Lecture 1 - Introduction

Digital Image Processing

群名称：CS270数字图像处理课程群2
群　号：832400640

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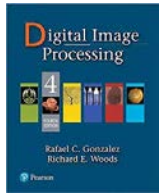
- **Textbook**

数字图像处理 第三版 (英文版)
作者:Rafael C. Gonzalez（拉斐尔 C. 冈萨雷斯）, Richard E. Woods（理查德 E. 伍兹）著,
出版社: 电子工业出版社

- **Reference book**



Digital Image Processing, 4th edition,
Rafael C. Gonzalez & Richard E. Woods
Pearson., 2017,

数字图像处理（MATLAB版）（第二版）
作者:（美）Rafael C. Gonzalez（拉斐尔 C. 冈萨雷斯）
出版社: 电子工业出版社

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Class Schedule

Week	Date	Topic	Reading
1	9月11日	Image fundamentals -Introduction, Image acquisition	CH1, CH2.1-2.3
	9月13日	Holiday	
2	9月18日	Image fundamentals - Sampling and Quantization, Pixels	CH2.4-2.5
	9月20日	Image fundamentals - Operation, Image registration and reconstruction	CH 2.6, CH 5
3	9月25日	Image fundamentals - Color space	CH2, CH6.1-6.2
	9月27日	Image enhancement - Spatial domain, Intensity transformation	CH3.1-3.2
	9月29日	Image enhancement - Histogram	Ch3.3-3.4, CH6.5
4	10月2&4日	Holiday	
5	10月9日	**Quiz 1: Image fundamentals**	
	10月11日	**Project Presentation 1: Image fundamentals**	
6	10月16日	Image enhancement - Spatial filtering	Ch3.5-3.6, CH6.6
	10月18日	Image enhancement - Image transform & Frequency domain	CH4,CH7,CH8
7	10月23日	Image enhancement - Frequency domain filtering	CH4.8-4.9
	10月25日	Multiresolution processing, Image compression	CH6, CH7
8	10月30日	Image Restoration - degradation function	CH5
	11月1日	Image Restoration - noise filtering	CH5
9	11月6日	**Quiz 2: Image enhancement and compression**	
	11月8日	**project Presentation 2: Image enhancement**	
10	11月13日	Image Restoration - spatial filtering	CH5
	11月15日	Image Restoration - frequency domain filtering	CH9.1-9.4
11	11月20日	Image segmentation - Morphological operation and algorithms	CH9
	11月22日	Image segmentation - edge detection	CH10.2
12	11月27日	**Quiz 3: Image restoration**	
	11月29日	**Project Presentation: Image restoration**	
13	12月4日	Image segmentation - thresholding and region detection	CH10.3-10.4
	12月6日	Image segmentation - morphological watersheds	CH10.5
14	12月11日	Image segmentation - Active contours	
	12月13日	Feature extraction - Represetation and Description	CH11
15	12月18日	Image pattern classification	CH12
	12月20日	Review	
16	12月25日	**Quiz 4: Image segmentation, feature extraction, pattern classification**	
	12月27日	**Project Presentation 4: Image segmentation**	

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Assessment

- **Quiz (50%) :**
  - 闭卷考试共四次，每次45分钟；英文试卷，可中英文作答；
  - 内容：课件中涉及的内容，重点考察上课时详细讲过的知识点；
  - 题型：选择、填空、综合分析题；
  - 可使用计算器，但不得使用电脑等可编程的电子产品。
- **Project (50%)**
  - Presentation: 5-min talk, 5-min Q&A; PPT in English, present in Chinese or English.
  - Project report (English) : 2 A4 pages including Objective, Method, Result and Discussion
  - Score requirement (每次满分100分)
    - ✓ Presentation (30分)：思路清晰，重点明确，结果符合要求，按时完成；
    - ✓ Q&A（20分）：正确回答问题，条理清楚；
    - ✓ Report（40分）：问题阐述明确，内容完整，图像清晰，结果准确，格式正确；
    - ✓ Codes（10分）：助教检查并运行结果；
    - ✓ Submission package：PPT, Report and Codes; 注意Project发布文档中提示的截止时间，无特殊情况逾期，24小时内扣20分，24小时以外扣除50分。未交或少交Package，该project计0分。

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Teaching Assistant

- **For Quiz**
  - 效琦， Email: xiaoqi@shanghaitech.edu.cn
- **For Project**
  - 陈宏博， Email: chenhb@shanghaitech.edu.cn
  - 曾宏业， Email: zenghy@shanghaitech.edu.cn

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Lecture 1 - Introduction

This lecture will cover:

- What is digital image processing?
- Steps of digital image processing
- Methods of digital image processing
- Image acquisition

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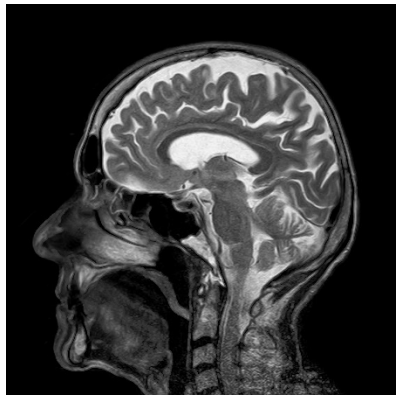
Image

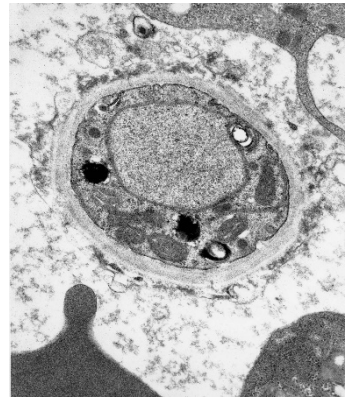
① **A reproduction or imitation of form of a person or thing.**

② **The optical counterpart of an object produced by a lens, mirror, etc.**

.....Noah Webster





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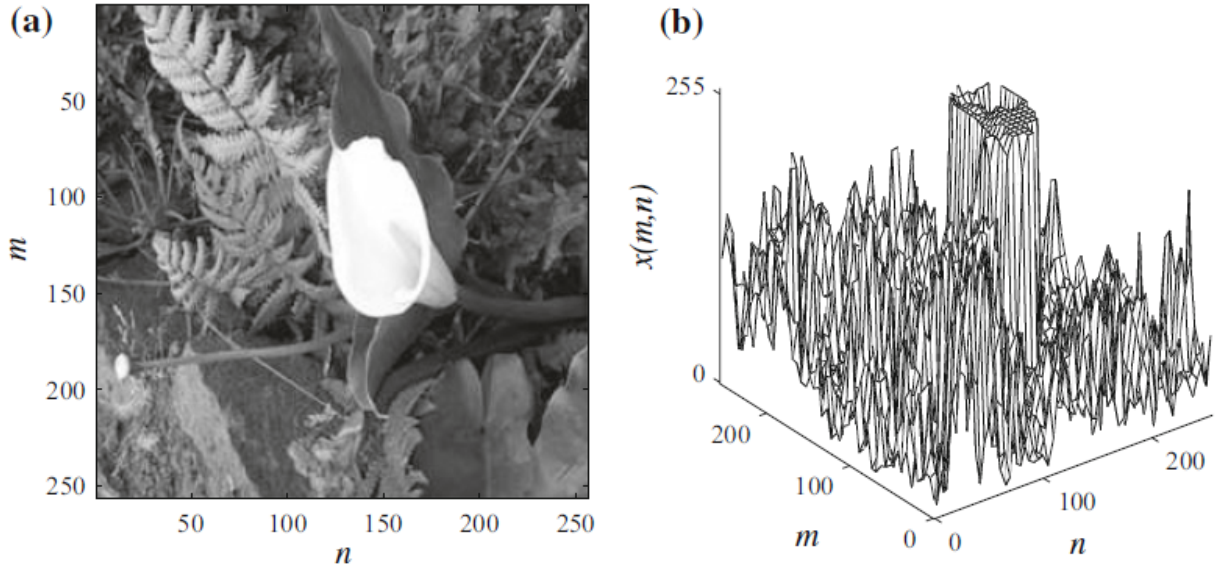
Digital image

- **A visual representation in form of a function *f*(*x*,*y*), where**
  - *f* is related to the intensity or brightness (color) at point
  - (*x*, *y*) are spatial coordinates
  - *x*, *y*, and the amplitude of *f* are finite and discrete quantities



(a) A 256X256 image with 256 gray levels; (b) its amplitude profile

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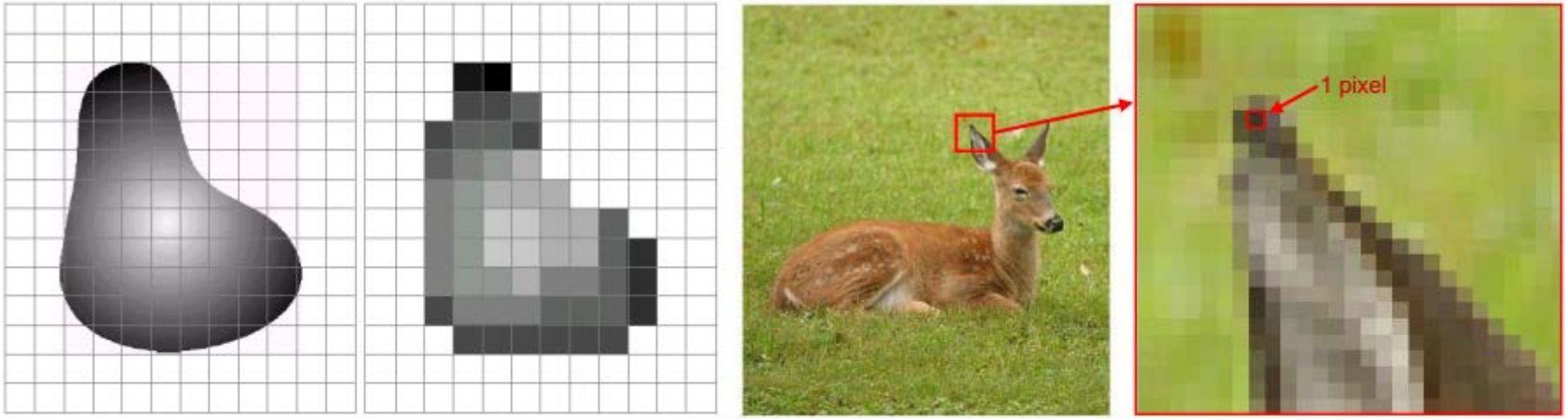
Pixel (像素)

- Composed of a finite number of elements - Pixel （Voxel (体素) in 3D）
- A pixel has a location and intensity information typically represent gray levels, colors, heights, opacities, etc.
- Digitization implies that a digital image is an approximation of a real scene.



The digitized intensity and location value of image Pixel

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Digital image

Images that have more than two coordinate dimensions,

- $f[x, y, z]$ 3-D monochrome image (e.g., optical hologram)
- $f[x, y, t]$ time-varying monochrome image over continuous time domain
- $f[x, y, t_n]$ time-varying monochrome image with discrete time samples (cinema)
- $f[x, y, \lambda]$ spectral image with continuous domain of wavelengths
- $f[x, y, \lambda_n]$ multispectral image, discrete set of wavelengths
- $f[x, y, t_n, \lambda_m]$ discrete samples in time and wavelength, e.g., color movie
- $f[x, y, z, t, \lambda]$ reality

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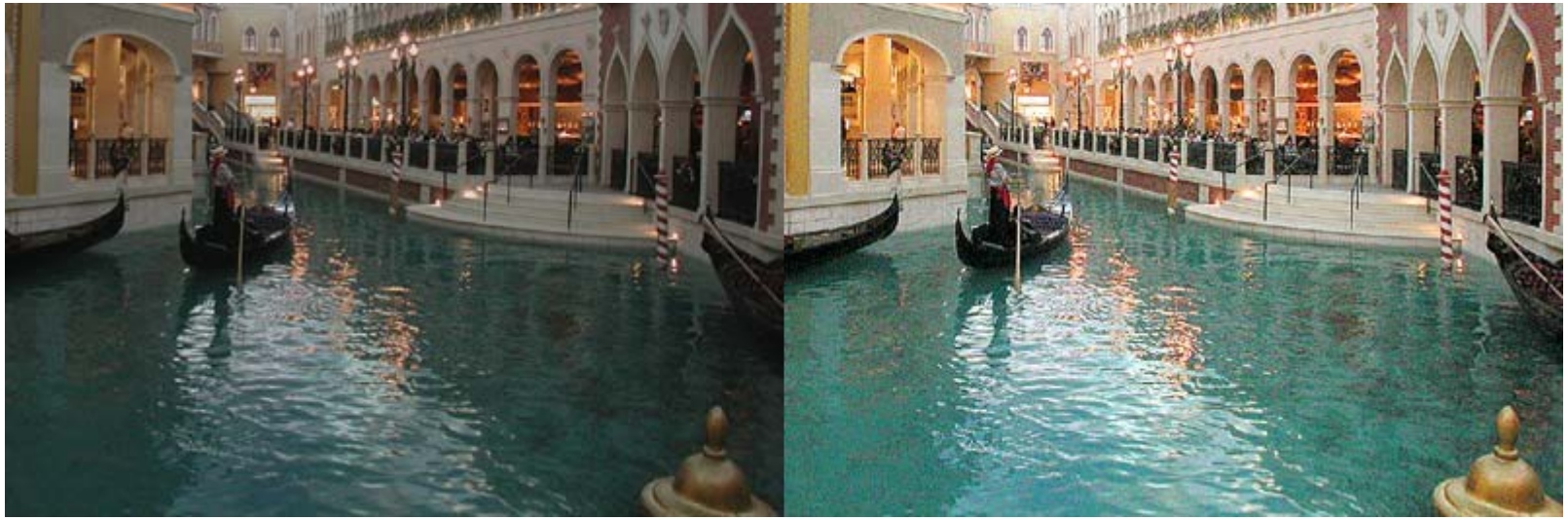
Digital image processing

Definition: Processing digital images by means of a digital computer.

AKA: Computer image processing



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Digital image processing

Digital image processing vs Computer graphics (CG)?

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Goal

Why do we need image processing

- Improvement of pictorial information for human interpretation
- Processing of image data for autonomous machine perception
  - Storage
  - Transmission
  - Representation
  - Description
  - Recognition
  - …… Many more.

Image processing is ubiquitous!

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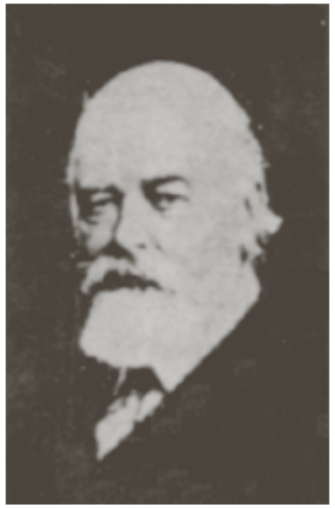
History of image processing

Early stage of digital image

A digital picture produced from a coded tape in 1921



A digital picture from a tape punched after the signal had crossed the Atlantic twice in 1922

Unretouched cable picture transmitted from London to New York by 15-tone equipment in 1929

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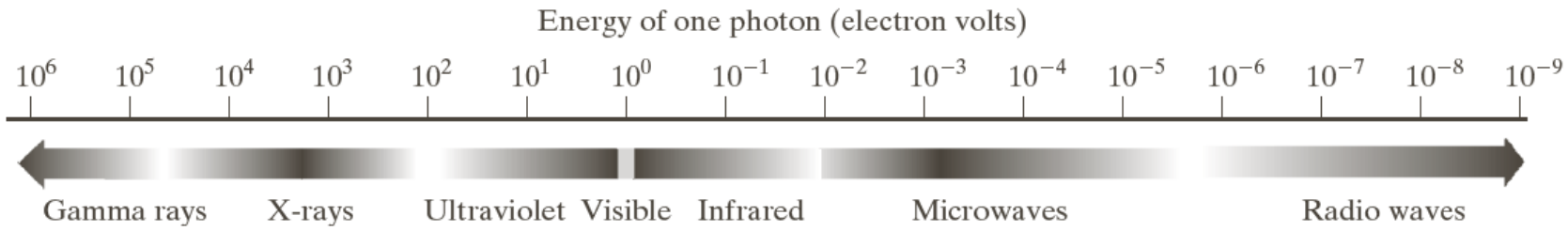
History of image processing

Modern digital image processing

- 1960s - Improvements in computing technology and develop of the space program
- 1970s – Medical application
- Until present, digital image processing techniques has been explored to
  - All kinds of tasks
  - All kinds of areas
  - All kinds of sources



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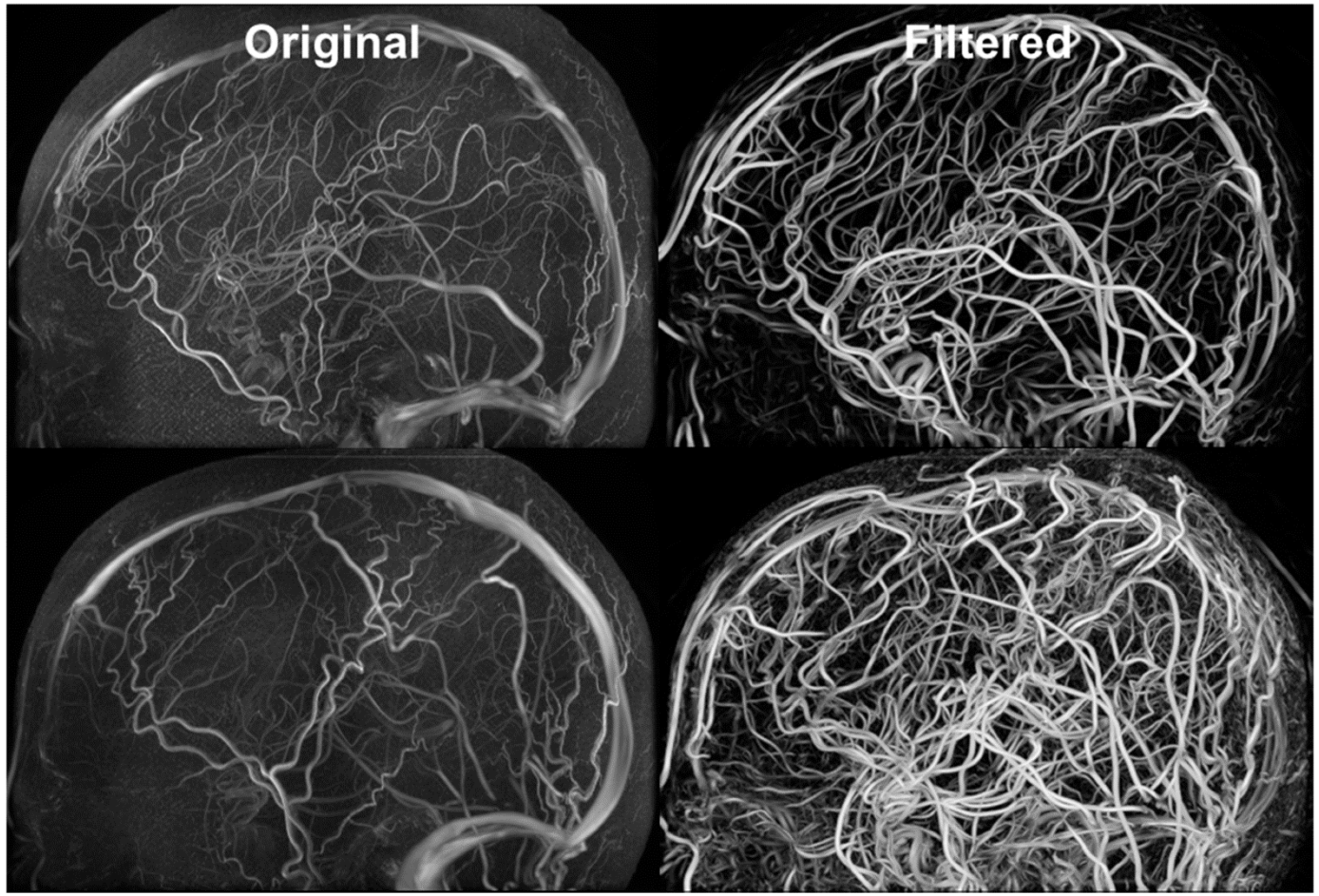
Application - Medicine



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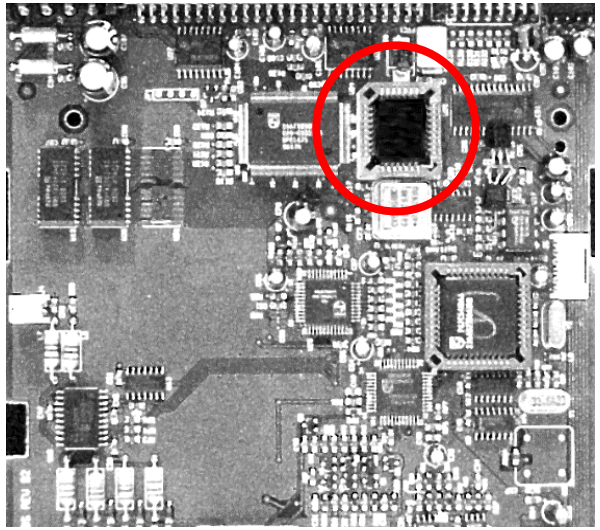
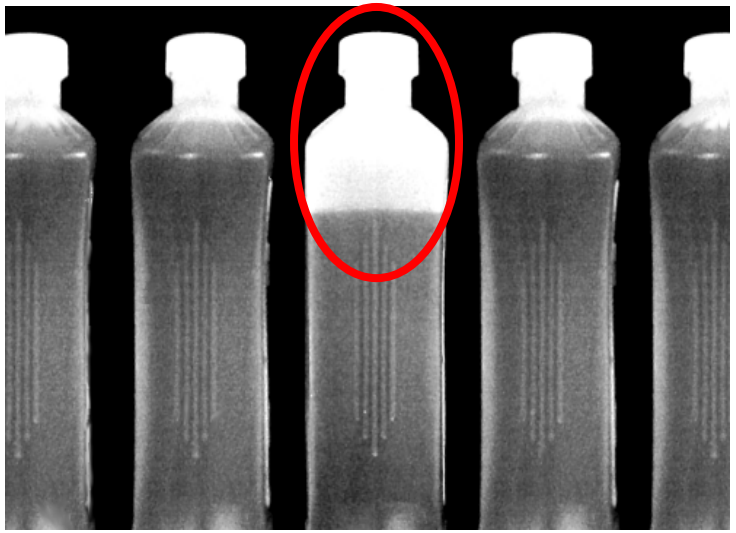
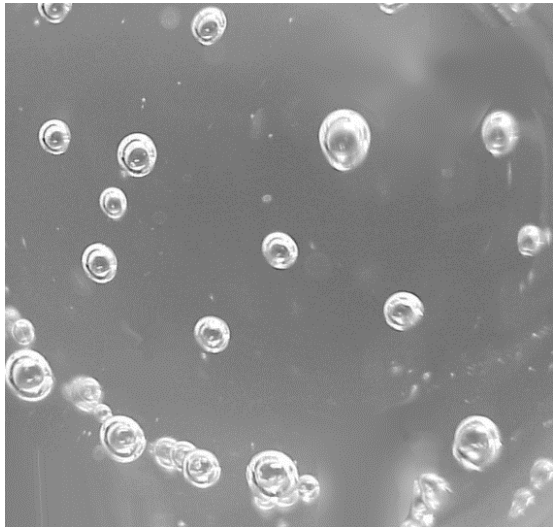
Application - Industry







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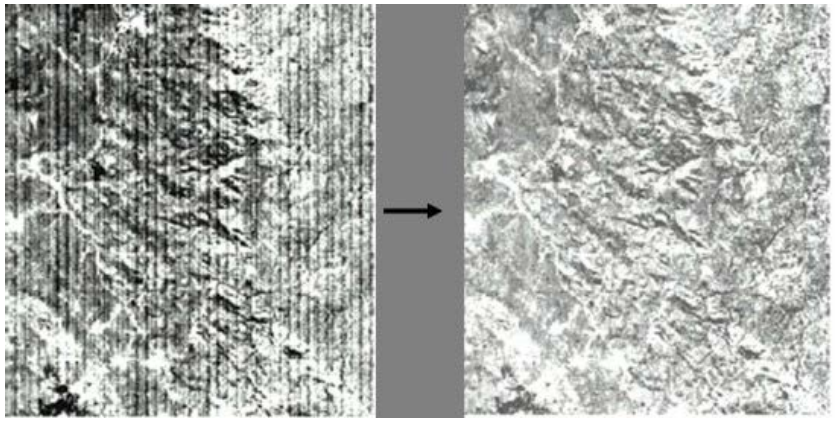
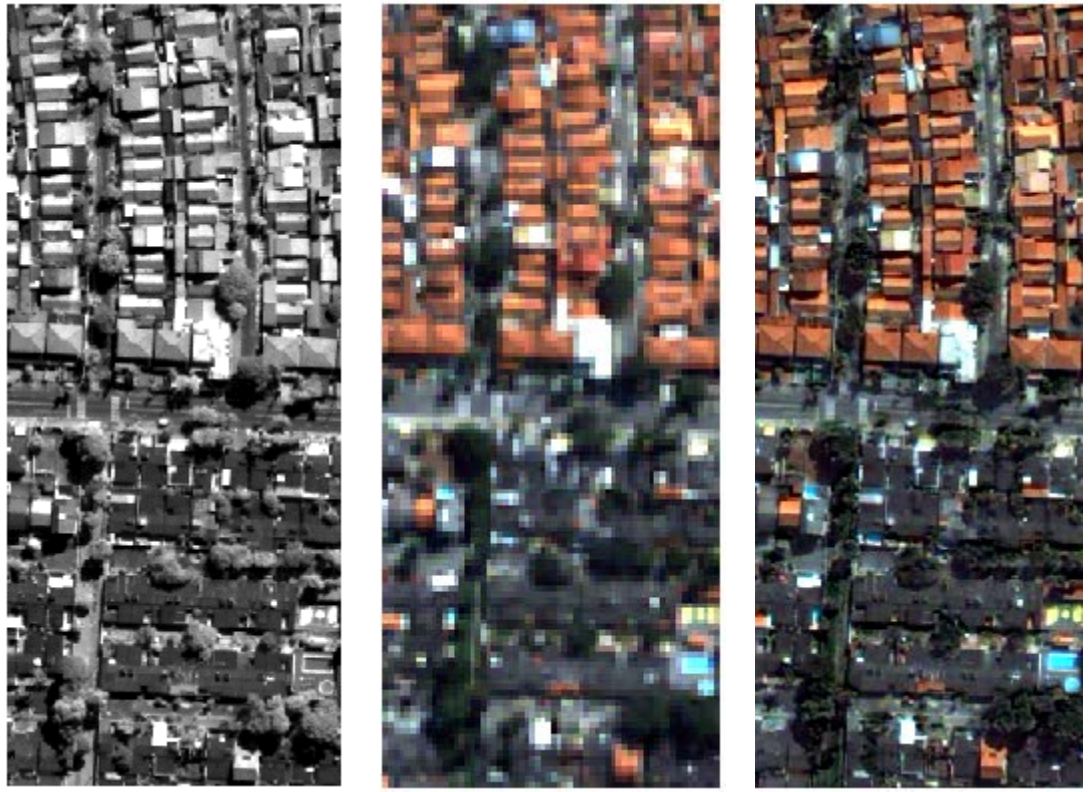
Application – Remote sensing





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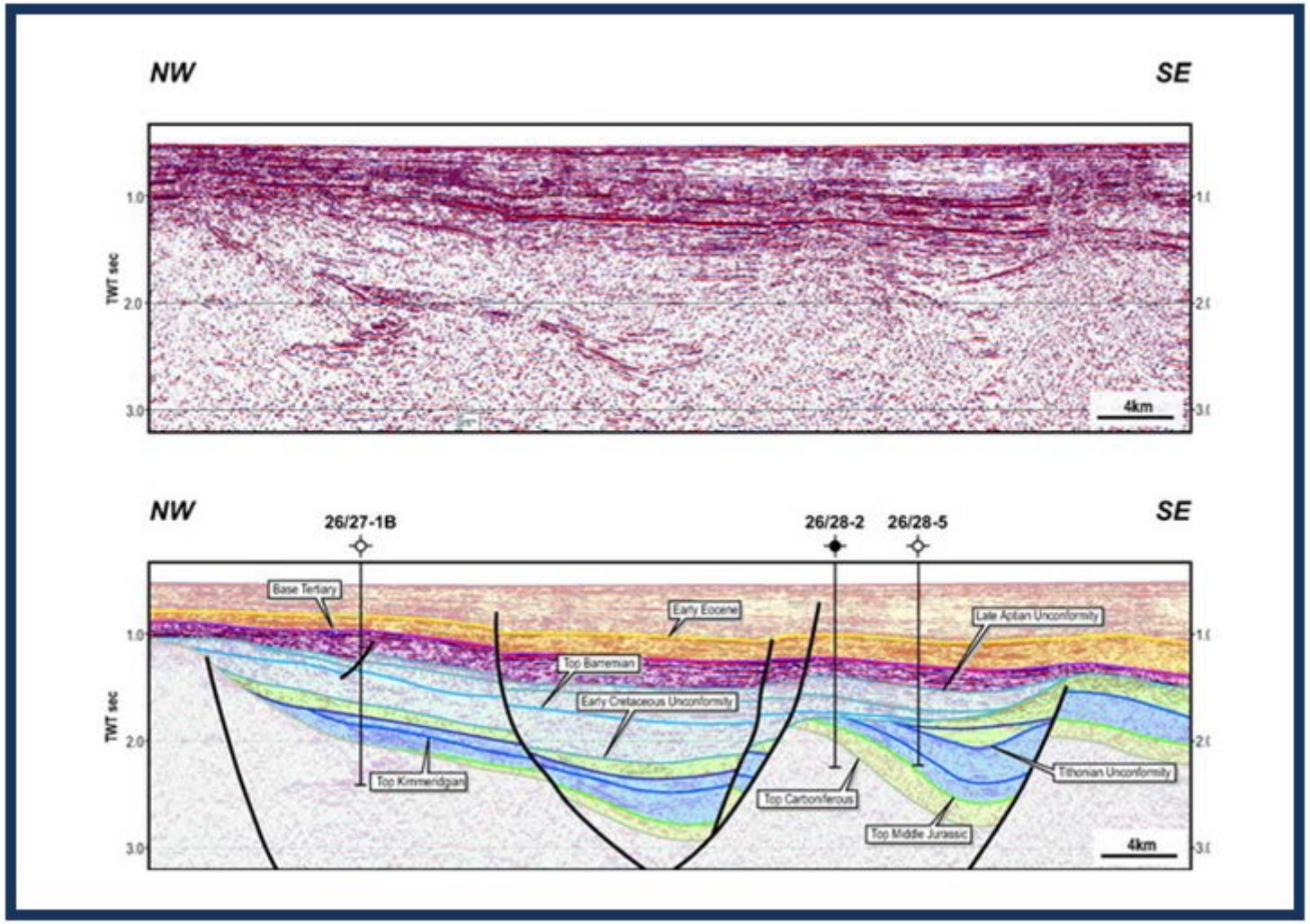
Application – Seismic imaging



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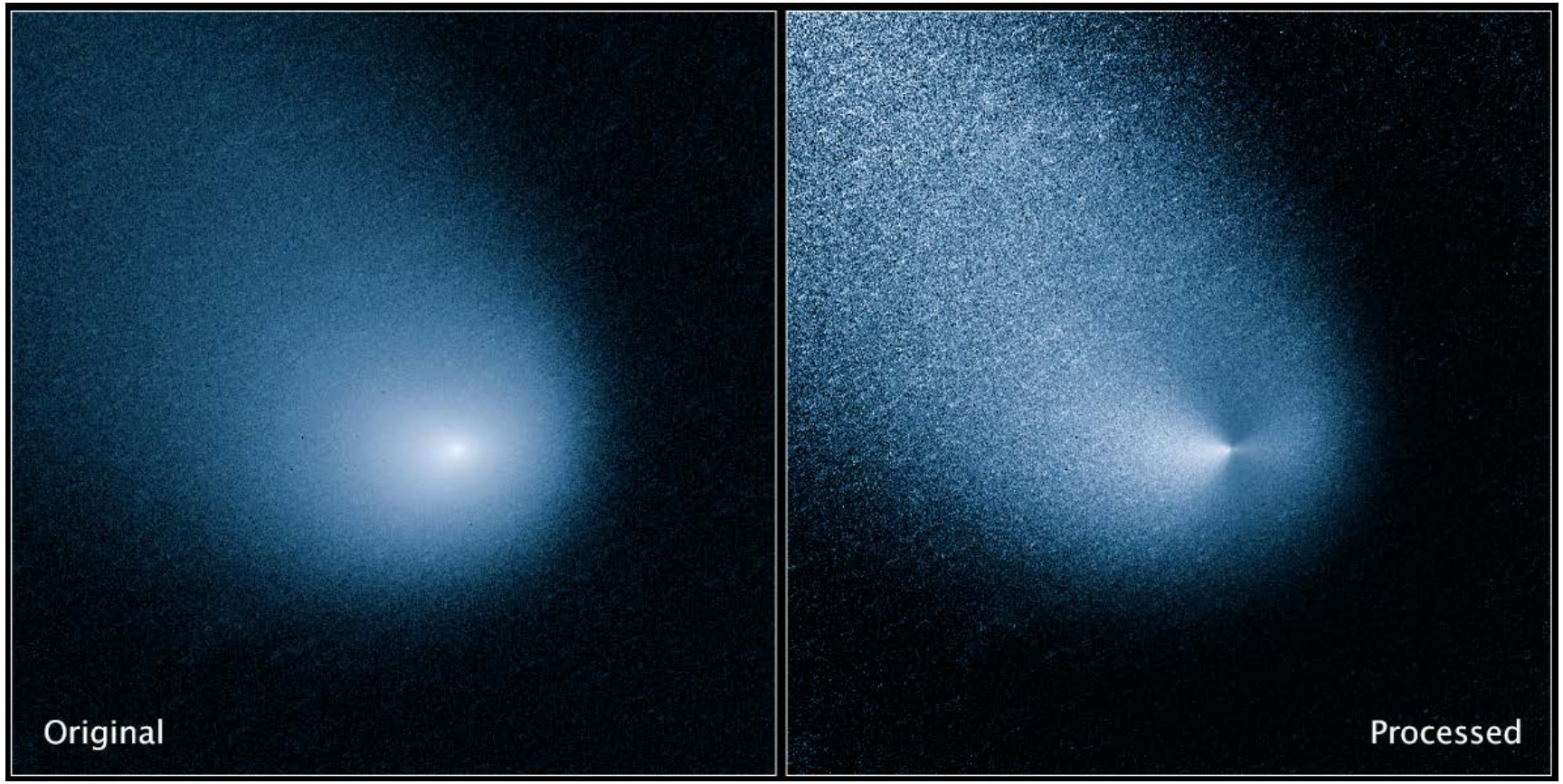
Application – Astronomical image



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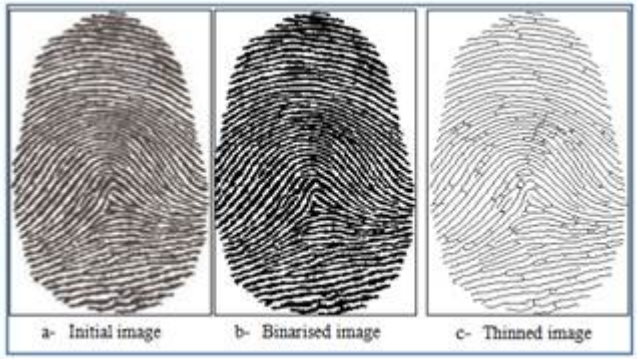
Application – Law enforcement

- Enhancement of CCTV footage
- License plate number recognition
- Face recognition
- Finger print recognition …etc



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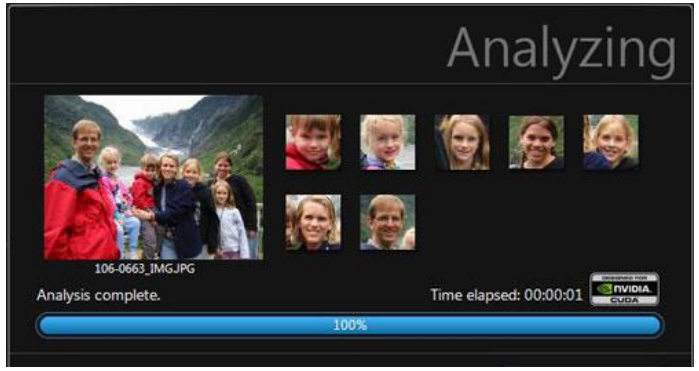
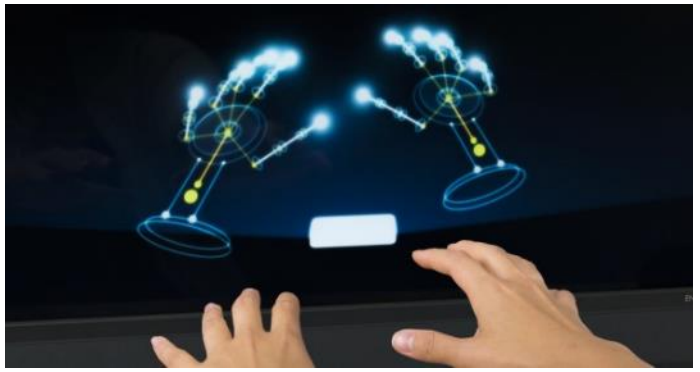
Application – HCI





Human Computer Interface

- Face recognition
- Gesture recognition
- Optical character recognition (OCR)
- Autonomous vehicles

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Stage of DIP

This Course

Low level process	Mid level process	High level process
INPUT: Image **OUTPUT:** Image **EXAMPLE:** Denoise Contrast enhancement Image sharpening	**INPUT:** Image **OUTPUT:** Attributes **EXAMPLE:** Segmentation Description Recognition	**INPUT:** Attributes **OUTPUT:** Understanding **EXAMPLE:** Image analysis Image understanding

There are no clear-cut boundaries
from image processing to computer vision

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Fundamental Steps in DIP

- Image acquisition (图像获取)
- Image enhancement (图像增强)
- Image restoration (图像还原)
- Image reconstruction (图像重建)
- Image compression (图像压缩)
- Image segmentation (图像分割)
- Image representation and description (图像的表示与描述)
- Object recognition (目标识别)

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Lecture 1 - Introduction

This lecture will cover:

- What is digital image processing?
- Steps of digital image processing
- Methods of digital image processing
- **Image acquisition**

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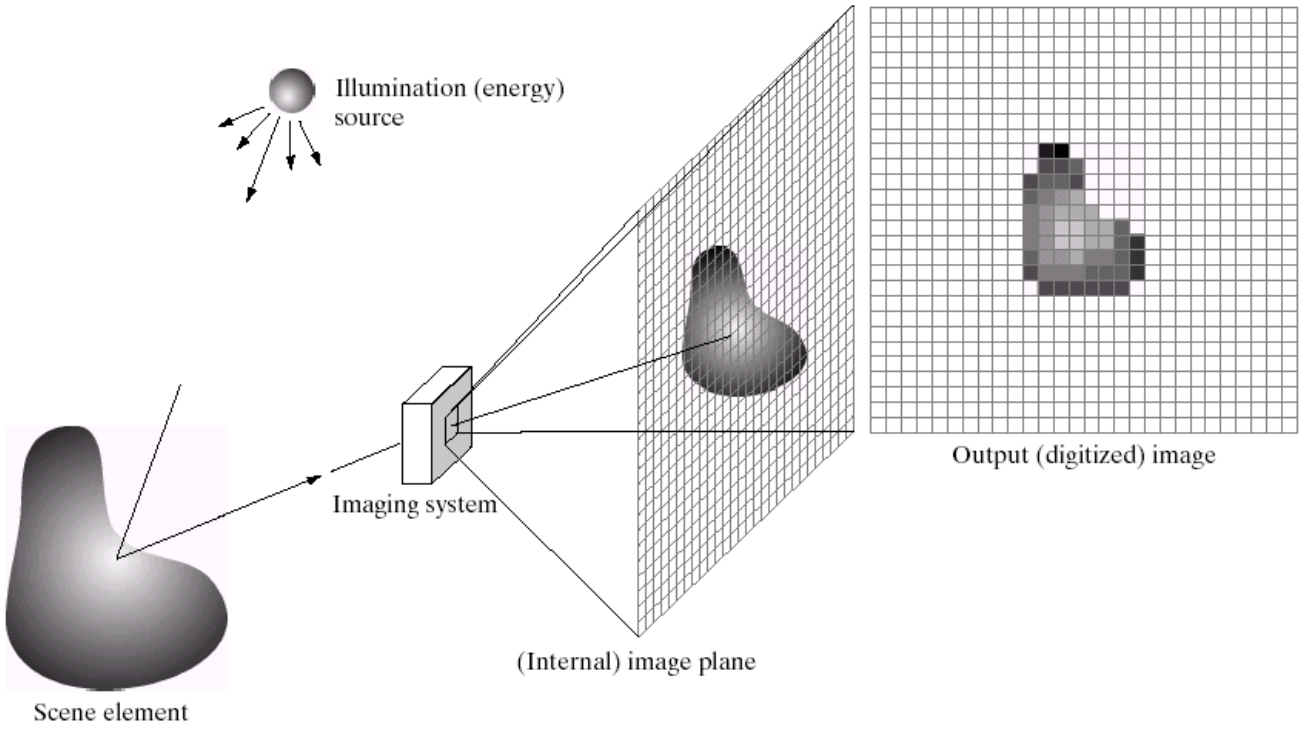
Image Acquisition System



$$f(x,y) = i(x,y)r(x,y) \qquad 0 < i(x,y) < \infty, 0 \le r(x,y) < 1$$

$$L_{min} < f(x_0,y_0) < L_{max} \qquad \text{where } L_{min} \text{ is positive}, L_{max} \text{ is finite}$$

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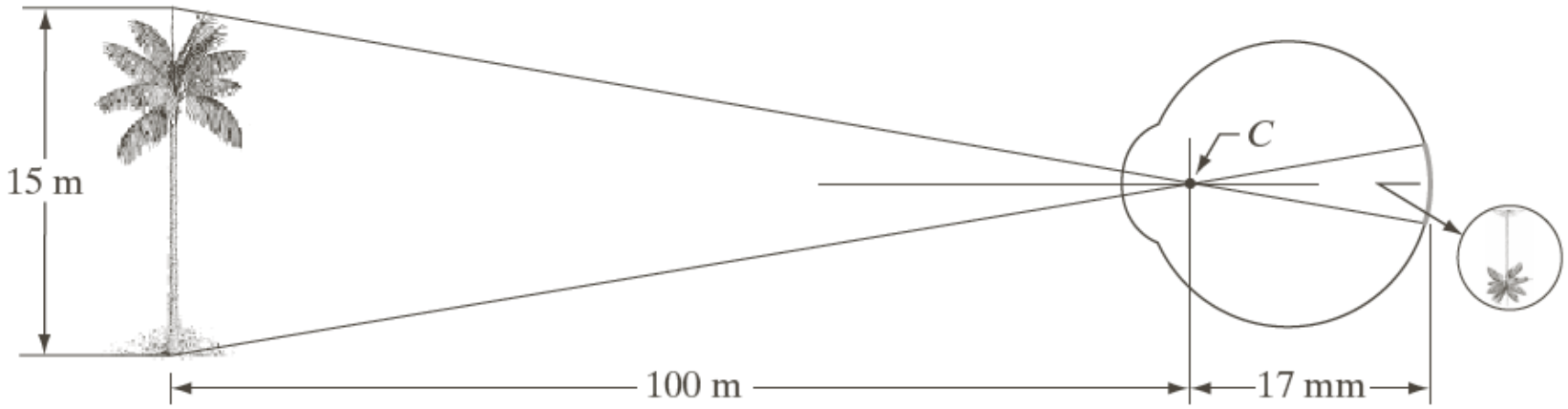
Graphical representation of human eye

- Objects captured as focused images on the image plane at retinas
- Perspective projection based on pinhole model geometry,
- Image size depends on distance of object
- In practice, optical devices with lens



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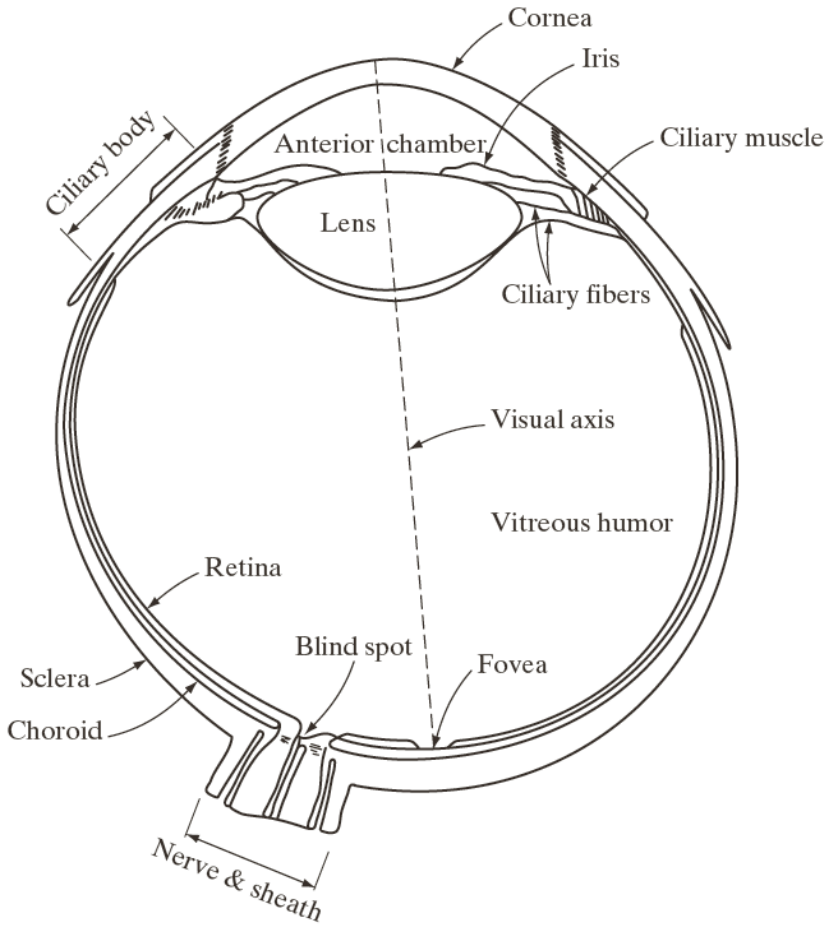
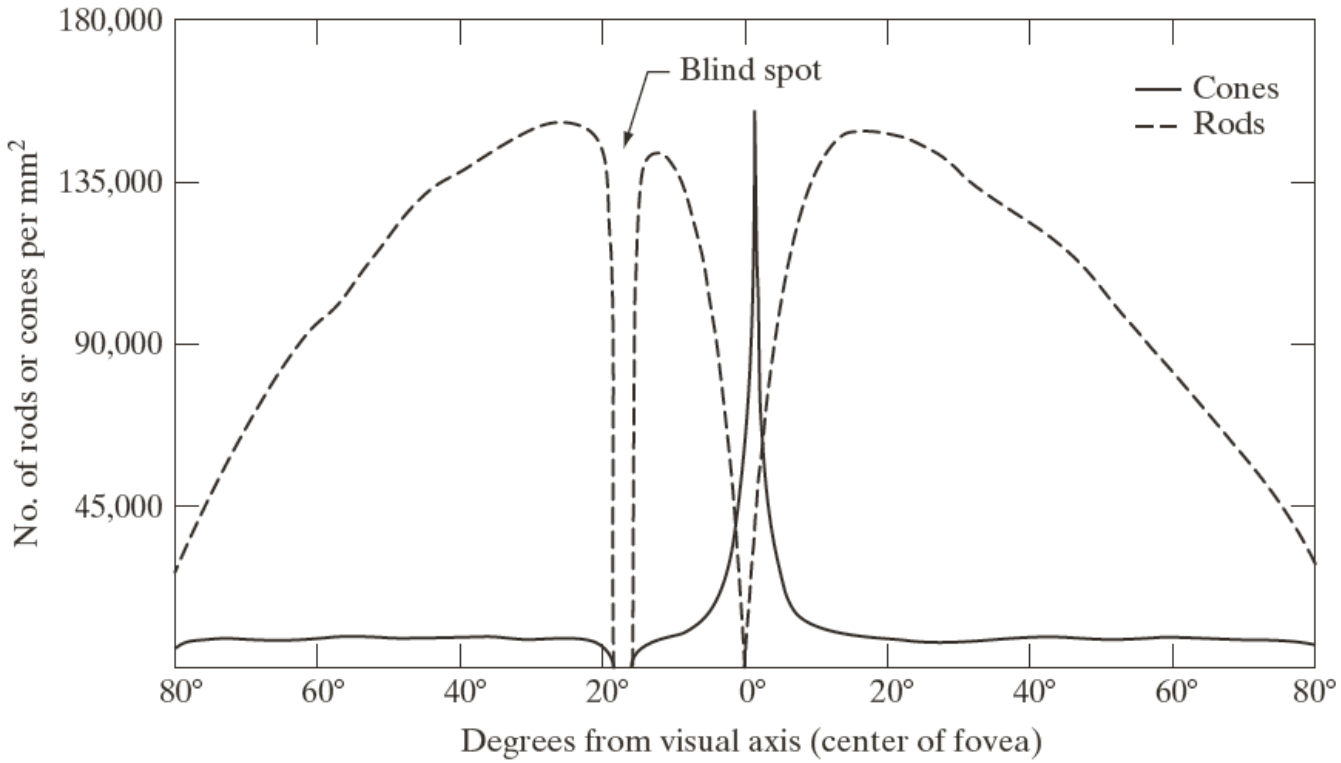
Human Visual Perception





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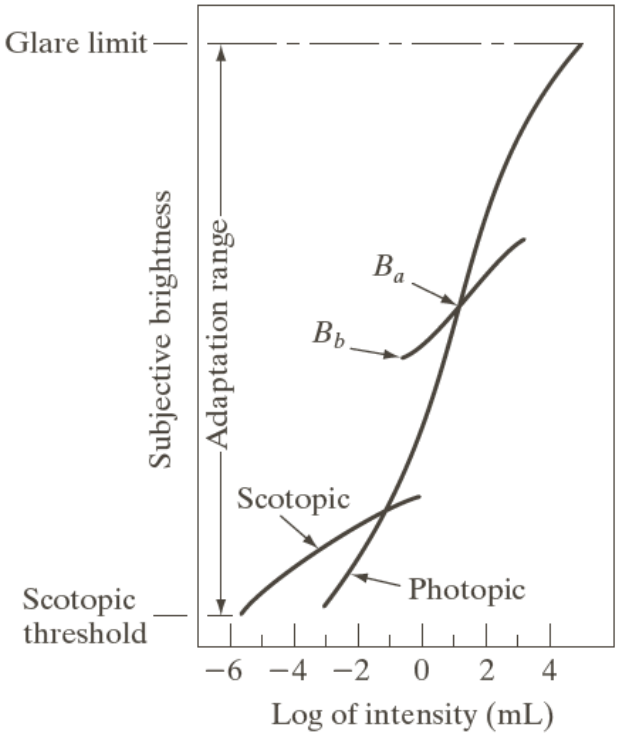
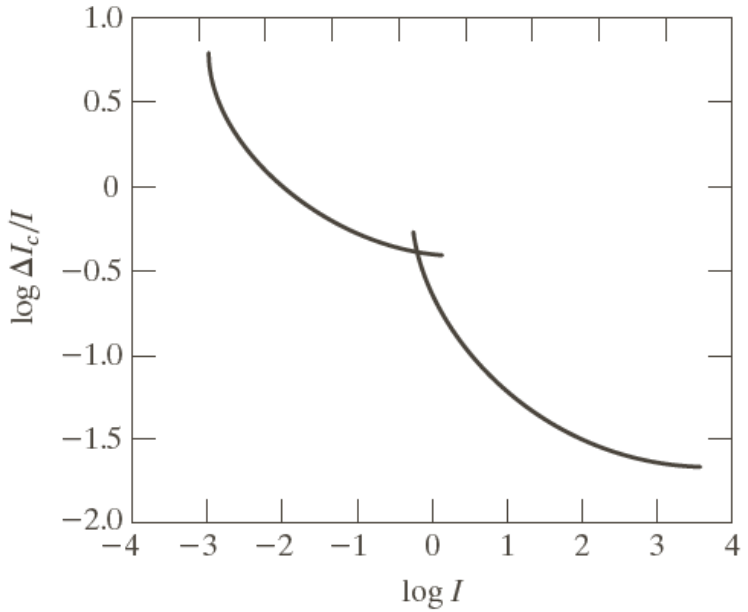
Characteristics of Human Visual System

- **Brightness adaption (视觉适应性)**
- Simultaneous contrast (同时对比效应)
- Mach band effect (马赫带效应)
- Optical illusion (视觉错觉)



Range of subjective brightness sensations showing a particular adaption level



Typical Weber ratio as a function of intensity

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Characteristics of Human Visual System

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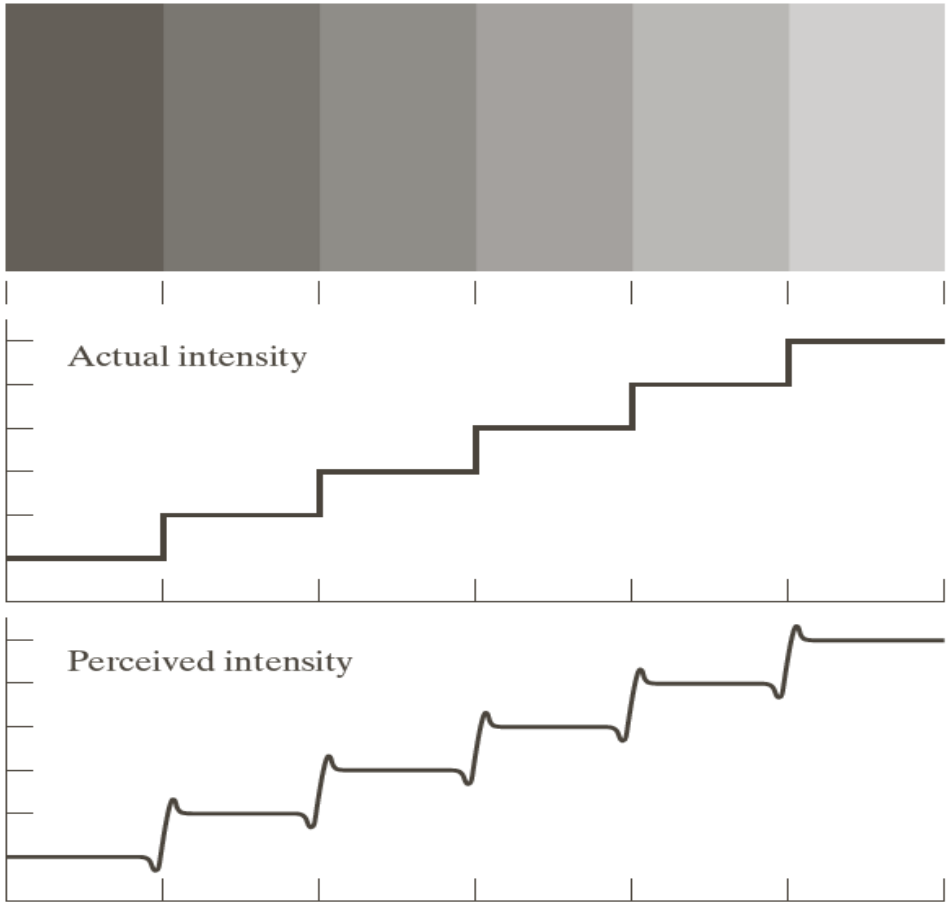

Perceived intensity is not a simple function of actual intensity

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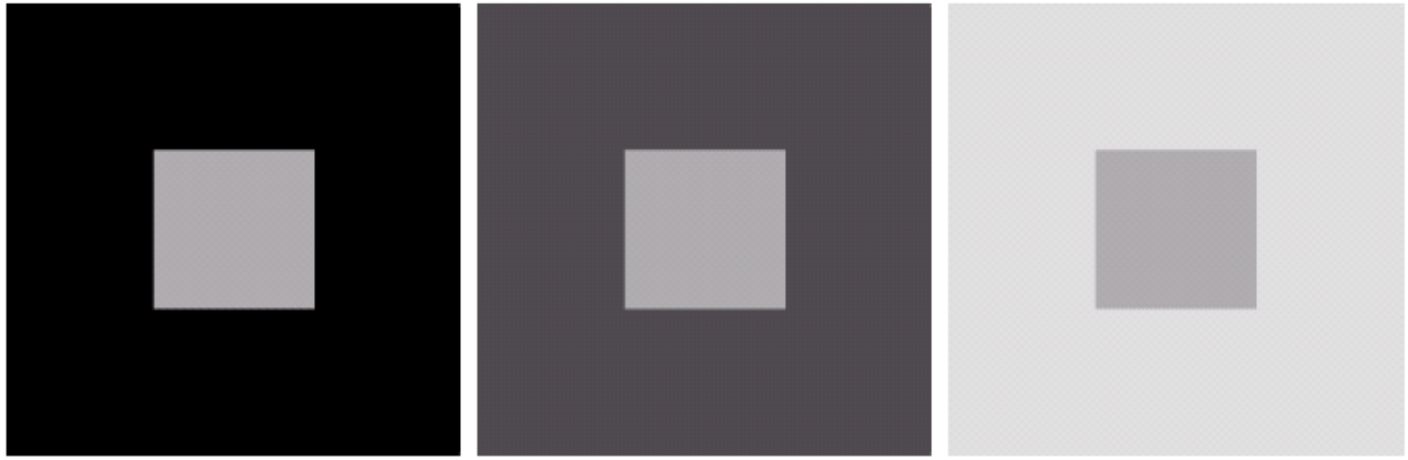

All the inner squares have the same intensity,
but they appear progressively darker as the background becomes lighter

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Characteristics of Human Visual System

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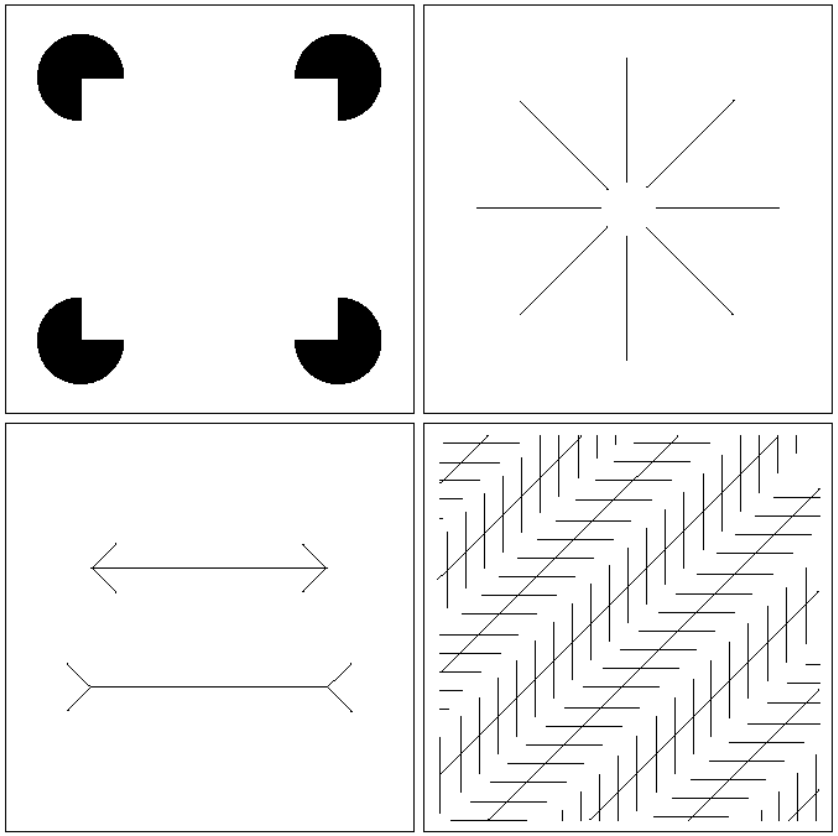

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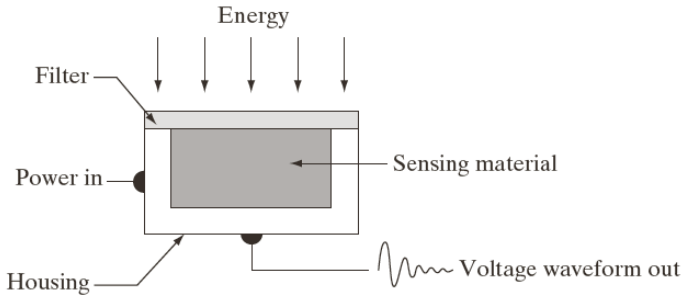
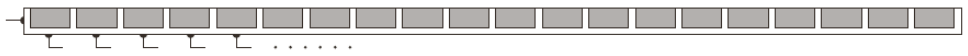
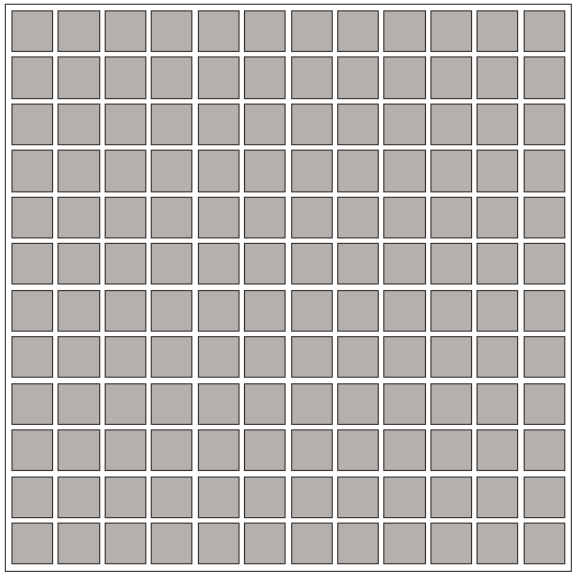
Imaging Sensors (传感器)







Transform energy to voltage:

- **Single Sensor**
  - Photodiode (光二极管)
  - Piezoelectric element (压电晶元)
- **Sensor Strips**
  - CAT
  - Airborne imaging
  - Ultrasound array transducer
- **Sensor Array**
  - CCD – digital camera
- **Color Images**

Use a Bayer's mosaic pattern of R/G/B filters to reduce cost, then use demosaicing to construct full resolution color images.

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