Chapter 1

Introduction

Chapter 1 Introduction

Outline

1. The Concept of Digital Image Processing
2. The Origins and Developments of Digital Image Processing
3. Examples of Fields that Use in Digital Image Processing
4. Fundamental Steps in Digital Image Processing
5. Components of an Image Processing System

Chapter 1 Introduction

1. The Concept of Digital Image Processing

Image

Image can be interpreted as: drawing, photograph or printing.
Image is the projection of the energy or state of the objective world in the form of visualization on the two-dimensional plane.

Digital Image

An digital image is equivalent to an M * n matrix (grid), each grid is filled with certain color elements.
A digital image consists of a limited number of elements, each of which has a position and a value.
These elements are called picture elements, pels, or pixels.

Digital Image Processing

Digital image processing, also known as computer image processing, refers to the method and technology of converting image into digital signal, and using computer to process it such as noise reduction, enhancement, restoration, segmentation, compression and feature extraction, so as to improve the practicability of the image and achieve the expected results。

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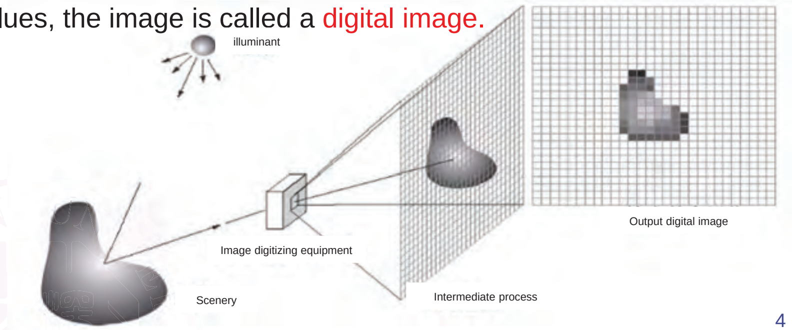
1. The Concept of Digital Image Processing

- Image digitization

An image can be defined as a two-dimensional function f (x, y), where x and y are the spatial coordinates, and the amplitude of f at the coordinates (x, y) is called the brightness or gray level of the point. When the amplitudes of x, y and f are finite discrete values, the image is called a digital image.



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1. The Concept of Digital Image Processing

- Digital image

(a) Original image (b) Sampling (c) Quantization

Sampling and quantization of images

Sampling —— Discretization in space

Quantization —— Discretization in amplitude

A digital image consists of a limited number of elements, each of which has a position and a value.

These elements are called picture elements, image elements, pels, or pixels.

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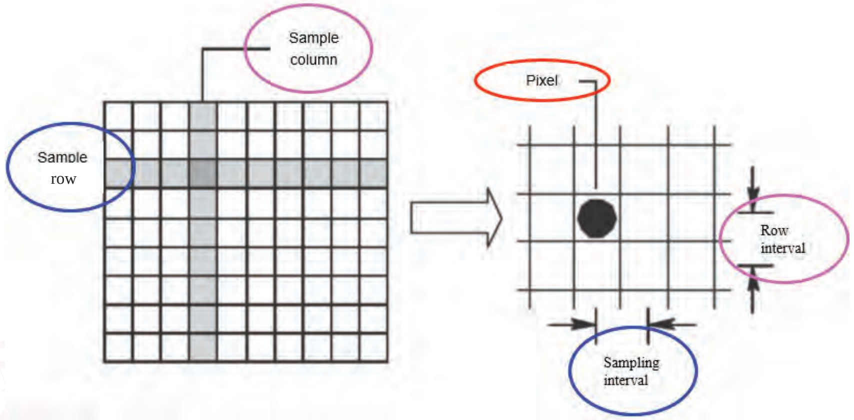
1. The Concept of Digital Image Processing

- Image sampling



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1. The Concept of Digital Image Processing

- Image sampling

- When sampling, if the number of horizontal pixels (columns) is M and the number of vertical pixels (rows) is N, the total number of pixels of the image is M* N pixels.
- Generally, the larger the sampling interval, the less the number of pixels, the lower the spatial resolution and the worse the quality of the image;
- The smaller the sampling interval, the more pixels, the higher the spatial resolution, the better the image quality, but the larger the amount of data.

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1. The Concept of Digital Image Processing

- Image resolution

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1. The Concept of Digital Image Processing

- Image quantization
  - The more the quantization level is, the richer the image level is, the higher the amplitude resolution is, the better the image quality is, but the amount of data is large;
  - The less the quantization level is, the less rich the image level is and the lower the amplitude resolution is, the false contour will appear and the image quality will be worse, but the amount of data is small.

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1. The Concept of Digital Image Processing

- Image quantization

Chapter 1 Introduction

1. The Concept of Digital Image Processing

- The main advantages of digital image processing:
  - High precision
  - Good reproducibility
  - Versatility and flexibility
- The purpose of processing:
  - Improve the visual quality of the image, in order to achieve the purpose of pleasing to human eyes;
  - Extract some features or special information contained in the image to facilitate computer analysis;
  - The image data is transformed, encoded and compressed, which is convenient for image storage and transmission.

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2. The Origins and Developments of Digital Image Processing

The history of digital image processing can be traced back to the 1920s. One of the earliest applications was in the newspaper industry. At that time, the **Bartlane cable image transmission system** was introduced. For the first time, an image was sent from London to New York by submarine cable across the Atlantic Ocean. In order to transmit the image by cable, the image is encoded first, and then reproduced by a special printing device at the receiving end. According to the technical level of 1929, if it is not compressed, it will take more than a week. After compression, the transmission time is reduced to 3 hours.

2. The Origins and Developments of Digital Image Processing

1.The first transmission of images by submarine cable in 1920s (Bartlane: London to New York)

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

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

The tonal quality and the resolution are improved obviously

2. The Origins and Developments of Digital Image Processing

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

Transmission time: 3 hours

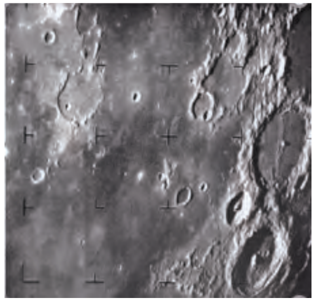
2. The Origins and Developments of Digital Image Processing

The history of digital image processing is closely related to the development of digital computer. In fact, digital image requires so much storage and computing power that it must rely on the development of digital computer and supporting technology including data storage and transmission in image processing.

2. The Origins and Developments of Digital Image Processing

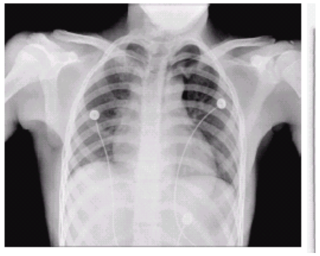
2. The first large-scale computer to perform meaningful image processing tasks appeared in the 1960s. The development of computer and space project development prompted people to pay attention to the potential of image processing concept, and use computer to improve the image work sent back by space detector

The first picture of the moon transmitted by the American spacecraft prowler 7 was taken 17 minutes before the impact on the moon at 9:09 (Eastern daylight time) on July 31, 1964

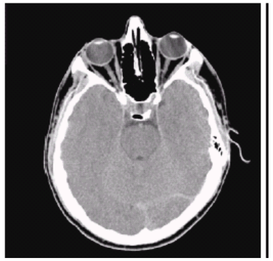


2. The Origins and Developments of Digital Image Processing

3. In the late 1960s and early 1970s, it began to be used in the fields of medical images, earth remote sensing, astronomy and so on



Chest X-ray image



Head CT image

Computerized tomography (CT) won the Nobel Prize in physiology or medicine (1979)
Magnetic resonance imaging (MRI) won the Nobel Prize in physiology or medicine (2003)
Charge coupled device (CCD) won the Nobel Prize in Physics (2009)

2. The Origins and Developments of Digital Image Processing

4. So far, it has been widely used in industry, medicine, bioscience, geography, archaeology, physics, astronomy and other fields

- Space technology: space technology, space defense, astronomy
- Biological Sciences: biology and medicine
- Security: fingerprint and face analysis
- National Defense: military detection
- Industrial applications: product testing
- Daily life applications: photo editing, film and television production

2. The Origins and Developments of Digital Image Processing

At present, deep learning technology is widely used in image processing

3. Examples of Fields that Use DIP

Image information processing is an important means of human visual continuity:

Human eyes can only see the visible light part, but from the current technical level, it is not only visible light that can be imaged. Generally speaking, the wavelength of visible light is 0.38 um ~ 0.8 um. So far, people have found that there are many kinds of imageable rays, such as:

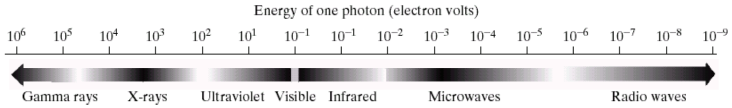


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

γ radial: 0.003 nm ~0.03 nm ;
x radial: 0.03 nm ~3 nm ;
Ultraviolet rays: 3nm ~300 nm ;
Infrared: 0.8 μm ~300 μm ;
Microwave: 0.3 cm ~100 cm ;

Electromagnetic spectrum arranged according to photon energy

Human vision: visible band

Imaging machine vision: all electromagnetic spectrum, ultrasonic, electron microscope, computer-generated imaging, etc.

3. Examples of Fields that Use DIP

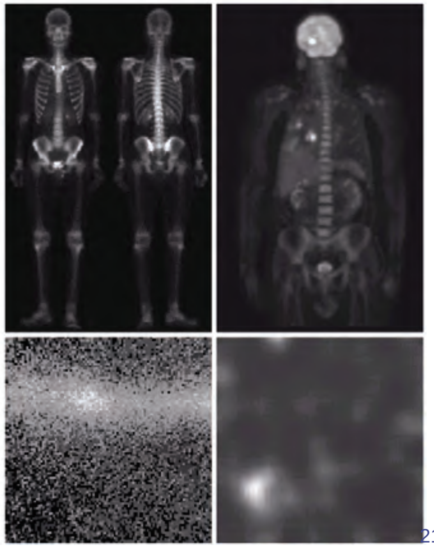
- **Gamma-ray**

Nuclear medicine and astronomical observation

(a) Bone scan
(b) Positron emission tomography (PET) image
(c) Cygnus Loop
(d) Gamma radiation from vacuum tubes of nuclear reactors

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.)



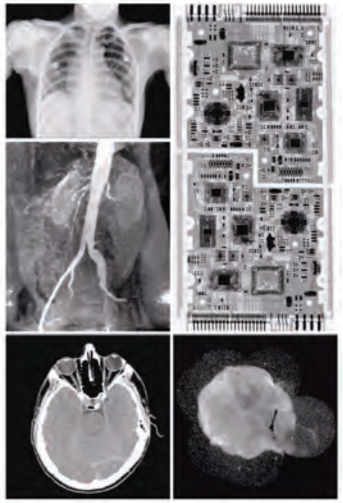
Inject isotopes, decay and emit positrons. When positrons encounter electrons, they annihilate and emit two gamma rays

3. Examples of Fields that Use DIP

- **X-ray**

Medical diagnosis, industry, astronomical observation

(a) Chest X-ray image
(b) Aortic angiogram
(c) Head CT
(d) Circuit board
(e) Cygnus Loop



a d
b
c e

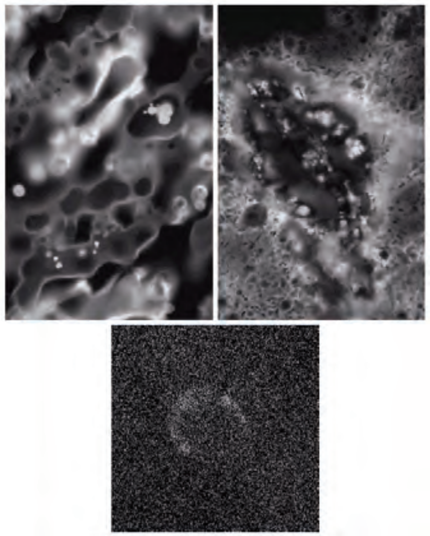
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical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

3. Examples of Fields that Use DIP

- **Ultraviolet imaging**

a b
c

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



Industrial detection, microscope method, laser

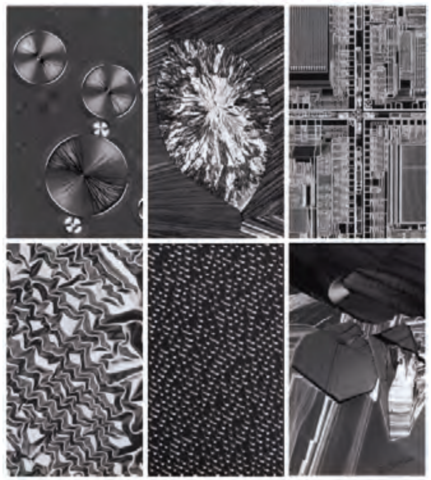
(1) Normal corn
(2) Smut corn
(3) Cygnus Loop

3. Examples of Fields that Use DIP

- **Visible light imaging**

Images obtained by visible light microscope

(1) Taxol (anticancer agent) 250 times
(2) Cholesterol 40 times
(3) Microprocessor 60x
(4) Nickel oxide thin film 600 times
(5) 1750 times the surface of audio CD
(6) Organic superconductivity 450 times



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.)

3. Examples of Fields that Use DIP

Visible light imaging

a b
c
d

FIGURE 1.15 Some additional examples of imaging in the visual 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.)

(a) Fingerprint
(b) Paper currency
(c) Automated license plate reading

3. Examples of Fields that Use DIP

Infrared imaging

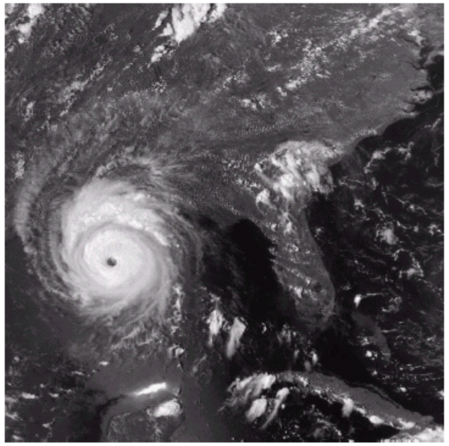


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

The hurricane eye is clearly visible in the image of Hurricane Katrina taken by visible and infrared sensors.

3. Examples of Fields that Use DIP

Infrared imaging

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

Infrared satellite images of America

The infrared imaging system works in the 10 to 13.4 micron band. It can observe the weak near-infrared emission near visible light on the earth's surface

——Calculate the power consumption in different areas

3. Examples of Fields that Use DIP

Infrared imaging

Figure 1.9 infrared temperature detection image

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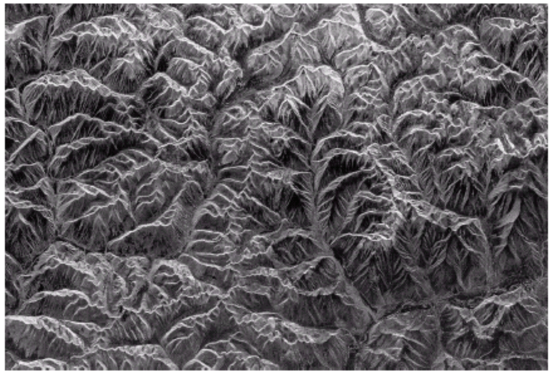
3. Examples of Fields that Use DIP

- **Microwave imaging**

Typical application: radar

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



Advantages: not affected by climate and light conditions, it can penetrate clouds and pass through vegetation, ice and extremely dry areas

The knowledge that can be seen in the radar image is the microwave energy transmitted to the radar antenna.

Detecting areas that are not accessible

Radar images taken by spacecraft in mountainous areas of Southeast Tibet

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3. Examples of Fields that Use DIP

Military application
Target tracking

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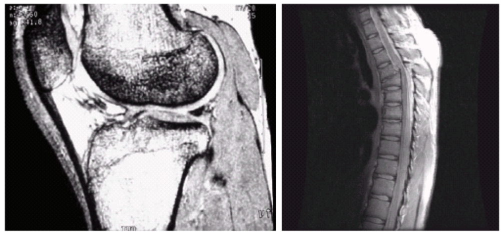
3. Examples of Fields that Use DIP

- **Radio wave imaging: similar to imaging applications at the other end of the spectrum (gamma rays) - medicine and astronomy**



a b (a) Knee (b) spine

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

Magnetic resonance imaging (MRI): place the patient in a strong magnetic field and let a short pulse of radio waves pass through the patient's body. The pulse causes the patient's tissue to emit corresponding radio pulses

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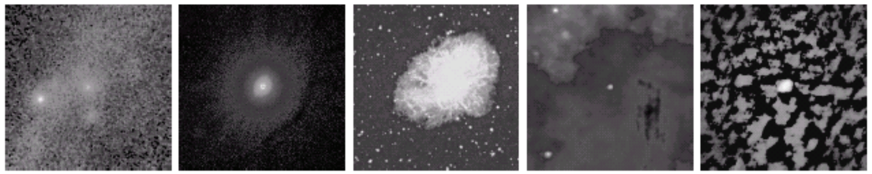
3. Examples of Fields that Use DIP



Gamma X-ray Optical Infrared Radio

FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Each image gives a completely different "view" of the pulsar

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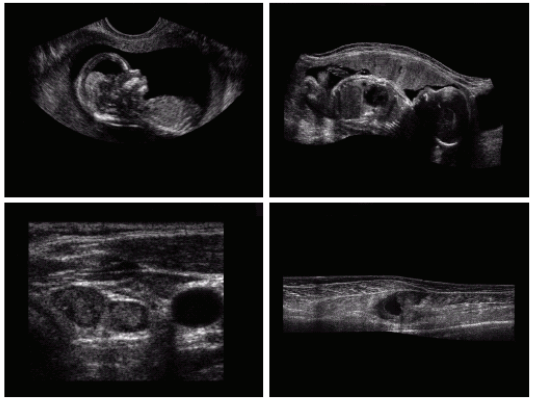
3. Examples of Fields that Use DIP

Ultrasonic (1 to 5MHz) imaging:
Medical field, petroleum exploration

- **Other image imaging methods**



a b
c d

FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Large steel flat plates and large trucks vibrate at a frequency of 100Hz, and the intensity and speed of the returned sound wave are determined by the components below the surface. Sound waves can be processed and analyzed to generate images

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3. Examples of Fields that Use DIP

- **Ultrasound -- Application in Biomedical Engineering**

Figure 1.7 Medical ultrasound imaging

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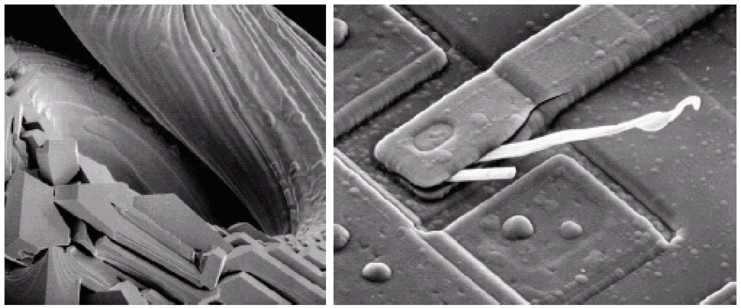
3. Examples of Fields that Use DIP

- **Other imaging methods: electron microscope imaging**



a b

(a) 250 times of tungsten wire damaged by overheating
(b) 2500 times of integrated circuit damaged

The magnification of the optical microscope is limited to about 1000, and the electron microscope can reach 10000 or more.

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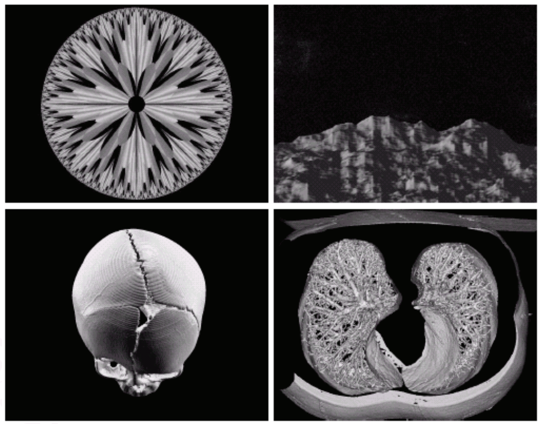
3. Examples of Fields that Use DIP

- **Other image imaging methods: computer generated (not from physical phenomena)**

(a) and (b) fractal images

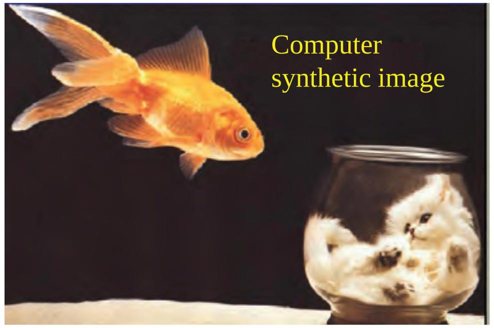
(c) and (d) an image generated from a 3-D computer models



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.)

3. Examples of Fields that Use DIP



4. Fundamental Steps in Digital Image Processing

Textbook Reading

There is no general agreement among authors regarding where image processing stops and other related areas, such as image analysis and computer vision, start. Sometimes a distinction is made by defining image processing as a discipline in which both the input and output of a process are images. We believe this to be a limiting and somewhat artificial boundary. For example, under this definition, even the trivial task of computing the average intensity of an image (which yields a single number) would not be considered an image processing operation. On the other hand, there are fields such as computer vision whose ultimate goal is to use computers to emulate human vision, including learning and being able to make inferences and take actions based on visual inputs. This area itself is a branch of artificial intelligence (AI) whose objective is to emulate human intelligence. The field of AI is in its earliest stages of infancy in terms of development, with progress having been much slower than originally anticipated. The area of image analysis (also called image understanding) is in between image processing and computer vision.

4. Fundamental Steps in Digital Image Processing

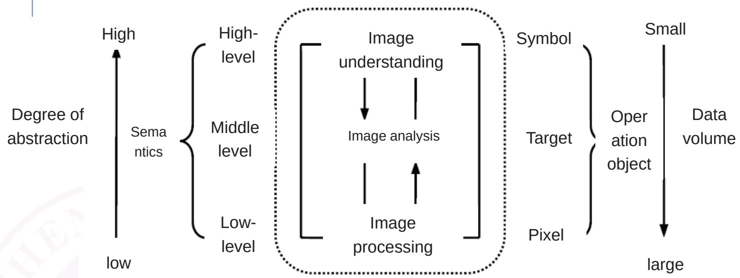
There are no clear-cut boundaries in the continuum from image processing at one end to computer vision at the other. However, one useful paradigm is to consider three types of computerized processes in this continuum: low-, mid-, and high-level processes. Low-level processes involve primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening. A low-level process is characterized by the fact that both its inputs and outputs are images. Mid-level processing on images involves tasks such as segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. A mid-level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects). Finally, higher-level processing involves "making sense" of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cognitive functions normally associated with vision.

Based on the preceding comments, we see that a logical place of overlap between image processing and image analysis is the area of recognition of individual regions or objects in an image. Thus, what we call in this book *digital image processing* encompasses processes whose inputs and outputs are images and, in addition, encompasses processes that extract attributes from images, up to and including the recognition of individual objects. As an illustration to clar-

4. Fundamental Steps in Digital Image Processing

Related fields of image engineering: image analysis and computer vision

- **Low level processing: the input and output are images (such as image scaling and image smoothing)**
- **Intermediate processing: input the image and output the extracted features (such as region segmentation and boundary detection)**
- **Advanced processing: understand and recognize images (e.g. driverless, automatic robot)**



Examples of text recognition

Figure 1.2.1 schematic diagram of three levels of image engineering

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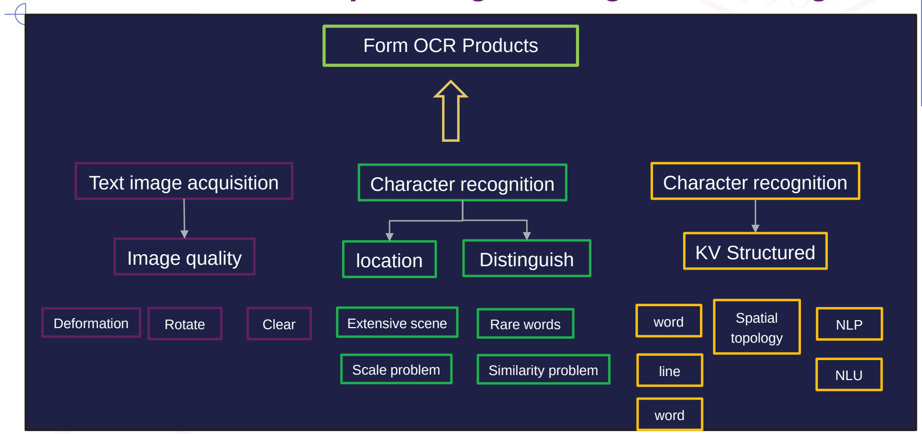
4. Fundamental Steps in Digital Image Processing



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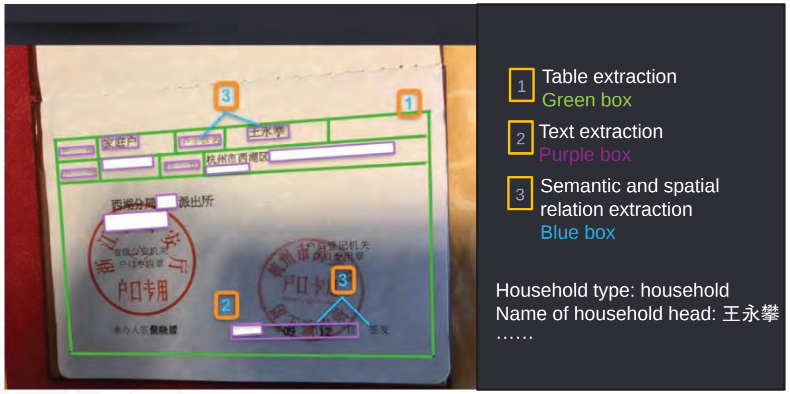
4. Fundamental Steps in Digital Image Processing

- Examples of text recognition



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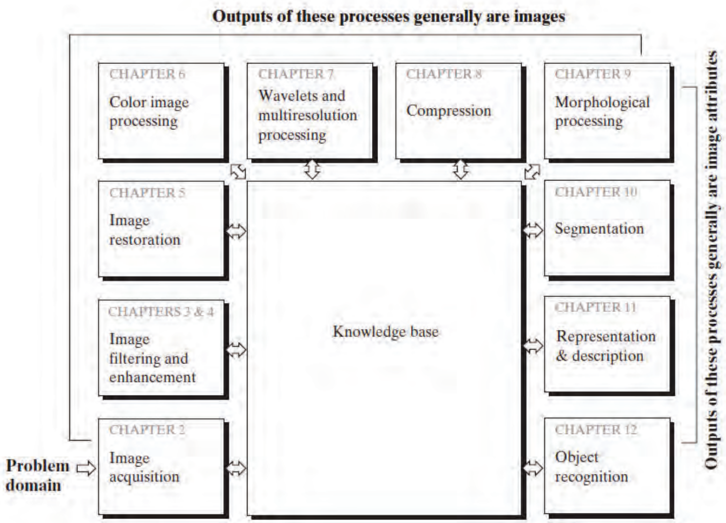
4. Fundamental Steps in Digital Image Processing



Chapter 1 Introduction

5. Components of an Image Processing System

- Composition of digital image processing system

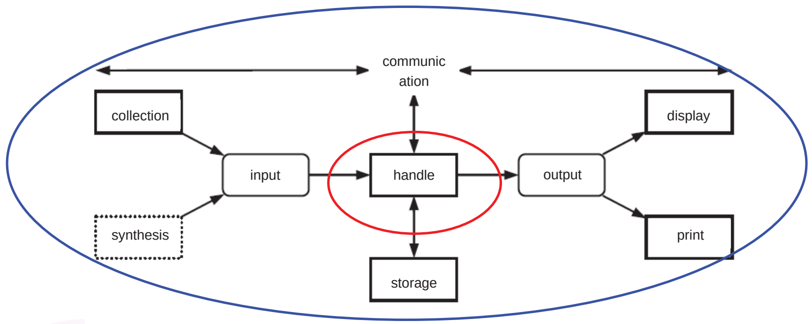


Figure 1.3.1 Schematic diagram of image processing system

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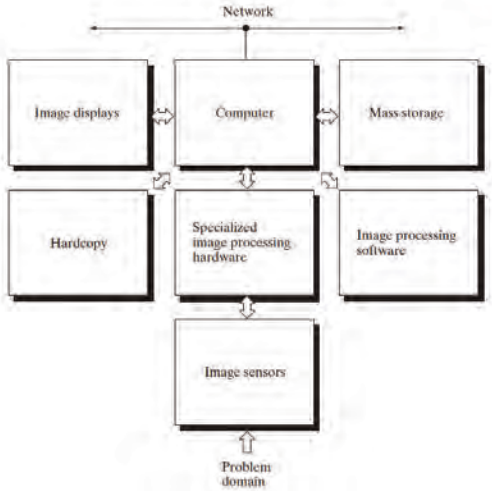
5. Components of an Image Processing System

- Components of a general-purpose image processing system



Chapter 1 Introduction

Summary of this Chapter

- The Concept of DIP
  - Image digitization and its advantages
  - Concepts of pixel, sampling interval and quantization level
- The Origins and Developments of DIP
  - Four main stages and three Nobel Prizes
- Examples of Fields that Use in DIP
  - Classification by electromagnetic wavelength
  - Other imaging methods
- Fundamental Steps and Systems of DIP
  - From the perspective of DIP engineering
  - From the perspective of system

Course Agenda

- Chap2: Digital Image Fundamentals
- Chap3: Intensity Transformations and Spatial Filtering
- Chap4: Filtering in the Frequency Domain
- Chap5: Image Restoration
- Chap8: Image Compression
- Chap9: Morphological Image Processing
- Chap10: Image Segmentation
- Chap6: Color Image Processing

Experiment Schedule

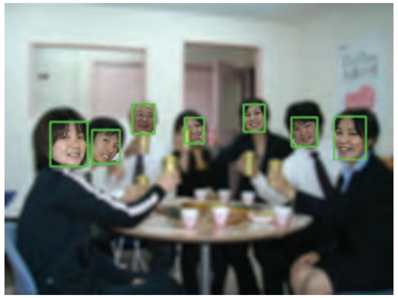
- Exp1: Basic Operations and Algebraic Operators of Digital Images
- Exp 2: Image Intensity Transformations and Spatial Filtering
- Exp 3: Frequency Domain Processing and Image Restoration
- Exp 4: Image Compression
- Exp5: Morphological Image Processing and Image Segmentation

Schedule (Draft)

Date	Week	Content	Experiment/Practice	Schedule
	1			
3/1	2	Course Intro、Chap1、Chap2 + Exp Setting		
3/8	3	Chap2	Exp1	
3/15	4	Chap3	Exp1	Submit Assignment1
3/22	5	Chap3		Submit ExpReport1
3/29	6	Excise/Exp2		
4/5	7	Chap4		Submit ExpReport2
4/12	8	Chap5		
4/19	9	Excise/Exp3		Submit Assignment2
4/26	10	Chap8		Submit ExpReport3
5/3	11	Spring break		
5/10	12	Chap8	Exp4	
5/17	13	Excise/Exp4		
5/24	14	Chap9		Submit ExpReport4
5/31	15	Chap10		Submit Assignment3
6/7	16	Chap6	Exp5	
6/14	17	Excise/Exp5		
6/21	18	Exp5		Submit ExpReport5

Bonus Task

- Exp1: Capture Images by Laptop Camera
- Exp2: Face Detection and Processing
- Exp4: DCT Watermarking
- Exp5: DIP Software with GUI (qt)



Additional Information about DIP

- Organization
  - CSIG：中国图象图形学会
  - CCF：中国计算机学会
  - IEEE Signal Processing Society

Additional Information about DIP

- **Difference between 图象 and 图像**
  https://wenku.baidu.com/view/4187d86acaaedd3383c4d30f.html

总之，“图象”与“图像”上有区别的，区别之处简单点说就是：图象是图形，图像是画面；图象是人为创作，图像是自然再现；图象注重形状、变化趋势，图像注重色彩、整体印象。

Additional Information about DIP

- Conference & Journal

中国计算机学会推荐国际学术期刊

（计算机图形学与多媒体）

一、A 类

序号	刊物简称	刊物名称	出版社	网址
1	TOG	ACM Transactions on Graphics	ACM	http://dblp.uni-trier.de/db/journals/tog/
2	TIP	IEEE Transactions on Image Processing	IEEE	http://dblp.uni-trier.de/db/journals/tip/
3	TVCG	IEEE Transactions on Visualization and Computer Graphics	IEEE	http://dblp.uni-trier.de/db/journals/tvcg/

https://www.ccf.org.cn/Academic_Evaluation/By_category/

Additional Information about DIP

- Conference & Journal

中国计算机学会推荐国际学术会议

（计算机图形学与多媒体）

一、A 类

序号	会议简称	会议名称	出版社	网址
1	ACM MM	ACM International Conference on Multimedia	ACM	http://dblp.uni-trier.de/db/conf/mm/
2	SIGGRAPH	ACM SIGGRAPH Annual Conference	ACM	http://dblp.uni-trier.de/db/conf/siggraph/index.html
3	VR	IEEE Virtual Reality	IEEE	http://dblp.uni-trier.de/db/conf/vr/
4	IEEE VIS	IEEE Visualization Conference	IEEE	http://dblp.uni-trier.de/db/conf/visualization/index.html

https://www.ccf.org.cn/Academic_Evaluation/By_category/

Additional Information about DIP

- IEEE ICIP
- How to download full-paper from IEEE?

Assignment 1

- From IEEE ICIP 2021, select a paper that interests you the most. Give the paper information such as

Y. Wang, Y. -K. Wang, L. Zhang, K. Zhang and Z. Deng, "Extended Dependent Random Access Point Pictures in VVC," *2021 IEEE International Conference on Image Processing (ICIP)*, 2021, pp. 2049-2053, doi: 10.1109/ICIP42928.2021.9506270.

- Answer the question: what is the research scope of this paper and why?

(Scope: Enhancement, Restoration, Compression, Segmentation, Color Processing, Morphological Processing, Image Analysis, Image Understanding, Image Recognition, Computer Vision, etc)

- After reading this paper, write a summary including but not limited to:
  - What is the motivation?
  - How does the proposed method work to address the motivation?
  - How is the performance (especially compared to SOTA)?

Course Evaluation

- Final exam: 40%
- Exp projects: 35% (5 Python Projects)
- Assignments: 15% (3 assignments)
- In-class Performance/Quiz: 10%

Requirement in Experiments

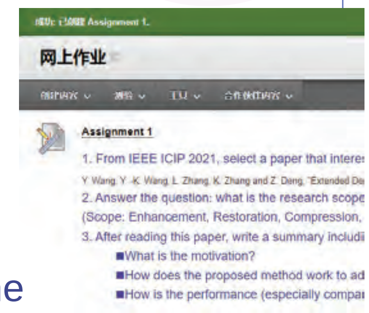
- Programming Enviroment
  - Anaconda + Python 3.8 (recommend)
  - Jupyter Notebook
- Submission
  - ipynb file (including annotation)
  - Exp report (including comments and analysis)
  - Submit it to Blackborad

Exp Evaluation

- Use the report template provided on BB
- Report
  - Correctness: codes and results
  - Conciseness: coding style
  - Completeness: comments and analysis
- Bonus Tasks

Requirement in Assignments

- Written in English with your own words
- Research Paper Reading
  - What is the motivation?
  - How does the proposed method work to address the motivation?
  - How is the performance (especially compared to SOTA)?



How to learn DIP well?

- 纸上得来终觉浅，绝知此事要躬行。

  ——陆游，《冬夜读书示子聿》

- 合抱之木，生于毫末；九层之台，起于累土；千里之行，始于足下。

  ——老子，《道德经》

- 无冥冥之志者无昭昭之明，无惛惛之事者无赫赫之功。

  ——荀子，《劝学》

天道酬勤，付出总有回报