EE 5098 – Digital Image Processing

1. Introduction

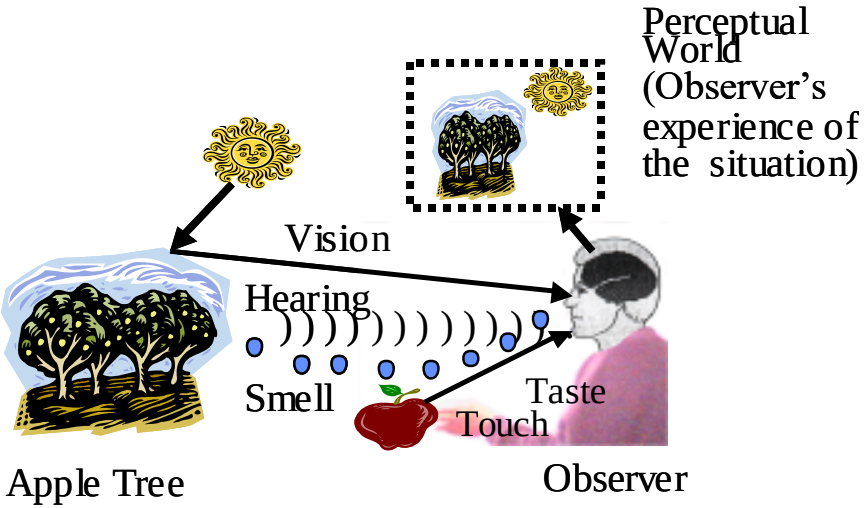
Source: Frank Liu

Instructor

- 陳宏銘 (Homer Chen)
  - Office hours: Monday 2-5 PM by appointment
  - Email: homer@ntu.edu.tw
  - Office: BL-423
  - Course website: https://ceiba.ntu.edu.tw/1101EE5098
- TA: 滕瑋安
  - Email: r09942054@g.ntu.edu.tw

Why Digital Image Processing

- A key enabling technology of today's digital society.
- A fundamental building block of digital photography, digital television, computer games, computer vision, and computer graphics.



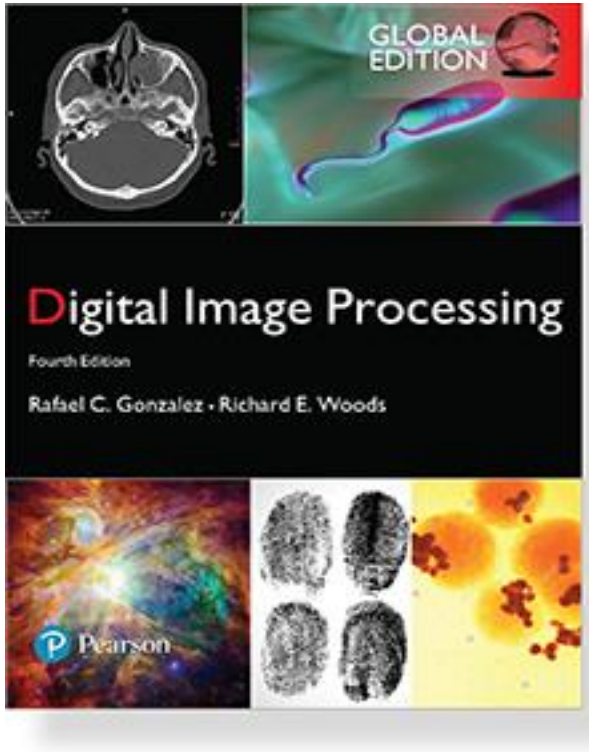
Objective

- Introduce the basic concepts and methodologies of digital image processing, with the following goals:
  - Develop a deep understanding of the field of image processing
  - Get familiar with the fundamental algorithms and their implementations
  - Gain experiences in applying image processing algorithms to real-world problems
  - Able to read the current image processing research literature
- The foundation learned from this course will be useful for further study and research in this field

You will learn

- Topics relate to the use of computer to
  - **Acquire/generate** images—digital representation of a scene or object
  - **Process/manipulate/store** images—noise removal, smoothing, sharpening, contrast enhancement, altering image appearance, compression, etc.
  - **Model/analyze/interpret/recognize** images
  - **Display** images—render the image data on reproduction media (monitors, printing papers)
- This course is much more than just using image processing tools. You will be able to put theory into practice through implementing various image processing tasks using computer programs.

Outline



1. Introduction
2. Digital Image Fundamentals
3. Intensity Transformations and Spatial Filtering
4. Filtering in the Frequency Domain
5. Image Restoration and Reconstruction
6. Color Image Processing
7. Wavelet and Other Image Transforms
8. Image Compression and Watermarking
9. Morphological Image Processing
10. Image Segmentation
11. Feature Extraction
12. Neural Networks and Deep Learning for Image Pattern Classification

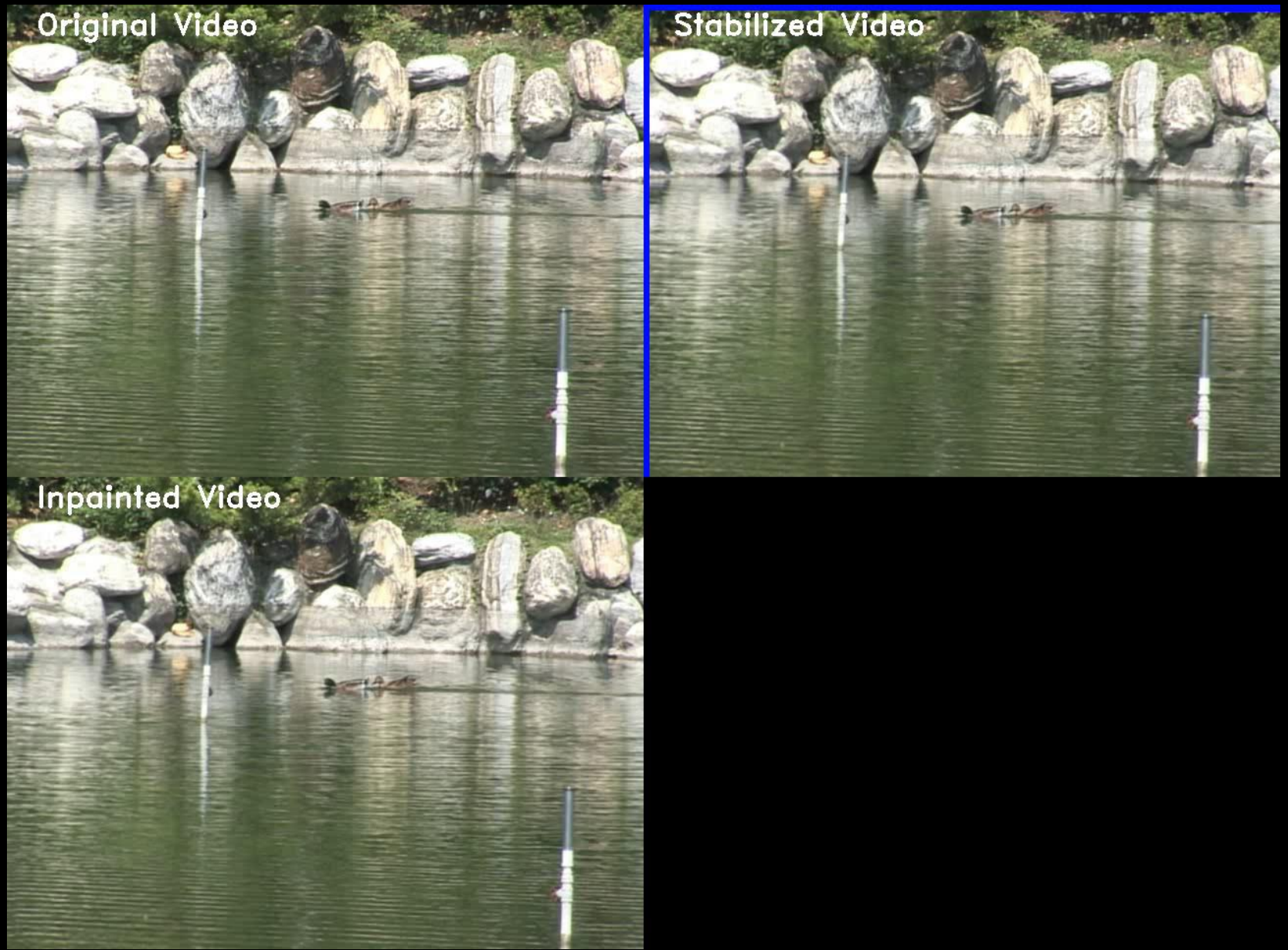
Grading

- Homework: 30%
  - 10 assignments
  - Late penality: 20% point reduction per day
- Midterm: 35%
  - Problems similar to homework
- Final Exam or Term Project: 35%
  - Presentations at the end of the semester

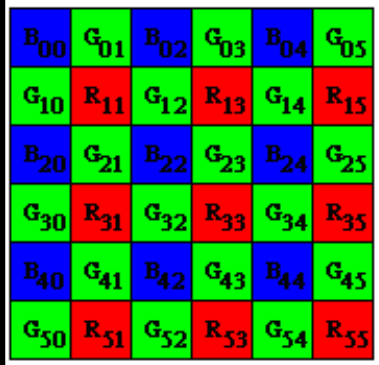
Hybrid Image

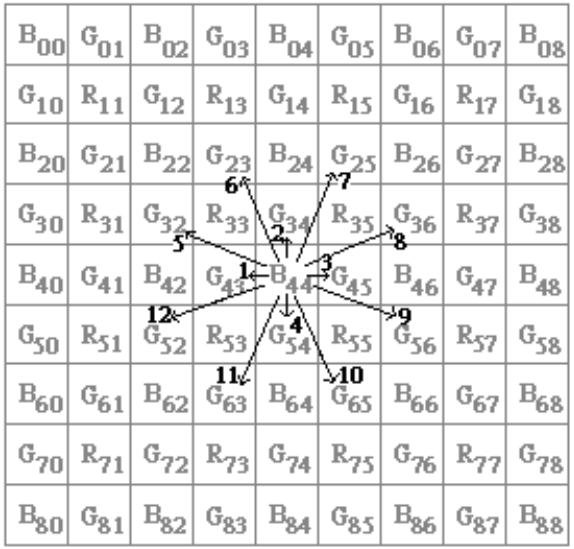
歐巴馬? 還是馬英九?

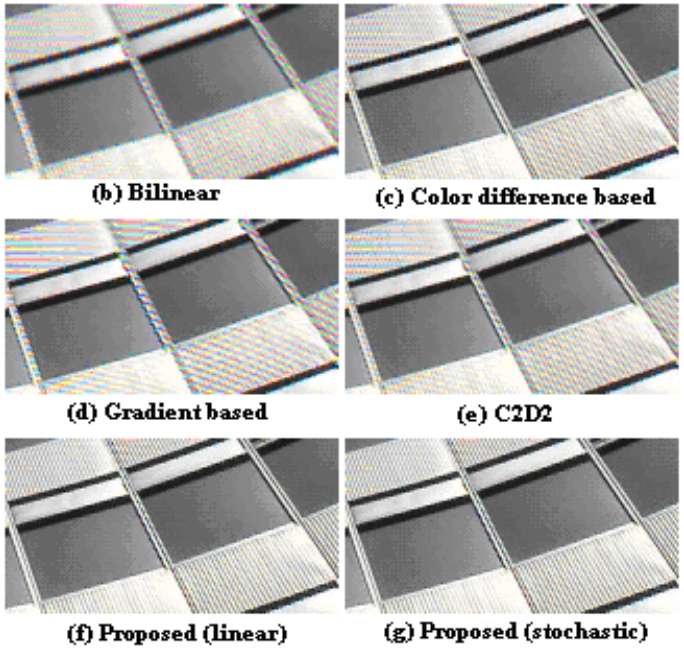
Motion Stabilization



Color Interpolation







(b) Bilinear (c) Color difference based

(d) Gradient based (e) C2D2

(f) Proposed (linear) (g) Proposed (stochastic)

Rolling Shutter Effect

MPAC Lab

Autofocus

Ours

iPhone SE (2020)

MPAC Lab

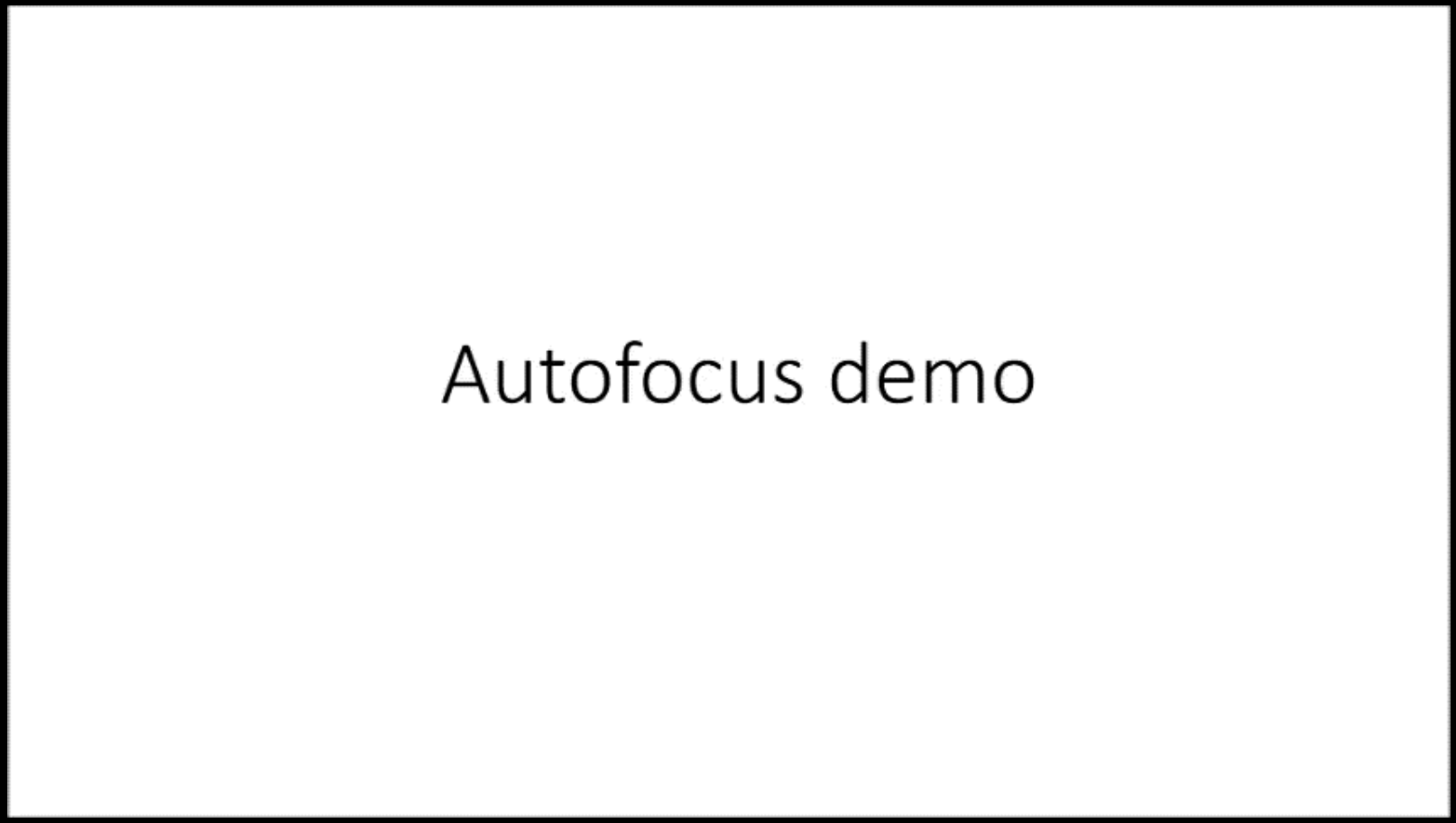
Autofocus

Ours

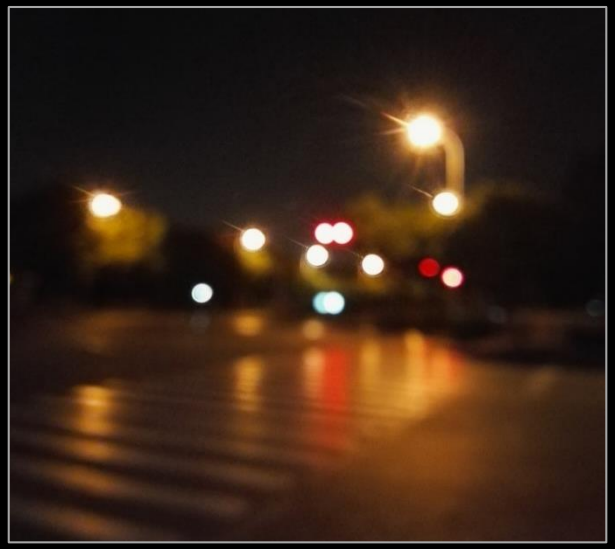
iPhone 11 Pro

MPAC Lab

AF-Net: AI-Based PDAF (Low Light)



Anti-Blooming



Before

After

Backlight Compensation

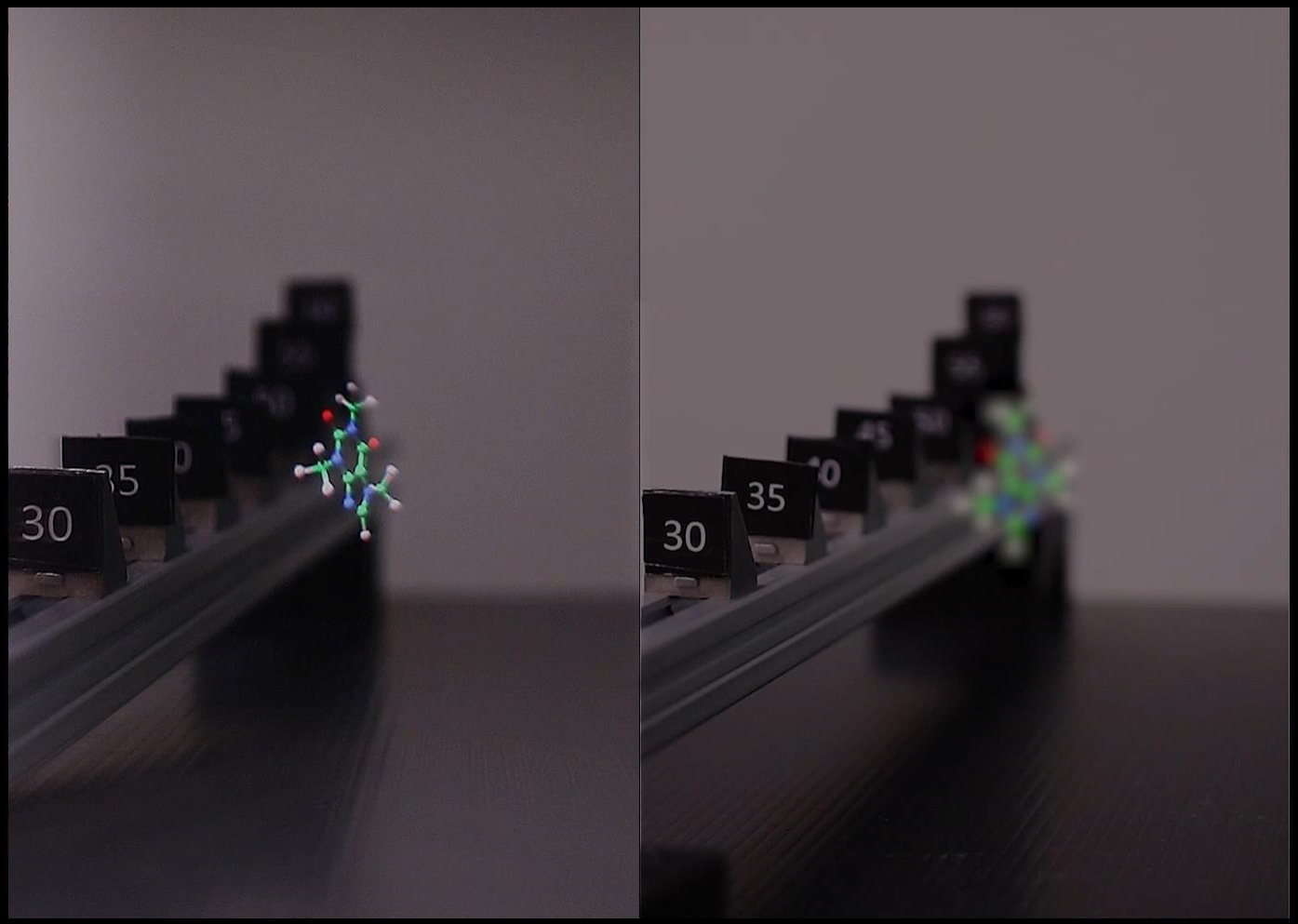
AR痛點：無法產生多景深效果

Near Focus

Far Focus

MPAC Lab

性能比較(原型機實拍影像)



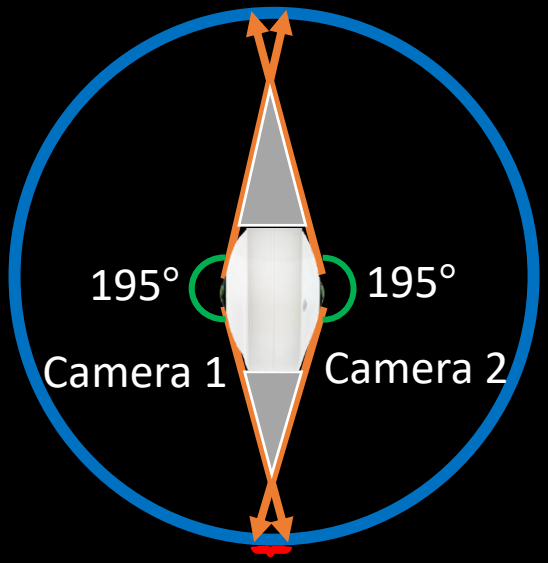
PetaRay

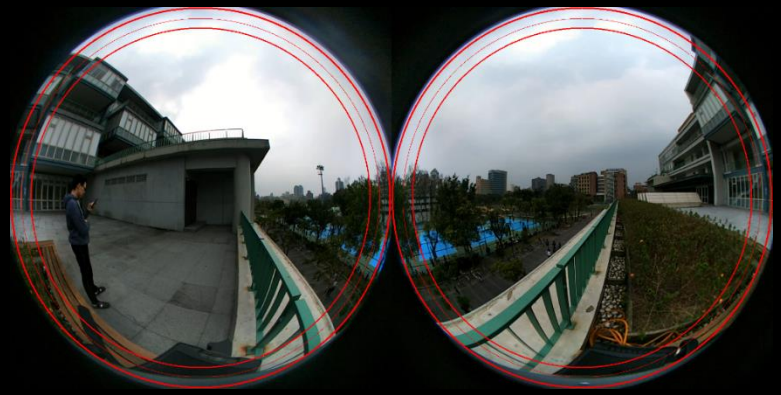
Others

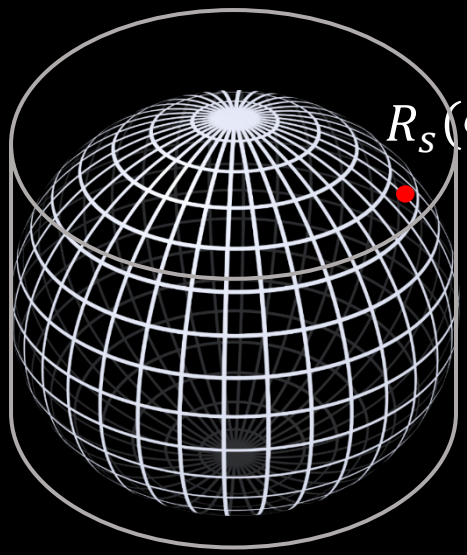
Multi-Exposure HDR

360度全景影像

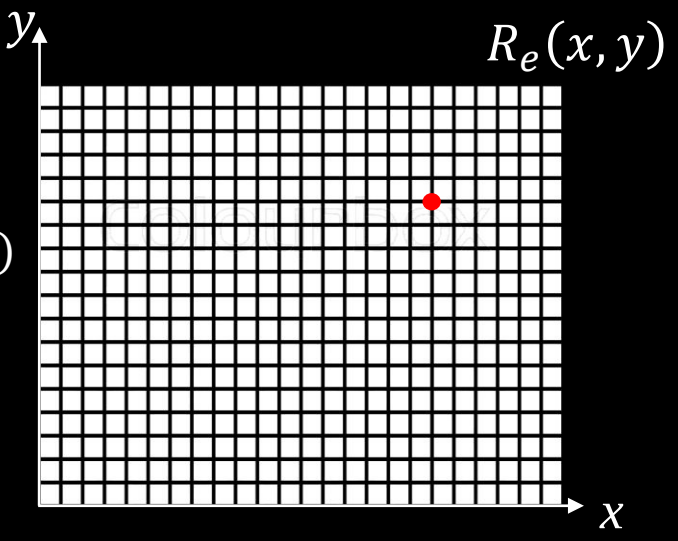
RICOH Theta S







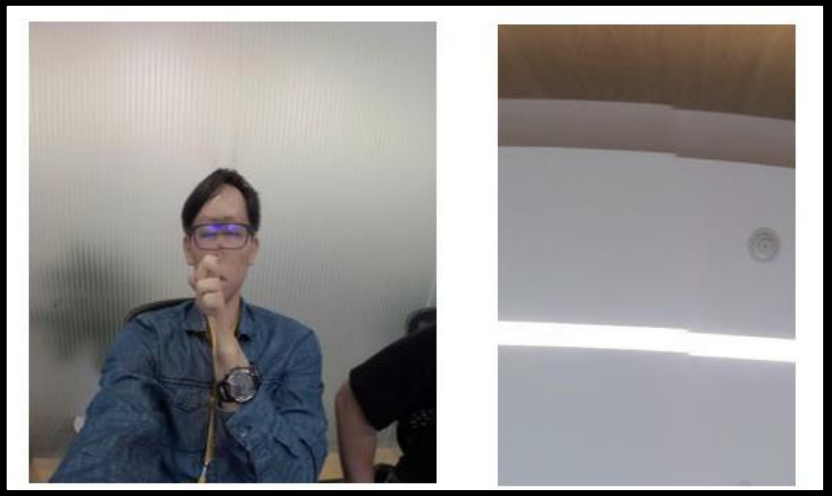
$$\begin{cases} x = \Phi \cdot \cos(\theta) \\ y = \theta \end{cases}$$

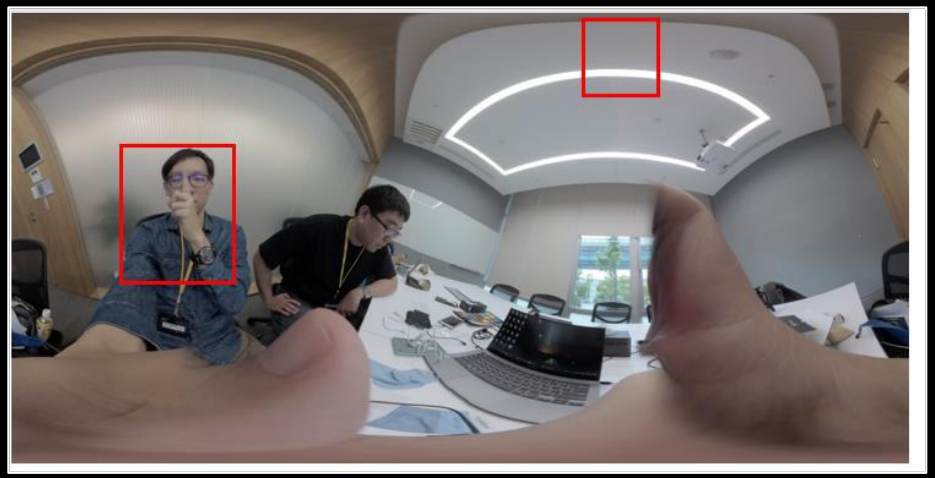


MPAC Lab

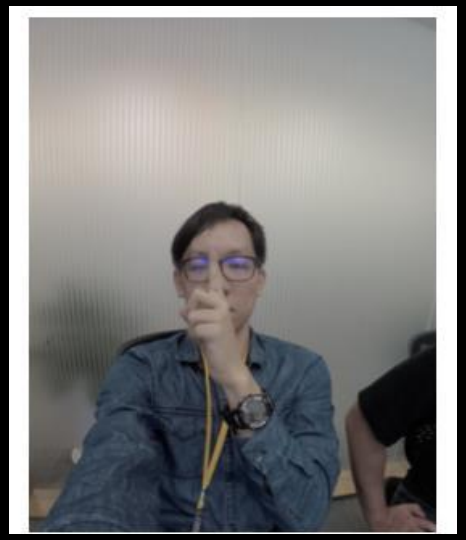
全景縫合

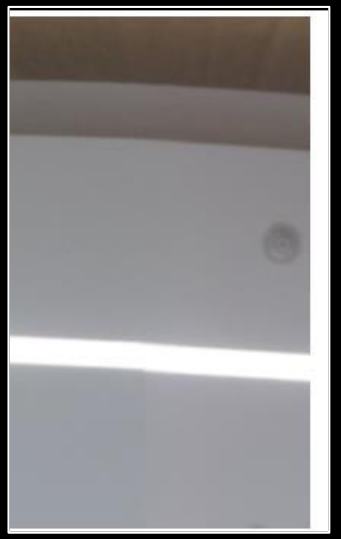
Built-in method





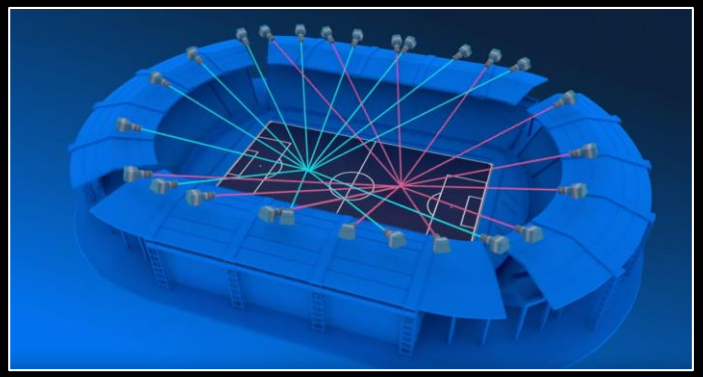
Our method





Free-View (360度全景播放系統)

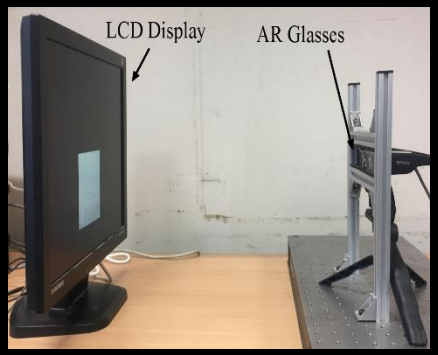
- A camera array installed in a stadium or stage
- Output a multi-view shot in five to ten seconds on a single PC
- Application: replay, entertainment, sports instruction

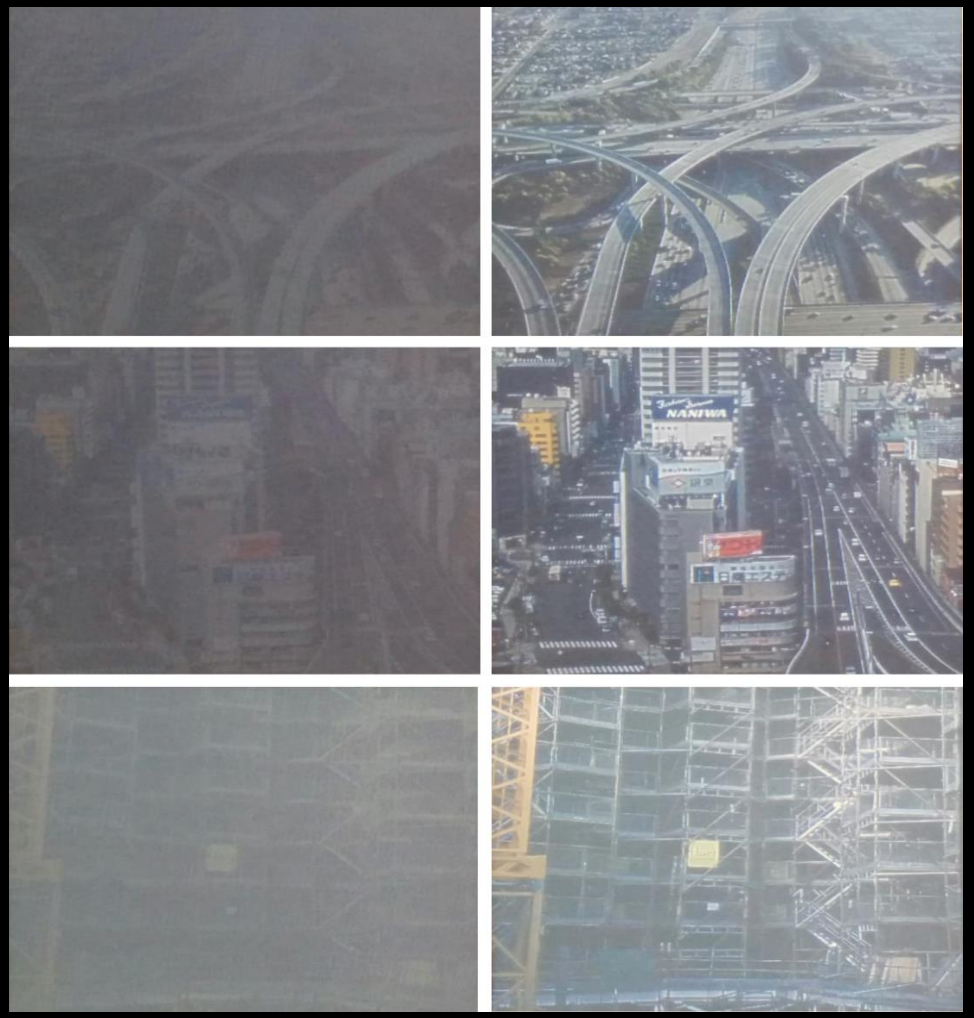


MPAC Lab

Perceptual Video Processing: Dehazing Using AR

see-through AR glasses

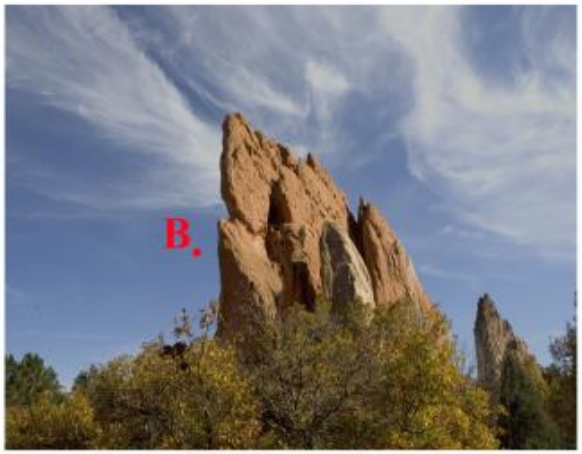




Perceptual Video Processing: Blocking Harmful Blue Light

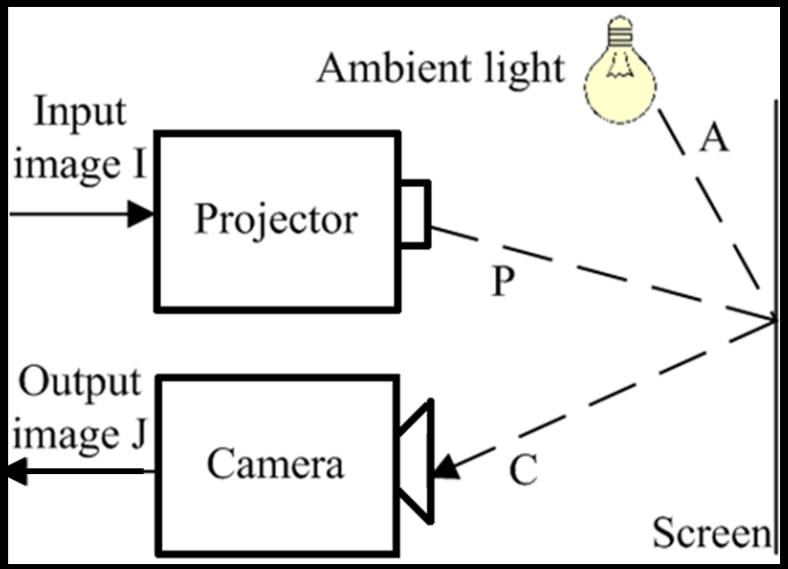
(a) Original image

(b) Distorted image



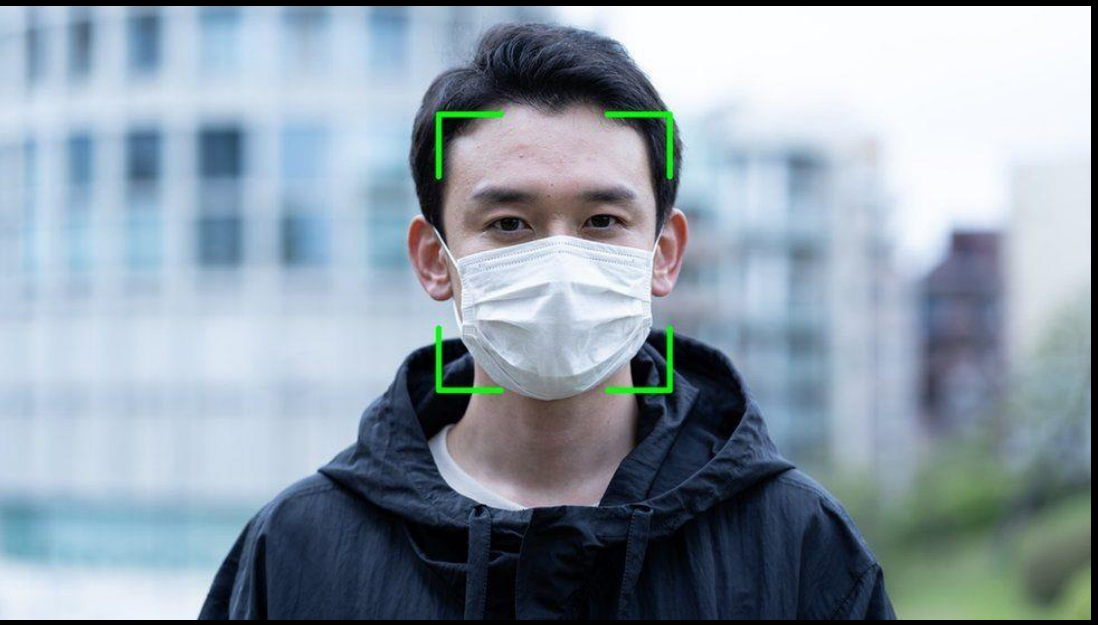
(c) Our result

Perceptual Video Processing: Non-White Projection Surface

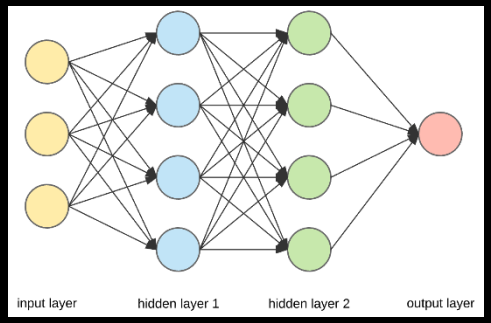


MPAC Lab

Masked Face Recognition



Deep Learning Model

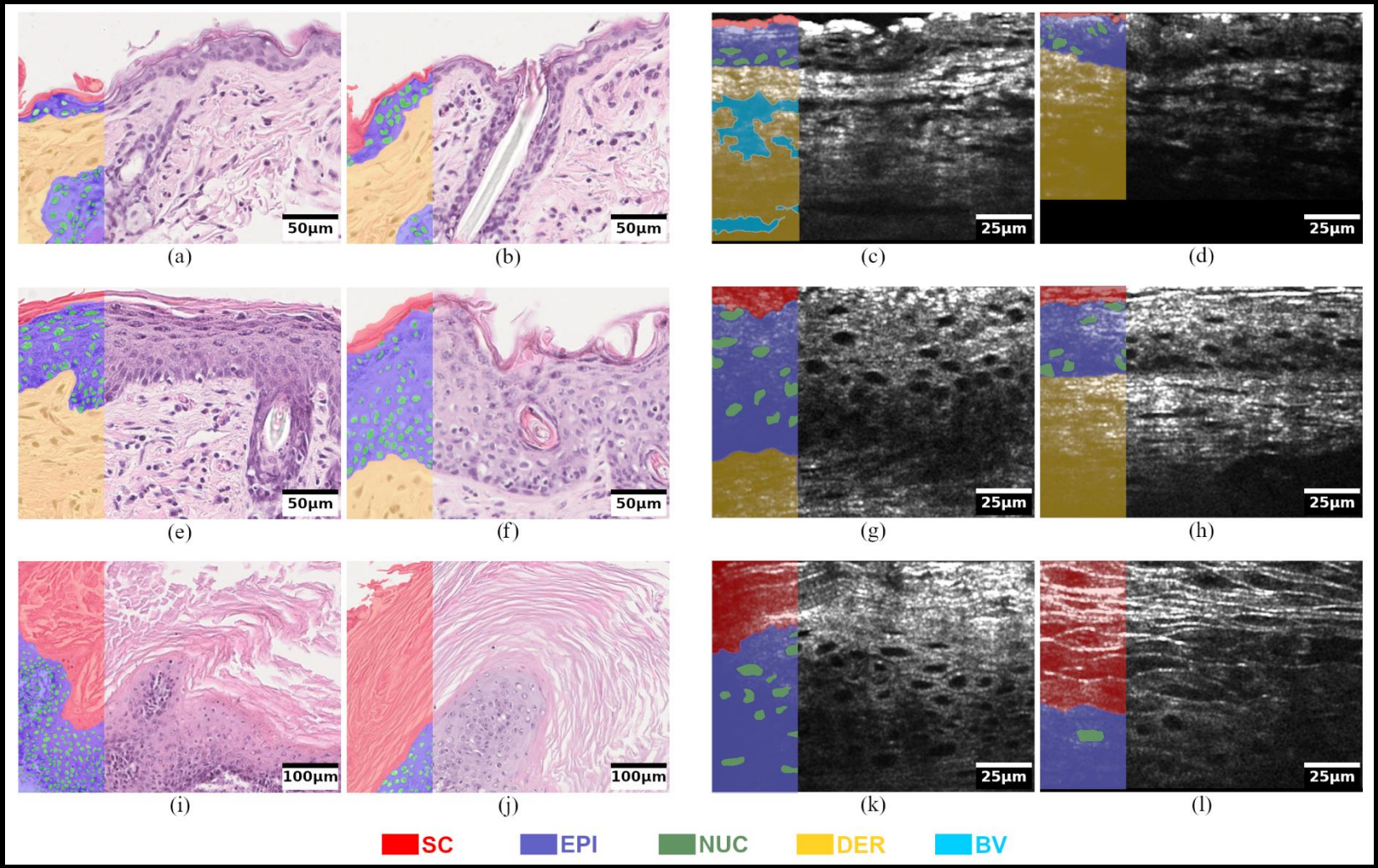


+

Unmasked Faces & Synthesized Masked Faces

MPAC Lab

OCT Image Processing



Collaborator: Prof. Sheng-Lung Huang

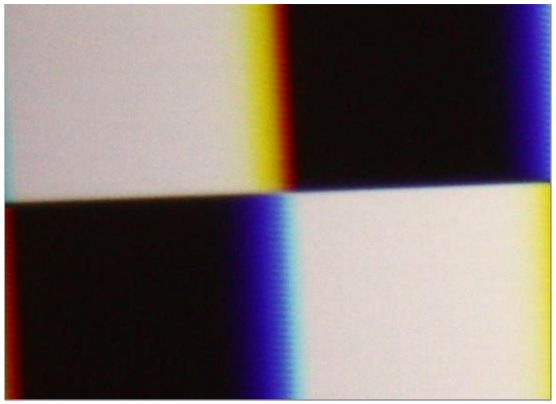
Image Debluring

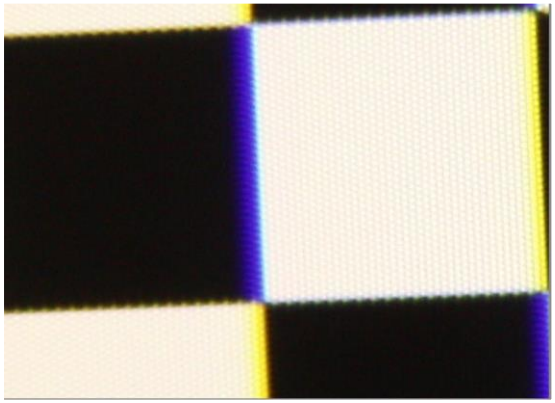
Original image

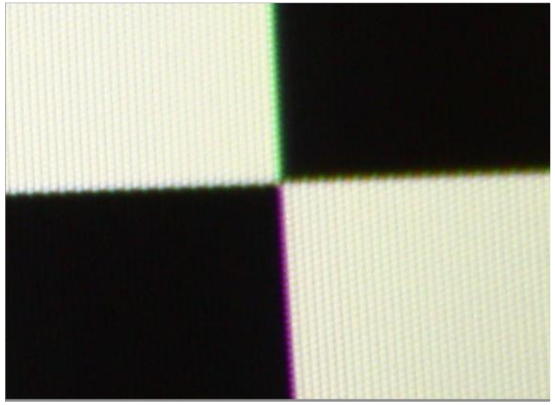
Image Debluring

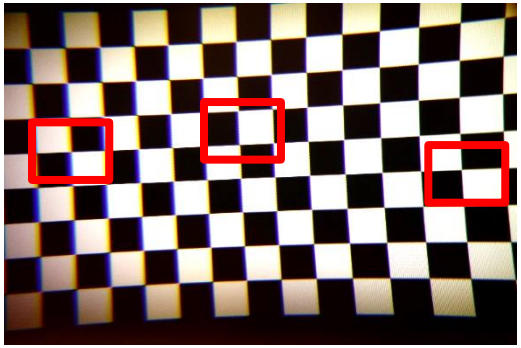
Deblurred image

Chromatic Aberation









讀書、讀書、讀書

以下這兩份名單，哪一份名單上你認識的人多一些？

傅以漸、王式丹、畢沅、林召堂、王雲錦、劉子壯、陳沆、劉福姚、劉春霖。

曹雪芹、胡雪巖、李漁、顧炎武、金聖嘆、黃宗羲、吳敬梓、蒲松齡、洪秀全、袁世凱。

答案揭曉：
前者全是清朝科舉狀元；
後者全是當時落第秀才！

人生無限，其實真正的考場從來就不在學校 ，儘管我們都從那裡出發！

======

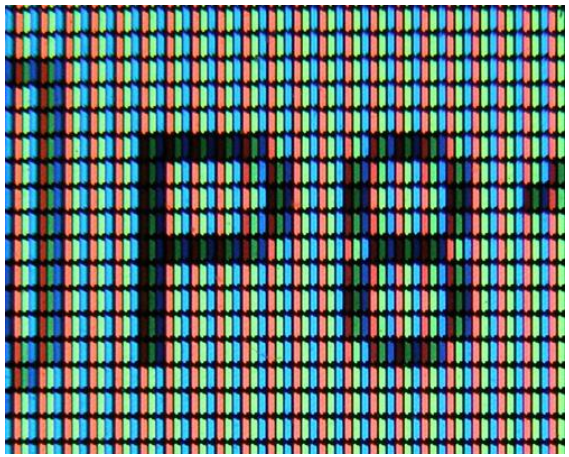
後言：清朝科舉考試的制度，三年一試，分別是解試、省試、殿試，殿試的第一名為狀元，所以清末，四萬萬同胞，每九年，才會產生一位狀元。如貼文所說，狀元(死讀書、讀死書、讀書死 的人)通常不會在歷史上留名的，只有那些不讀死書的人才容易千古留名的！😎😎😎

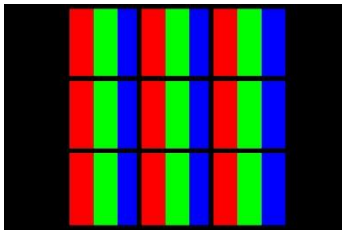
Chapter 1. Introduction

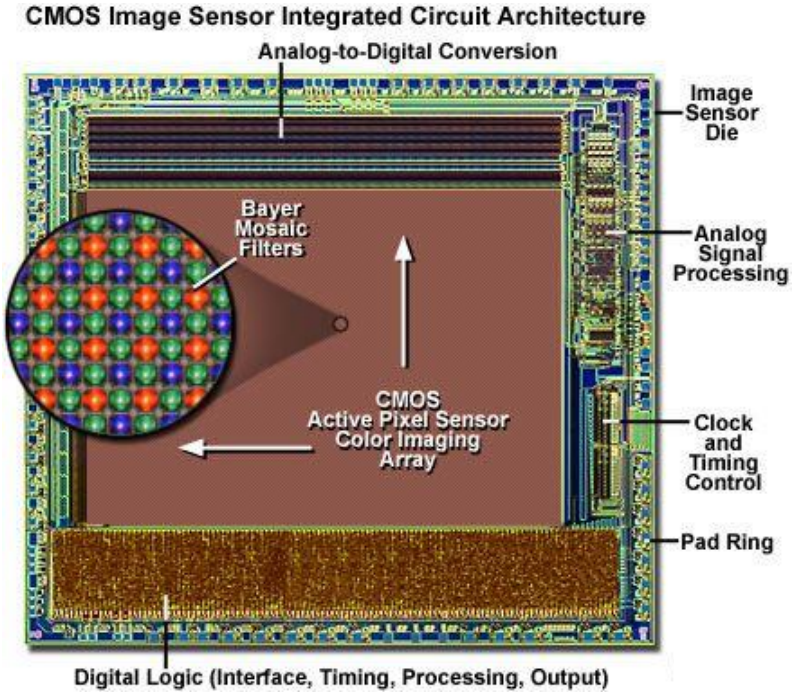
- Scope of the digital image processing field
- Historical perspective of DIP
- Overview of the state-of-the-art of DIP
- Principal approaches of DIP
- Overview of a DIP system
- Pointers to DIP literature

Image

- An image is a two-dimensional signal f(x,y)
- When x, y, and the value of f(x,y) are all finite, it's called a digital image
- Each element of the image is call pixel or pel







Scope

- The field of DIP refers to processing digital images by means of a digital computer
  - low-level: inputs and outputs are images
  - mid-level: outputs are attributes extracted from input images
  - high-level: an ensemble of recognition of individual objects

Origins of DIP

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

Sent by submarine cable between London and New York, the transportation time was reduced to less than three hours from more than a week.

FIGURE 1.2
A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

FIGURE 1.3
Unretouched cable picture of Generals Pershing (right) and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

Origins of DIP

FIGURE 1.4
The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

Sources of Images

- Electromagnetic (EM) energy spectrum
- Acoustic
- Ultrasonic
- Electronic
- Computer synthesized images

Electromagnetic (EM) energy spectrum

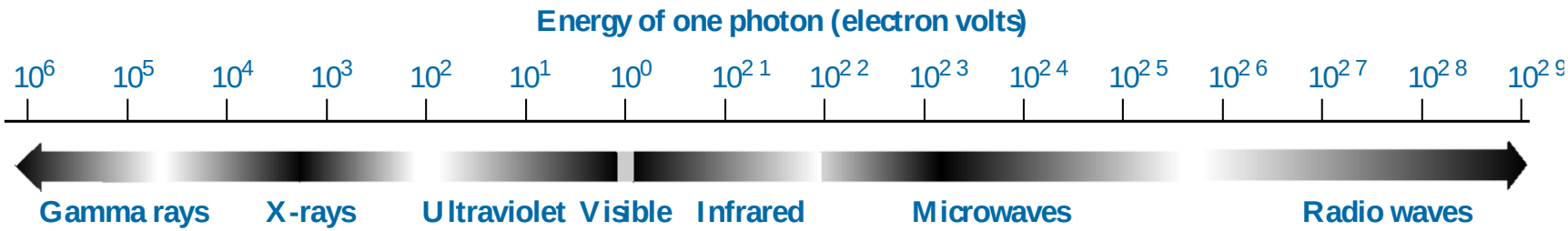
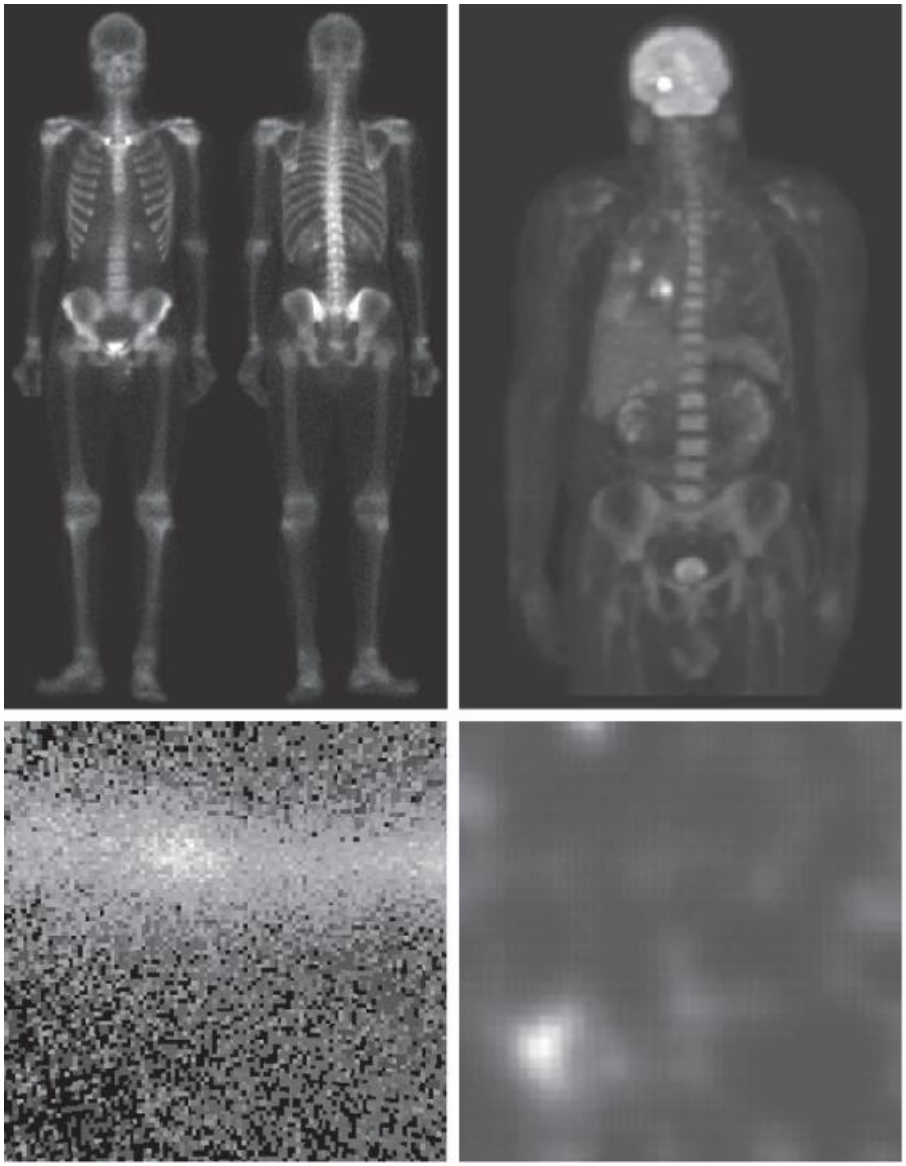


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Major uses

- **Gamma-ray imaging**: nuclear medicine and astronomical observations
- **X-rays**: medical diagnostics, industry, and astronomy, etc.
- **Ultraviolet**: lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations
- **Visible and infrared bands**: light microscopy, astronomy, remote sensing, industry, and law enforcement
- **Microwave band**: radar
- **Radio band**: medicine (such as MRI) and astronomy

Gama-Ray Imaging

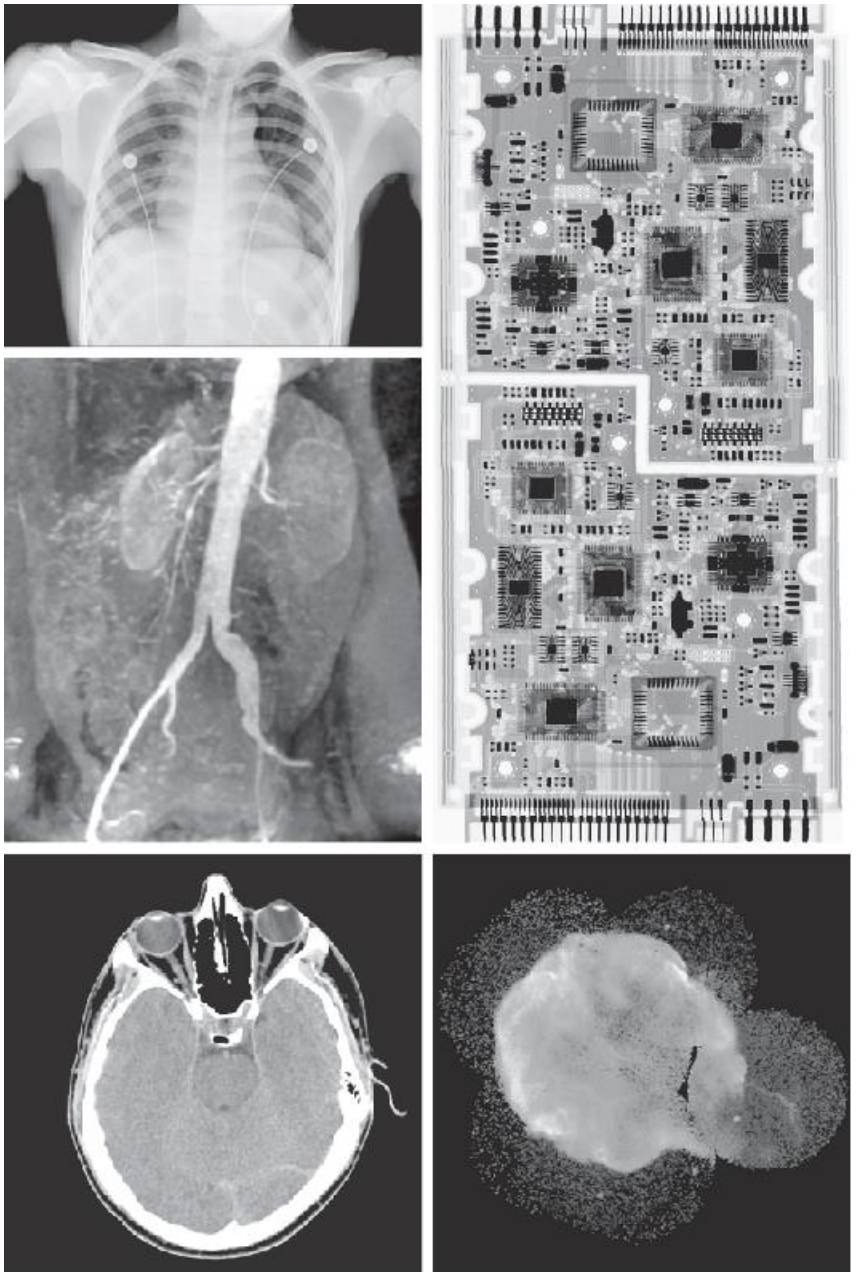


a b
c d

FIGURE 1.6
Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems; (b) Dr. Michael E. Casey, CTI PET Systems; (c) NASA; (d) Professors Zhong He and David K. Wehe, University of Michigan.)

天鵝座

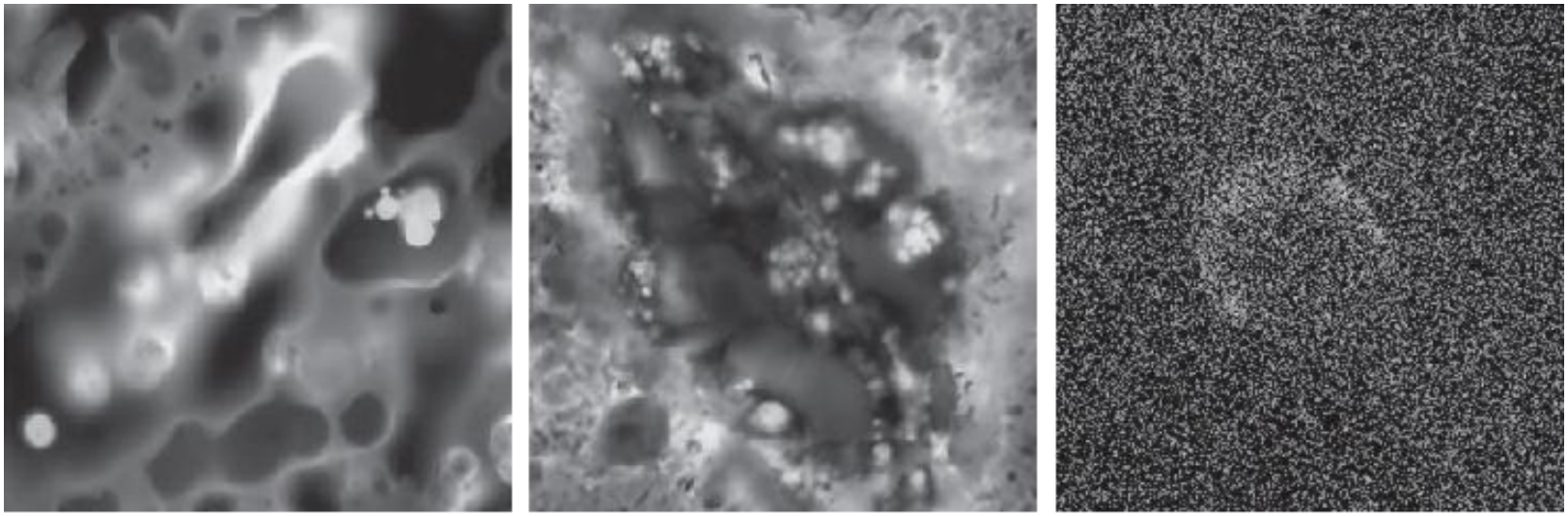
X-Ray Imaging



a d
c
b e

FIGURE 1.7
Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, Univ. of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

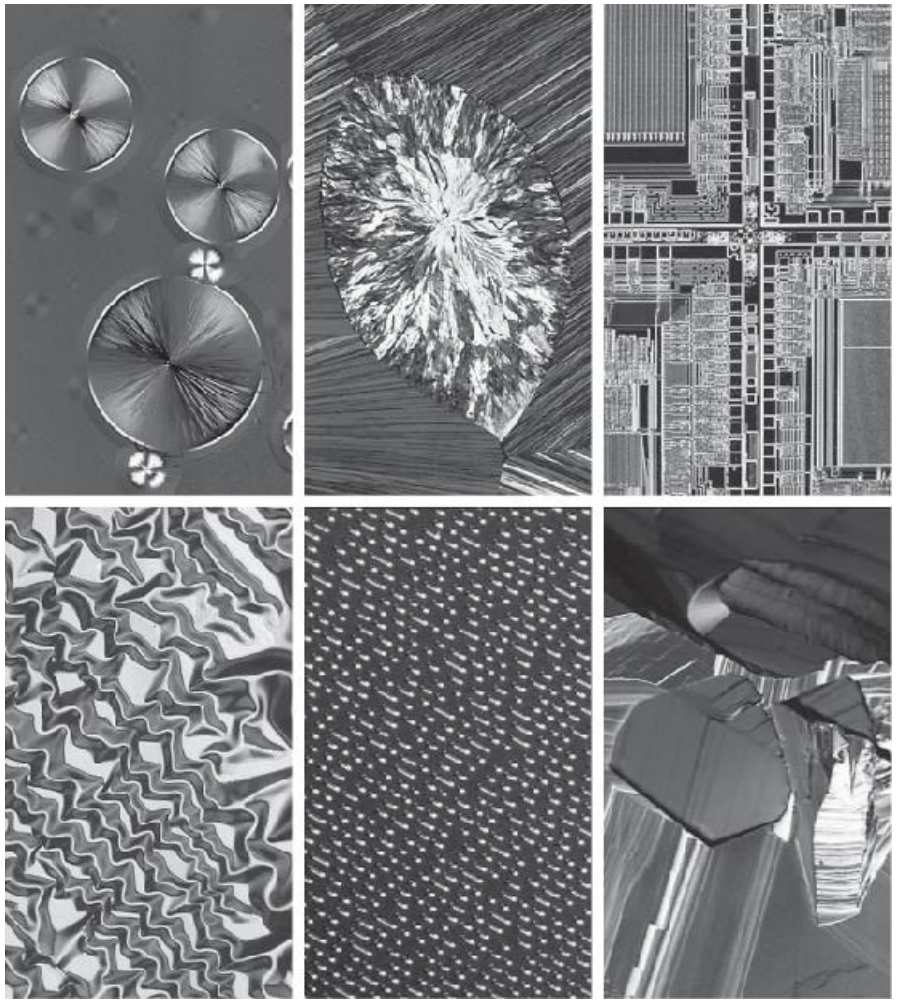
Ultraviolet Imaging



a b c

FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn. (b) Corn infected by smut. (c) Cygnus Loop. (Images (a) and (b) courtesy of Dr. Michael W. Davidson, Florida State University, (c) NASA.)

Light Microscopy Imaging



a b c
d e f

FIGURE 1.9
Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250 ×. (b) Cholesterol—40 ×. (c) Microprocessor—60 ×. (d) Nickel oxide thin film—600 ×. (e) Surface of audio CD—1750 ×. (f) Organic superconductor— 450 ×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Visual and Infrared Imaging

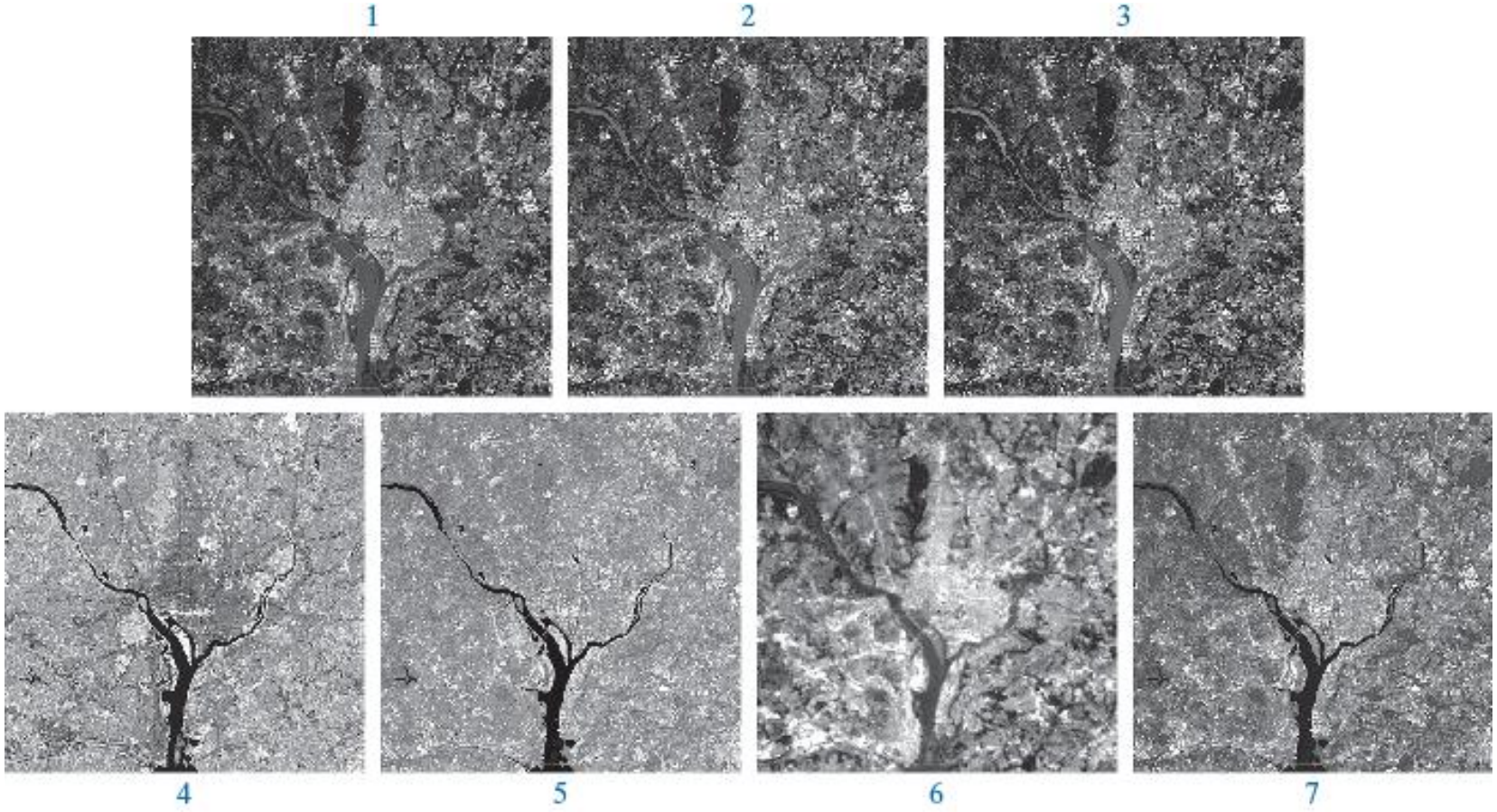


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.) Note the river is well defined in bands 4 and 5.

Satellite Image for Weather Observation

FIGURE 1.11
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)

Using sensors in the visible and infrared bands.

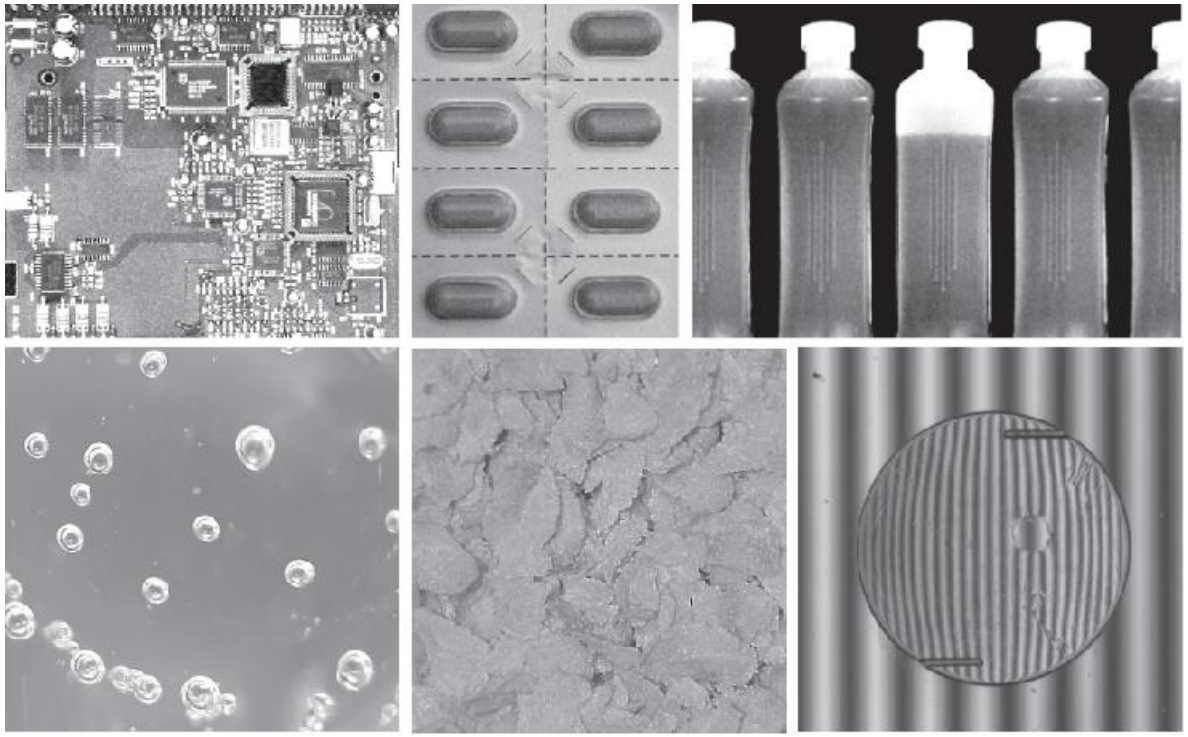
Infrared Imaging

2003

FIGURE 1.12
Infrared satellite images of the Americas. The small shaded map is provided for reference. (Courtesy of NOAA.)

Infrared in the band 10.0 to 13.4 μm.

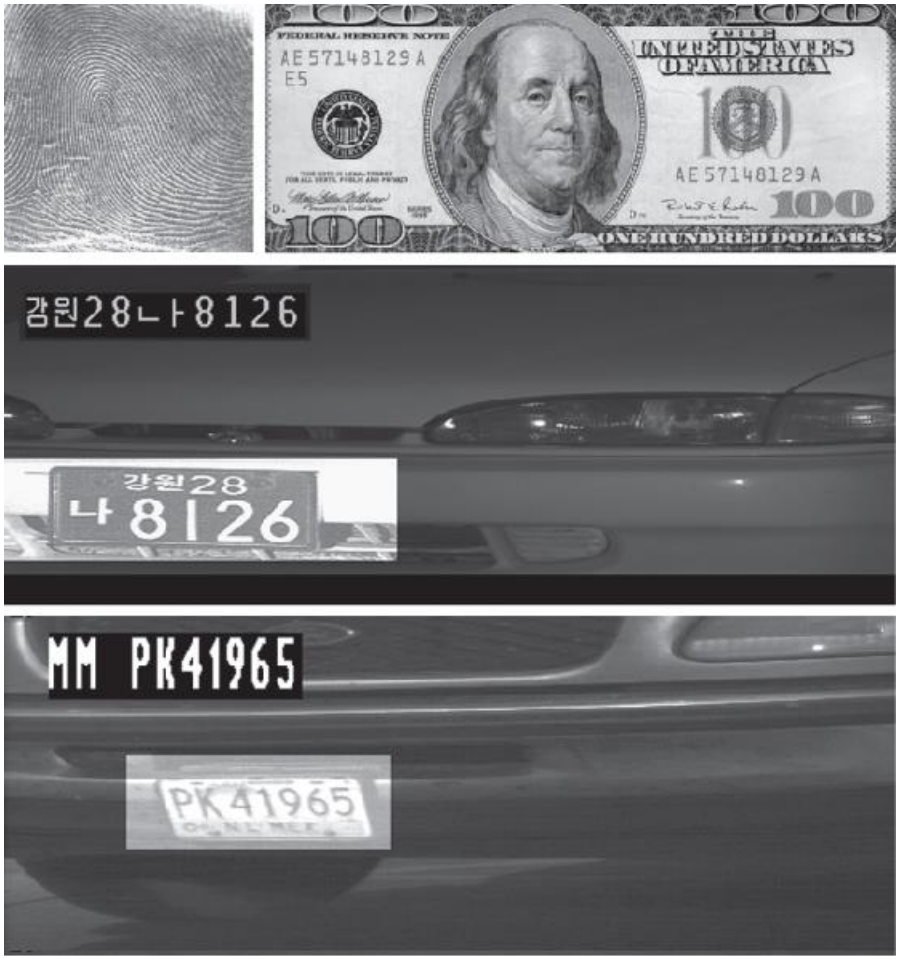
Automated Visual Inspection



a b c
d e f

FIGURE 1.14 Some examples of manufactured goods checked using digital image processing. (a) Circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear plastic product. (e) Cereal. (f) Image of intraocular implant. (Figure (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

Results



a b
c
d

FIGURE 1.15
Some additional examples of imaging in the visible spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

Radar Imaging

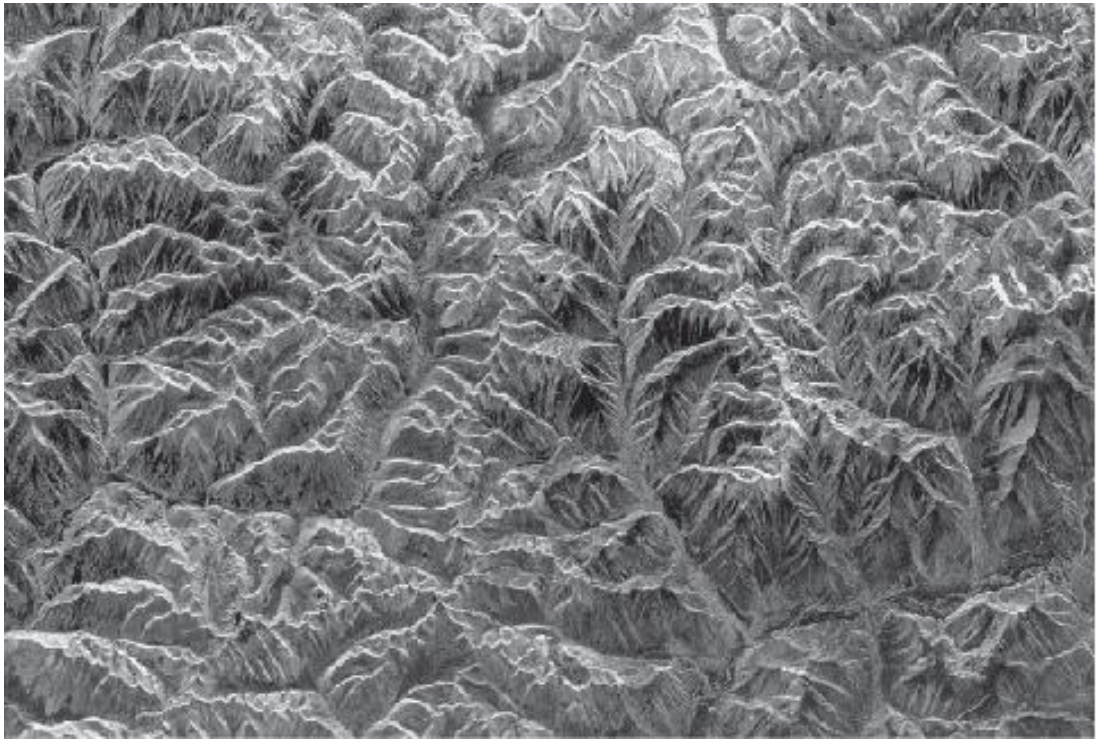
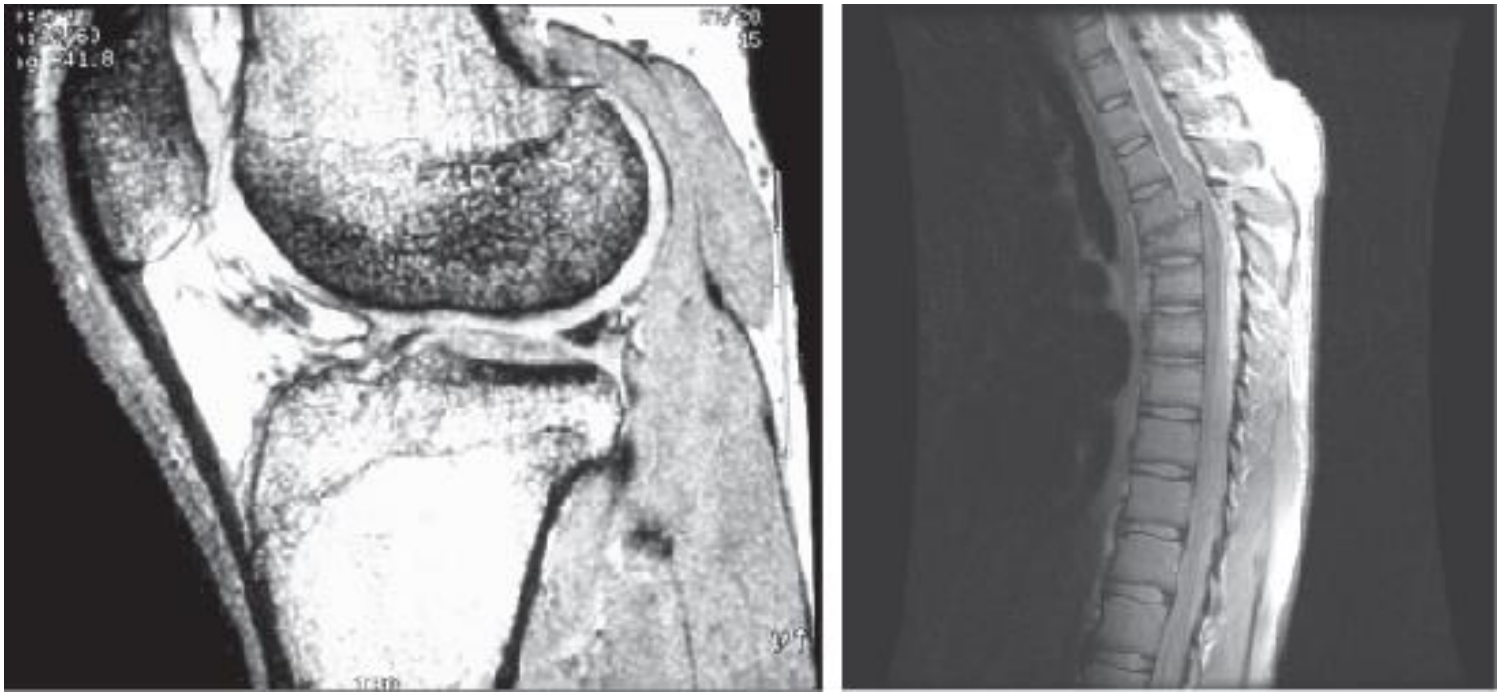


FIGURE 1.16
Spaceborne radar image of mountainous region in southeast Tibet. (Courtesy of NASA.)

MRI (Radio Band)



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Figure (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

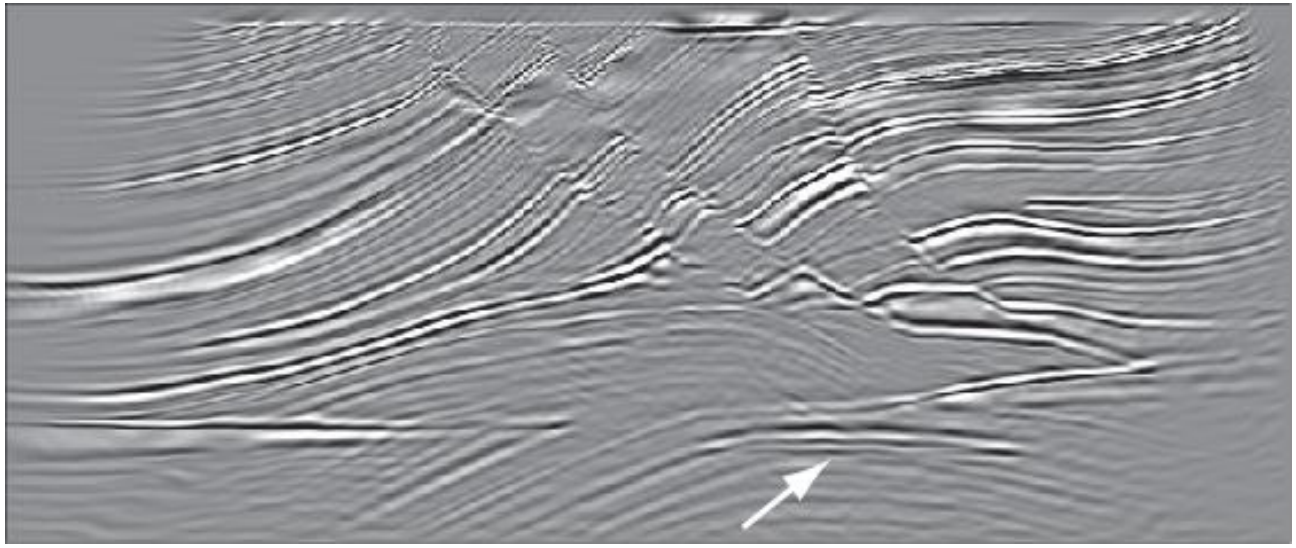
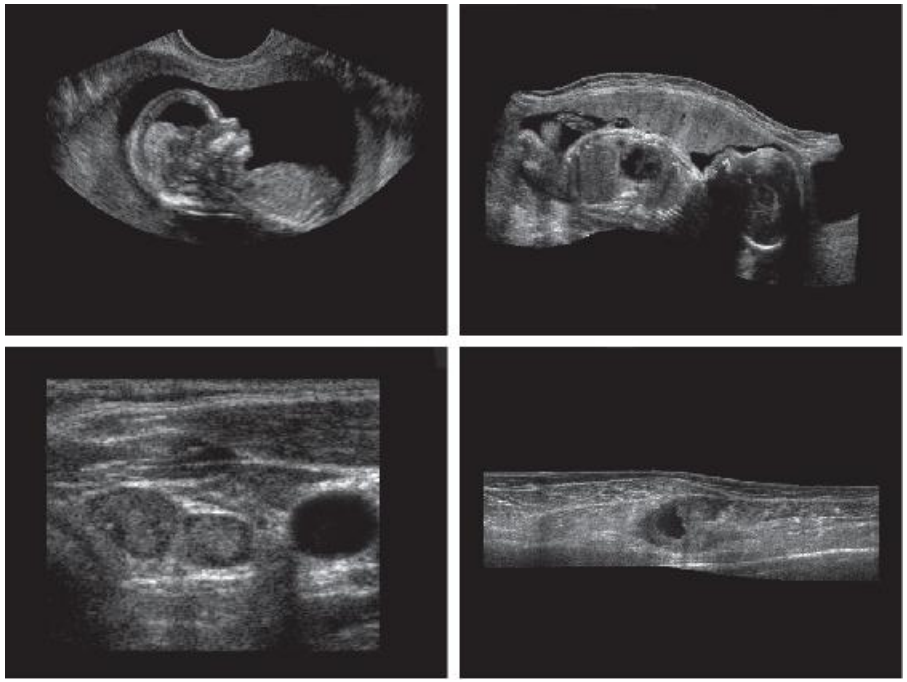


FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Ultrasound Imaging

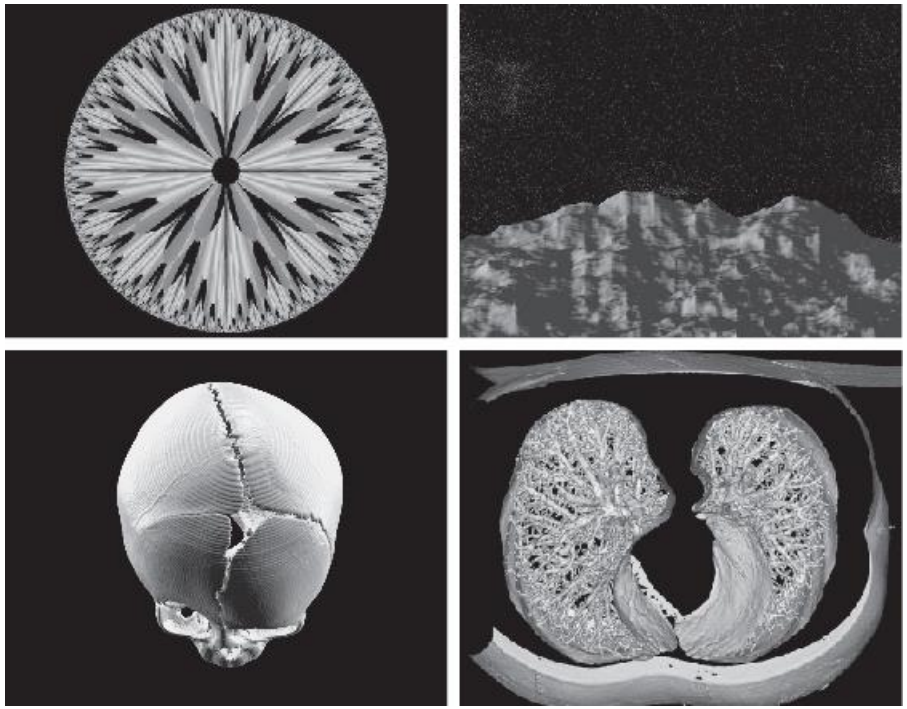


a b
c d

FIGURE 1.20
Examples of ultrasound imaging. (a) A fetus. (b) Another view of the fetus. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

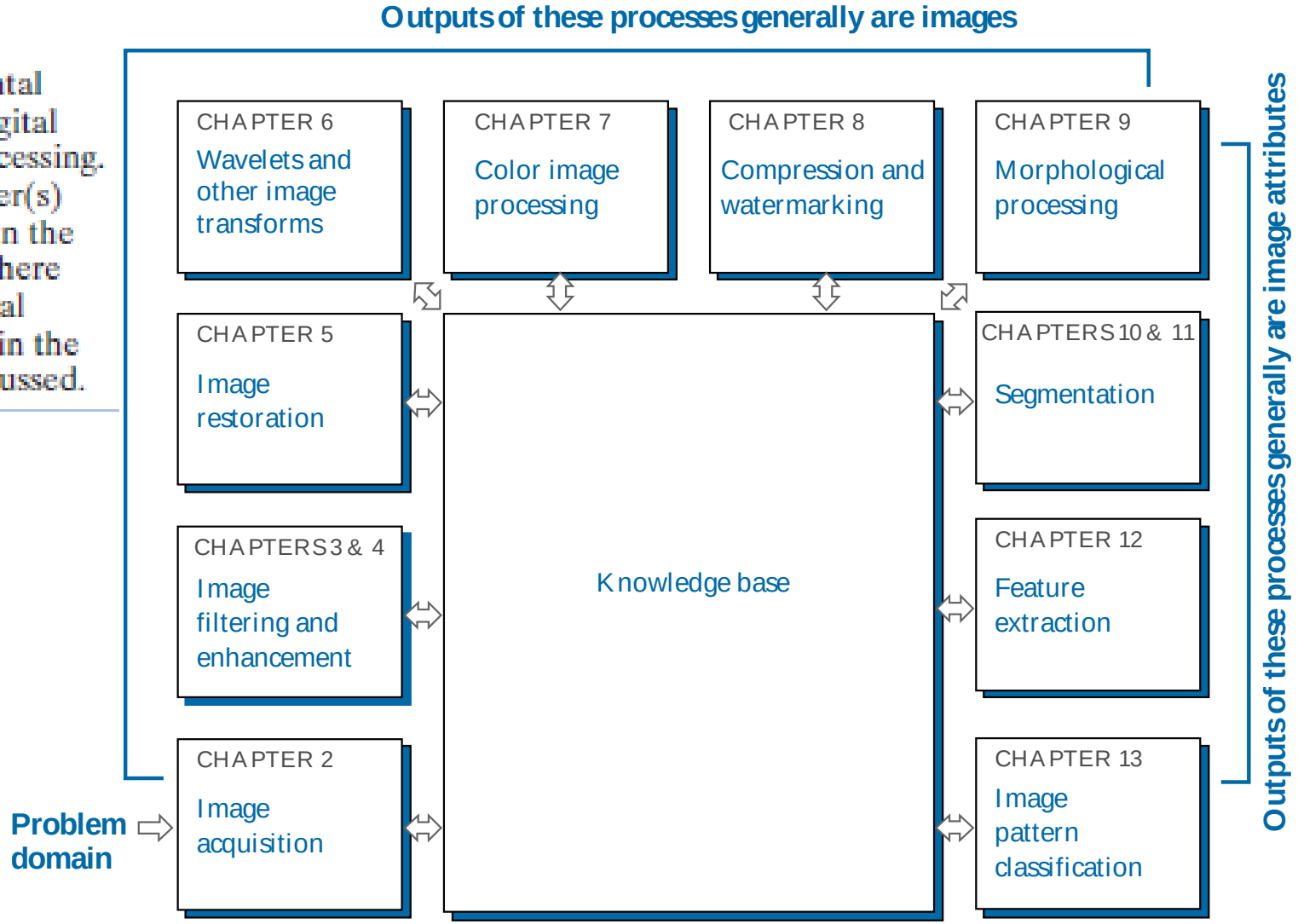
a b
c d

FIGURE 1.22
(a) and (b) Fractal images.
(c) and (d) Images generated from 3-D computer models of the objects shown.
(Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College; (c) and (d) courtesy of NASA.)



Fundamental Steps

FIGURE 1.23
Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.



Components

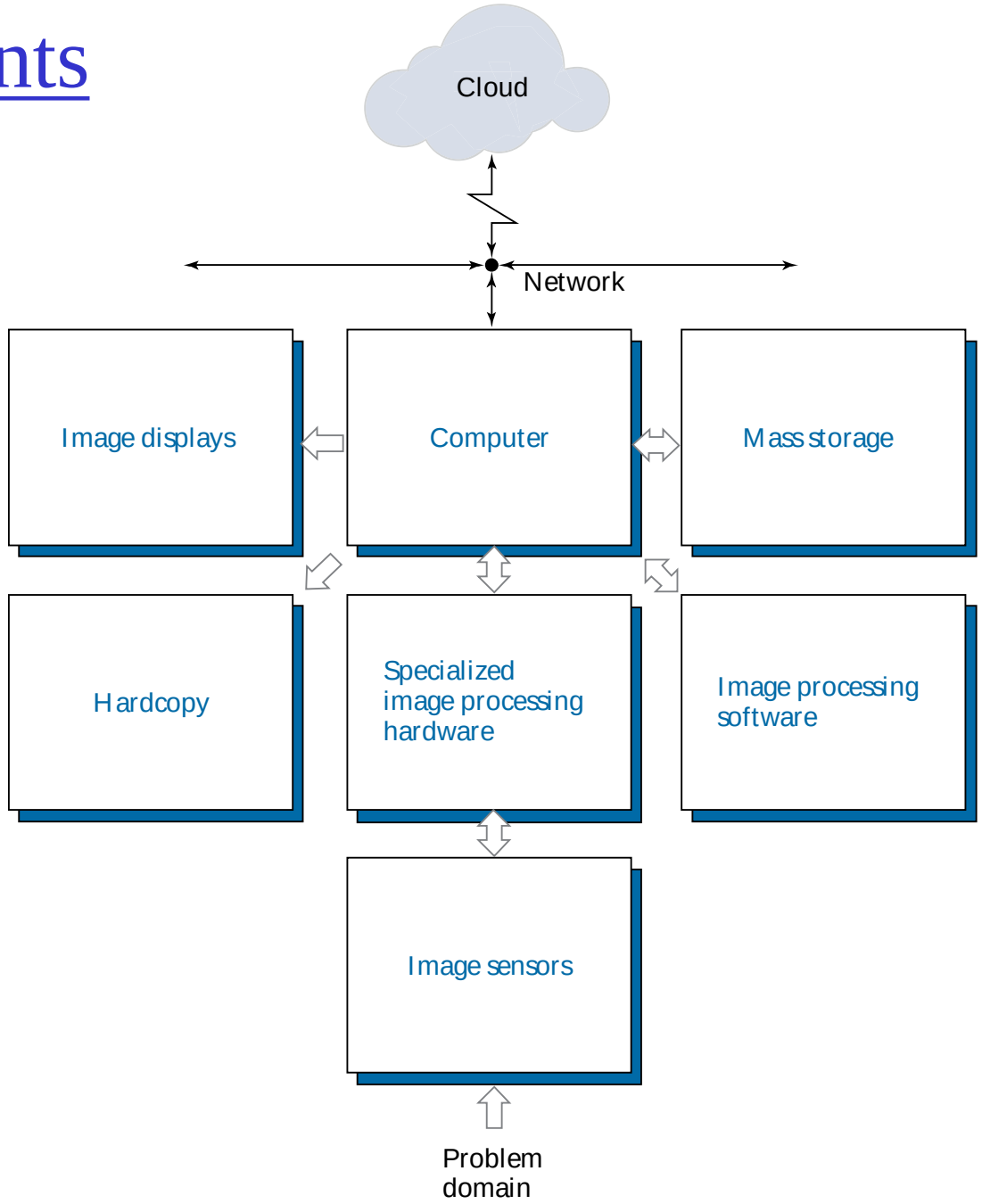
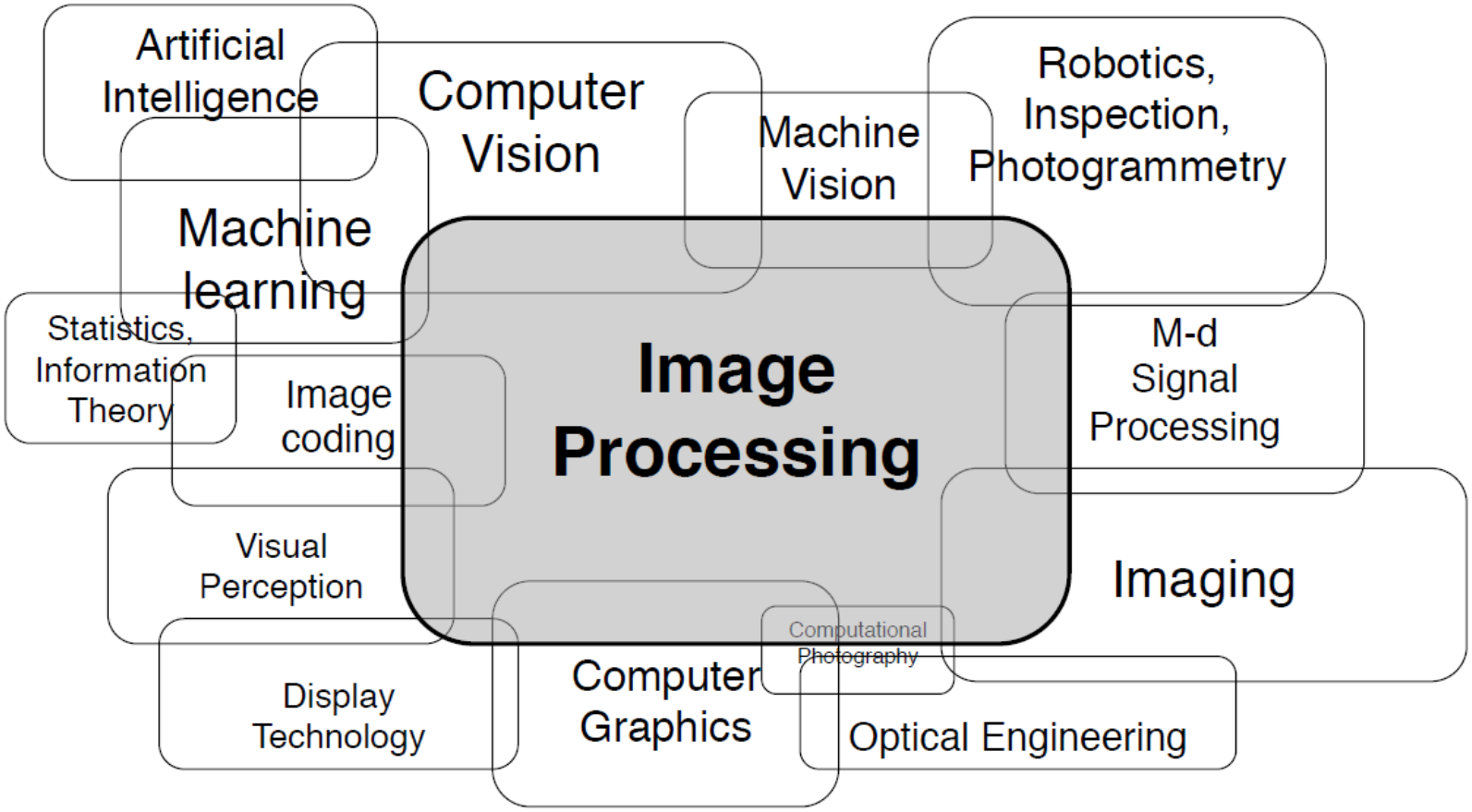


FIGURE 1.24
Components of a general-purpose image processing system.

Image Processing and Related Fields



Source: Bern Girod