Chapter 3

Introduction to Computer Graphics

2017.03

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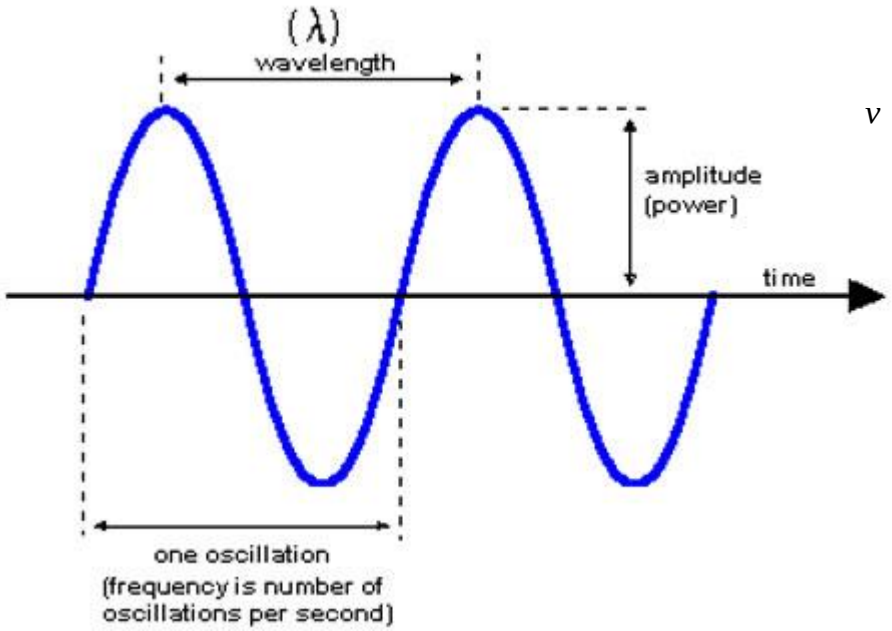
Contents

- Human Eye Characteristics
- Computer graphics
  - Bitmap image and vector graphic
- Image application
- File format and editing SW

How to Recognize Color?

- Def. of wavelength (λ) of light signal

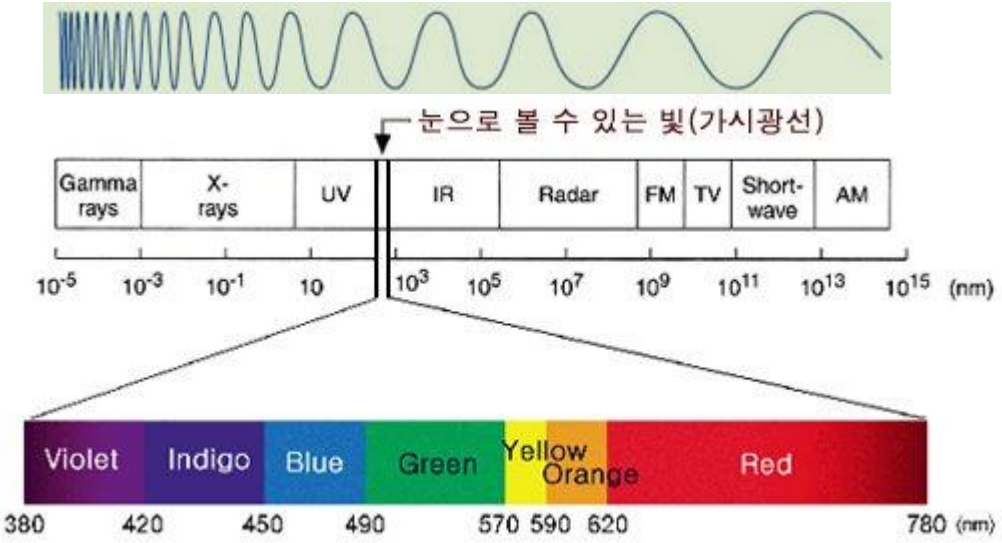


v = light speed, λ = wavelength , f = frequency

$$v = \lambda \cdot f \leftrightarrow \lambda = \frac{v}{f}$$

f = frequency = # of repetition per second

Human visible light in term of wavelength



UV = *Ultra* – *Violet* (자외선)

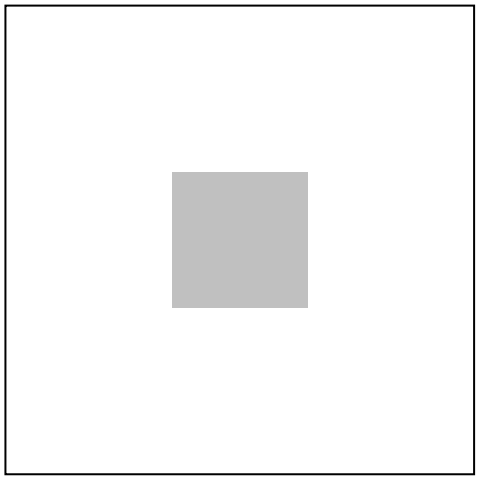
IR = *Infrared* (적외선)

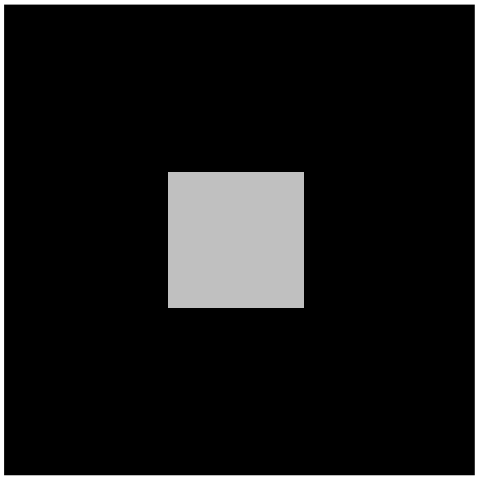
7 Colors depending on the light wave length

- Visible light – wavelength of 380nm ~780nm
  - If $\lambda > \lambda_{vl}$, then IR, If $\lambda < \lambda_{vl}$, then UV
  - Human eye is **most sensitive to Red, Green, Blue** and **recognize color as a mix of RGB**

Human Eye Characteristics

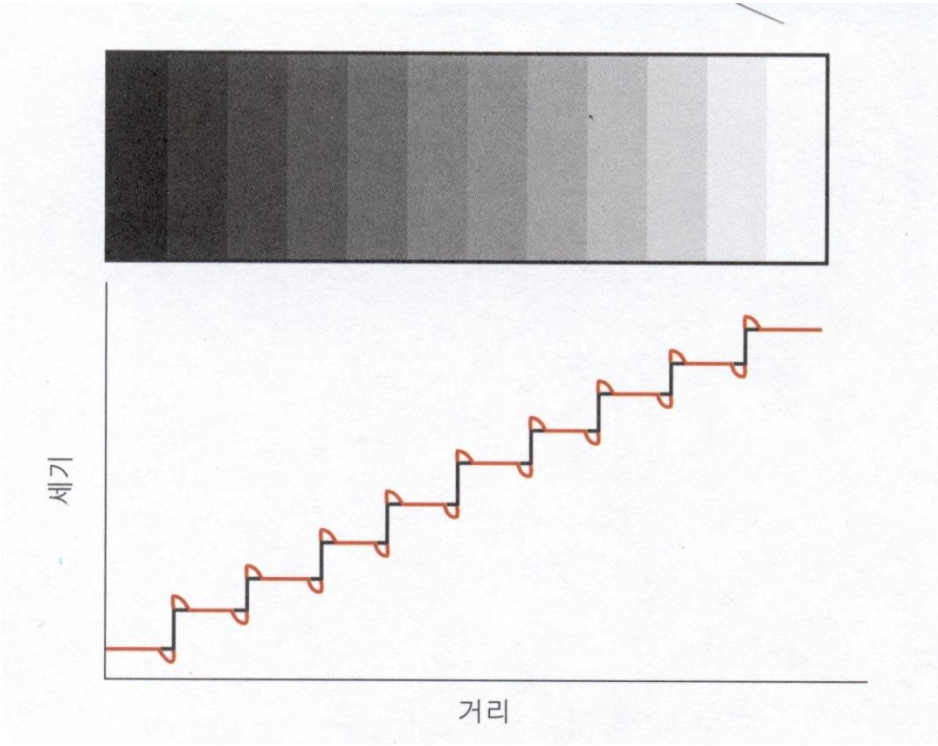
- **Simultaneous contrast**
  - Human eye is more sensitive to the light difference than light strength
  - Which looks more clear to you?





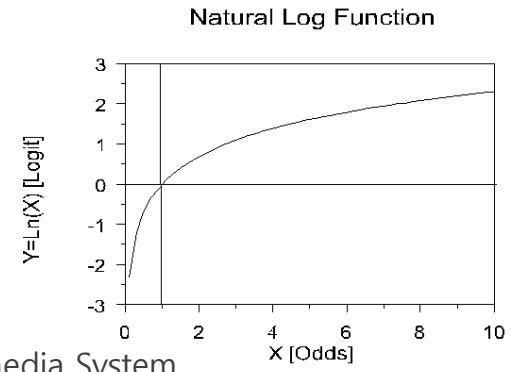
❖ Mach band effect

- When the light brightness changes gradually in step, human eye is sensitive to the changing edge



Logarithmic sensitivity

- Human eye sense the light brightness proportional to log function
  - Even the light brightness is small, human eye is very sensitive to small change of brightness
  - With high light brightness, human eye is not much sensitive even with large amount of change in brightness



How to recognize scene or Image ?

spatial = 2D space

Image pixel is located at 2D position (x_0, y_0)

- Human brain recognize scene or image through analysis of spatial frequency
  - Background – low frequency component
  - Edge – high frequency component
- **Frequency spectrum concept** again!

Image and Graphic

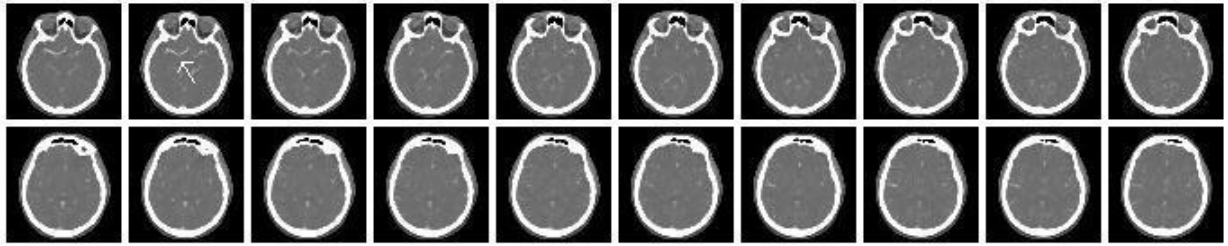
- Natural image exist in **analog form**

- How to get digital image?
  - Digitize printed image with a scanner
  - Capture image from digital camera
  - Grab frame from video camera

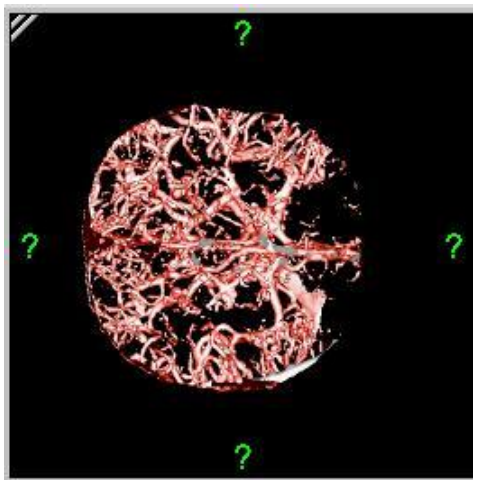
- How to get graphic?
  - Naturally born in digital

- Image – naturally generated in analog form and converted into digital
  - Digital Photo, Satellite Image, X-ray image
- Graphics – artificially created by computer, so digital in nature
  - **Animation, 3-D graphics**
- Combined form
  - Medical image, X-ray, MRI scan, 3D volume rendering

CT: Computed Tomography



3-D volume rendering



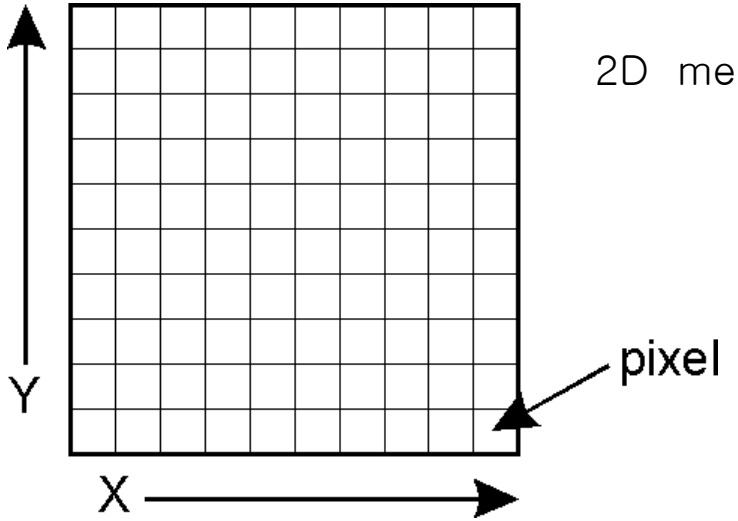
Bone removed, vessels shown

IMAGE Basics

- Basic Element
  - Pixel, Resolution, Color Mode (later in Chap 5!)

- Pixel
  - Pixel = Picture Element or Pel
  - Smallest image element
  - Pixel based image is stored as Bitmap format

Image and pixel



2D media consist of pixels

Color mode and bits

- B/W
  - **Monochrome** : 1bit/pixel, ex) Fax
  - **Gray-level image** : 8 bit/pixel, 0(B) ~ 255(W) Express 256 level brightness
- Color
  - **True color** format : Represent R, G, B by 8bits respectively, 24 bit/pixel
  - **Hi Color** format : Represent R,G,B in total of 16bit/pixel

Resolution

- A measure of how finely a device approximates continuous images using finite pixels
  - Scanner and printer – pixel density (dots per inch, dpi)
  - Video frames and computer monitors – pixel dimensions (width X height)
  - Digital still camera – total number of pixels in the largest image it can record

72 dpi, 198 × 149 px

600 dpi, 1654 × 1240 px

Resolution and pixel dimensions

Image Display on Monitor

- Image is displayed on monitor as **array of pixels**
  - Rectangular (usually square) dots of color

- To display image on the monitor
  - Program (e.g. Web browser) sets pixels to an appropriate color to produce desired image
  - Set pixel value by **graphics library** that communicate with display hardware such as monitor

Production of Graphics

- Artificially created animation or 2D, 3D graphics by computer
  - Two steps : **Modeling – Rendering**

- Modeling
  - Generate model in geometric form to produce desired graphic
- Rendering
  - Convert model in 2D image by calling functions from a graphic library

Bitmap and Vector

- Bitmap image
  - Image is modeled as an array of pixel values
  - Stored as bitmap format

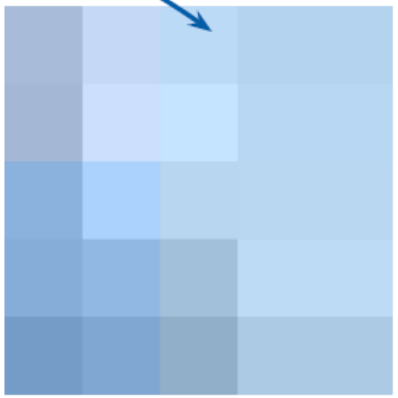
- Vector graphic
  - Graphic is modeled and rendered as mathematical description of curves, shapes, lines drawing - So, represented as vector
  - Before display on monitor, need to convert vector values to pixels
  - Stored as vector format

A vector drawing and a digital photograph

logical pixels

physical pixels

9BB5FF	B1CFFF	B0D2FF	A9CFFF	9FCBFF
86B5F9	B0DBFF	ADD9FF	A9D6FF	9FD3FF
7AACEB	A0CCFF	A6D3FF	A1D0FF	A0D0FF
74A8E2	87B7F9	99C4FF	A3D0FF	A2D0FF
6698D3	6491D5	7AA6EF	A1CEFF	A5D2FF



Simple bitmapped image representation

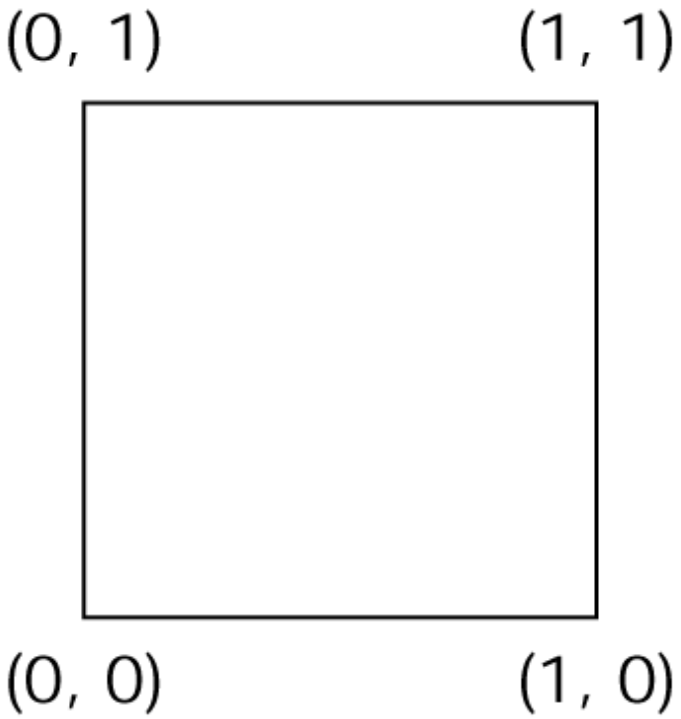
Vector Graphic Example

- Pen-Plotter Model
  - **Drawing Function**

```
moveto(x,y);
lineto(x,y);
```

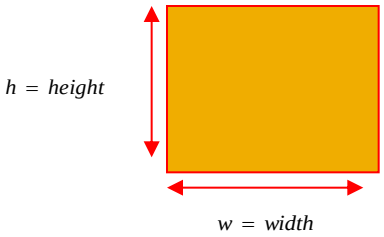
Examples>

```
moveto(0,0);
lineto(1,0);
lineto(1,1);
lineto(0,1);
lineto(0,0);
```



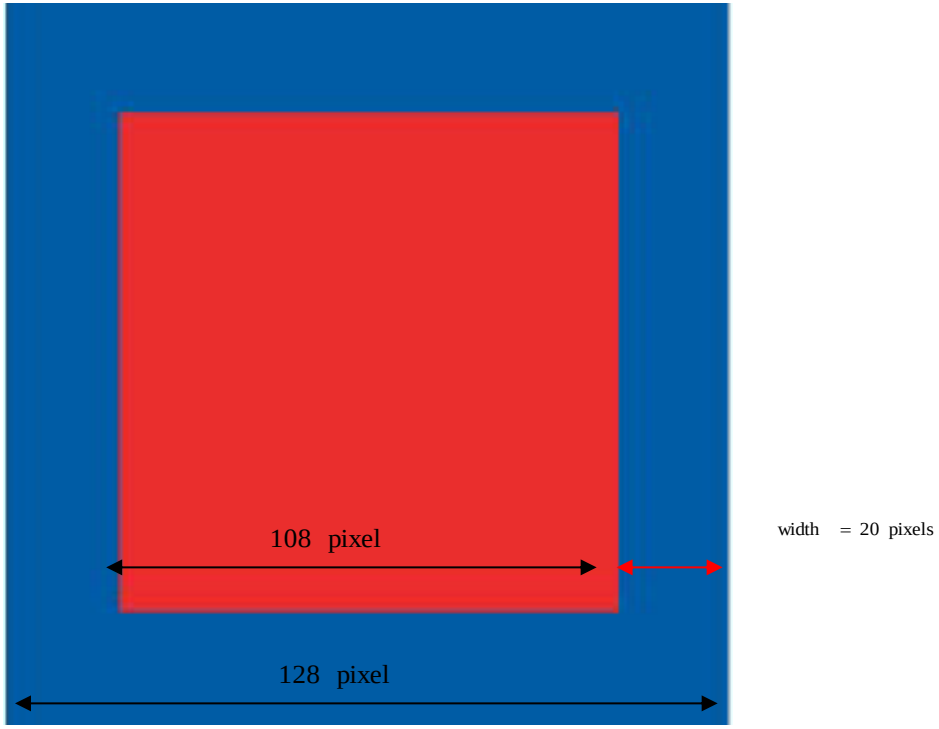
Memory Requirement

- Bitmapped
  - Any picture of w * h pixels, using c bytes per pixel occupies w*h*c bytes



- Vectors
  - Require memory space depends on complexity of picture (how many shapes, segments of path, lines, etc.)
  - Usually vector graphics < bitmapped image

- Ex) Comparing memory requirement for bitmap and vector format
  - 128 pixel square with red square inside

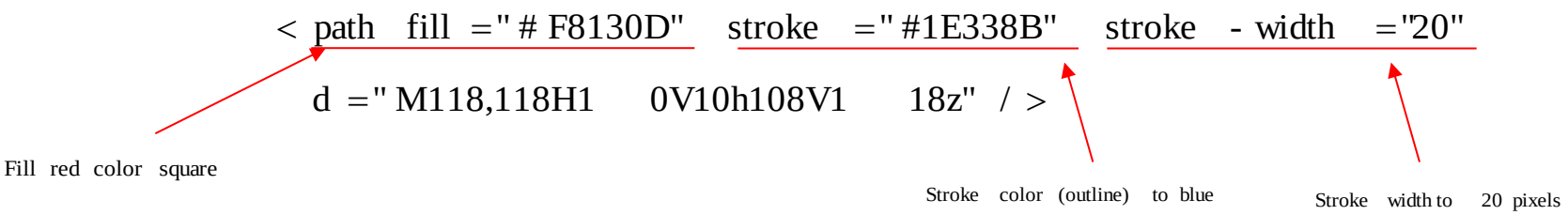


Compare memory requirements

- Bitmap image
  - Using 24 bits (3bytes) per pixel (True color)

    ⇒ 128 x 128 x 3 = 48kbytes

- Vector graphic in SVG format (W3C)



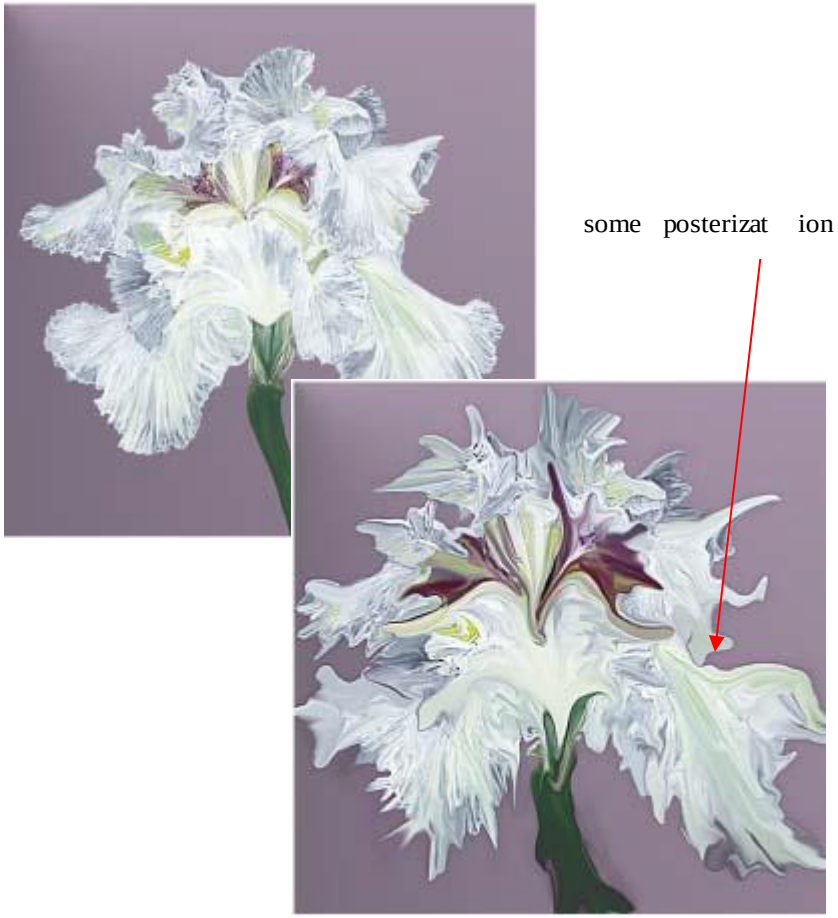
  - 86 Bytes + some SVG header = **284 bytes**

❖ Comparing Bitmap and Vector

	Vector Graphic	Bitmap Image
Expression	Mathematical description of geometry - shapes, lines,…	Pixels
Advantage	- Less memory - Easy and no quality loss for zoom in, transformation	- Good for gradual color change representation - Fast display speed on monitor
Disadvantage	- Slow display speed on monitor - Poor for gradual color change representation	- Large memory - Complicate and low quality for zoom in, transformation

Transformation

Vector : Changing Objects



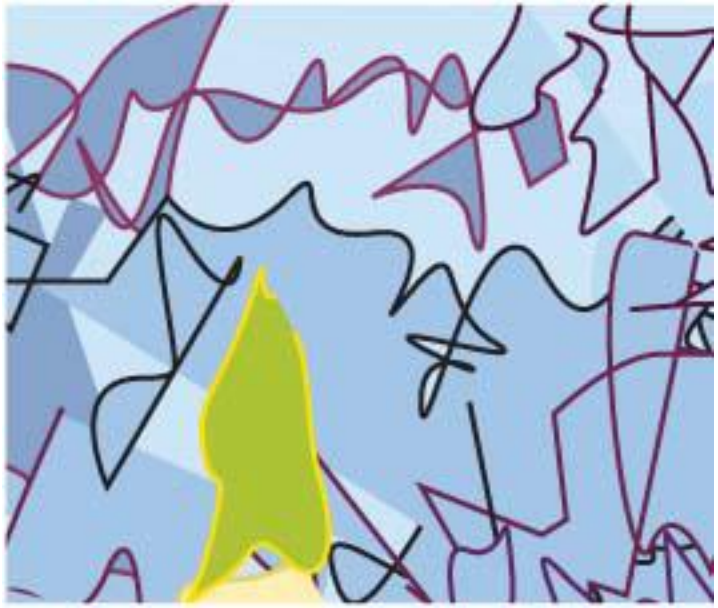
Bitmap : Changing Pixel location, value

Scaling (Zoom In)

- Vectors
  - Scaling is a simple mathematical operation on stored description
  - Curves and lines can remain smooth at all sizes

- Bitmaps
  - Interpolate pixel values - More or less sophisticated algorithm
  - Produces loss of quality, blurring, jaggedness (들쑥날쑥한)

- Scaling by 8 times



Vector Graphics

loss of quality and blurring

Bitmap Images

Transform Vectors & Bitmaps

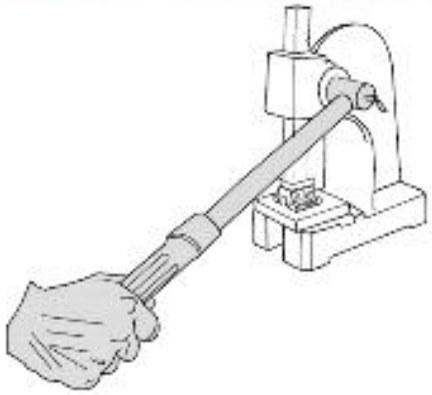
- **Rasterize**: Vector → Bitmap
  - Lose all vector properties
  - Apply complex strokes to vectors to approximate bitmapped appearance

- **Tracing** : Bitmap → Vector
  - Sometimes called Vectorization
  - Difficult and can only produce an approximation

Vectorization (Tracing)

Bitmap image

Vector graphic



Layer Concept

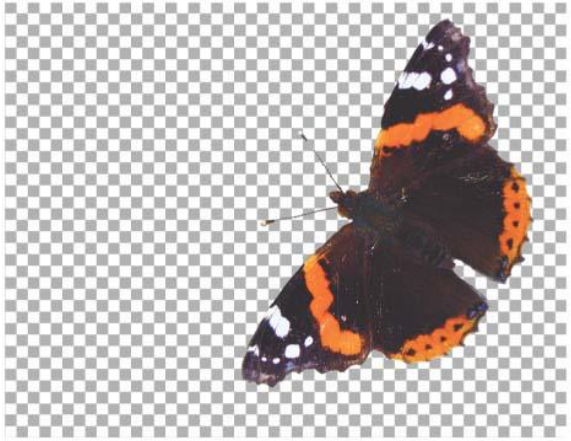
- Especially useful in bitmap image
  - Permits separation and manipulation of different parts of a bitmapped image
  - Layer - digital version of clear sheets of acetate (투명필름) stacked on each other
  - **Compositing** – combine layers using different blending modes

    → digital collage (배합법)

Layer example)

Photo/Layer 1

Photo 2



Layer 2 extracted from photo 2

Composited layers

Image Digitization

- Natural Image is analog, so, it must converted to digital
  - Digitizer : Image scanner, Digital camera

- Digitization method (two steps)
  - Sampling: (X,Y) 2D sampling → pixel
  - Quantization: Binary allocations to each pixel

Image Sampling

- (X, Y) 2D sampling to pixel
- Direct relationship with image Resolution
  - Same image but different resolution

Sampling **512X512** **128X128** **64X64** **16X16**

number of pixels in row X number of pixels in column

Image Quantization

- Bit allocation to each pixel of image
  - Represent pixel brightness (B/W) or color depth
  - Monochrome : 1bit/pixel, ex) FAX
  - Gray-level image: 8bit/pixel, 0(B) ~ 255(W)
  - True Color (24bit/pixel), High Color (16bit/pixel)

- Quantization for gray-level image

6bit

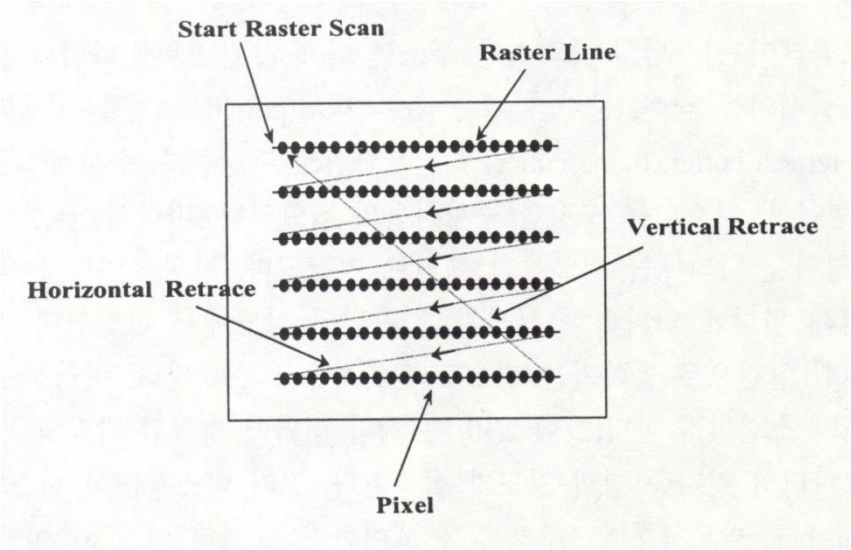
4bit

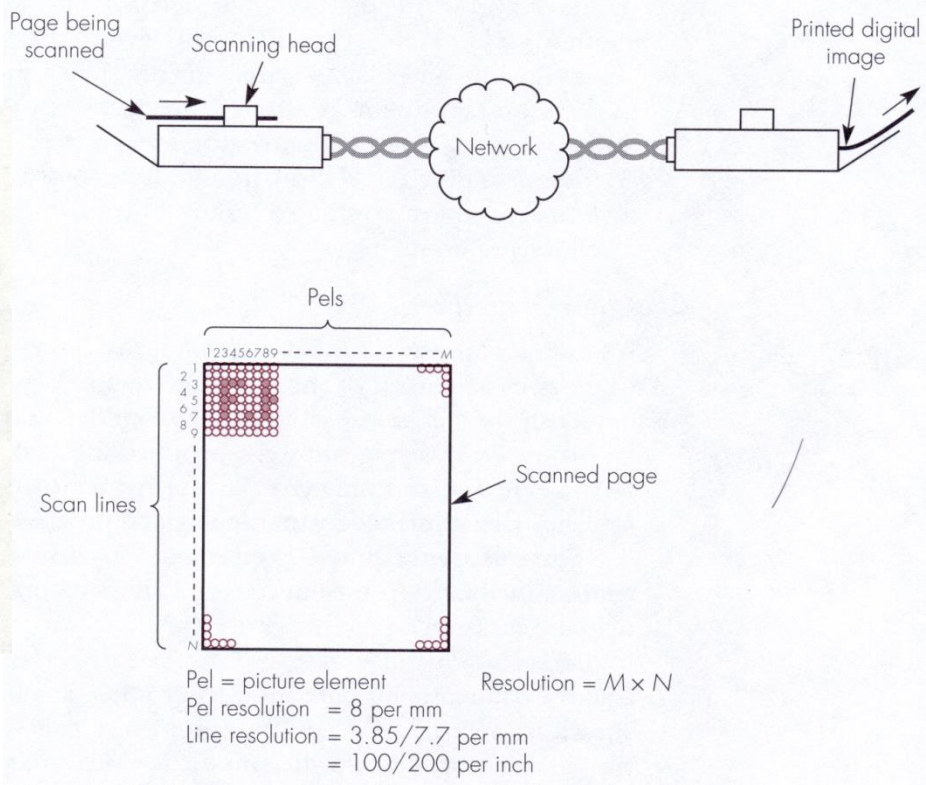
3bit

2bit

Image Applications

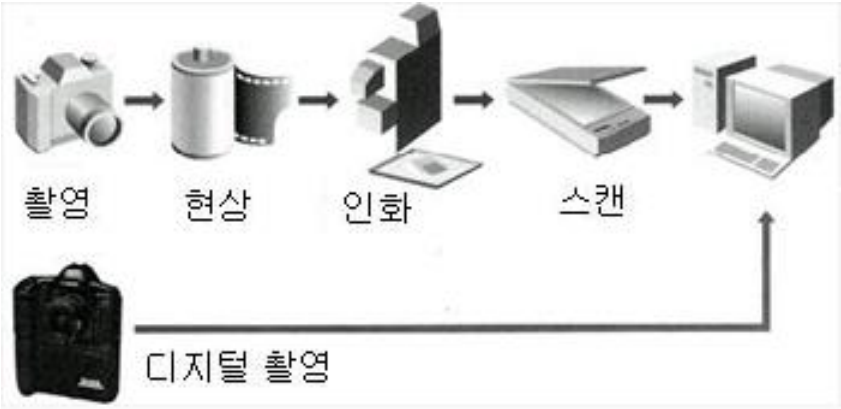
- FAX (1 bit monochrome)

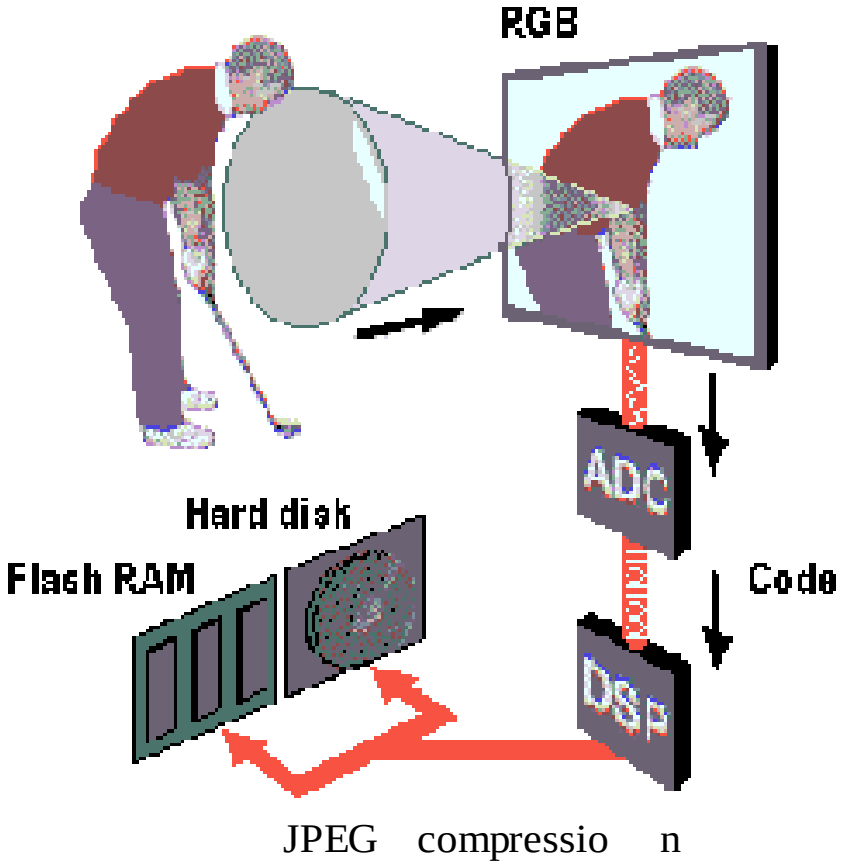




Analog and Digital Camera

Analog camera processing to get digital copy in your computer





File Formats

- Many different image and graphic file formats
  - Depending on different ways of encoding image data

- For bitmap image
  - Tells different compression methods
  - Lossless – image can be reconstructed exactly from compressed version
  - Lossy – some information discarded, image can only be reconstructed approximately

Bitmapped Formats

- GIF (Compuserve Graphics Interchange Format)
  - Lossless, 256 colors (indexed)
  - Patent by Unisys, used by Compuserve

- JPEG (Joint Picture Experts Group)
  - ISO/IEC JTC 1, SC29 - WG1
  - Lossy compression
- PNG (Portable Network Graphics)
  - W3C standard
  - Lossless, variable number of colors, but not used widely

Vector Formats

- SVG (Scalable Vector Graphics)
  - W3C standard, not presently widely used
  - 2-D vector graphics
- SWF (Small Web Format, Shockwave Flash)
  - Primarily for vector animation, but can be used for still vector graphics; de facto standard
- EPS (Encapsulated PostScript)
  - Primarily for printer, superseded by PDF

Image and Graphic Editing SW

- Vectors – drawing programs
  - Select individual graphic objects (shapes, paths, lines, etc.)
  - Able to transform and changing attributes
  - Ex) Visio, Adobe Illustrator

- Bitmaps – painting programs
  - Select areas of pixels to apply for effects and filters
  - Ex) PhotoShop, PaintBrush

Homework #3

- Image Layer
  - Take any two images you want
  - Show composite example using layer concept
  - Describe and display your example