數位影像原理
Digital Image Fundamentals

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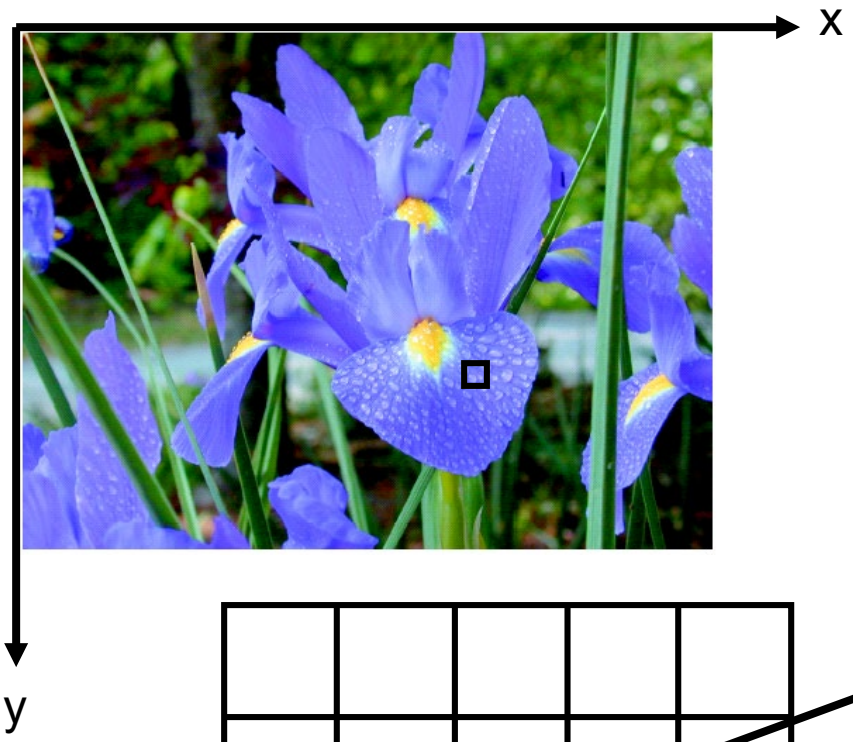
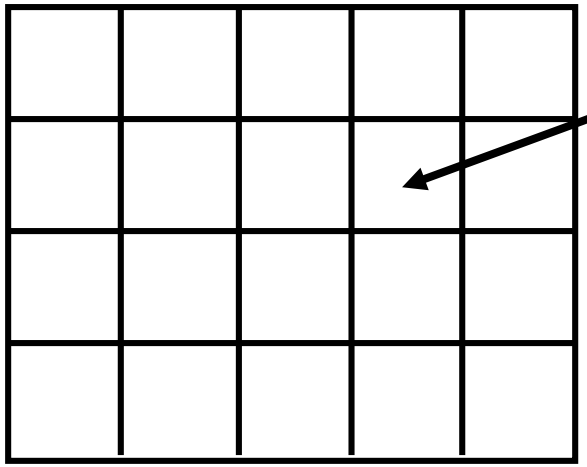
中山電機系

What is digital image?





Pixel: picture element

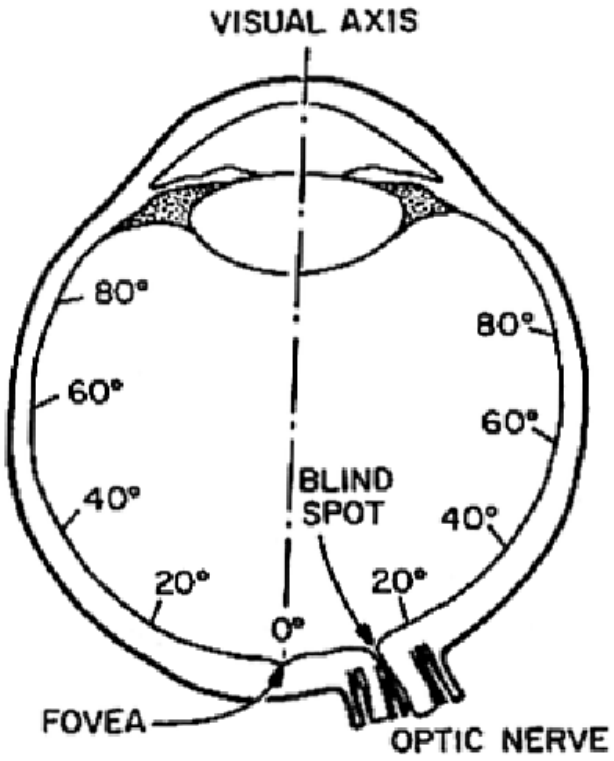
$f(x,y)$: *intensity* or *gray level* of the image at (x,y)

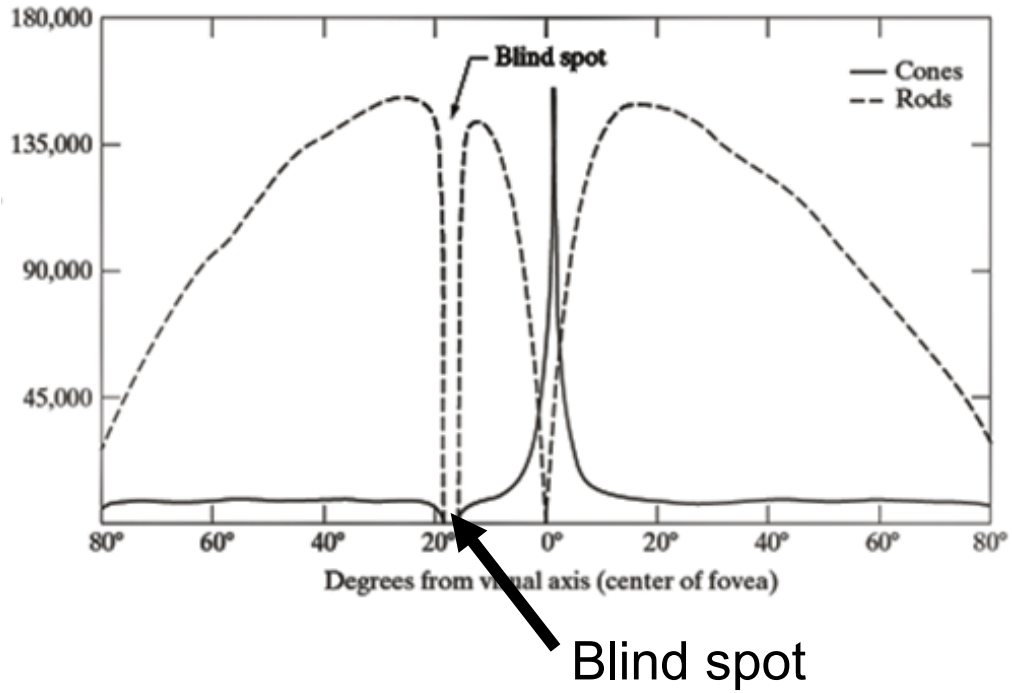
Visual Perception

Continuous Image Characterization

"Digital Image Processing", *Wiliam K. Pratt, 3rd ed., John Wiley & Sons. Inc.,2001*

Structure of the Human Eye

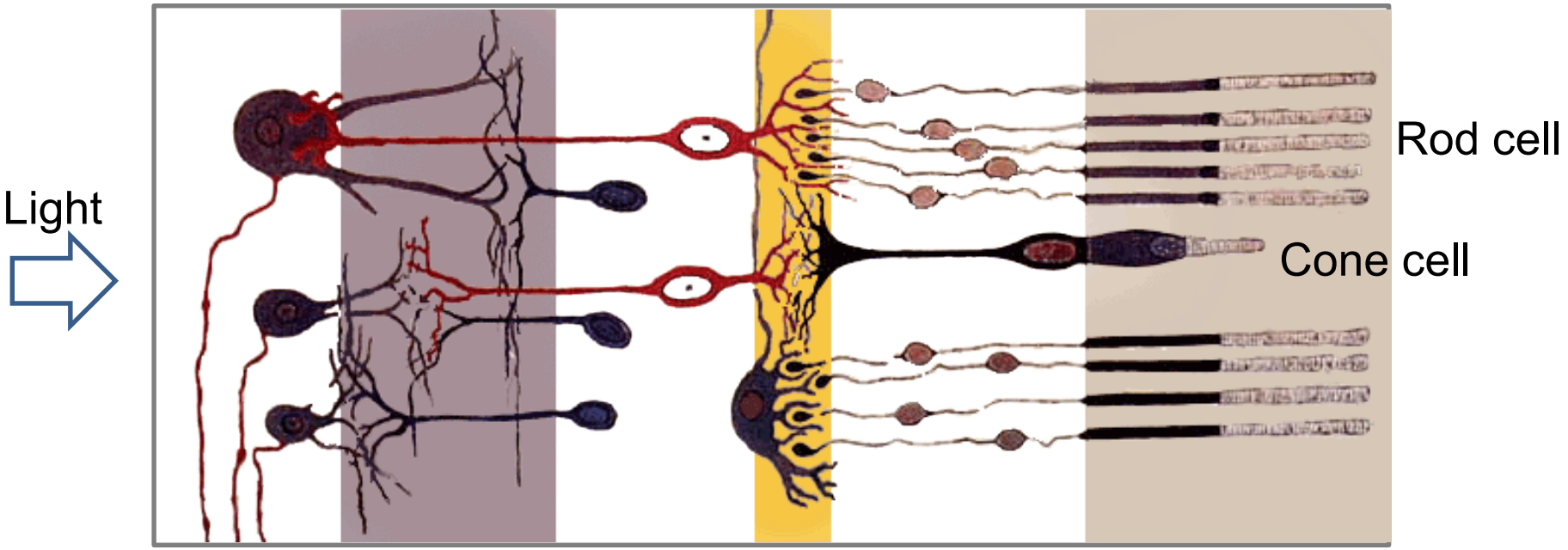




Rods (柱狀細胞) – 對弱光敏感，無法辨識顏色

Cones (錐狀細胞) – 對顏色敏感，高解析度

Structure of the Human Eye



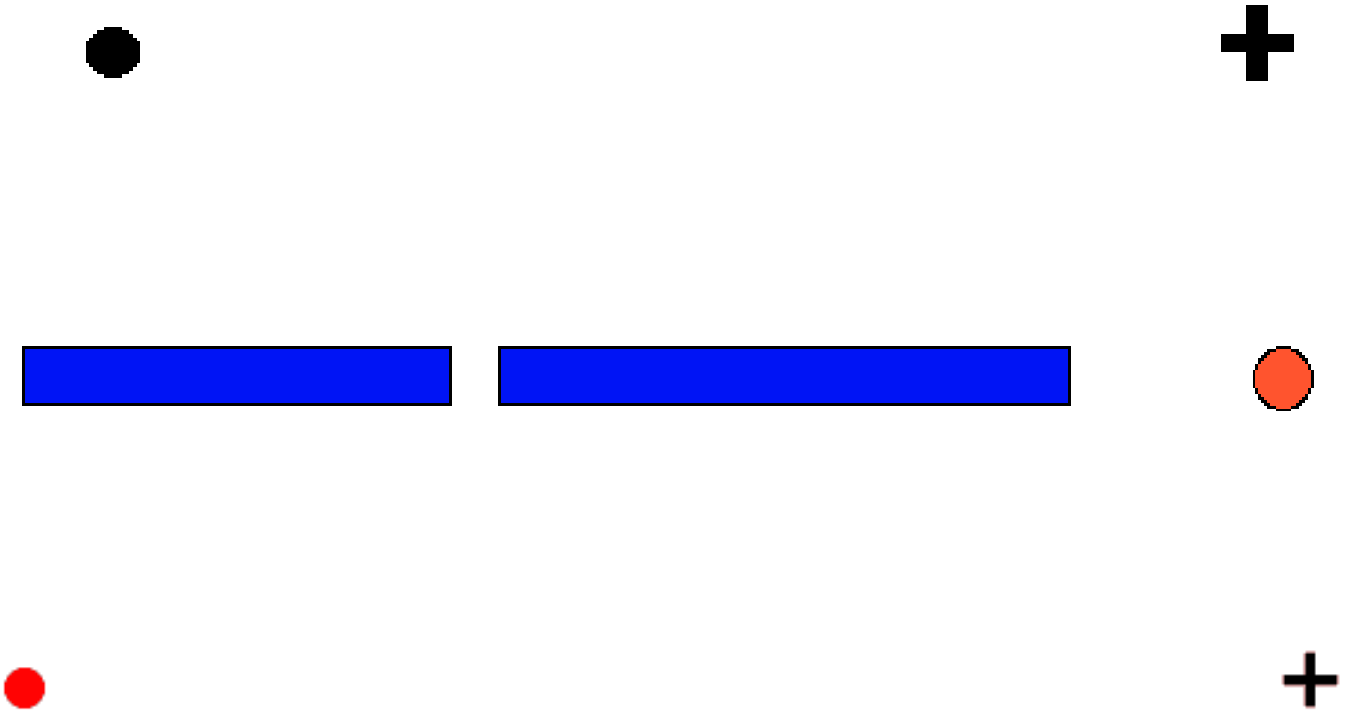
For each human eye,

~ 120 million Rods → night vision, peripheral vision

~ 6 million Cones → direct light vision, high acuity

Blind Spot Test

http://faculty.washington.edu/chudler/chvision.html



How to define brightness?

- Brightness
  - A subjective descriptor of light perception
  - Impossible to measure practically
- Luminous flux：光通量
  - The perceived power of the light source (unit: lumen or lm)
- Luminance ：輝度、亮度
  - The perceived power per unit area in a given direction (unit: cd/m^2)
- Illuminance：照度
  - The amount of luminous flux per unit area over a given surface (unit: lux, lm/m^2)

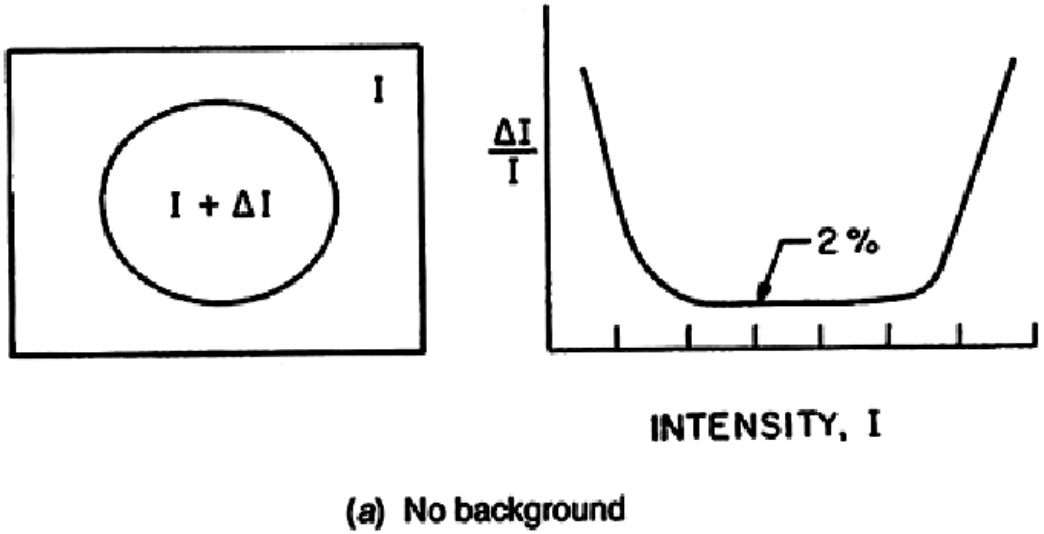
Visual Phenomena

- The response of the eye to changes in the intensity of illumination is known to be nonlinear.
  - The range of sensible light intensity is enormous ~ 10^{10}

環境	照度（lux）
烈日	100,000
陰天	8,000
閱讀	500
教室	300
路燈	5
滿月	0.2
星光	0.0003

Visual Phenomena

- Contrast Sensitivity
  - ΔI : 剛好使人能區別

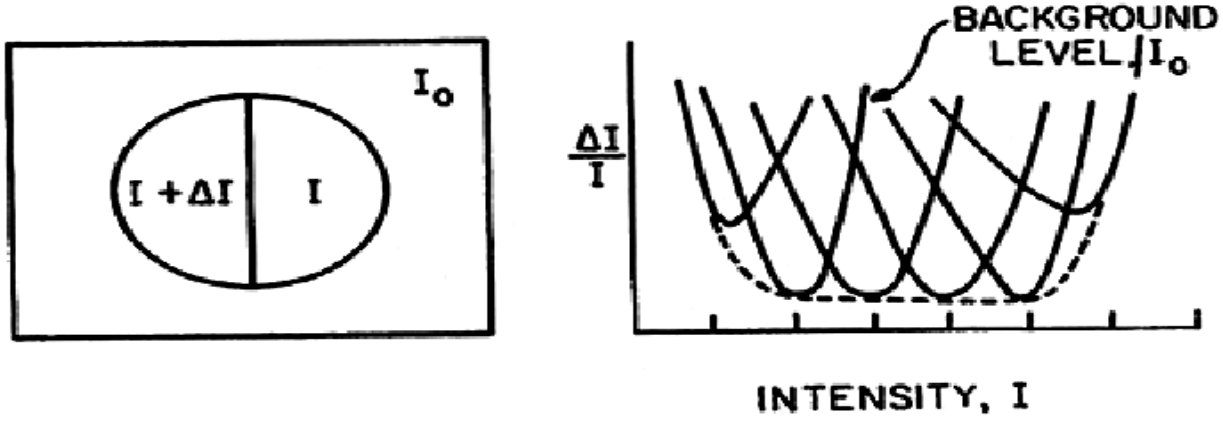


(a) No background

ΔI /I = Weber fraction (ratio)

= 0.02 for wide ranges of values of *I*

Visual Phenomena

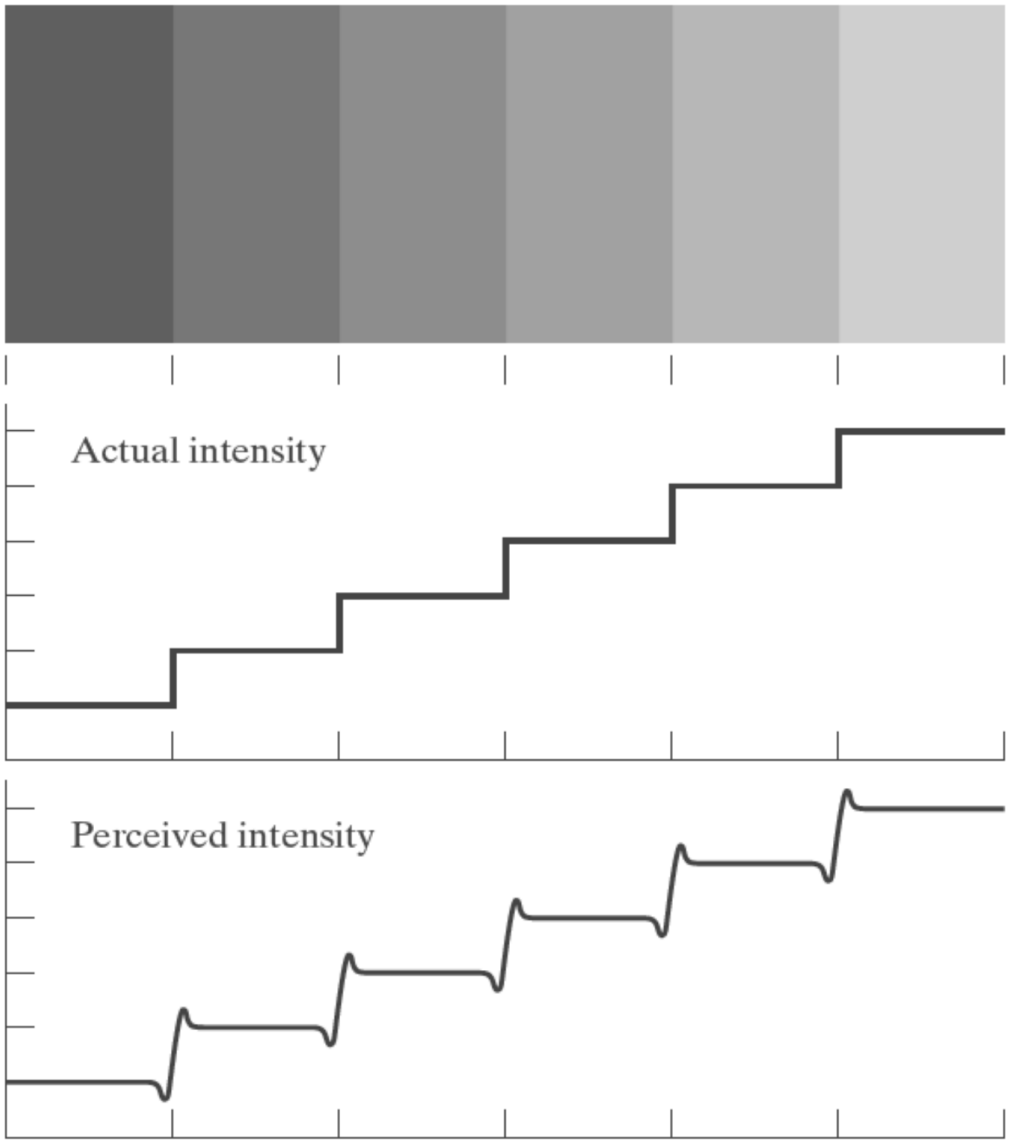


(*b*) With background

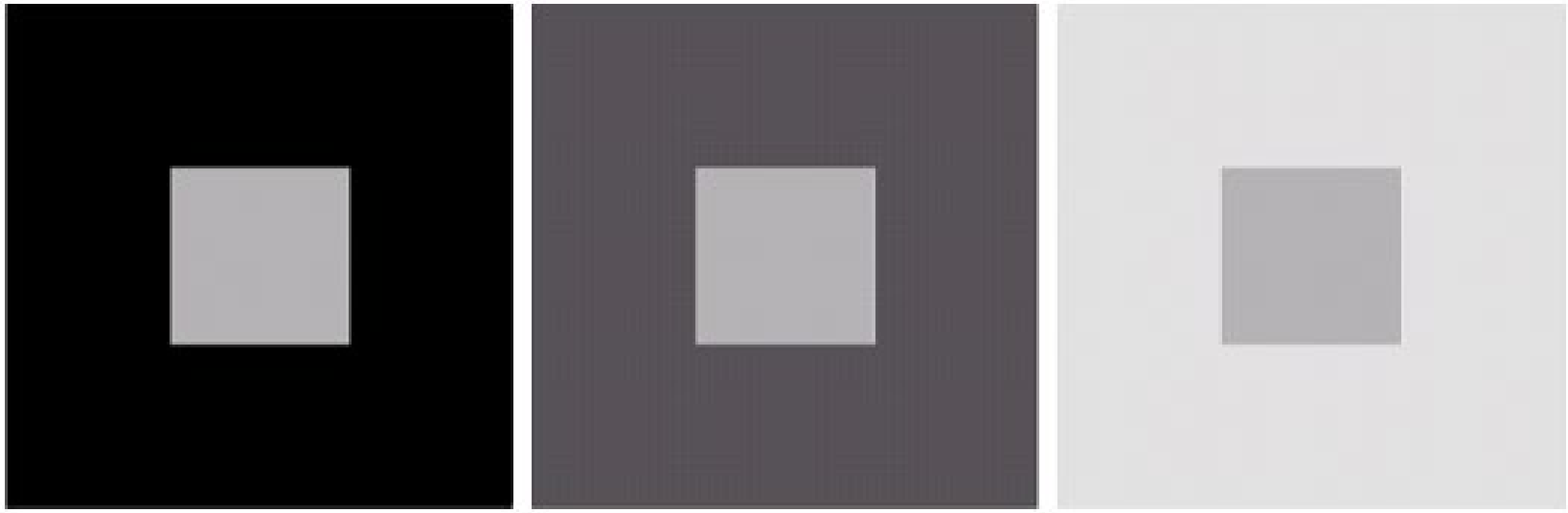
$$\frac{d}{dI}\log I = \frac{1}{I} \rightarrow d[\log I] = \frac{dI}{I} \rightarrow \Delta[\log I] = \frac{\Delta I}{I} = 0.02$$

人的視覺用log model 較準確!

Mach Band Effect



Simultaneous Contrast

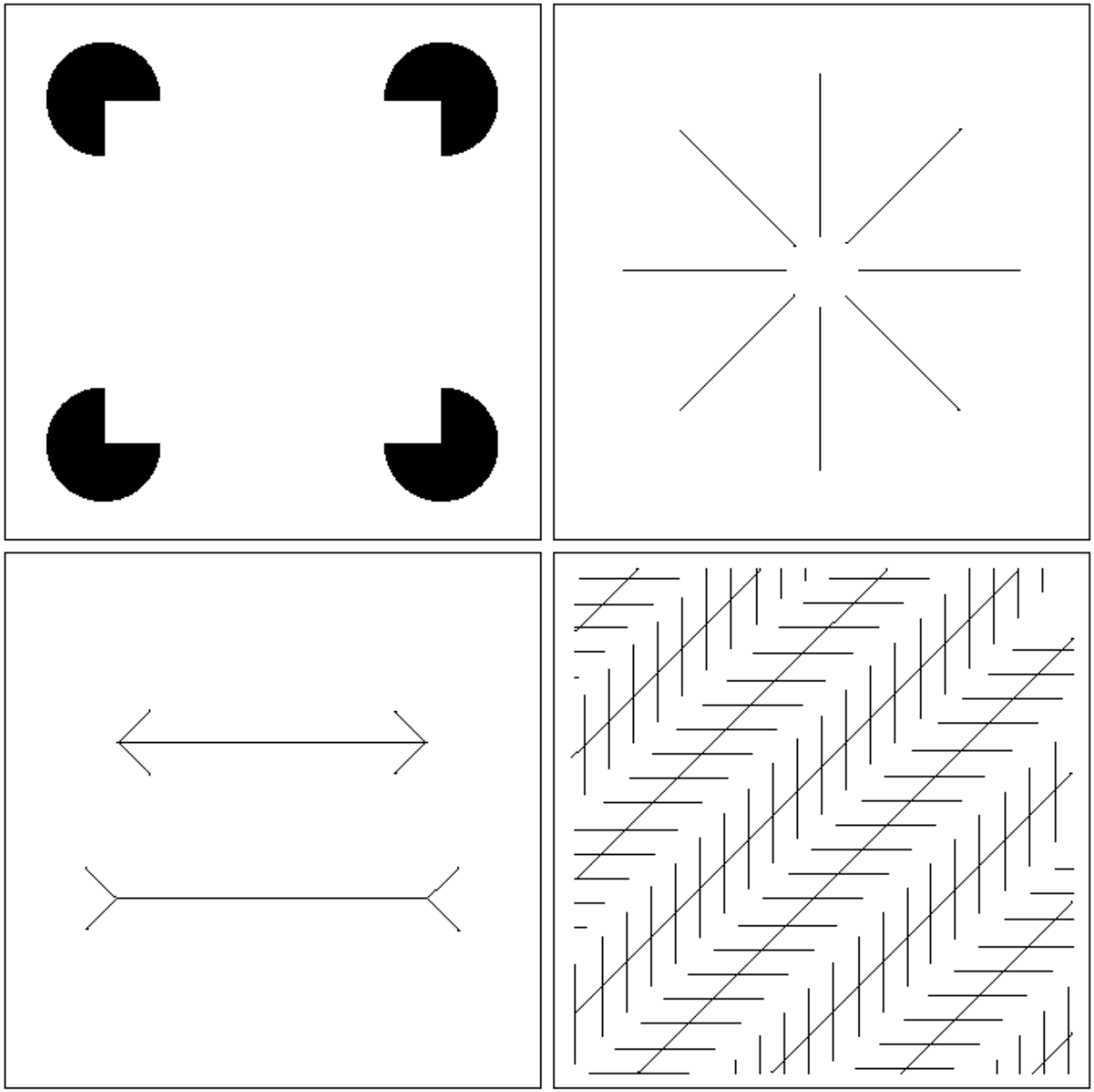


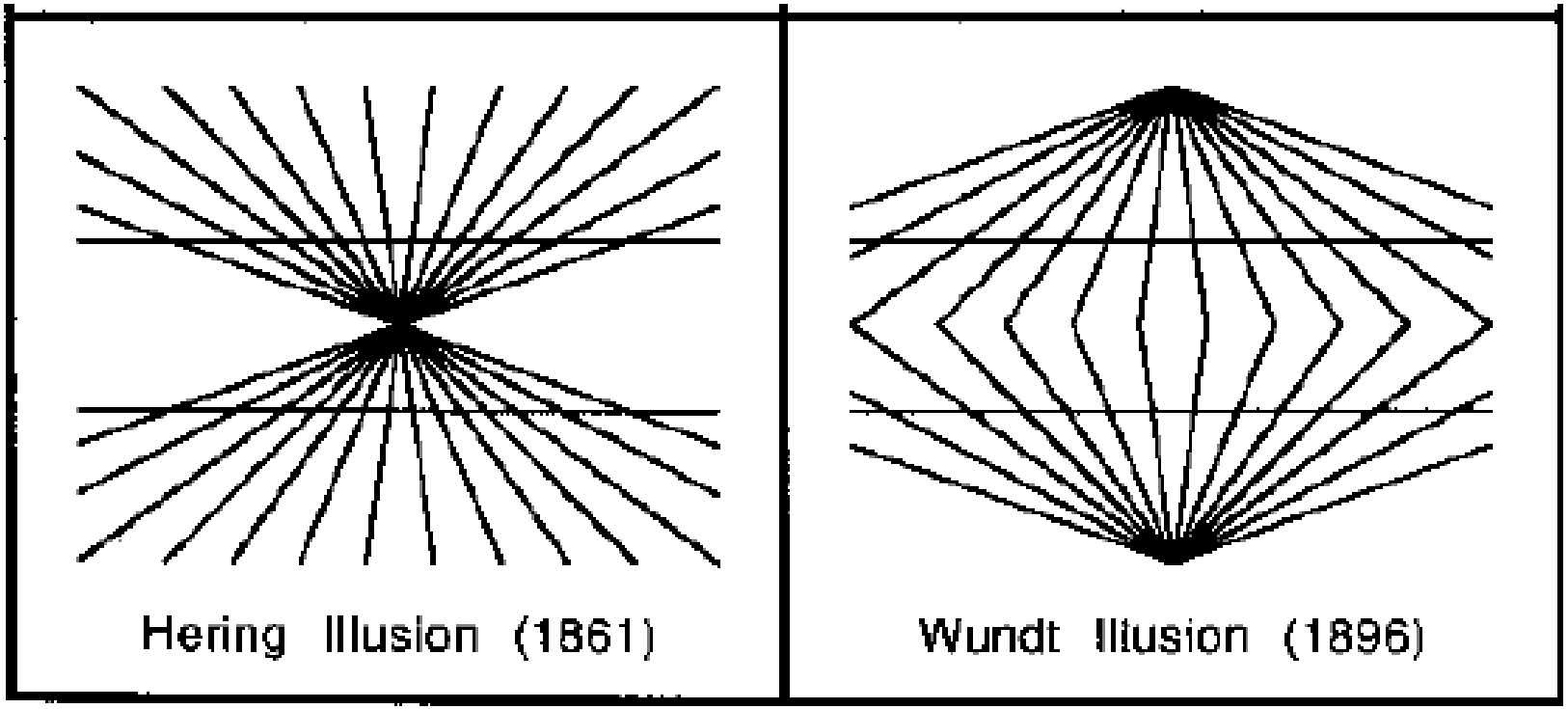
Visual perception

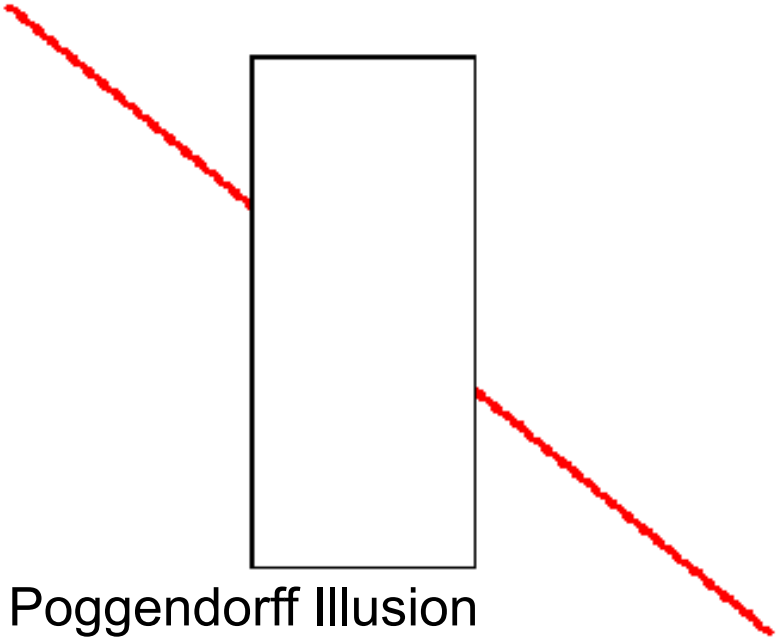
- The perceived brightness of human eyes is a non-linear function of:
  - Illuminance
  - Contrast
  - Spatial distribution of textures
  - …

眼見為憑？

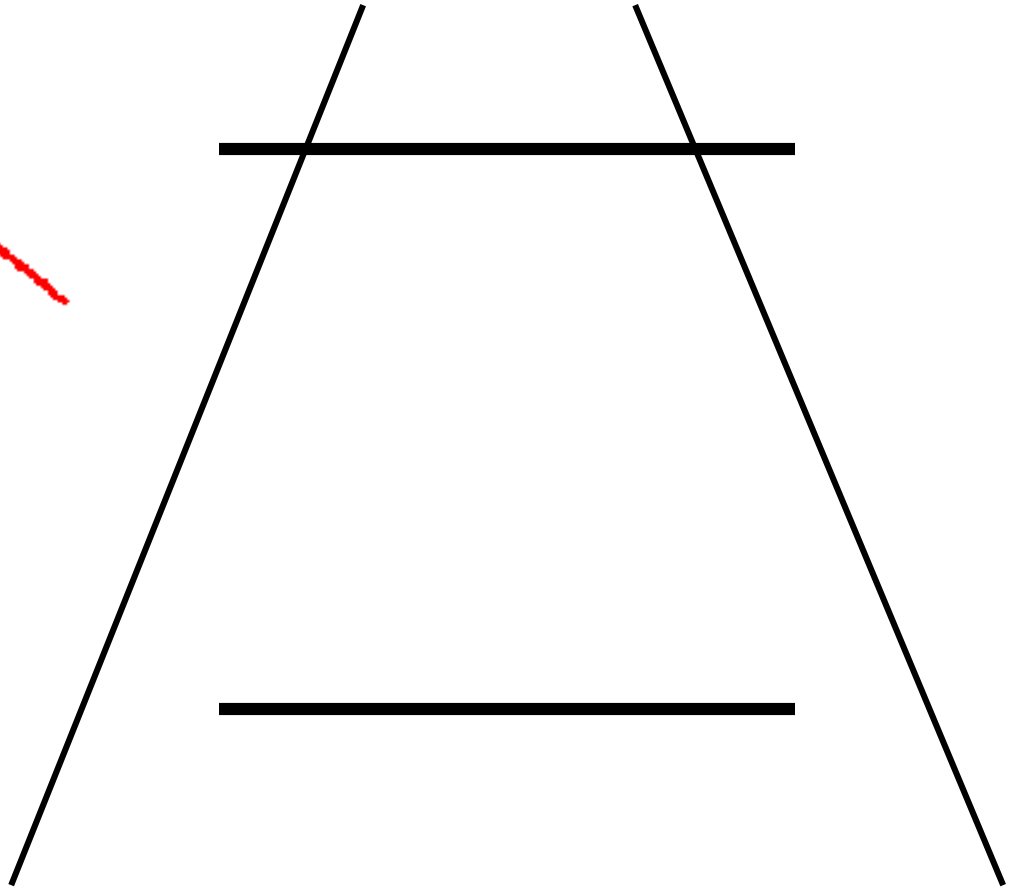
Optic illusion!




Hering Illusion (1861)
Wundt Illusion (1896)

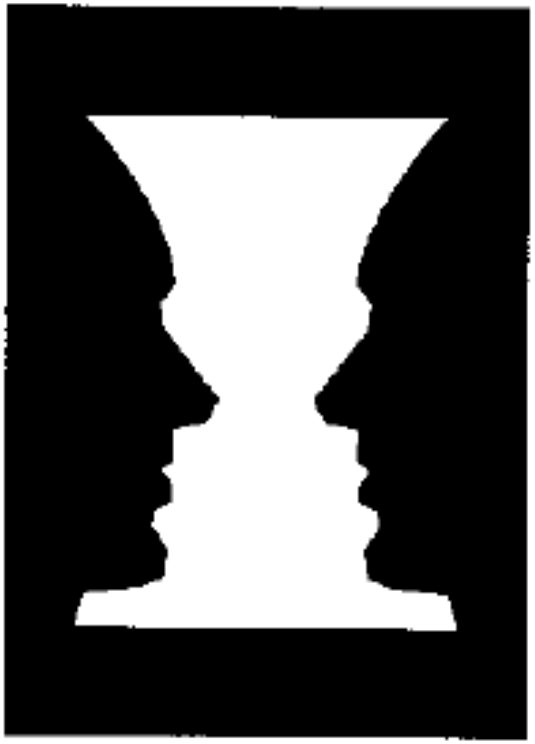


Poggendorff Illusion

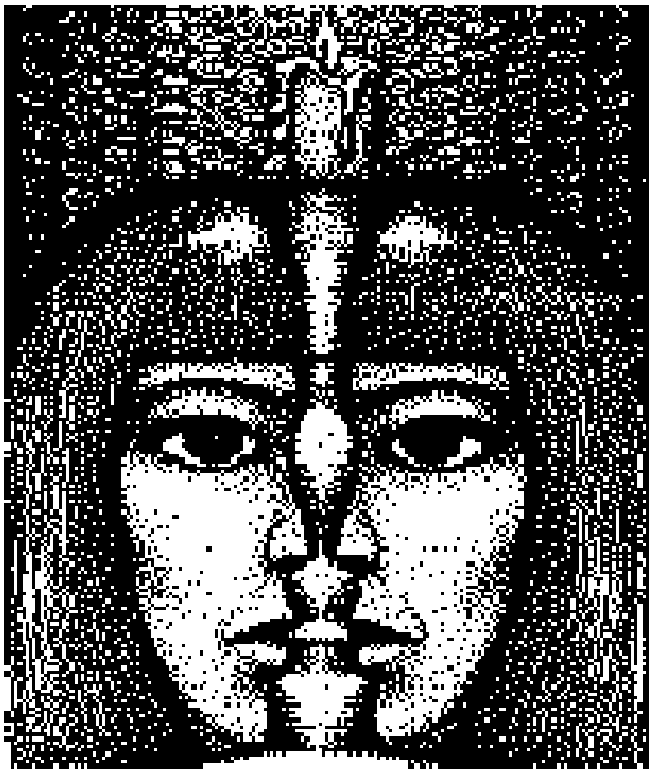


Ambiguities

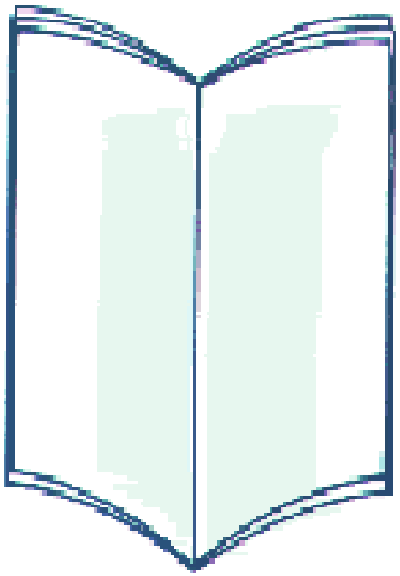
Young Girl / Old Woman

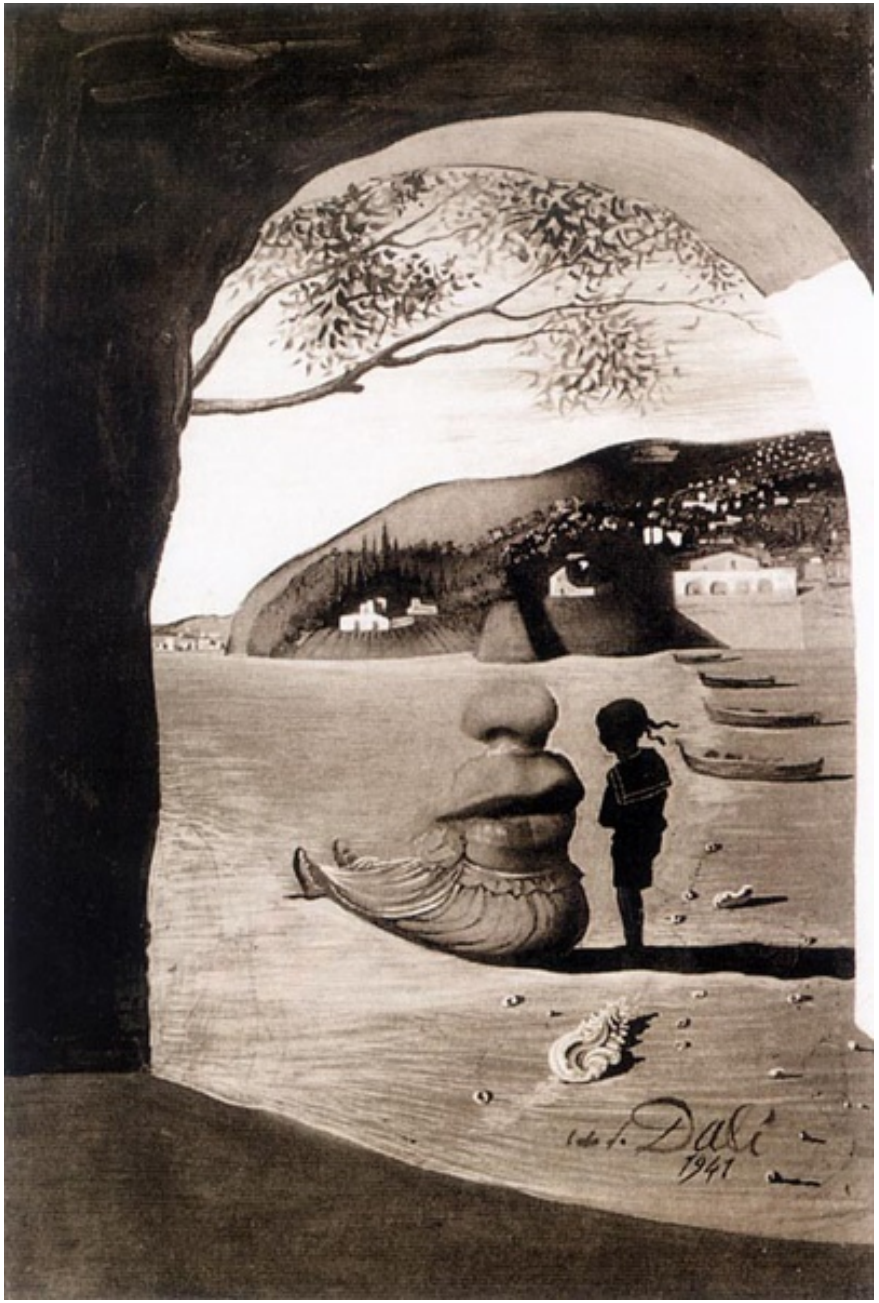


Vase / Faces

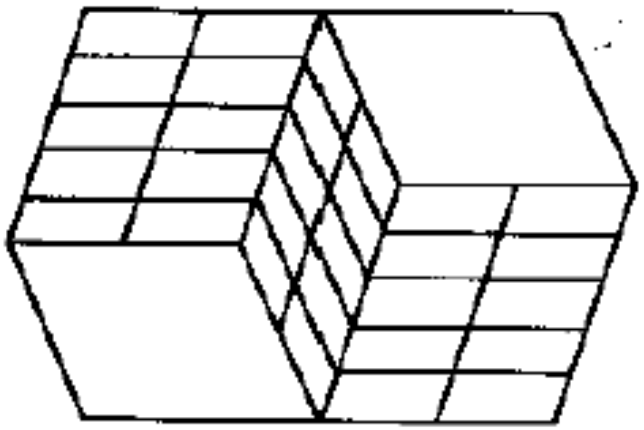


American Indian or an Eskimo? two faces or one?

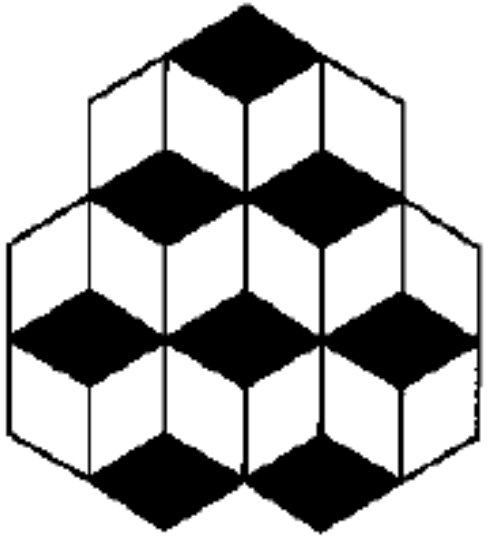



Dalí
1941

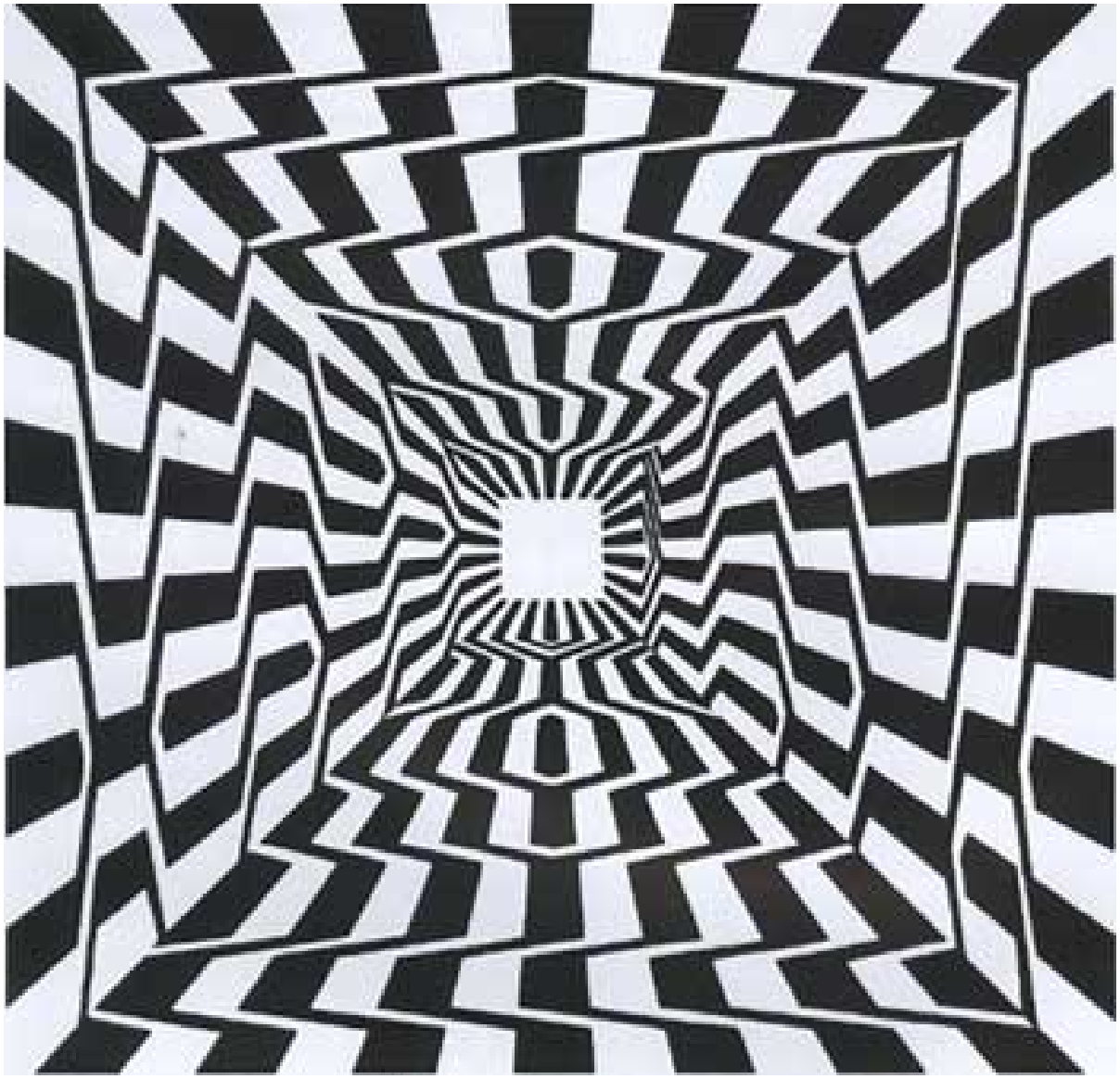

www.rasiel.com
Paranoiac Visage, 1935 - Dali



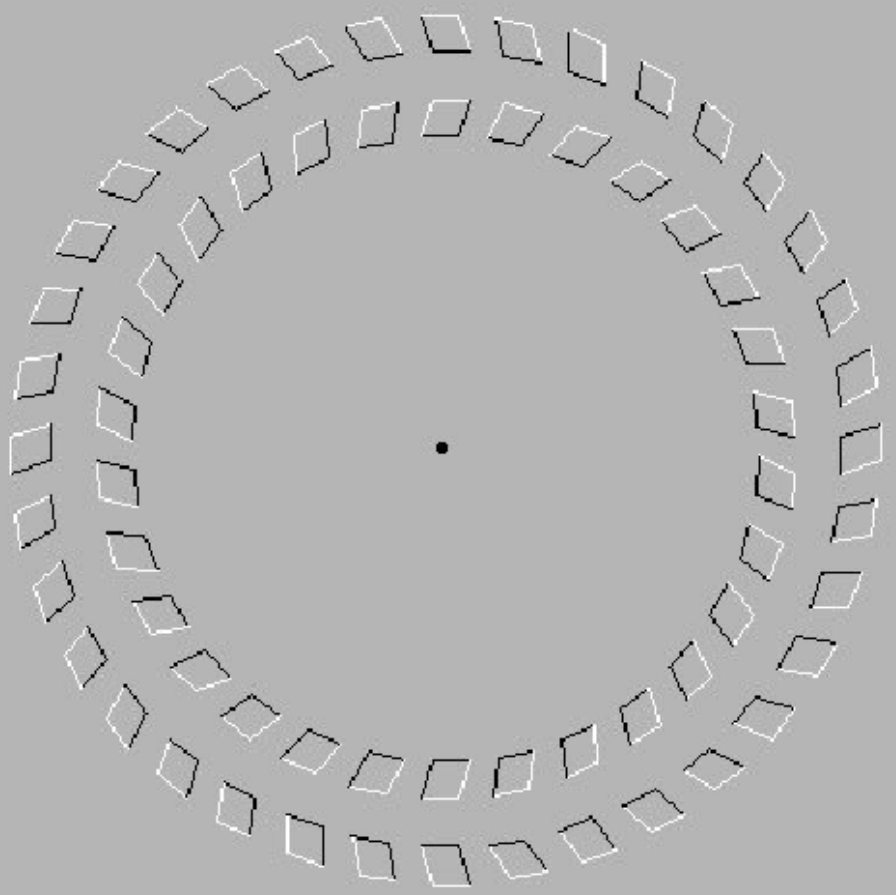
Pop In/Pop Out

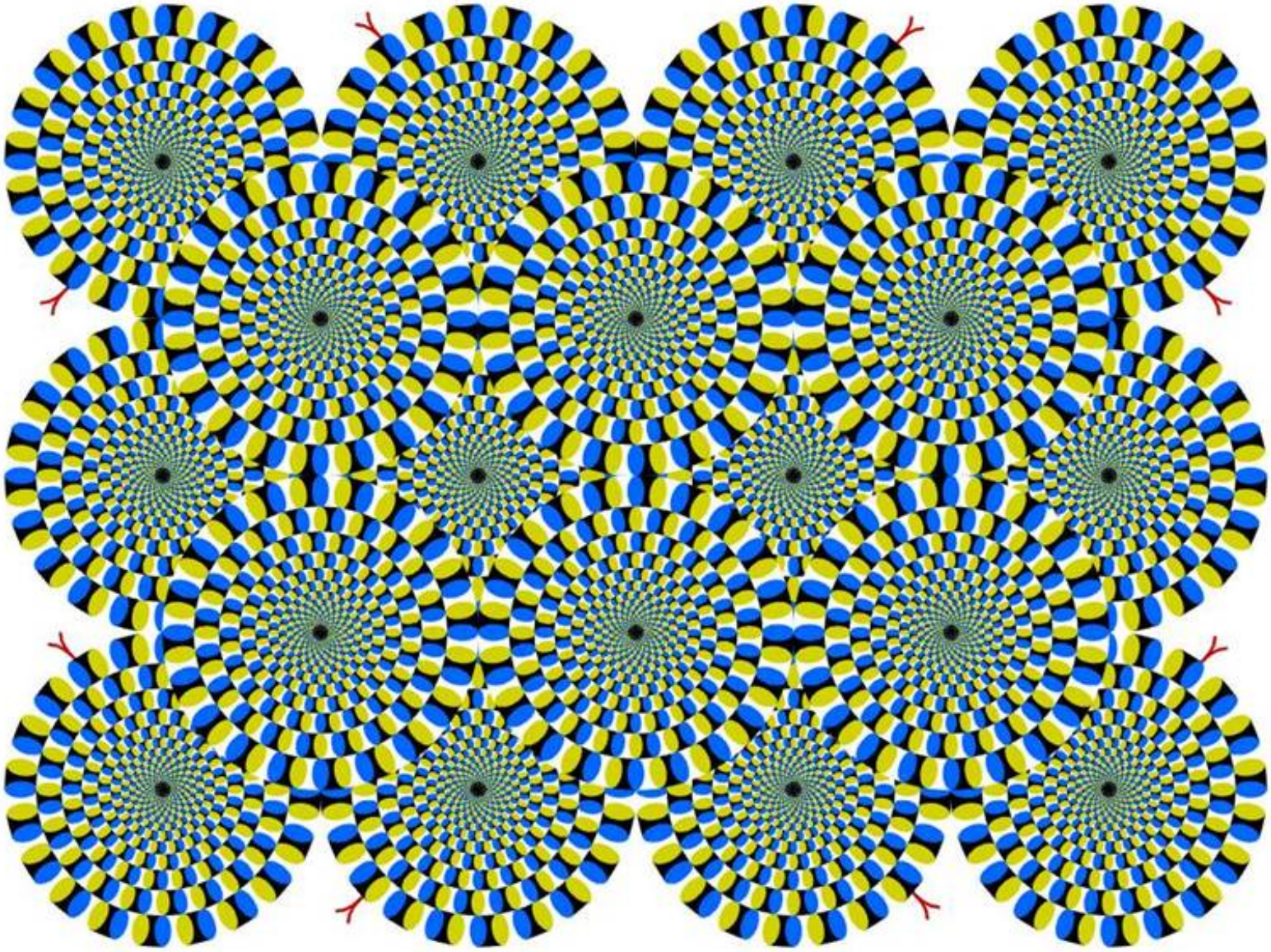


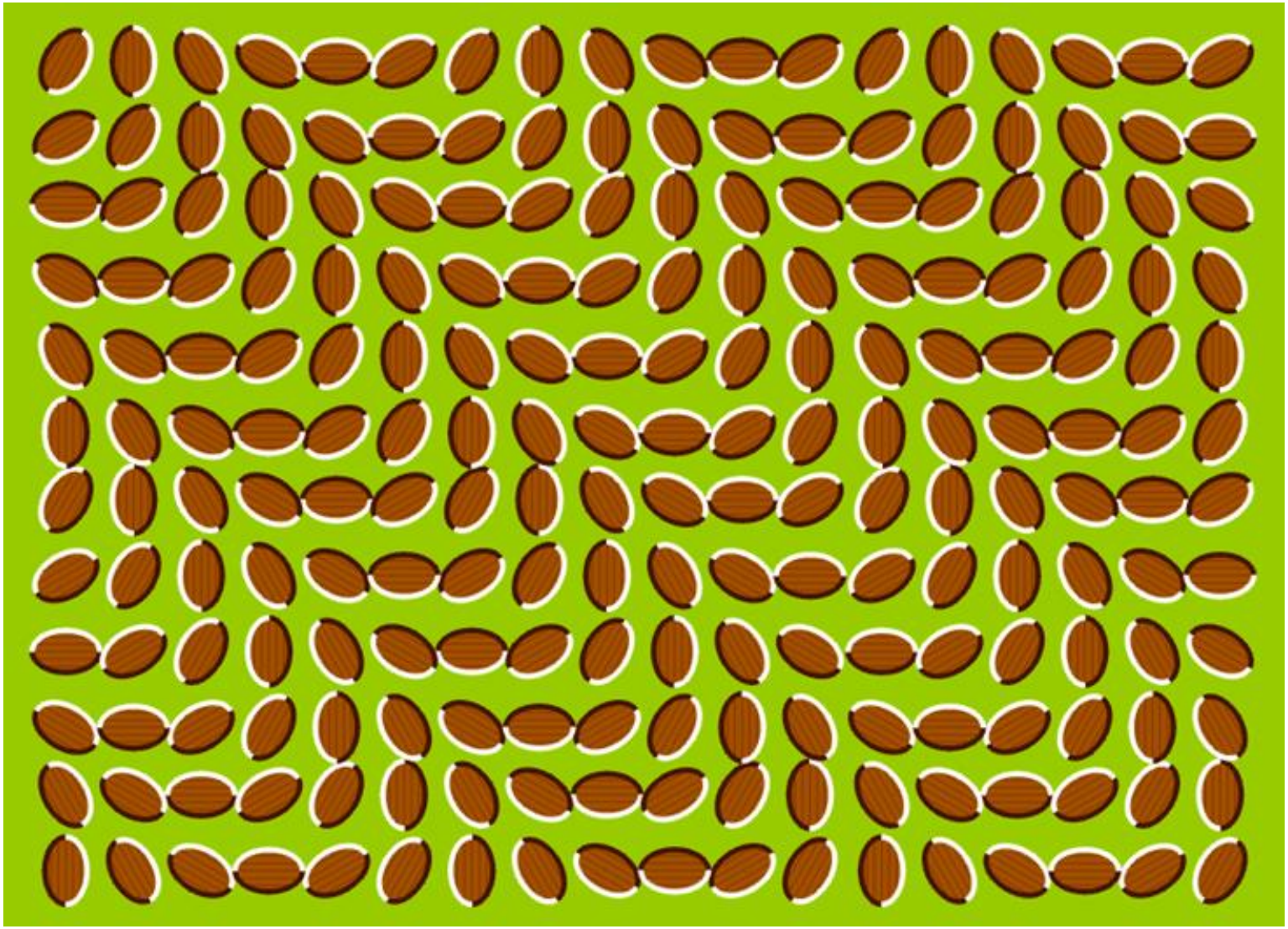
Six Cubes/Seven Cubes

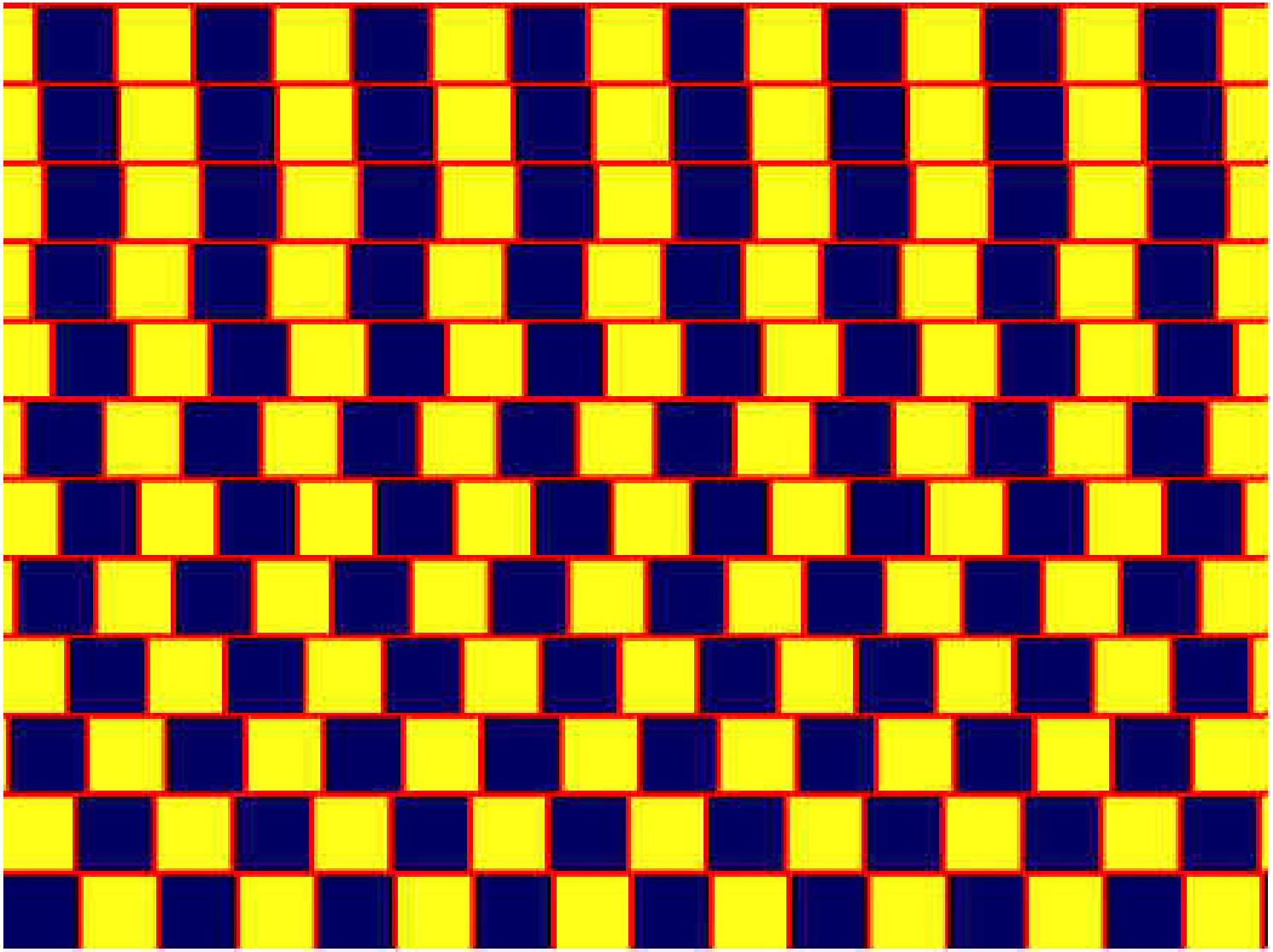


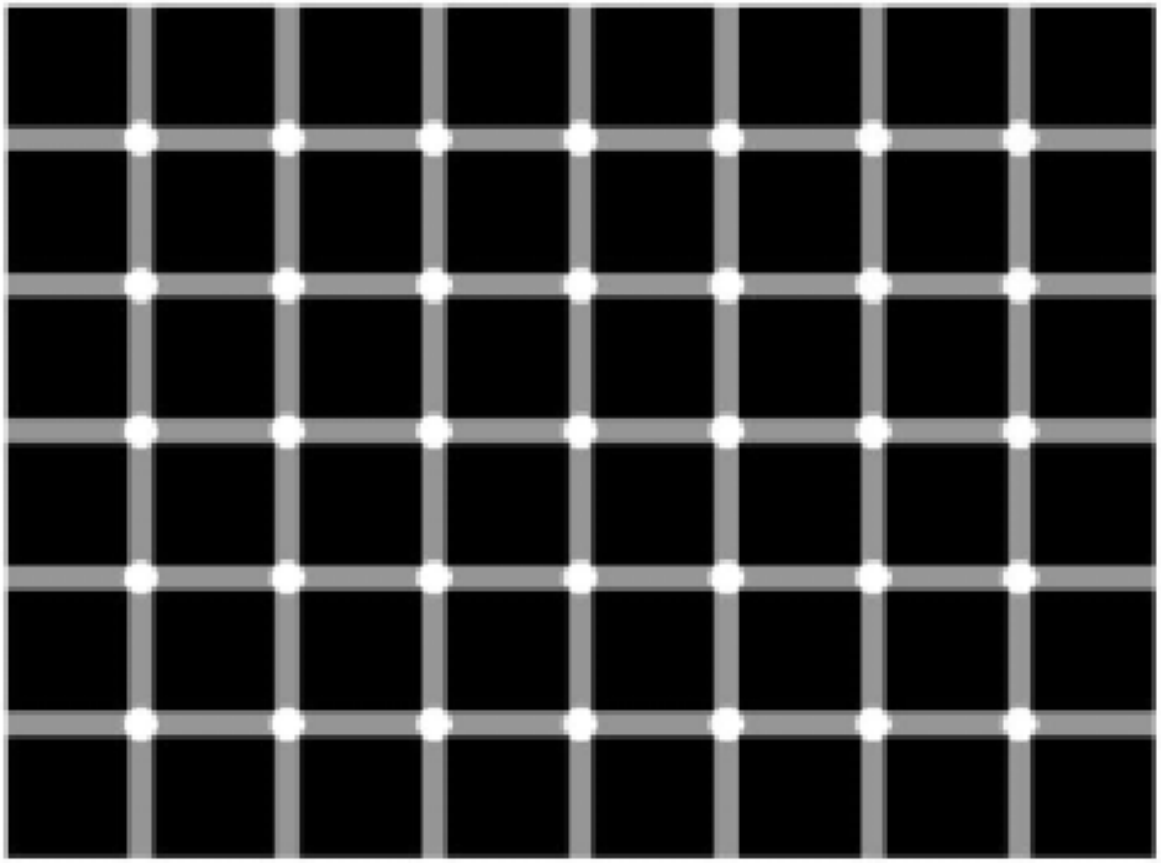
move your head forwards and backwards while looking at the dot











Count the black dots! :o)

Image Acquisition

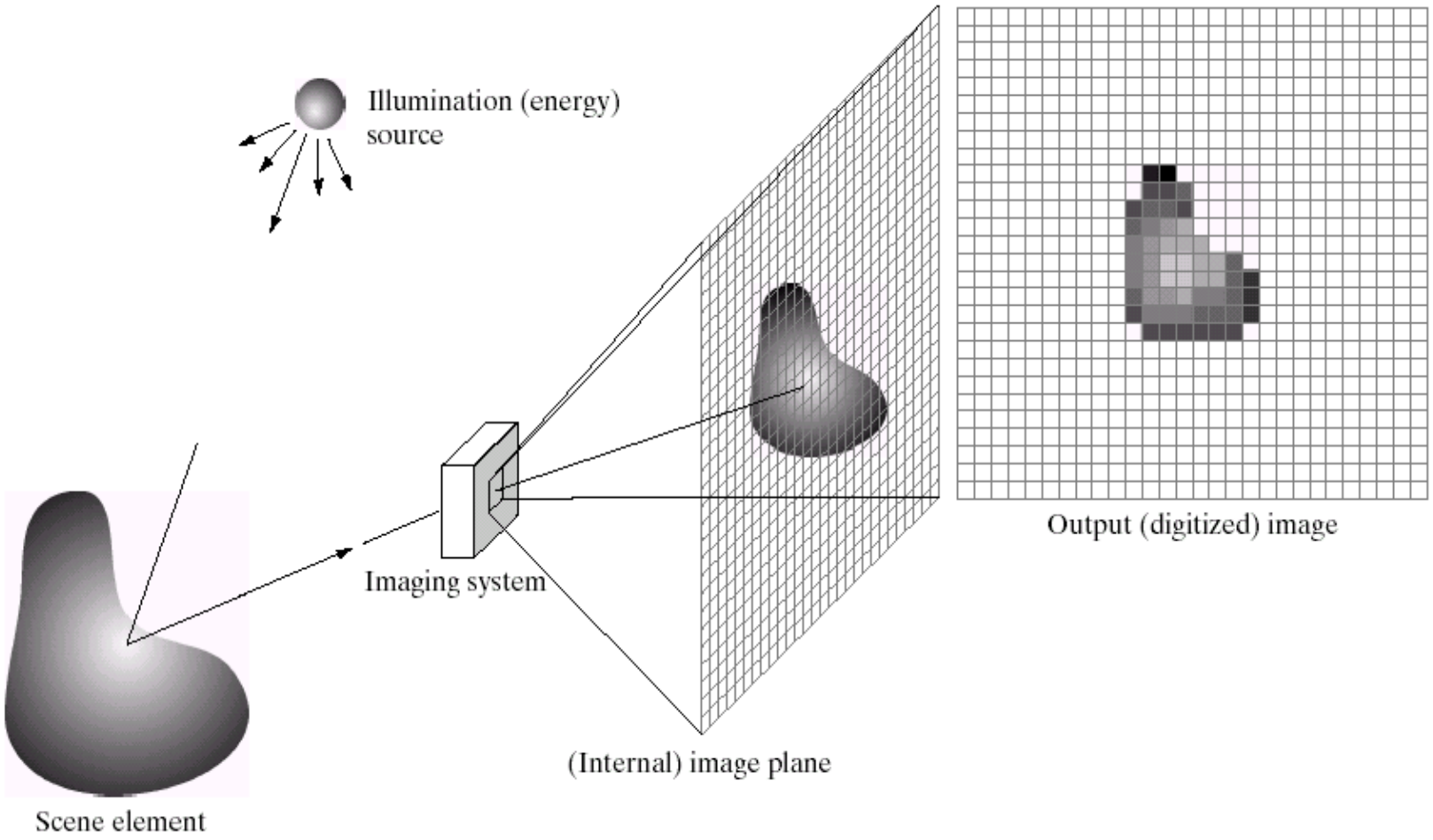
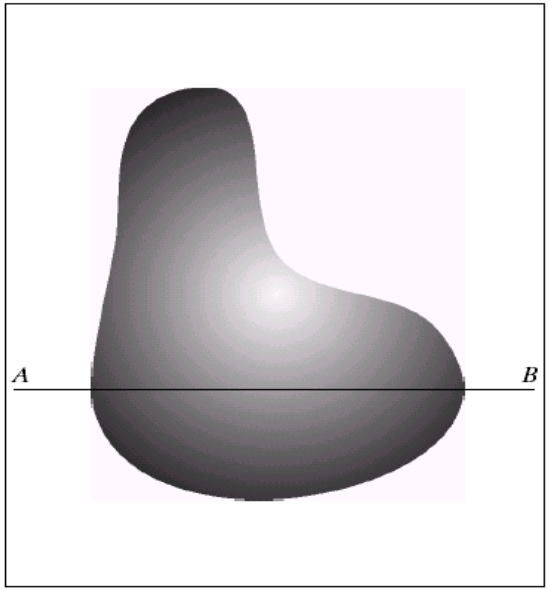
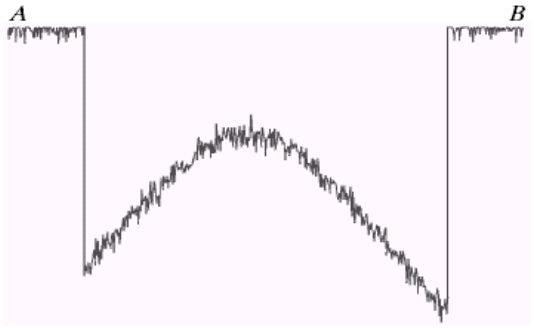
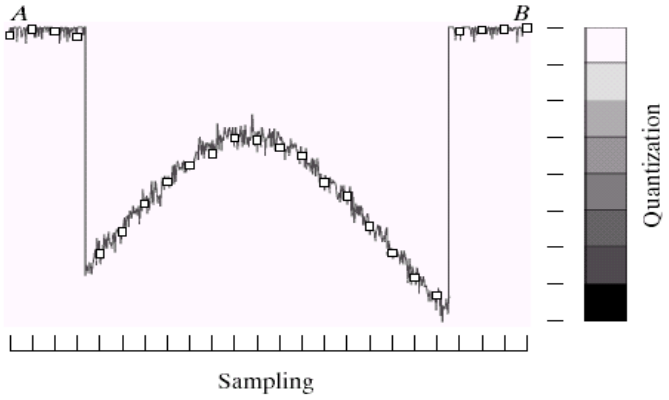


Image Sampling & Quantization







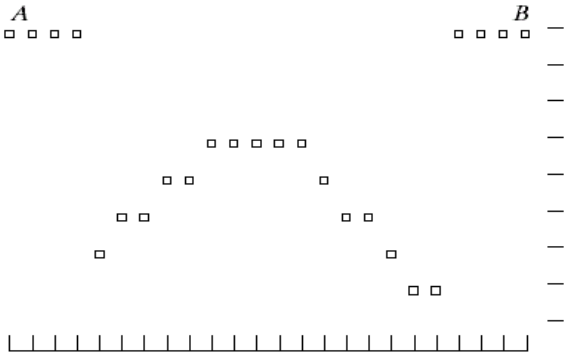
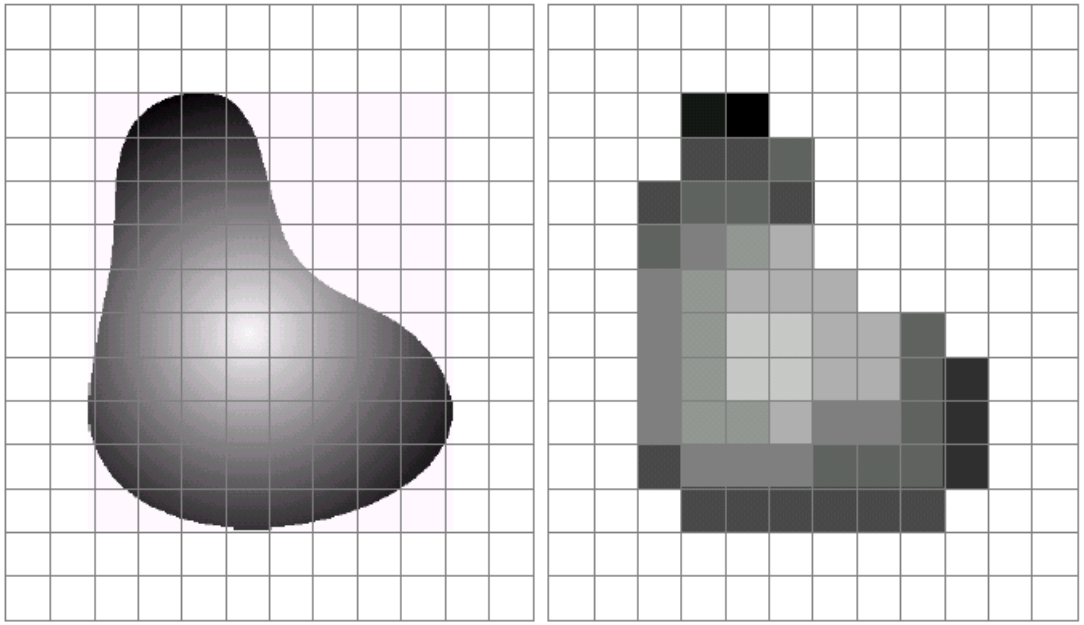
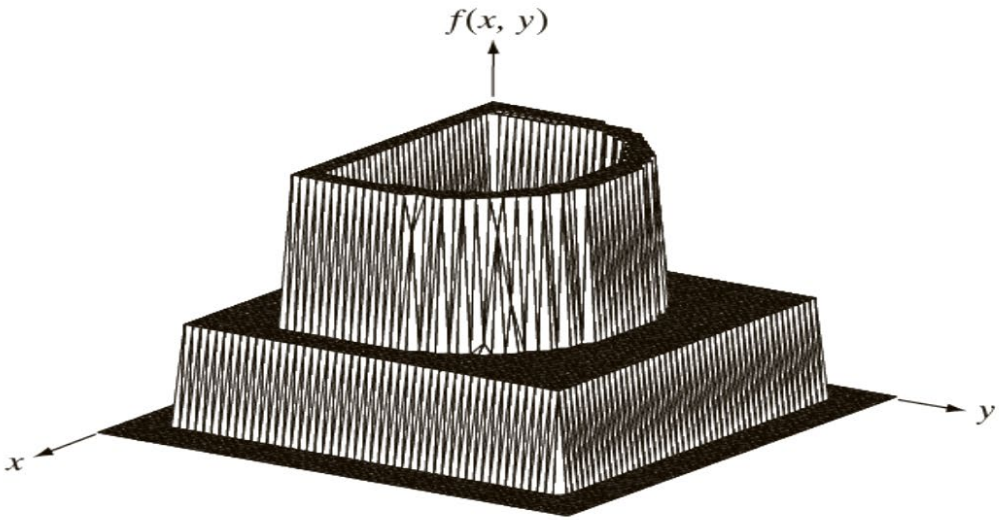


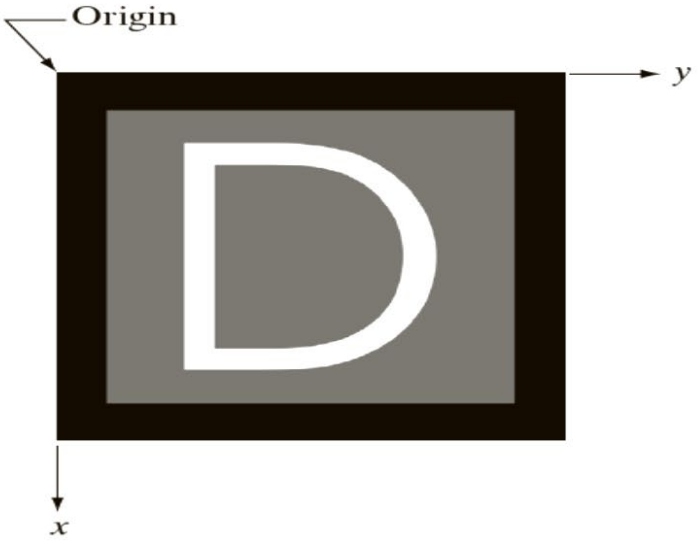
Image Sampling & Quantization

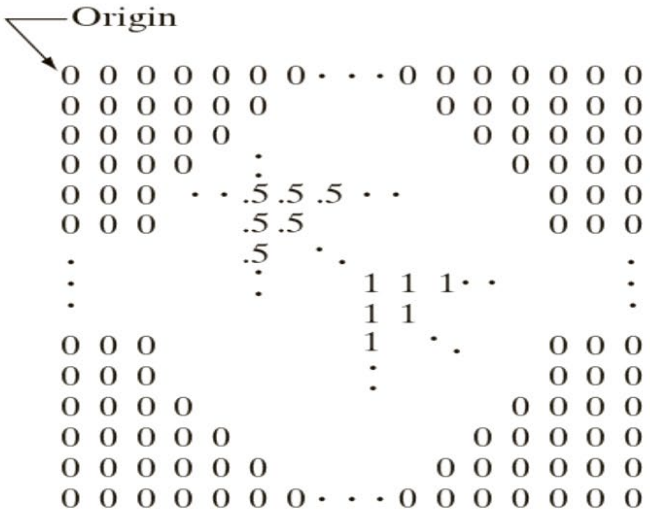
- Sampling – 空間位置的數位化
- Quantization –灰階值的數位化



Digital Image Representation



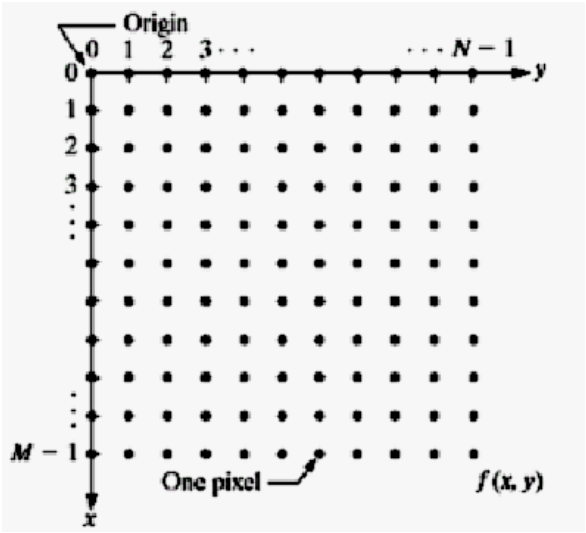




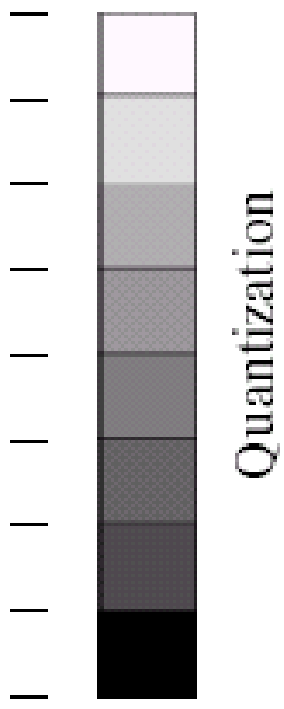
Digital Image Representation

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

- Column vs. Row
- Vector vs. Matrix



Digital Image Representation

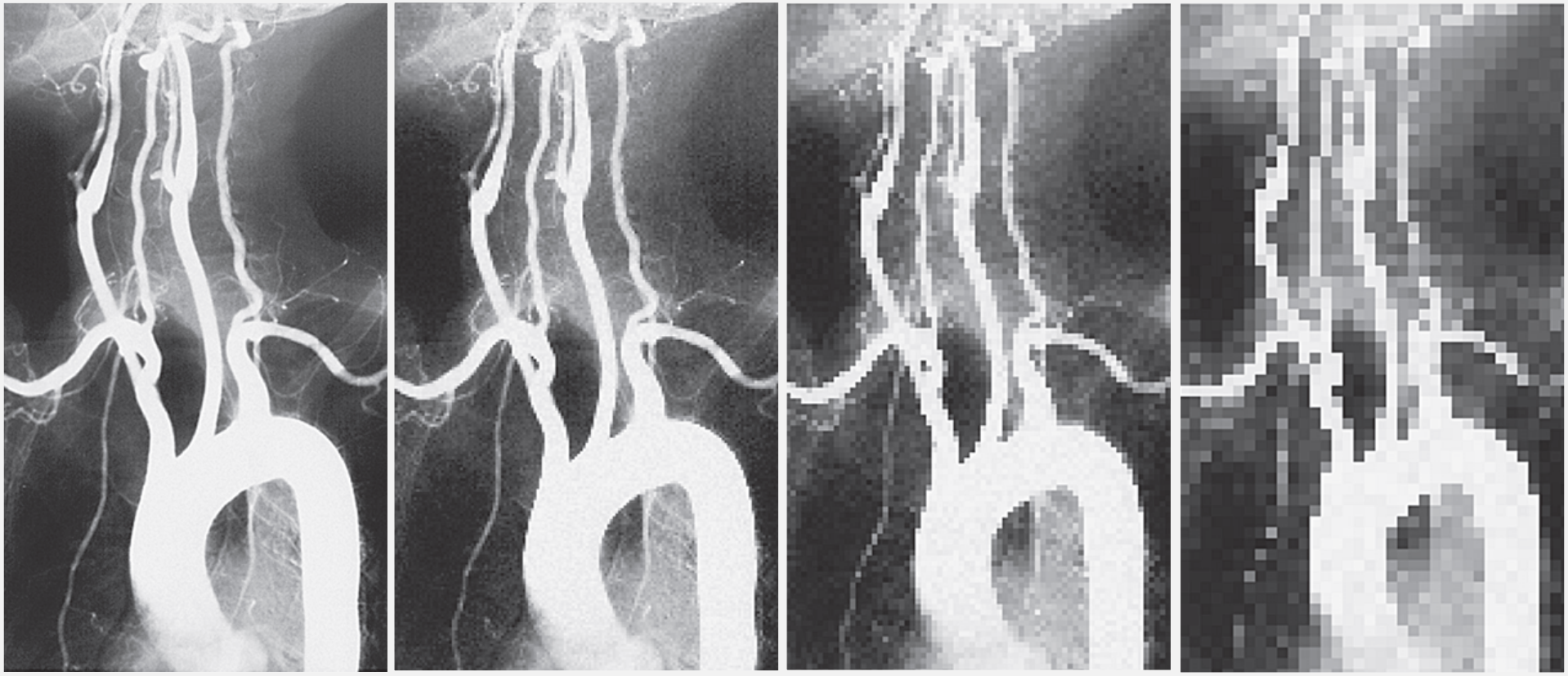


- $L = 2^k$
  Gray level → [0, L-1]

- Bits required to store a image:
  $b = M \times N \times K$
- 256 gray level → 8-bit image
- 1920 × 1080, 8-bit image
  → 16,588,800 bits (~2 MB)

Spatial resolution

- Sampling is the principal factor determining the spatial resolution of an image.



Original pixel size 2x 4x 8x

Gray-level Resolution

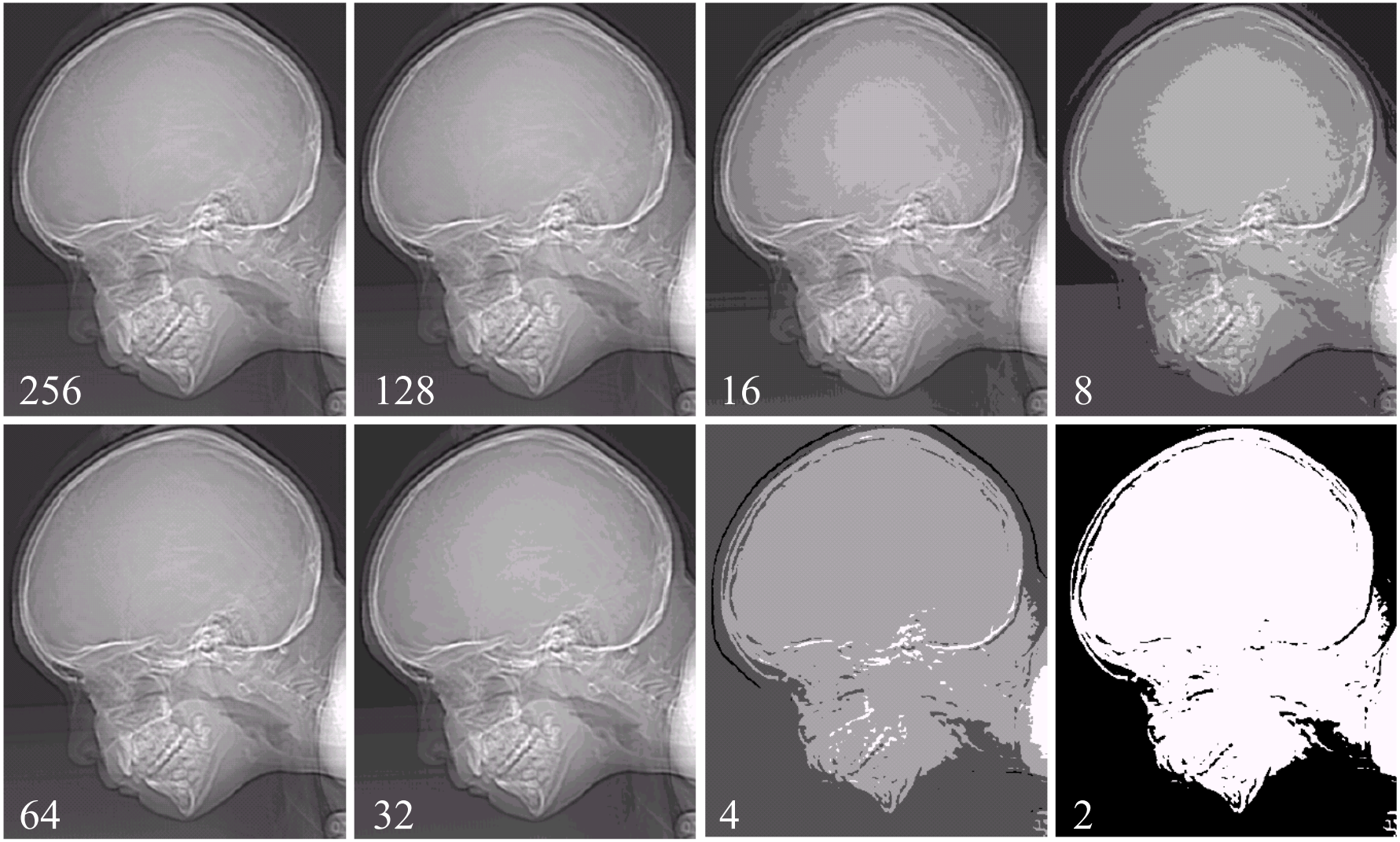
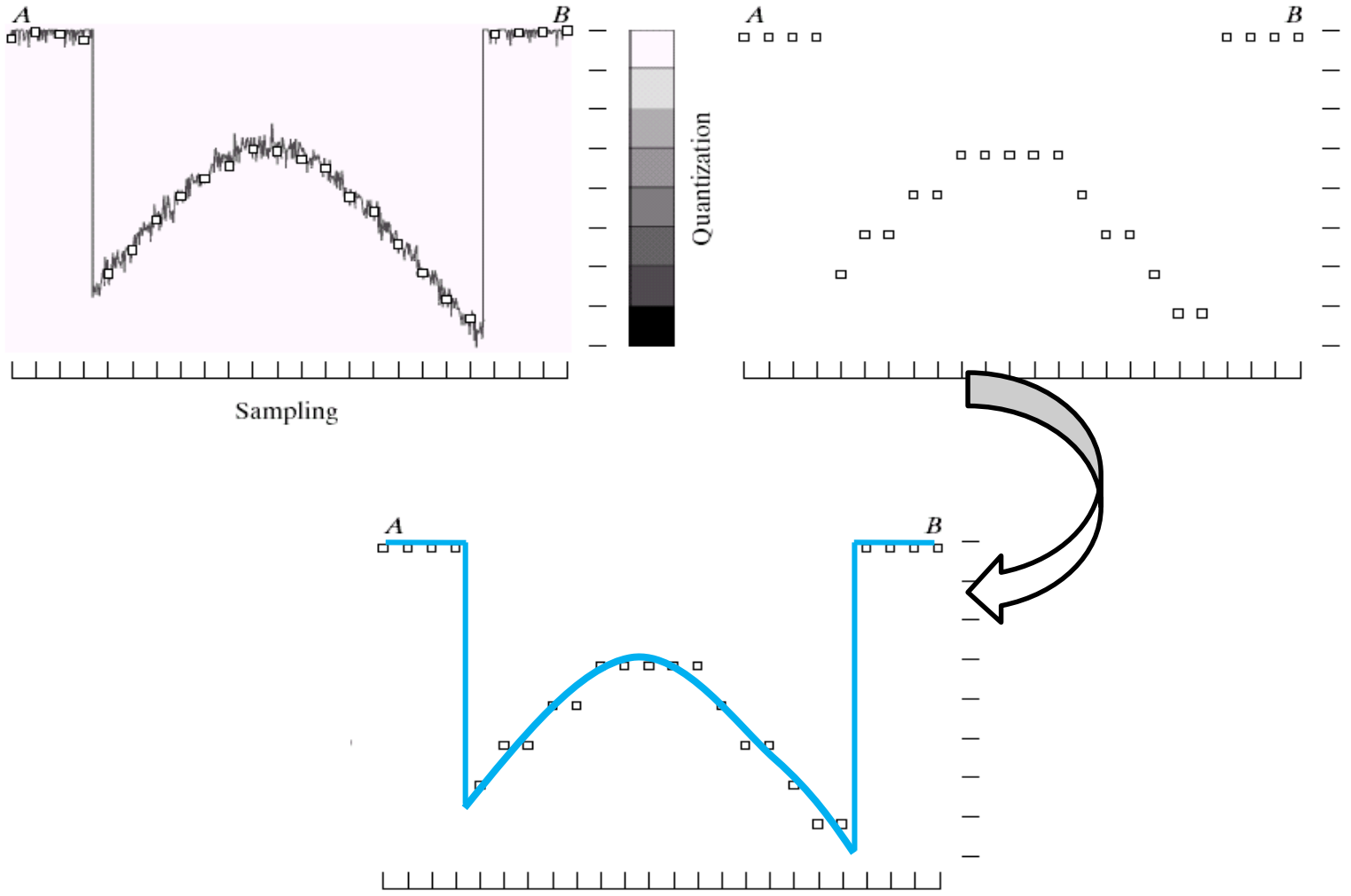


Image sampling & recovering

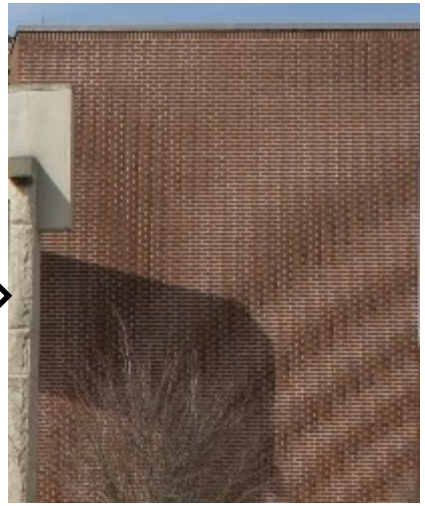
- Nyquist-Shannon sampling theorem
  If the band-limited function is sampled at a rate equal to or greater than twice its highest frequency, it is possible to recover completely the original function
- Perfect recovering is possible!
- Under-sampling → image aliasing

Image sampling & recovering



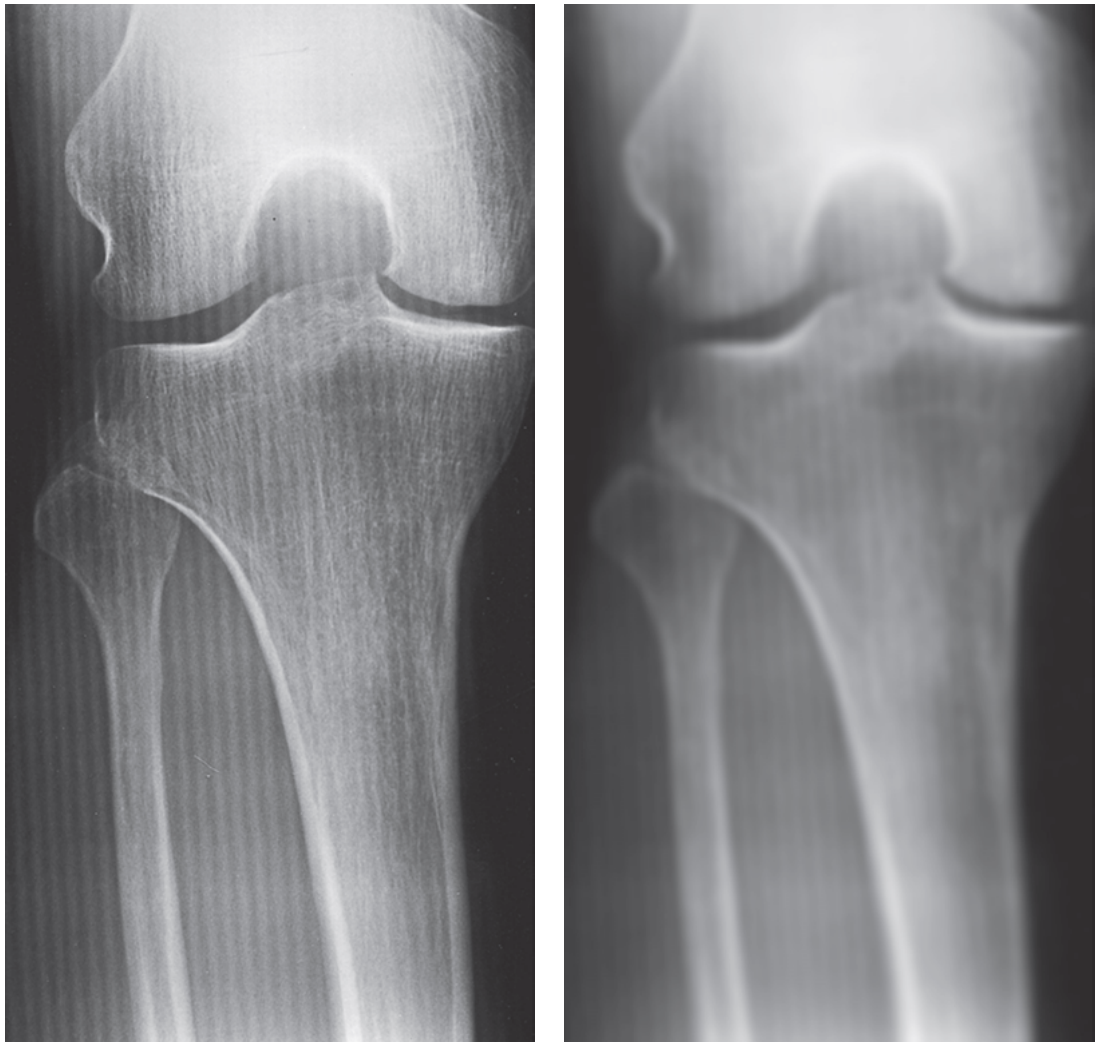
Aliasing in image

Down-sampling



Moiré pattern

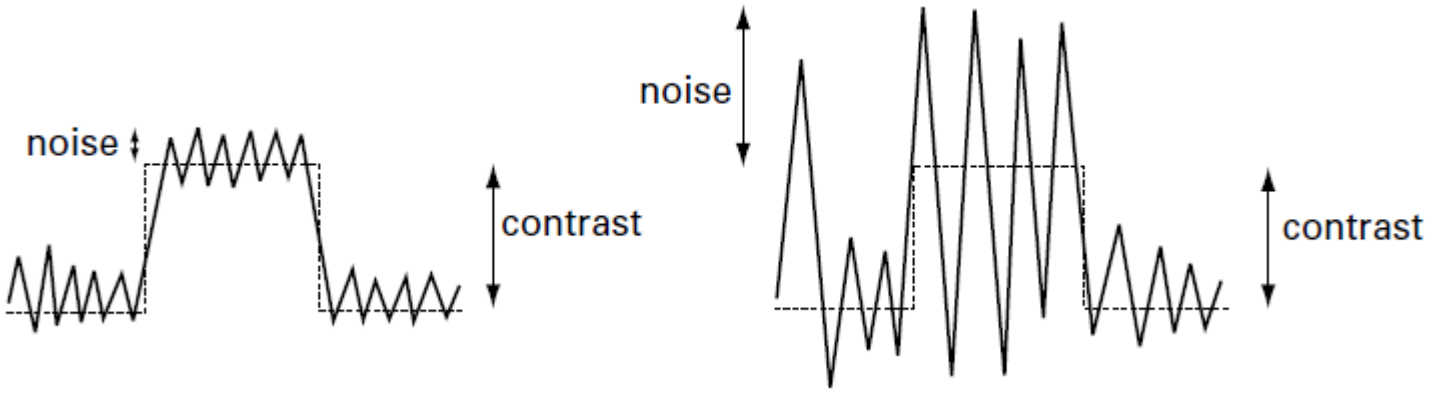
Effect of insufficient sampling



A Moiré pattern in a radiography image (left) and the result of smoothing it (right)

Quality of a digital image

- Spatial resolution: depends on image modality
- Brightness resolution: 8 bits or more
- Noise content: in comparison with contrast



Formation of medical imaging

- According to different modalities, the intensity of a medical imaging can represent…
  - Absorption, Attenuation (X-ray, CT, ultrasound)
  - Reflection (ultrasound)
  - Density of molecules/nuclei (NM, fluoroscopy, MRI)

- It is important to understand the physics first!

Conventional storage of medical images

- Manual storage, retrieve, and transportation
  - Labor-intensive
- Difficulty in reproduction and storage
  - One time at a place
  - Space
  - Temperature/Humidity

Digital system of medical images

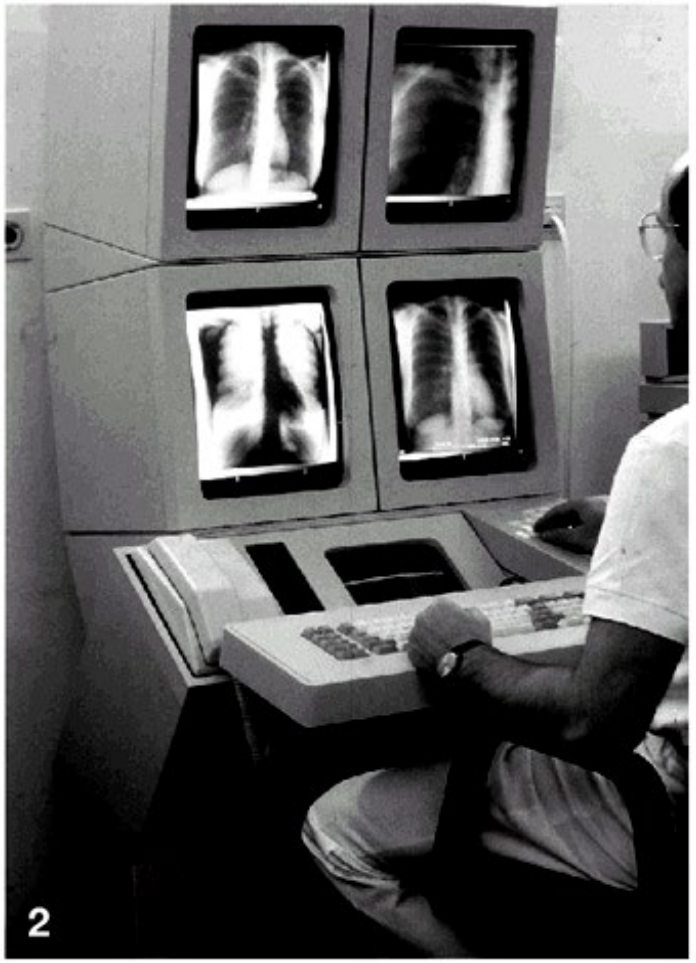
- Originate in 1980s
  - First filmless hospital:

    early 1990s

MAR-view (Philips, Hamburg, Germany)

1986 in Münster.

Now at German Roentgen Museum.



PACS

- Picture Archive & Communication System
  - 影像檔案管理與傳輸系統
- Introduced in the mid 1980s
- Mature in the late 1990s
- Benefiting in storage, retrieval, distribution and presentation
- Easy image processing

DICOM

- Digital Imaging COmmunications in Medicine
  - 數位影像通訊
- The most common image format in PACS
- Supporting all image formats from different vendors and different modalities
- Use TCP/IP to communicate between systems

不過就是數位化？

- 大量的儲存設備
- 高速網路傳輸
- 資料庫管理
- 人員訓練

- $$$$$!!

Review

- What is digital image?
- Human visual perception
- Basic ideas of DIP
  - Image acquisition
  - Spatial resolution
  - Gray scale
  - Sampling and aliasing
- Medical images in digital format

生醫影像研究方法：

數位影像原理