

Digital Image Processing

Chapter 1

Introduction

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介紹
良基
工
江外國
良基



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What is Digital Image Processing

- The elements are referred to as picture elements, image elements, pels, and pixels. (Pixel is the most widely used.)
它影像的一個點。
- The area of image analysis (image understanding) is in between image processing and computer vision.
 - Low level processes:** both inputs and outputs are images.
 - Reduce noise, contrast enhancement 對比 圖像和底 ($input \rightarrow output$) 底和圖 ($output \rightarrow input$)
 - Middle level processes:** the inputs in general are images but its outputs are **attributes extracted from those images** (e.g. edges, contours and objects) 輸出不是一張空圖
 - High level processes:** involves "making sense" of an ensemble of recognized objects. 圖指人臉→人臉特徵

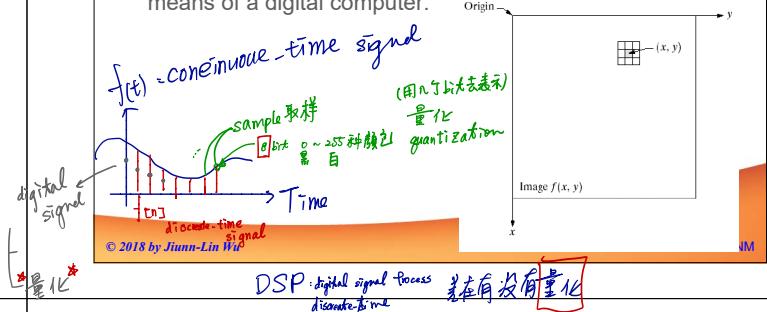
魏謙

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What is Digital Image Processing

- 振幅**
The amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point.
大多用灰
來指「大多用 8 位元
翻譯
- Digital image: x, y, f are finite and discrete quantities.
離散
- Digital image processing: process the digital images by means of a digital computer.



The Origins of Digital Image Processing

- One of the first application of digital image was in the newspaper industry.
 - Specialized printing equipment coded pictures for cable transmission,
 - Then reconstructed them at the receiving end.



FIGURE 1.1 A digital picture produced in 1923 from a coded tape by a telegraph printer with special type faces. (McFarlane.)

FIGURE 1.2 A digital picture made in 1923 from a tape punched after the transatlantic had crossed the Atlantic twice. Some errors are visible. (McFarlane.)

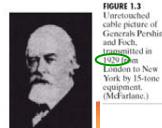


FIGURE 1.3 An encoded cable picture of General Pershing made in 1923 and transmitted in 1927 to New York by 15-line equipment. (McFarlane.)



The origins of Digital Image Processing

- In parallel with space applications, digital image processing techniques began in the late 1960s and early 1970s to be used in **medical imaging**, **remote Earth resources** observations an astronomy. 天文學



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.)

- The invention in the early 1970s of **computerized axial tomography (CT)** is one of the most important events in the application of image processing in **medical diagnosis**.

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Examples of Fields that Use DIP

- Gamma-ray imaging**
 - Most uses of imaging based on gamma rays include nuclear medicine and astronomical observations
 - Images are produced from the emissions collected by gamma ray detectors.



FIGURE 1.4 Examples of gamma-ray imaging. (a) PET scan image. (b) Loops (d) Gamma radiation light spectrum from a radioactive source. (Images courtesy of GE Medical Systems, (a) Dr. Michael E. Cooley, CTI PET Systems, (b) NASA, (c) Professor Zhou Bin, and David K. Weis, University of Michigan.)

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Examples of Fields that Use DIP

- Images based on radiation from the EM spectrum are the most familiar, especially image in the X-ray and visual bands of the spectrum.

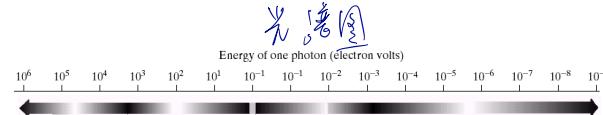
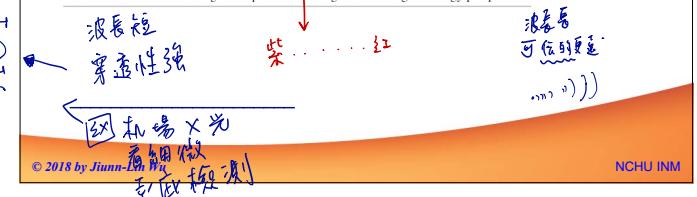


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

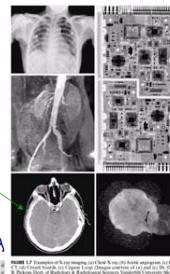


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Examples of Fields that Use DIP

- X-ray imaging**
 - X-rays are among the oldest sources of EM radiation used for imaging.
 - The best known use of X-rays is medical diagnostics.
 - They are used extensively in industry and other areas, like astronomy.
 - CAT (CT) has 3-D capabilities.



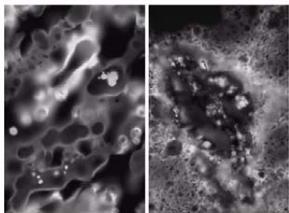
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Examples of Fields that Use DIP

- Imaging in the Ultraviolet band
◆ Ultraviolet light is used in fluorescence microscopy.

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.)



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Examples of Fields that Use DIP

- Imaging in visible and infrared bands
 - ◆ Another major area of visual processing is **remote sensing**, which usually several bands in the visual and infrared regions of the spectrum.
 - ◆ **LANDSAT:**
 - The difference between visual and infrared image features are quite noticeable

TABLE 1
Theoretical
in NAS
LANDS
Availability

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	For measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biosensor and shrubline mapping
5	Middle infrared	1.35–1.75	Moisture content of soil
6	Thermal infrared	10.4–12.5	Sat moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

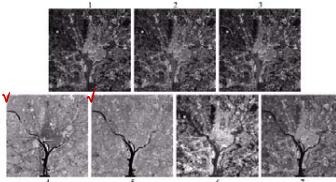


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

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Examples of Fields that Use DIP

- #### ■ Imaging in visible and infrared bands

- ◆ It is the **most familiar** in all our activities.
 - ◆ It is not surprised that imaging in this band outweighs by far all the others in terms of scope of application.

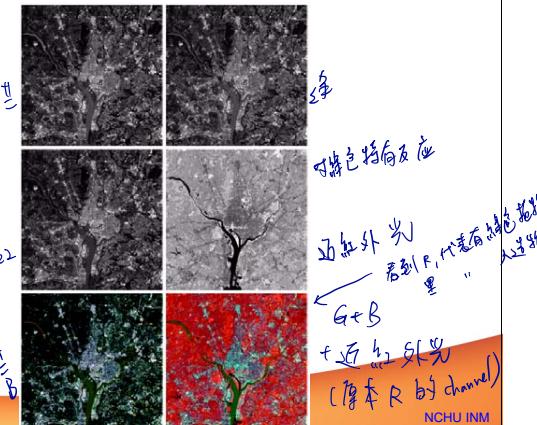
- ◆ Light microscopy:

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醫
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院
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FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250 \times ; (b) Cholesterol—40 \times ; (c) Microprocessor—60 \times ; (d) Nickel thin film—600 \times ; (e) Surface of audio CD—1750 \times ; (f) Organic superconductor—450 \times . (Images courtesy of Carl Zeiss, Inc.)

Multispectral Images



Multispectral Images

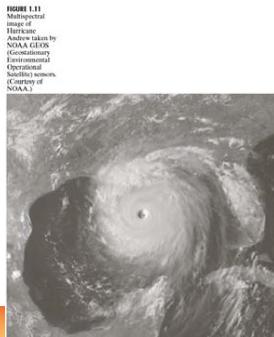
- 中央大學太空及遙測中心從福衛二號衛星影像，比對廬山溫泉區在辛樂克風災前後衛星影像，發現大部分建物被蓋在水位地帶旁。圖中圈出八處土石流嚴重區域，大部分房舍蓋在黃線區水位地上。黃圈即此次倒塌的綺麗飯店。文／洪德宜、圖／中央大學太空及遙測研究中心提供 [\[近紅外光\]](#)



Examples of Fields that Use DIP

- Imaging in visible and infrared bands

◆ Weather observation and prediction also are major application of multi-spectral imaging from satellites.



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Remote Sensing System

- Overview of remote sensing system

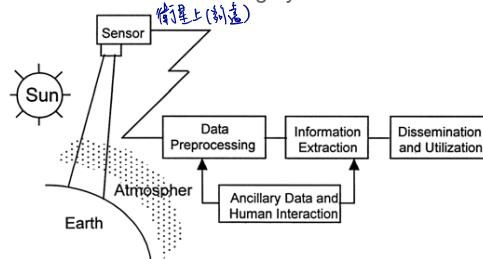


Figure 1-1. An Overview of Remote Sensing System.

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Remote Sensing System 物體識別

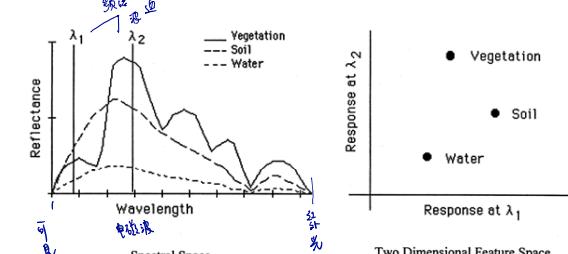


Figure 1-3. Spectral Space and Feature Space Representations of Spectral Responses.

誤讀反應很多
用於辨識

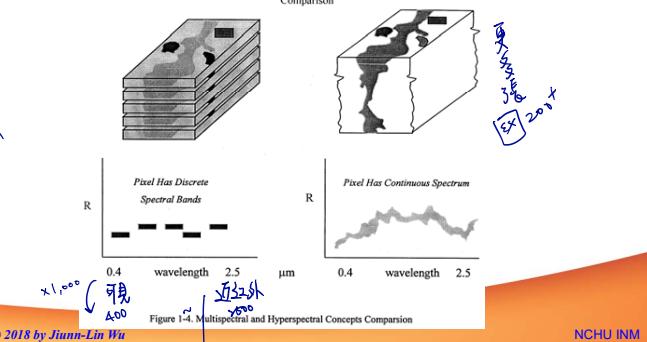
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Remote Sensing System

- Multispectral / Hyperspectral Remote Sensing Data

多光譜影像 高光譜影像
Multispectral / Hyperspectral Comparison



↑ 計算不錯
 $\times 1K \rightarrow 10^6$

福爾摩沙二號-遙測酬載儀器規格

- 全色態(PAN) 0.45~0.90μm

- 多頻譜(MS)

- ◆ 0.45~0.52μm (藍)
- ◆ 0.52~0.60μm (綠)
- ◆ 0.63~0.69μm (紅)
- ◆ 0.76~0.90μm (近紅外線)

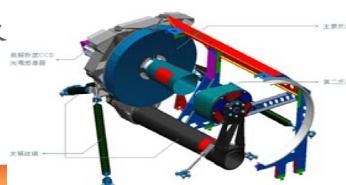
↑ 很滿意
(900多字沒有)

- 遙測對地解析度 全色態(黑白)影像 2公尺

- 多頻譜(彩色)影像 8公尺

- 像幅寬 24公里

- 任務壽命 5年



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福爾摩沙衛星二號

- 為地球遙測應用衛星。

- 重量：742公斤左右（含酬載及燃料）。

- 形狀尺寸：六角柱形，高2.4米，外徑約1.6米（太陽電能板未展開時）。

- 軌道：高度891公里，太陽同步軌道，每日通過台灣上空二次。

- 繞行地球一週時間：約103分鐘。

- 遙測對地解析度：黑白影像2公尺，彩色影像8公尺。
(空間分辨率)

- 影像拍攝範圍 $\geq 24\text{km}$ ；側視角範圍 $\pm 45^\circ$ ，可進行立體攝影。

- 任務壽命：5年。

- 發射日期：2004年5月21日（台北時間）



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福爾摩沙衛星五號

項目	特性說明
衛星種類	為地球遙測應用衛星
重量	475公斤(含酬載及燃料)
形狀尺寸	八角柱形，高的2.8公尺，外徑約1.6公尺
軌道	高度720公里，太陽同步軌道
取像率	每秒1.01次
影像下傳速率	150M位元/秒
取像範圍	正對地表直向，前後各左右各 45°
繞行地球一週時間	約99分鐘
任務壽命	5年
安裝面積	$\leq 2\text{公尺}^2$ (立視地鏡)
安裝面積可供	$\leq 390\text{cm}$ (無地面控制站)
安裝機動性	Roll : $\pm 24^\circ/\text{sec}$; Pitch : $\pm 24^\circ/\text{sec}$; Yaw : $\pm 7^\circ/\text{sec}$
對地解析度	全色: 2公尺(立視地鏡); 彩色: 4公尺(立視地鏡)
列幅	24.5公尺(立視地鏡)
對比傳達函數(CTF)	≥ 0.1 (全色) ≥ 0.2 (藍光、綠光、紅光) ≥ 0.16 (紅外光)
信噪比(SNR)	全色: ≥ 28 B1 (紅光): 95 B2 (綠光): 95 B3 (藍光): 100 B4 (紅外光): 100
遙測軌道工作週期	$\geq 8\%$ (任一軌道)
影像資料儲存	$\geq 80\text{GB}$ 磁元

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MODIS

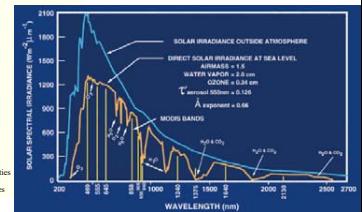
- MODIS (Moderate-resolution Imaging Spectroradiometer) is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite.
- The instruments capture data in **36 spectral bands** ranging in wavelength from $0.4 \mu\text{m}$ to $14.4 \mu\text{m}$ and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km).
- Together the instruments image the entire Earth **every 1 to 2 days**.
- They are designed to provide measurements in **large-scale global dynamics** including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere.

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MODIS Bands

Band # & #	Pixel Resolution (m)	Reflective Bandwidth (nm)	Estimated Bandwidth (nm)	Potential Applications
1	250	620-670		Absolute Land Cover Transformation, Vegetation Chlorophyll
2	250	841-876		Cloud Amount, Vegetation Land Cover Transformation
3	500	459-479		Soil/Vegetation Differences
4	500	545-565		Green Vegetation
5	500	1230-1250		Leaf Canopy Differences
6	500	1628-1652		Snow/Cloud Differences
7	500	2105-2155		Cloud Properties, Land Properties
8	1000	405-420		Chlorophyll
9	1000	438-448		Chlorophyll
10	1000	483-493		Chlorophyll
11	1000	526-536		Chlorophyll
12	1000	546-556		Sediments
13b	1000	662-672		Atmosphere, Sediments
13l	1000	662-672		Atmosphere, Sediments
14b	1000	673-683		Chlorophyll Fluorescence
14l	1000	673-683		Chlorophyll Fluorescence
15	1000	743-753		Aerosol Properties
16	1000	862-877		Aerosol Properties, Atmospheric Properties
17	1000	890-920		Atmospheric Properties, Cloud Properties

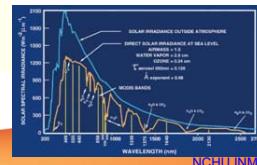


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MODIS Bands

18	1000	931-941	Atmospheric Properties, Cloud Properties
19	1000	915-965	Atmospheric Properties, Cloud Properties
20	1000	3,660-3,840	Sea Surface Temperature
21	1000	3,929-3,989	Forest Fires & Volcanoes
22	1000	3,929-3,989	Cloud Temperature, Surface Temperature
23	1000	4,020-4,080	Cloud Temperature, Surface Temperature
24	1000	4,433-4,498	Cloud Fraction, Troposphere Temperature
25	1000	4,482-4,549	Cloud Fraction, Troposphere Temperature
26	1000	1360-1390	Cloud Fraction (Thin Cirrus), Troposphere Temperature
27	1000	6,535-6,895	Mid Troposphere Humidity
28	1000	7,175-7,475	Upper Troposphere Humidity
29	1000	8,400-8,700	Surface Temperature
30	1000	9,580-9,880	Total Ozone
31	1000	10,780-11,280	Cloud Temperature, Forest Fires & Volcanoes, Surface Temp.
32	1000	11,770-12,270	Cloud Height, Forest Fires & Volcanoes, Surface Temperature
33	1000	13,185-13,485	Cloud Fraction, Cloud Height
34	1000	13,485-13,785	Cloud Fraction, Cloud Height
35	1000	13,785-14,085	Cloud Fraction, Cloud Height
36	1000	14,085-14,385	Cloud Fraction, Cloud Height



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MODIS TrueColor Image



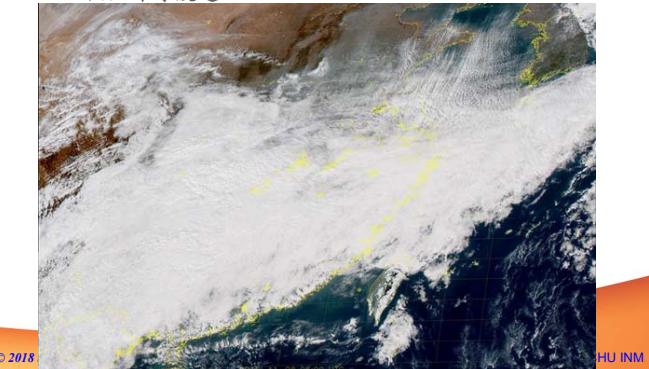
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向日葵衛星

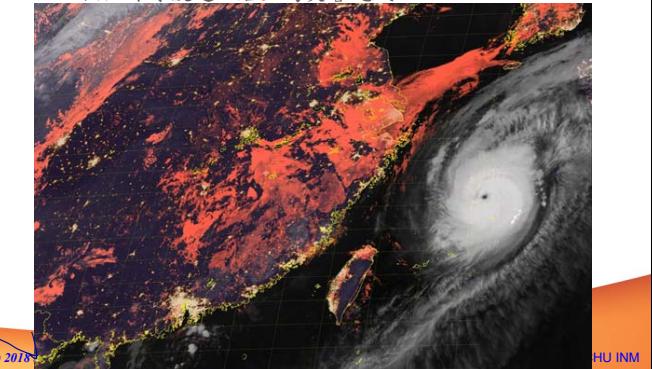
Windy.com
風速小於

- 該衛星共有16波道，包含了3個可見光波道、3個近紅外波道、10個紅外線波道。



向日葵衛星

- 該衛星共有16波道，包含了3個可見光波道、3個近紅外波道、10個紅外線波道。右上為芙蓉颱風。



Examples of Fields that Use DIP

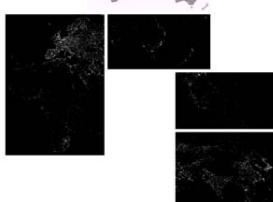
- Imaging in visible and infrared bands

- Infrared image:

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



FIGURE 1.13 Infrared satellite images of the remaining non-American part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)



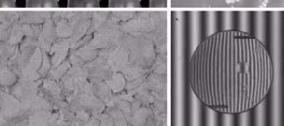
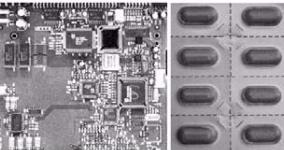
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Examples of Fields that Use DIP

- Imaging in visible and infrared bands



FIGURE 1.14 Some examples of manufactured goods often examined using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bubbles in clear plastic products. (d) Cereals. (e) Intracardiac implants. (Fig. 1 courtesy of Mr. Pete Sines, Perceptics Corporation.)



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Examples of Fields that Use DIP

■ Imaging in visible and infrared bands



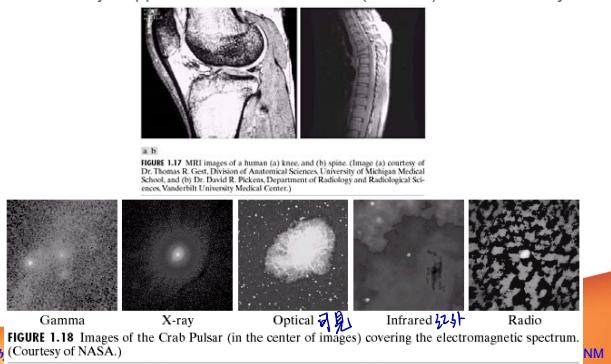
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FIGURE 1.15 Some additional examples of imaging in the visible spectrum.
(a) Thumb print.
(b) Paper
curling.
(c) and
(d) Automobile license plate
reading. (Figure
(a) courtesy of the
National Institute
of Standards and
Technology.
Figures (c) and
(d)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

Examples of Fields that Use DIP

■ Imaging in the radio band

- ◆ The major applications are in medicine (ex. **MRI**) and astronomy.



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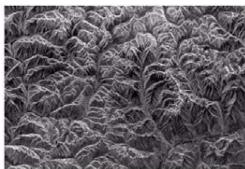
FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Department of Anatomical Sciences, University of Michigan Medical School; Image (b) courtesy of David R. Pogue, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Examples of Fields that Use DIP

■ Imaging in the microwave band

- ◆ The dominant application is radar.
- ◆ The unique feature is its ability to collect data over virtually any region at any time, regardless of weather or ambient light condition.

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



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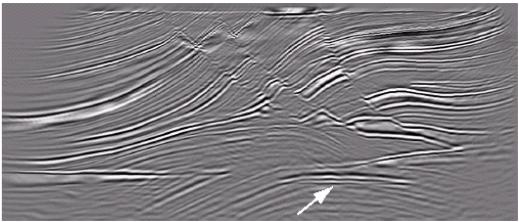
Examples of Fields that Use DIP

■ Examples in which other imaging modalities are used

- ◆ Acoustic imaging, electron microscopy and synthetic imaging 超声波

- Imaging using “sound” finds applications in geological exploration, industry and medicine.

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.)



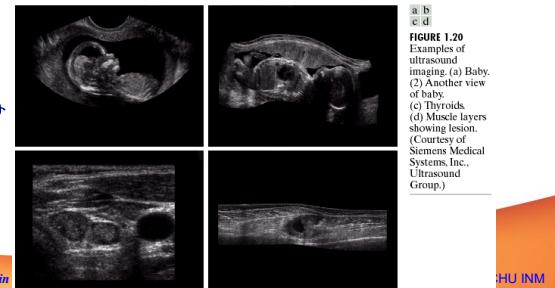
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Examples of Fields that Use DIP

- Examples in which other imaging modalities are used
 - ◆ Although ultrasound imaging is used routinely in manufacturing, the best known applications of this technique are in medicine, especially in obstetrics, where unborn babies are imaged to determine the health of their development.

生物
材料
的
固
化
與
成
像

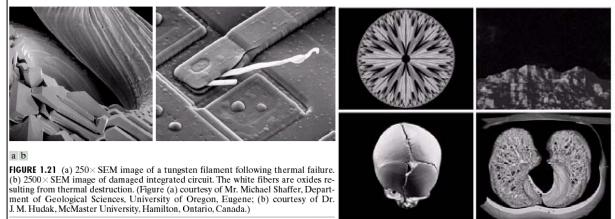


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Examples of Fields that Use DIP

- Examples in which other imaging modalities are used
 - ◆ Electron microscopy
 - ◆ Synthetic (CG) imaging

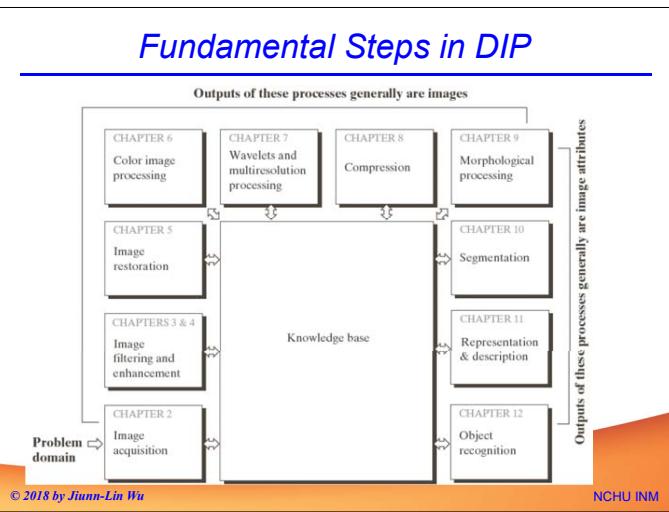


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Fundamental Steps in DIP

Outputs of these processes generally are images

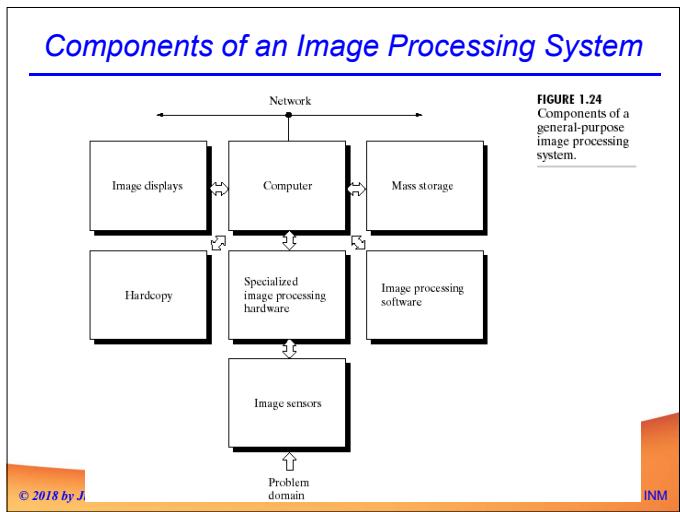


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Components of an Image Processing System

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



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