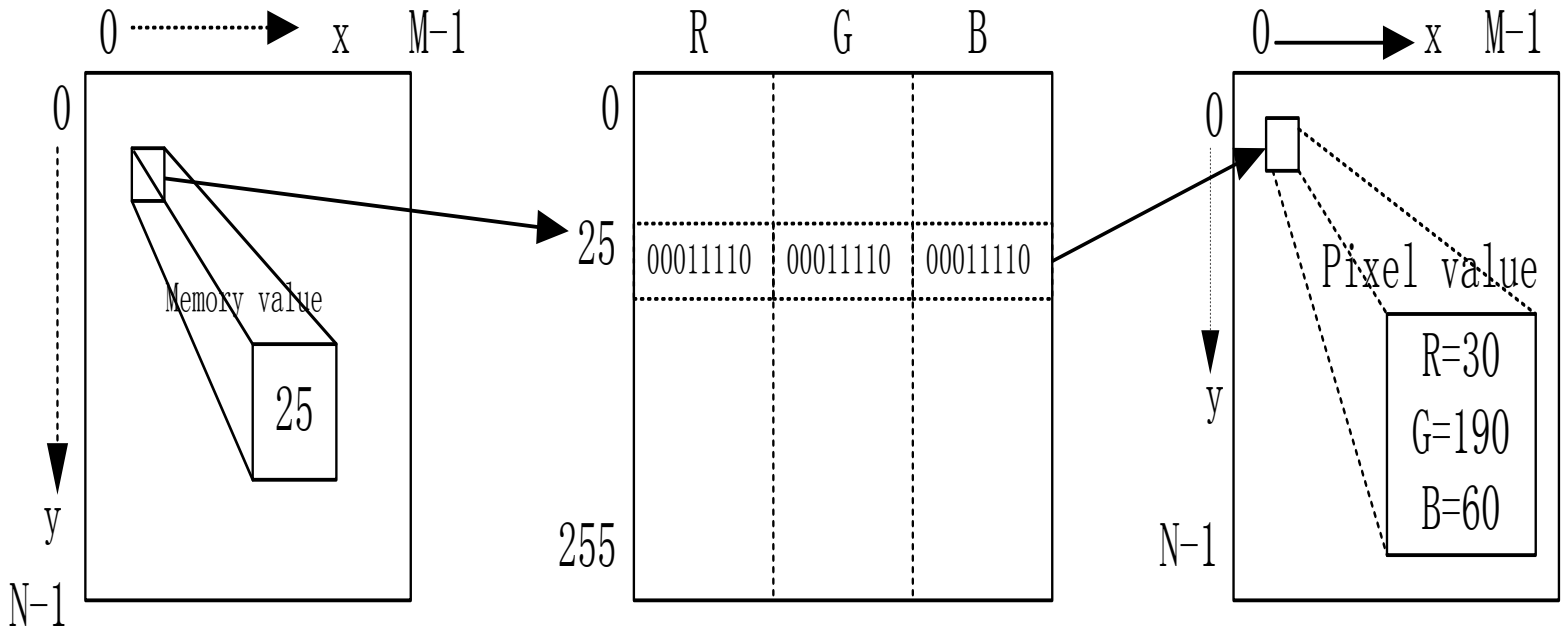
8-Bit Color Image VS 24-Bit Color Image

1.4 8-Bit Color Image: Features

- The idea of using Lookup table(palette)
  - An image store a set of bytes， not the real color
  - Bytes value is the index to a 3-bytes color table
  - Choosing what colors to put in table is important

- Choose the most important 256 colors
  - Generated by clustering the 256×256×256 colors
  - Median-cut Algorithm
  - More accurate version of the Median-cut Algorithm

1.5 Color Lookup Tables: Case



Value as the Index to Table

Get the color values by Searching

The RGB value of the pixel

1.5 Color Lookup Tables： How to apply

- **Change color by adjusting the LUT**
  - LUT less than image, with the advantage of speed

Example： change LUT

Index	R	G	B
1	255	0	0

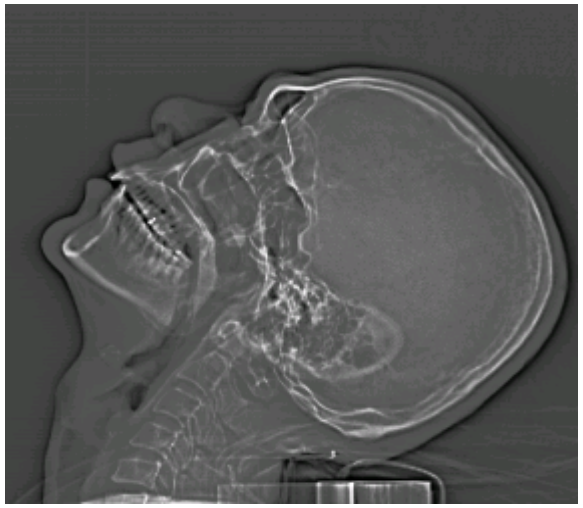
into

Index	R	G	B
1	0	255	0

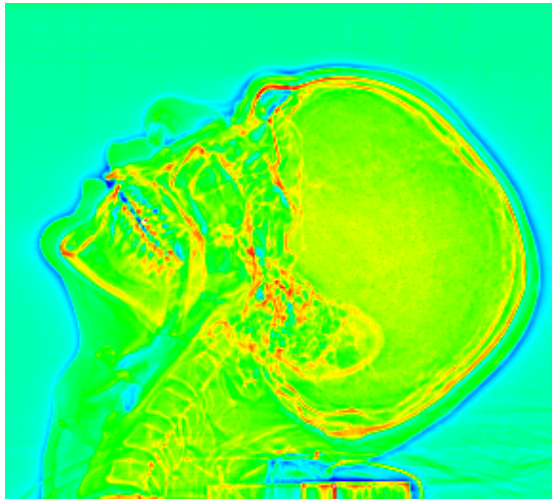
For the color index by 1, that is to convert red to green

- **An important application： Medical Image**
  - Convert the grey image into color image

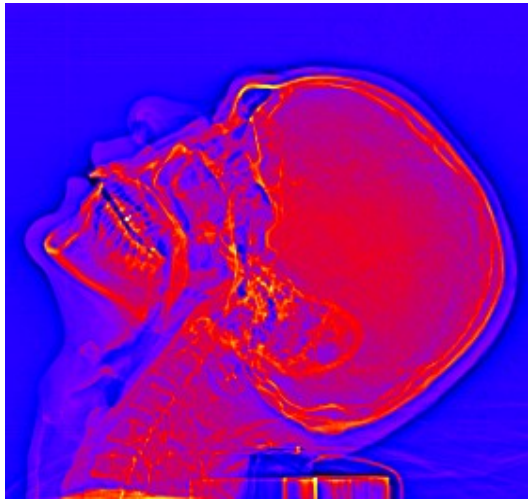
1.5 Color Lookup Tables： medical image



Grey Image



Color Image-1



Color Image-2

By modifying the LUT to convert grey image into color image

1.5 Color Lookup Tables： Medical image

Index	R	G	B
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
…	…	…	…
64	64	64	64
65	65	65	65
66	66	66	66
67	67	67	67
68	68	68	68
69	69	69	69
…	…	…	…
254	254	254	254
255	255	255	255

正常灰度LUT

Index	R	G	B
0	0	0	0
1	0	0	7
2	0	0	15
3	0	0	23
…	…	…	…
64	0	255	255
65	0	255	247
66	0	255	239
67	0	255	231
68	0	255	223
69	0	255	215
…	…	…	…
254	255	248	248
255	255	252	252

彩虹编码LUT

Index	R	G	B
0	0	0	0
1	0	0	4
2	0	0	8
3	0	0	12
…	…	…	…
64	0	0	255
65	4	0	255
66	8	0	255
67	12	0	255
68	16	0	255
69	20	0	255
…	…	…	…
254	255	255	248
255	255	255	252

热金属编码LUT

2、Popular image file format

GIF; JPEG; BMP; PNG

TIFF; EXIF; others

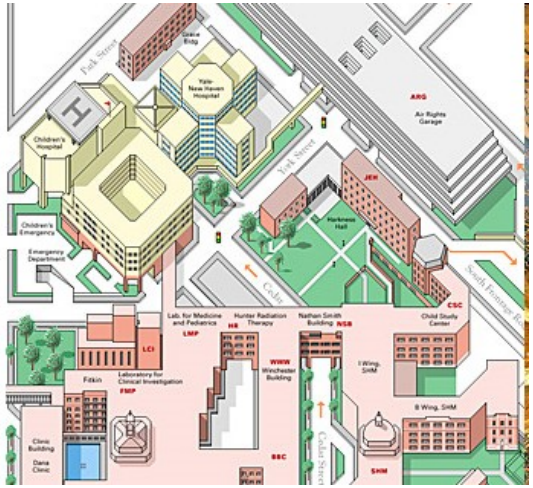
2.1 GIF Image: Case

2.1 GIF Image： features

- GIF (Graphics Interchange Format)
  - Invented by UNISYS Corporation and Compuserve in 1987
  - Initially transmit graphical image through telephone line
  - Not belong to any application program, presently supported by almost all relevant software

2.1 GIF Image： features

- Using LZW（Lempel-Ziv-Welch）Compression Algorithm
  - LZW algorithm is lossless format with continuous color, compression rate about 50%



The LZW compression built into the GIF graphic format is very good at efficiently saving diagrammatic graphics (right) but poor at compressing more complex photographic images (left).

2.1 GIF Image： features

- Limited to 8-bit（256）color image
  - GIF image depth from l-bit to 8-bits
  - GIF image supports 256 colors
    - Suitable for storing graphics with relatively few colors such as simple diagrams, shapes, logos and cartoon style images.
    - It also supports animation and is still widely used to provide image animation effects.

2.1 GIF Image: features (Cont.)

- **Interlacing**
  - Decode speed fast
  - Store in interlacing method
  - Can Gradually Display by four passes
- **The GIF89a supporting animation**
  - Storing multiply color images in one image file

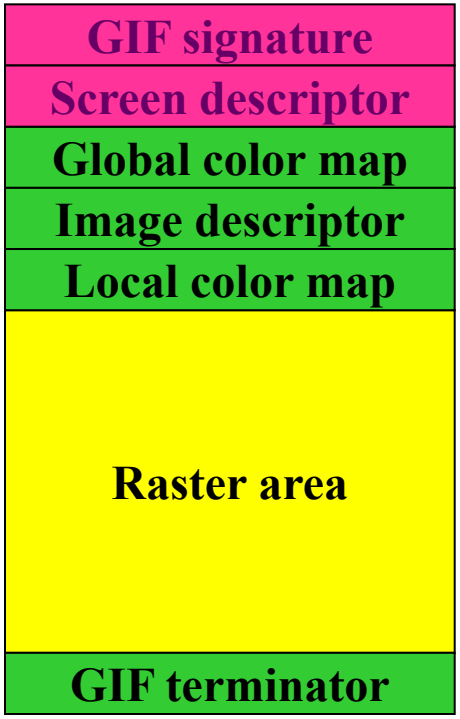
2.1 GIF Image : Case Analysis

- One 120*160 gif image

Offset	Length	Contents
0	3 bytes	"GIF"
3	3 bytes	"87a" or "89a"
6	2 bytes	<Logical Screen Width>
8	2 bytes	<Logical Screen Height>
10	1 byte	bit 0: Global Color Table Flag (GCTF) bit 1..3: Color Resolution bit 4: Sort Flag to Global Color Table bit 5..7: Size of Global Color Table: 2^(1+n)
11	1 byte	<Background Color Index>
……		

Gif: file head information

offset, length, contents



Gif file format

2.1 GIF Image : Case Analysis

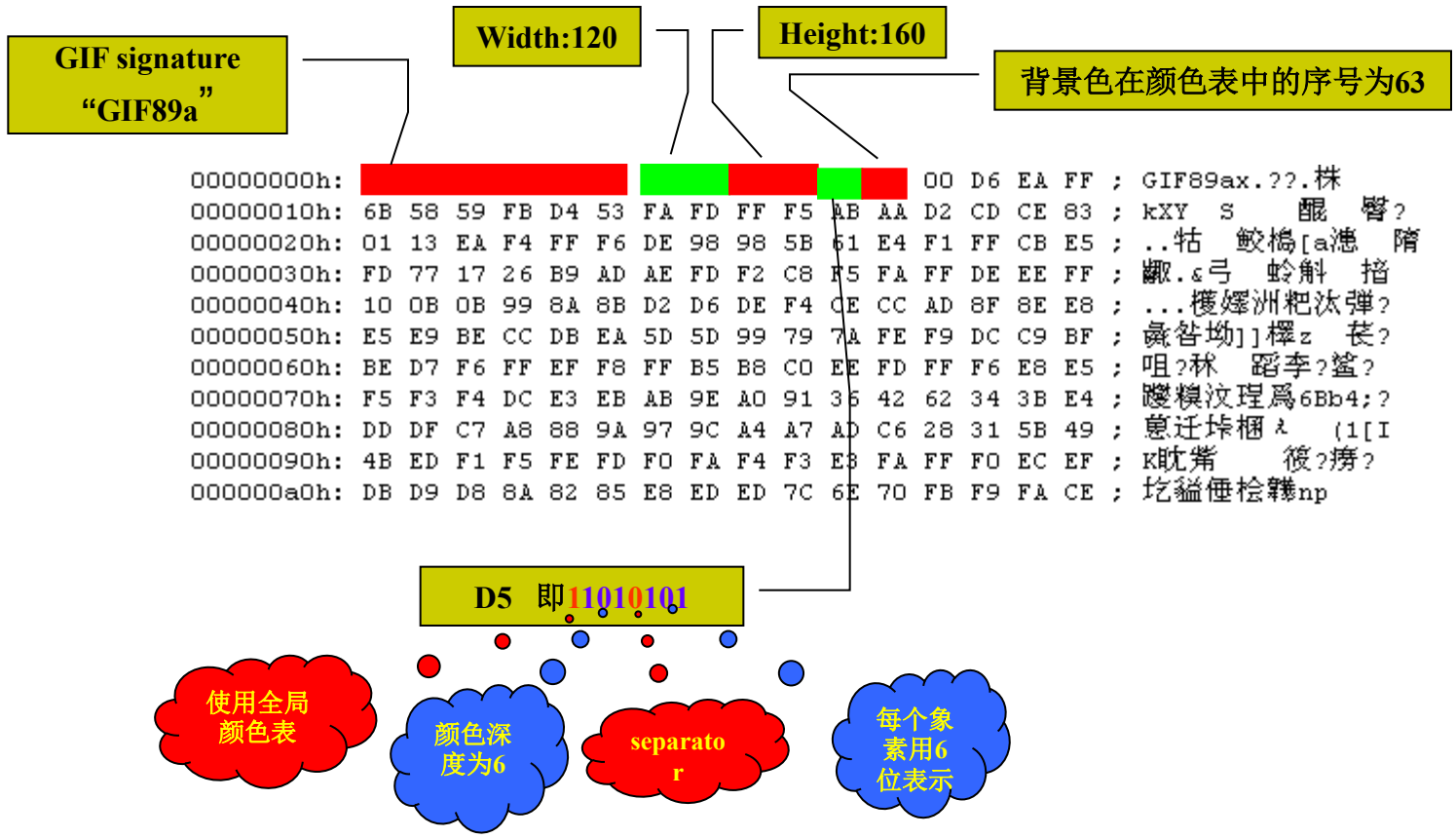


Image file analysis opened by Ultra-edit

2.2 JPEG Image : Case

2.2 JPEG Image: Features

- JPEG（Joint Photographic Experts Group）
  - Created by the Task Group of the International Standard Organization（ISO）
- Take advantage of some limitations of human vision system
  - JPEG achieve high rates of compression
- A lossy compression method
  - Allow user to set a desired level of quality, or compression ratio (input divided by output)

2.2 JPEG Image：Example1

JPEG Image (1)：252kB

2.2 JPEG Image：Example2

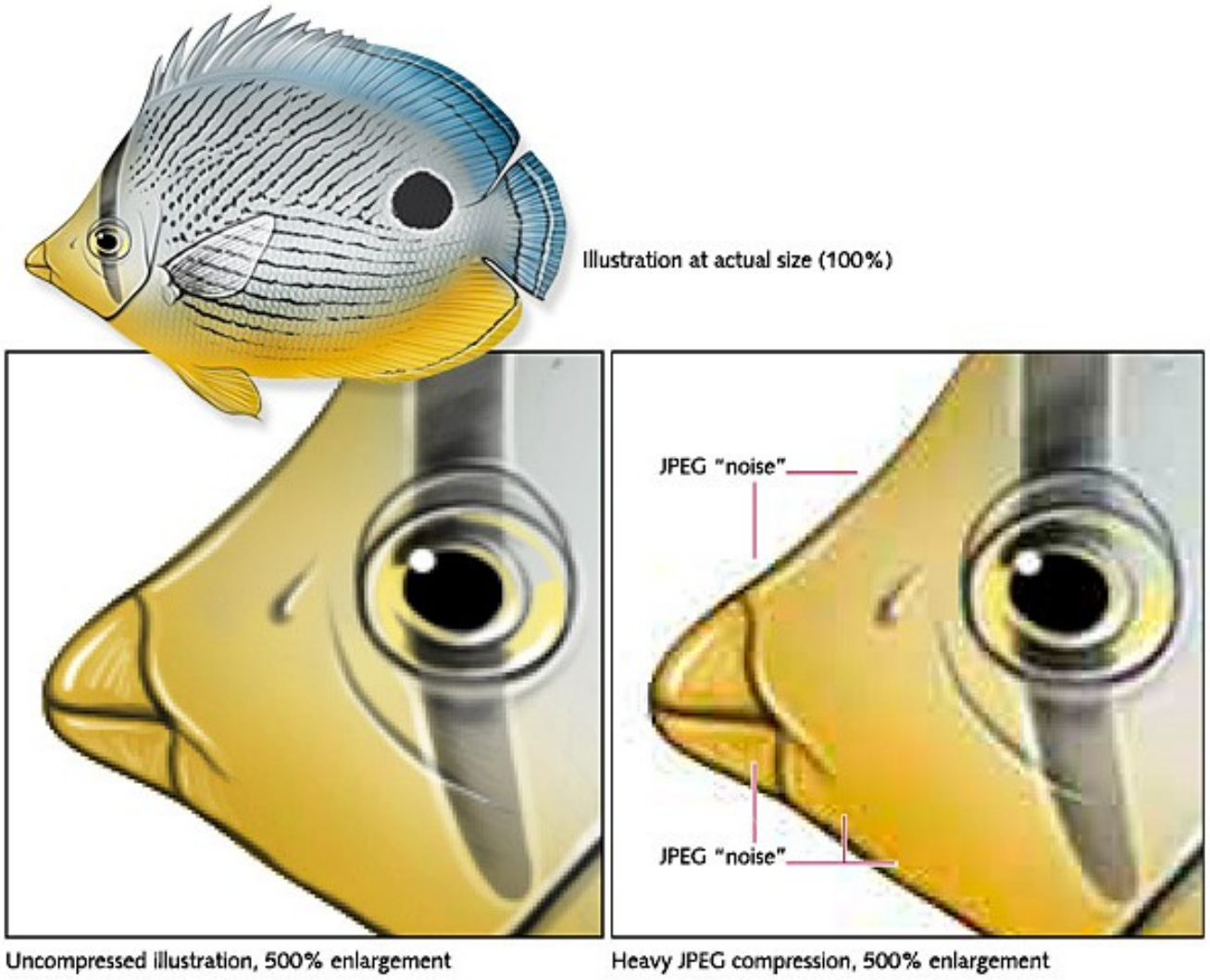
JPEG Image(2): 45.2kB

2.2 JPEG Image: Example3

JPEG Image (3): 9.21kB

2.2 JPEG Image: Usage

- Small file, high quality, widely supported
  - The compression when not too severe does not detract noticeably from the image. It's suitable for web images.
- JPEG files can suffer generational degradation when repeatedly edited and saved.
  - Photographic images may be better stored in a lossless non-JPEG format if they will be re-edited in future, or if the presence of small "artifacts" (blemishes), due to the nature of the JPEG compression algorithm, is unacceptable.
- JPEG is also used as the image compression algorithm in many Adobe PDF file.



JPEG compression comes at a cost: a big increase in visual noise and other compression artifacts that degrade the image quality if over-used

2.3 BMP Image

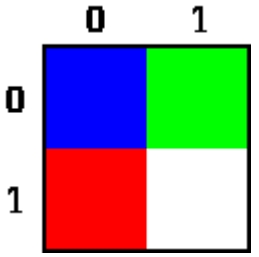
- Created by Microsoft as Window's main image format，can store 1bit, 4bits, 8bits, as well as real color data
- Best image quality, large file, the advantage is their simplicity and wide acceptance in Windows programs.
- BMP file has three storage forms:
  - Original data without compression, most popular
  - Run Length Encoding: Used for 8-bits image（256 colors）BI-RLE8
  - RLE: used for 4-bits image (16 colors) BI_RLE4

2.3 BMP Image

- **BMP file consists four components:**
  - **File Head：type and other information**
  - **Information head of bitmap：length，width，compression algorithms and so on**
  - **Palette：Color LUT table，24-bits real color image with no palette**
  - **Image Data：Real color image stores (R,G,B) three components，image with palette stores the index to the palette**

2.3 BMP Image

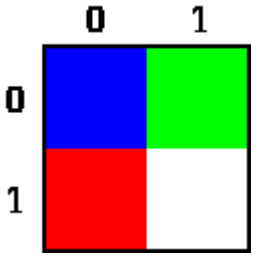
- **Case analysis: 2x2 Pixel Bitmap, with 24 bits/pixel encoding**



Offset	Size	Hex Value	Value	Description
0h	2	42 4D	"BM"	Magic Number (unsigned integer 66, 77)
2h	4	46 00 00 00	70 Bytes	Size of the BMP file
6h	2	00 00	Unused	Application Specific
8h	2	00 00	Unused	Application Specific
Ah	4	36 00 00 00	54 bytes	The offset where the bitmap data (pixels) can be found.
Eh	4	28 00 00 00	40 bytes	The number of bytes in the header (from this point).
12h	4	02 00 00 00	2 pixels	The width of the bitmap in pixels
16h	4	02 00 00 00	2 pixels	The height of the bitmap in pixels
1Ah	2	01 00	1 plane	Number of color planes being used.
1Ch	2	18 00	24 bits	The number of bits/pixel.
1Eh	4	00 00 00 00	0	BI_RGB, No compression used
22h	4	10 00 00 00	16 bytes	The size of the raw BMP data (after this header)
26h	4	13 0B 00 00	2,835 pixels/meter	The horizontal resolution of the image
2Ah	4	13 0B 00 00	2,835 pixels/meter	The vertical resolution of the image
2Eh	4	00 00 00 00	0 colors	Number of colors in the palette
32h	4	00 00 00 00	0 important colors	Means all colors are important

2.3 BMP Image

- **case analysis: 2x2 Pixel Bitmap, with 24 bits/pixel encoding** (cont')



Start of Bitmap Data				
36h	3	00 00 FF	0 0 255	Red, Pixel (1,0)
39h	3	FF FF FF	255 255 255	White, Pixel (1,1)
3Ch	2	00 00	0 0	Padding for 4 byte alignment (Could be a value other than zero)
3Eh	3	FF 00 00	255 0 0	Blue, Pixel (0,0)
41h	3	00 FF 00	0 255 0	Green, Pixel (0,1)
44h	2	00 00	0 0	Padding for 4 byte alignment (Could be a value other than zero)

2.3 Other typical image formats

- PNG（Portable Network Graphics）
  - Successor of GIF, support true color(16 million colors).
  - It Excels when the image has large areas of uniform color.
  - The lossless PNG format is best suited for editing pictures.
- TIFF （Tagged Image File Format）
- EXIF（Exchange Image File）
- Others

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The End

Thanks!