Digital Image Processing

CHAP. 01

Introduction

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Objectives

1. To define the scope of image processing
2. To give a historical perspective of image processing
3. To give an idea of the state of the art in image processing
4. To discuss the principal approaches
5. To give an overview of the components in a typical, general-purpose image processing system
6. To provide direction to the books and other literature

Digital Image ?

- 영상을 숫자로 표현
  - Numeric processor VS. Symbolic processor
- 2차원 함수 f(x,y)로 정의
  - f(): Intensity or gray level at 2-D spatial coordinate (x,y)
- Digital image
  - f, x, y가 이산값(discrete value)일 때
- Pixel or pel (화소)
  - Picture element of digital image

Human vision VS. Computer vision

- Human vision
  - 가장 진화된 감각기관
  - 사람의 인지 과정에 가장 중요한 역할
  - Limited to the visual band of the electromagnetic spectrum
    - 가시광선 대역
- Computer vision
  - To emulate human vision by using computer
  - Covers almost the entire EM spectrum ranging from gamma to radio waves
  - A branch of Artificial Intelligence
    - C.f Natural Language Understanding, Expert System

Image processing VS. Computer vision

- No clear-cut boundaries in the continuum from image processing at one end to computer vision at the other
  - Image processing 과 Computer vision 을 나눈 명확한 경계 X
- Image analysis (AKA image understanding) is in between image processing and computer vision

Types of processes

- Low-level processing
  - Involves primitive operation
  - 입력과 출력이 모두 영상
  - Eg. Noise reduction, Contrast enhancement, image sharpening
- Mid-level processing
  - Involves some tasks
  - 입력은 영상, 출력은 영상에서 추출한 속성
    - Example of attributes: edge, contour, identity of objects
  - Eg. Segmentation, Description, Classification
- High-level processing
  - Involves "making sense" of an ensemble of recognized objects performing the cognitive functions

Digital image in Newspaper

- One of 1st application of digital image
- Bartlane cable transmission system (1921)
  - London과 New York사이의 해저 cable
  - 전송시간을 3시간 이내로 단축
  - Gray level: 5 levels ⇨ 15 levels (1929)

Digital picture with special type faces (1921)

Improved digital picture (1922)

Digital picture with 15 grey levels (1929)

Advances in Digital computer (1)

- Two key concepts of modern computer
  - Introduced by John von Neumann (1940s)
  1. Memory to hold stored program and data
  2. Conditional branch
- Key advances that led to modern computer
  1. The invention of the transistor at Bell Lab. (1948) : switching
  2. The development of the high-level programming language COBOL and FORTRAN (1950s, 1960s)
  3. The invention of integrated circuit at Texas Instruments (1958)
  4. The development of operating system (1960s)
  5. The development of the microprocessor by Intel (1970s)
  6. Introduction of personal computer (1981)

Advances in Digital computer (2)

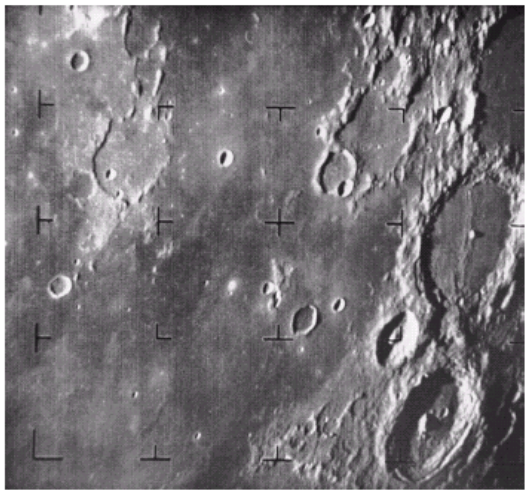
- Key advances that led to modern computer (continued)

  7. The progressive miniaturization of components
     - Large scale integration (late 1970s)
     - Very large scale integration (1980s)
     - Ultra large scale integration (present)

- Fundamental requirements for image processing system
  - Mass storage
  - Display system
  - Fast processor

Digital image processing begins

- Early 1960s
  - 영상처리가 가능한 컴퓨터의 출현
  - 우주탐사선에서 전송한 사진의 처리
- Jet Propulsion Laboratory (1964)
  - Ranger 7에서 전송된 달 사진의 개선
  - Space programs
    - Surveyor: 달 탐사
    - Mariner: 화성 탐사
    - Apollo: 유인 달 탐사
- Late 1960s and early 1970s
  - 의료 영상, 원격 관측, 천문학 등에 응용



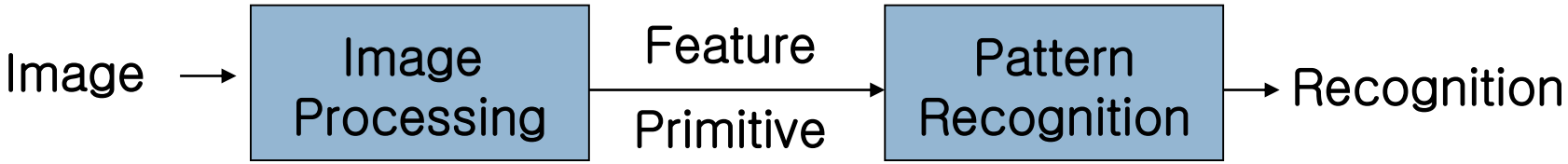
Ranger 7에서 전송된
최초의 달 사진
(1964.7.31)

Application areas – image enhancement

화질 개선

- Space program
- Medicine
  - Computerized Tomography
- Geography
  - To study pollution patterns from aerial and satellite imagery
  - Image enhancement and restoration procedure are used to process degraded images of unrecoverable objects or experimental results too expensive to duplicate
- Archeology (고고학)
  - Successful restoration of blurred pictures that were the only available records of rare artifacts lost or damaged after being photographed
- Astronomy, Biology, Nuclear Medicine, Law Enforcement, Defense, Industrial application, so on

Application areas – machine perception



- Character recognition
- Machine vision for inspection
- Military recognizance
- Automatic processing of fingerprints
- Machine processing of aerial and satellite imagery, etc.

Electromagnetic spectrum

- Electromagnetic waves
  - can be conceptualized as propagating sinusoidal waves of varying wavelengths
  - Or, can be thought of as a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light

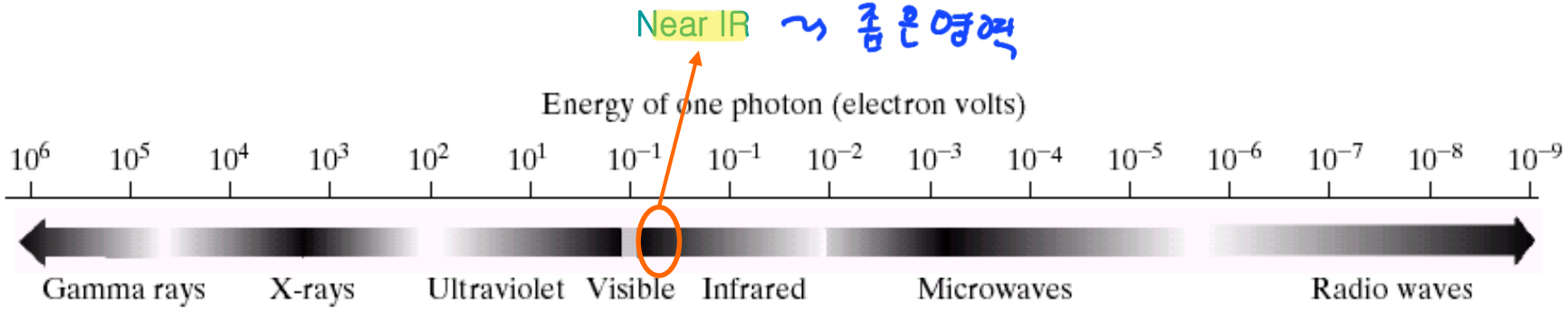


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Gamma-ray imaging

- 핵 의학 (nuclear medicine)
  - 감마선을 방출하는 방사선 동위원소를 체내에 주입

  a) Bone scan

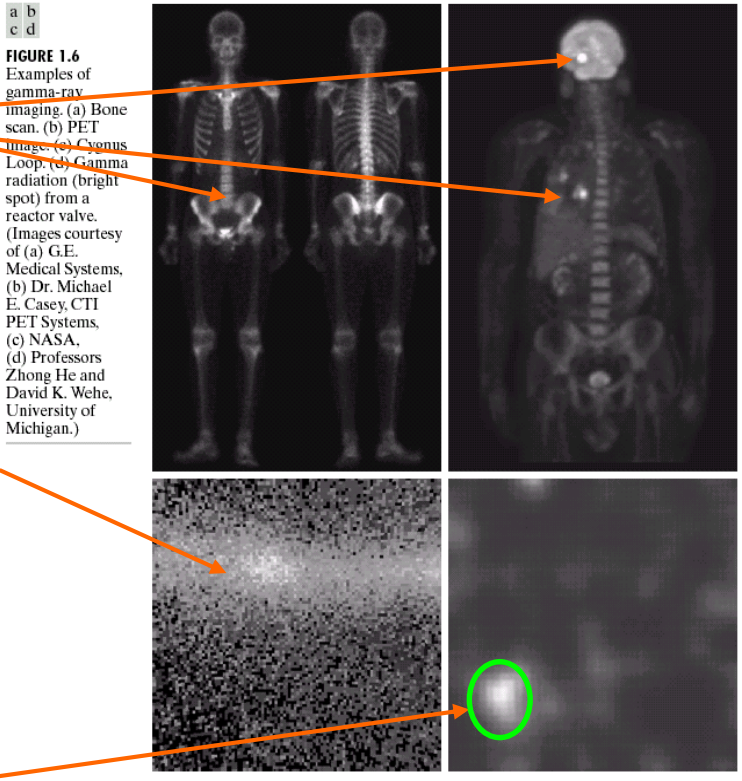
  b) PET 영상 : 뇌와 폐에 종양

  (positron emission tomography)

- 천문관측 (astronomical observation)
  - 자연상태에서 방출되는 감마선 영상

  c) 백조좌 (Cygnus loop)
    - 고열의 개스 구름
    - 15000년 전 폭발

  d) 원자로 내 밸브의 감마선 방출



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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.)

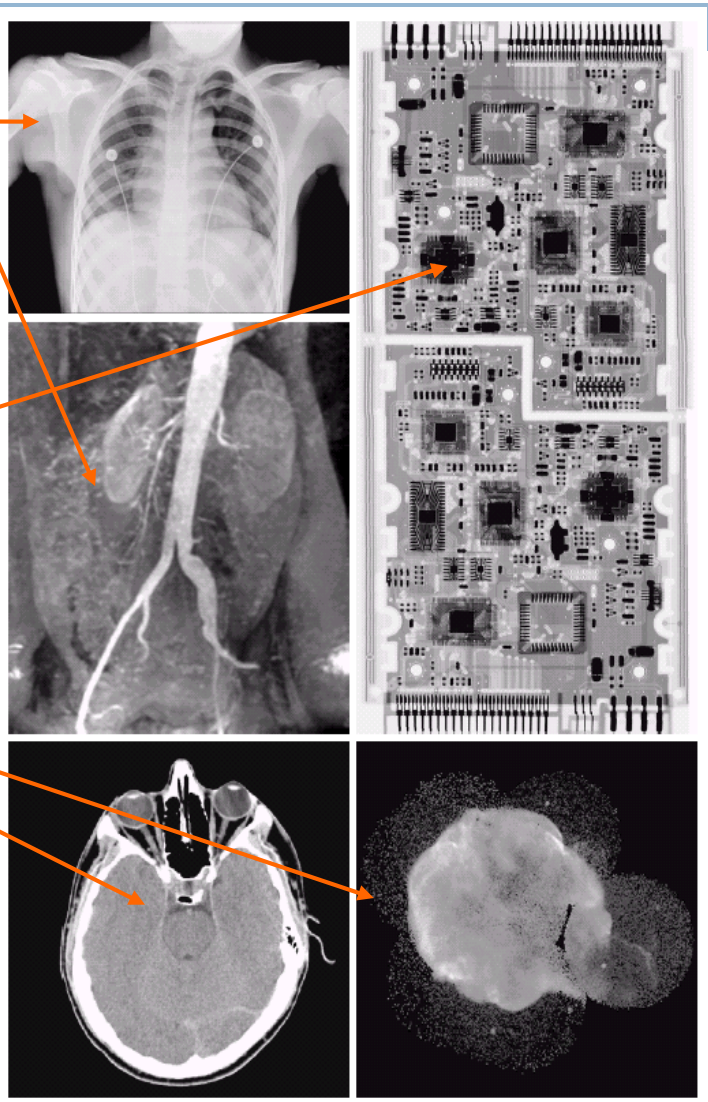
X-ray imaging (1)

- The oldest source of EM radiation for imaging
- 의료진단, 산업, 천문학

- X-ray의 발생 원리
  - 진공관의 cathod를 가열하면, 자유전자가 여기
  - Anode (양전하)를 향하여 고속으로 날아감
  - 핵과 충돌하여 X-ray를 방출
- Digital radiography
  - Digitizing X-ray film
  - 또는 피사체를 투과한 X-ray를 light로 변환한 후 light를 digitizing

X-ray imaging (2)

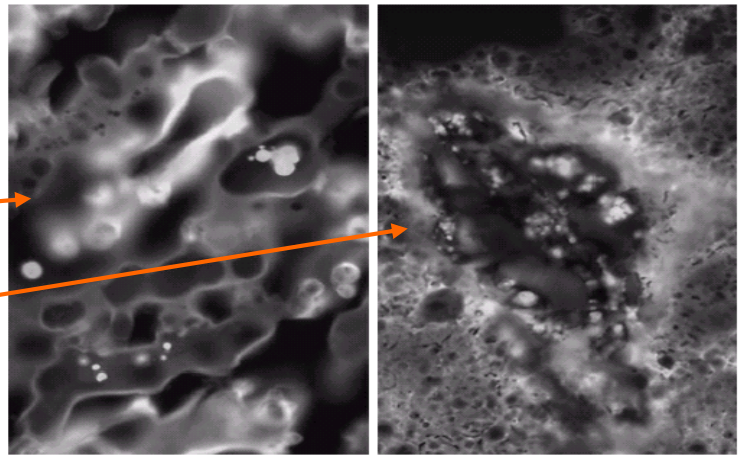
- Chest X-ray
- Aortic angiogram(대동맥 혈관촬영)
  - Angiogram of blood vessel
  - Enhance contrast of blood vessel
- Head CT
- Circuit board
- Cygnus loop in X-ray band



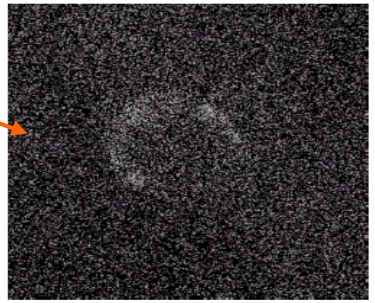
Imaging in Ultraviolet band

- 자외선 자체는 보이지 않으나 형광물질에 조사되면 가시광선 (red)을 방출
- Lithography, fluorescence microscopy, laser, industrial inspection, biological imaging, 천문관측 등에 응용

- Fluorescence microscopy imaging
  - 정상 옥수수
  - 깜부기병에 감염된 옥수수



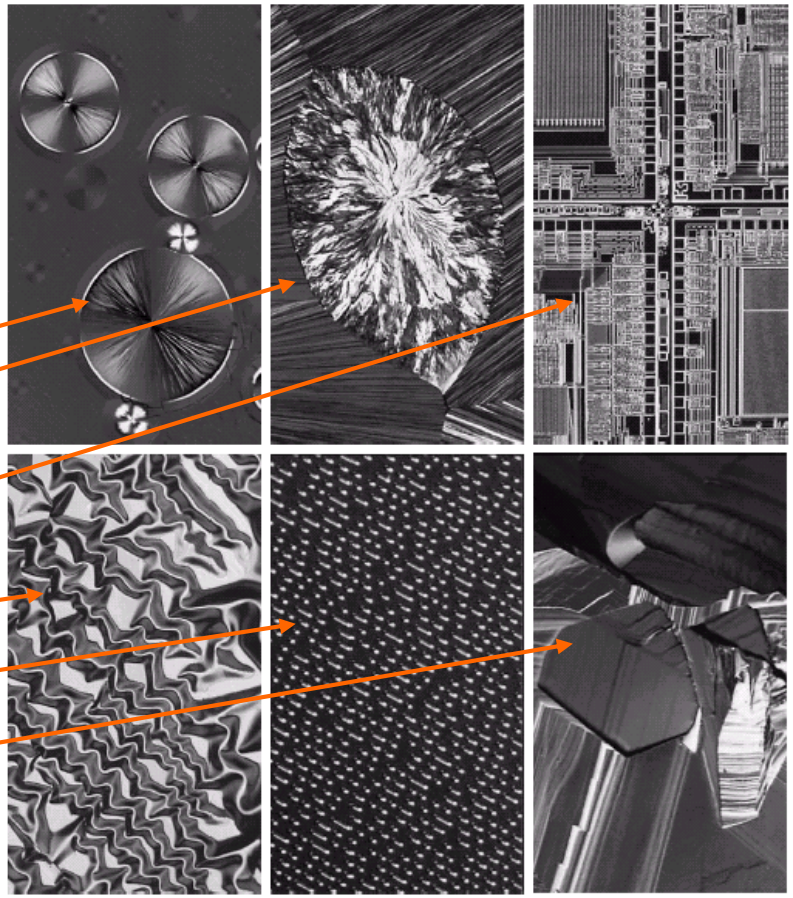
- Cygnus loop in Ultraviolet band



Imaging in Visible and Infrared bands

- 광학현미경, remote sensing 등 응용

- Optical microscopy imaging
  - 250배 Taxol (항암제)
  - 40배 Cholesterol
  - 60배 Microprocessor
  - 600배 Thin film
  - 250배 CD 표면
  - 250배 초전도체



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.)

LANDSAT Imagery (1)

- LANDSAT (위성)
  - Satellite for monitoring environmental conditions on the planet
  - 지구 환경 감시, 수해 예방 등을 위한 지표 사진
- Multispectral imaging

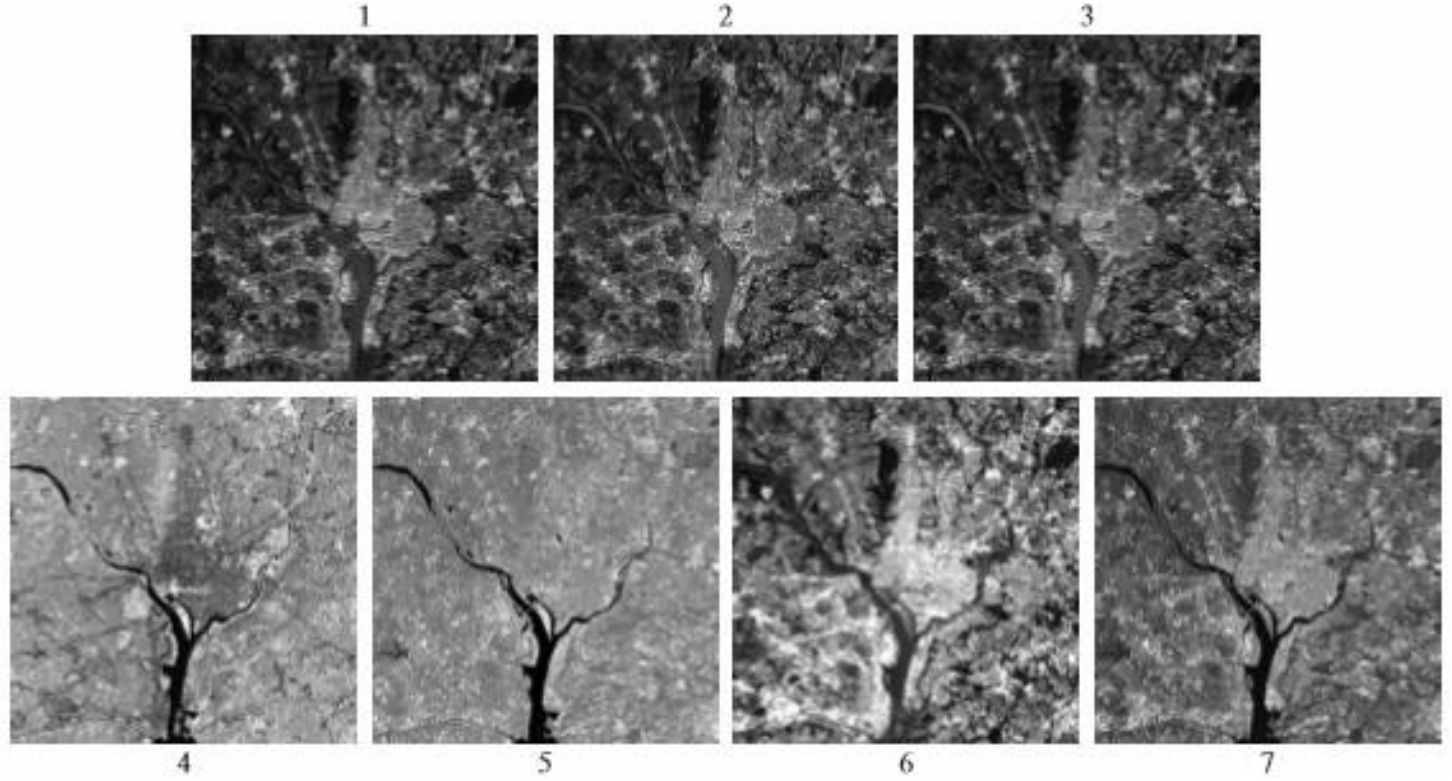
TABLE 1.1 Thematic bands in NASA's LANDSAT satellite.

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	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

LANDSAT Imagery (2)

- LANDSAT images of the Washington D.C. area

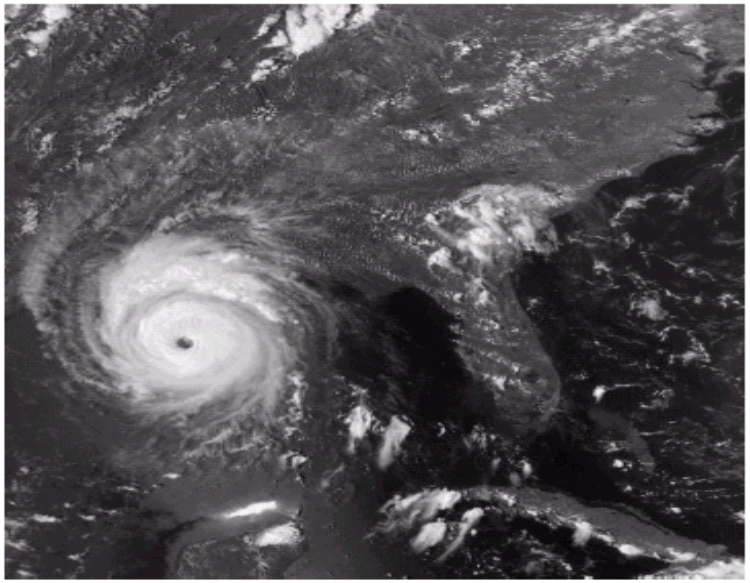
visible blue visible green visible red



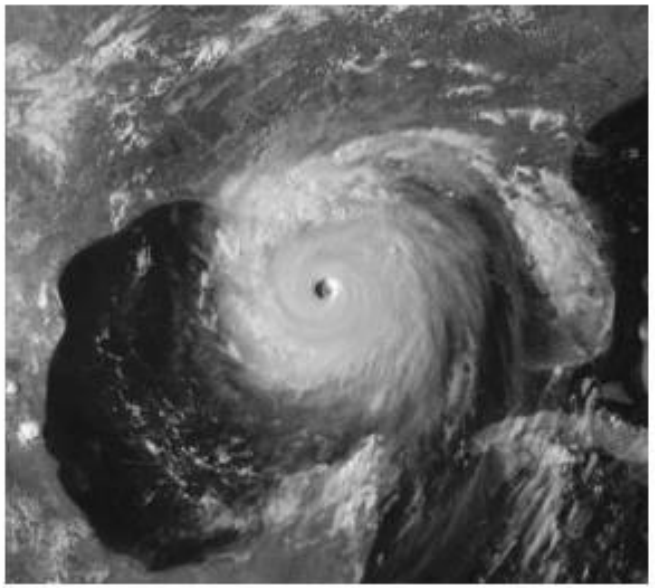
near infrared middle infrared thermal infrared middle infrared

NOAA satellite imagery (1)

- National Oceanographic and Atmospheric Administration
- Satellite for weather observation and prediction
- Multispectral imaging (visible and infrared bands)



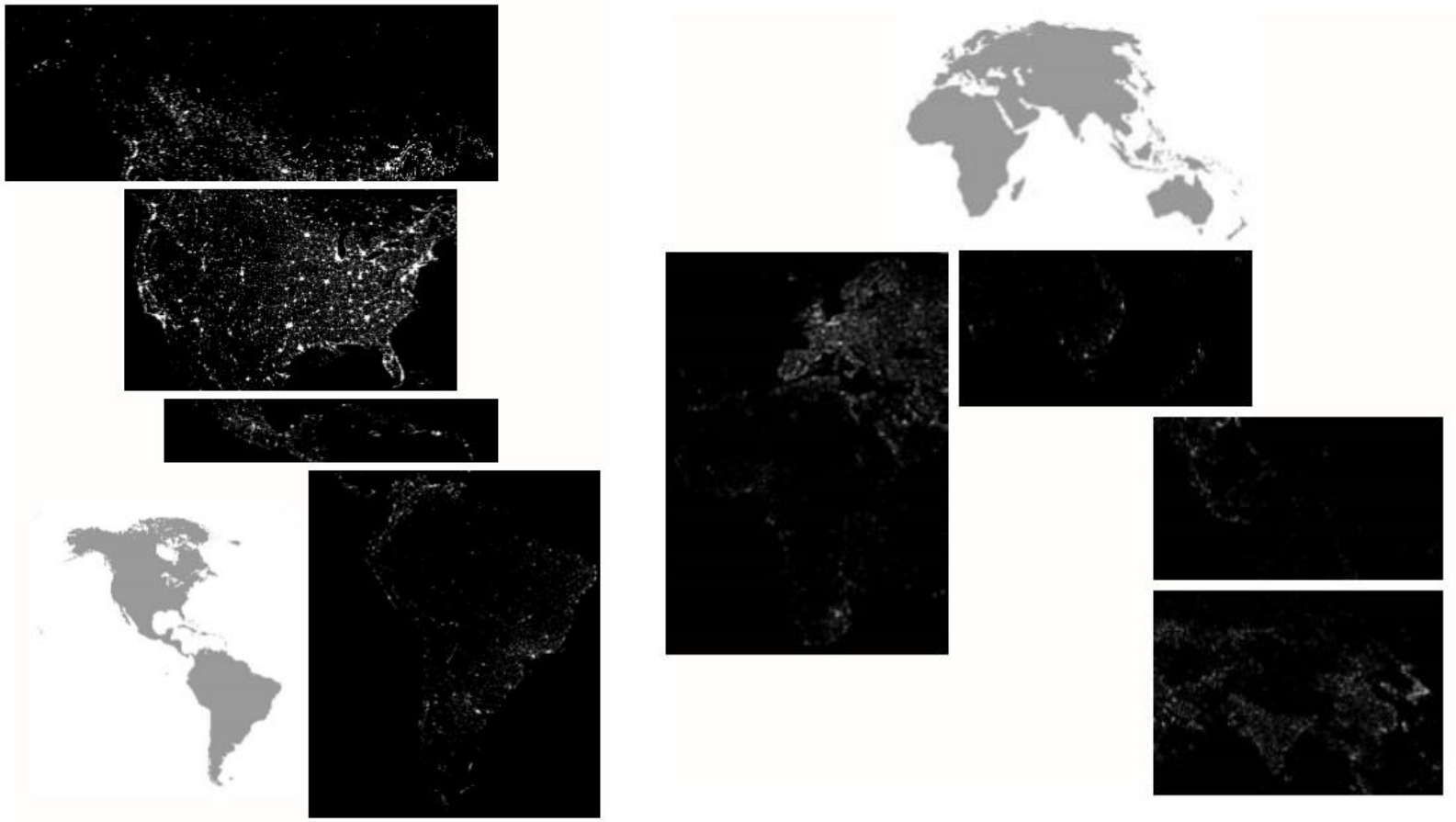
Satellite image of
Hurricane Andrew



Satellite image of
Hurricane Katrina

NOAA satellite imagery (2)

- Nighttime Lights of the World
  - Infrared image providing a global inventory of human settlements



Automated visual inspection (1)

- Missing part, 외관 결함 등을 검사
  - Controller board
    - Missing parts
  - Packaged pills
    - Missing pill
  - Bottle
    - 충진 여부
  - Bubbles in plastic
  - Cereal
    - Burned flake
  - Intraocular implant
    - Lens deformation

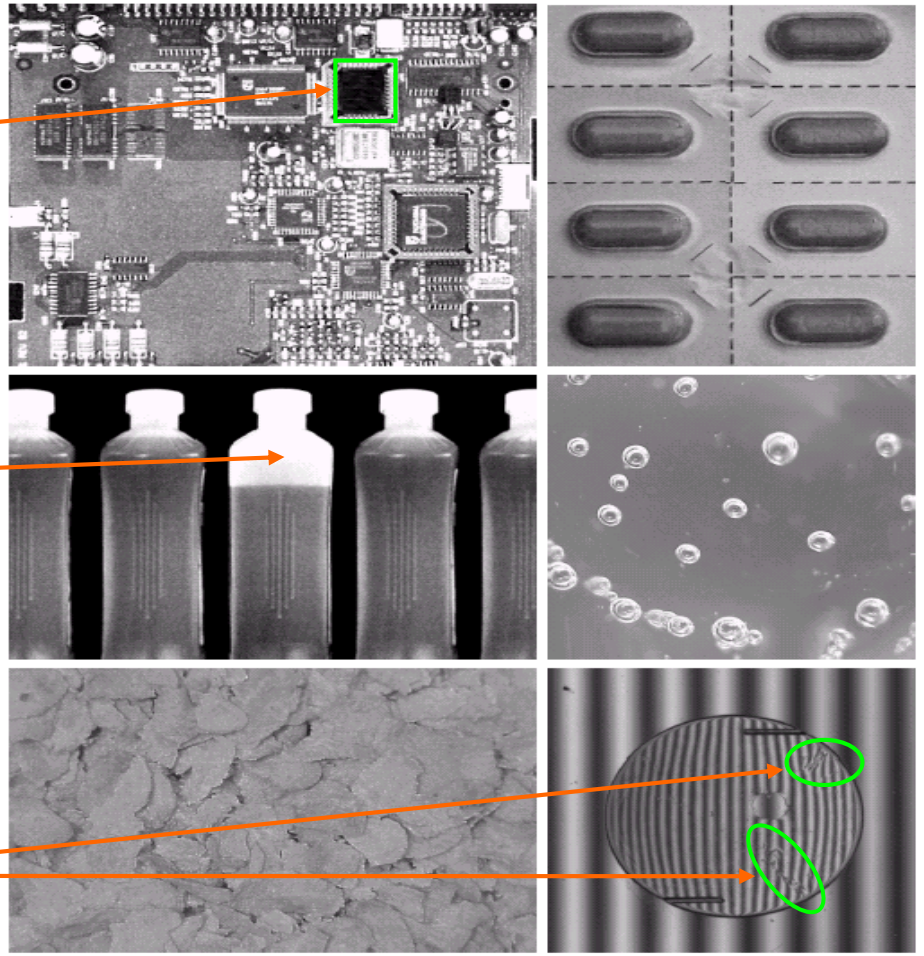


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FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig.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

Automated visual inspection (2)

- Identification, or Recognition
  - Fingerprint
    - Identification
    - Law enforcement
  - Paper currency
    - Automated counting
    - 일련번호 인식
  - License plate
    - Traffic monitor
    - surveillance

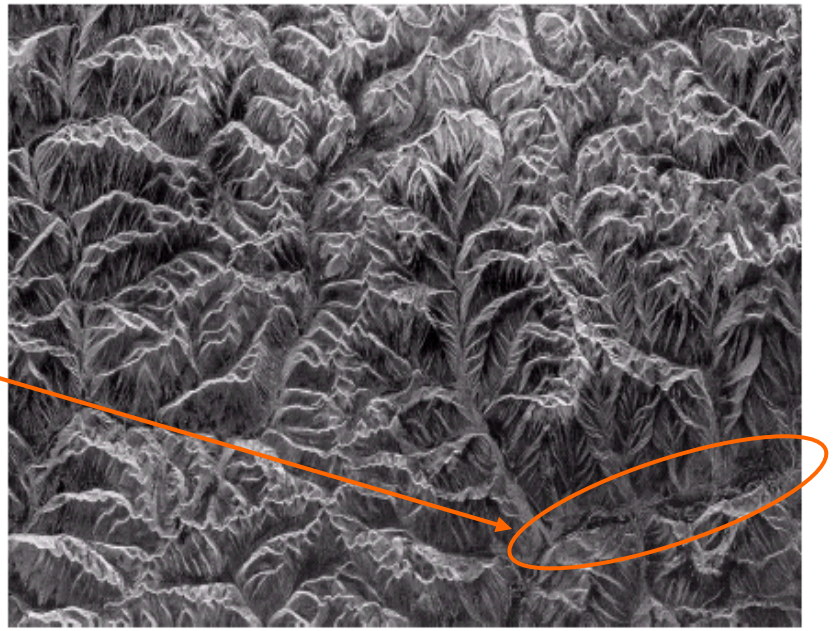
a b
c
d

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.)

Imaging in the microwave band

- Radar
  - Dominant application of imaging in microwave band
  - Only way to explore inaccessible regions of the Earth's surface regardless if weather or ambient lighting conditions
  - Spaceborne radar image of southeast Tibet

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



Imaging in the radio band (1)

- Major application
  - Medicine
    - Eg. Magnetic Resonance Imaging
  - Astronomy

MRI images of human knee spine

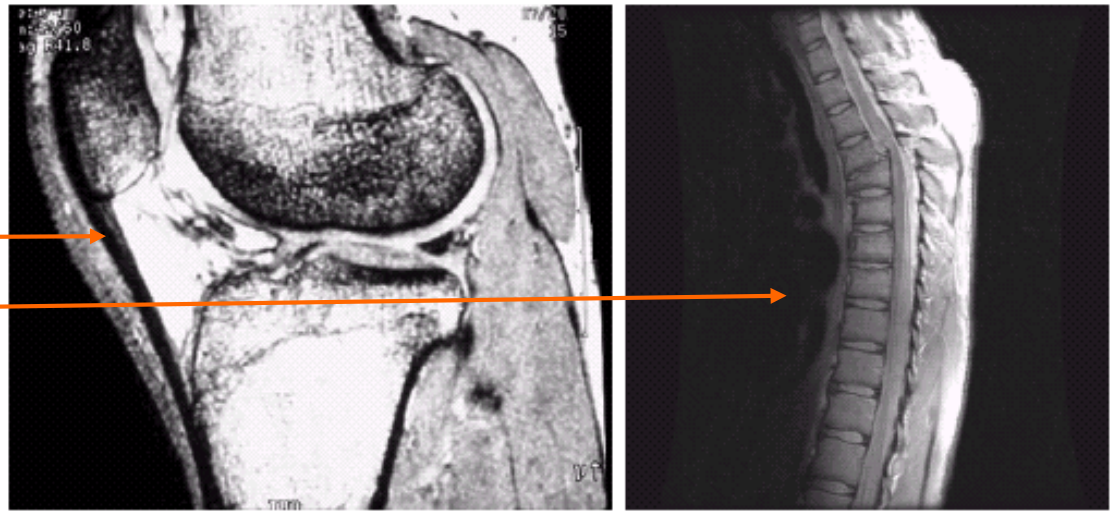


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FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences,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

Imaging in the radio band (2)

- Major application
  - Medicine
    - Eg. Magnetic Resonance Imaging
  - Astronomy

Images of Crab pulsar (맥동성)

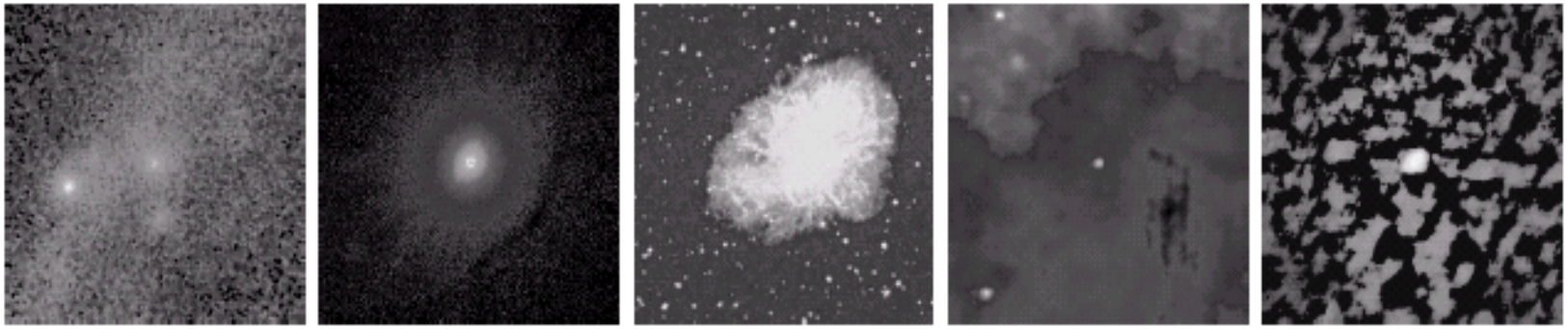
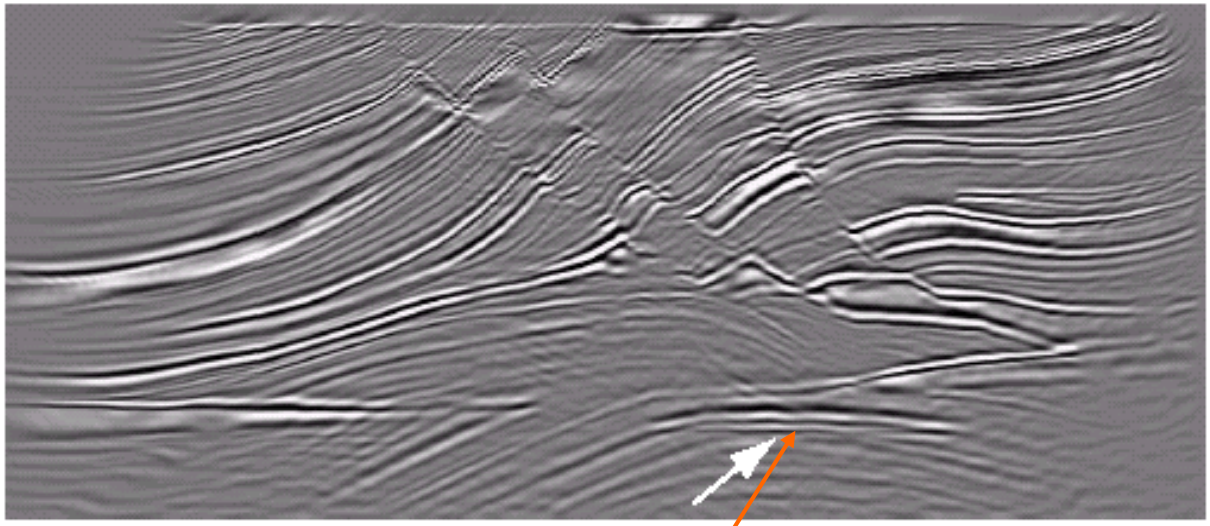


FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Acoustic imaging (1)

- Acoustic imaging
  - 저주파(수백 Hz): 광물 및 석유 탐사
  - 초음파(수백만 Hz): 산업 응용 및 의료 응용

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.)



Cross-sectional image of a seismic model

Hydrocarbon trap

Acoustic imaging (2)

- Ultrasound imaging
  - 1~5 MHz sound pulse

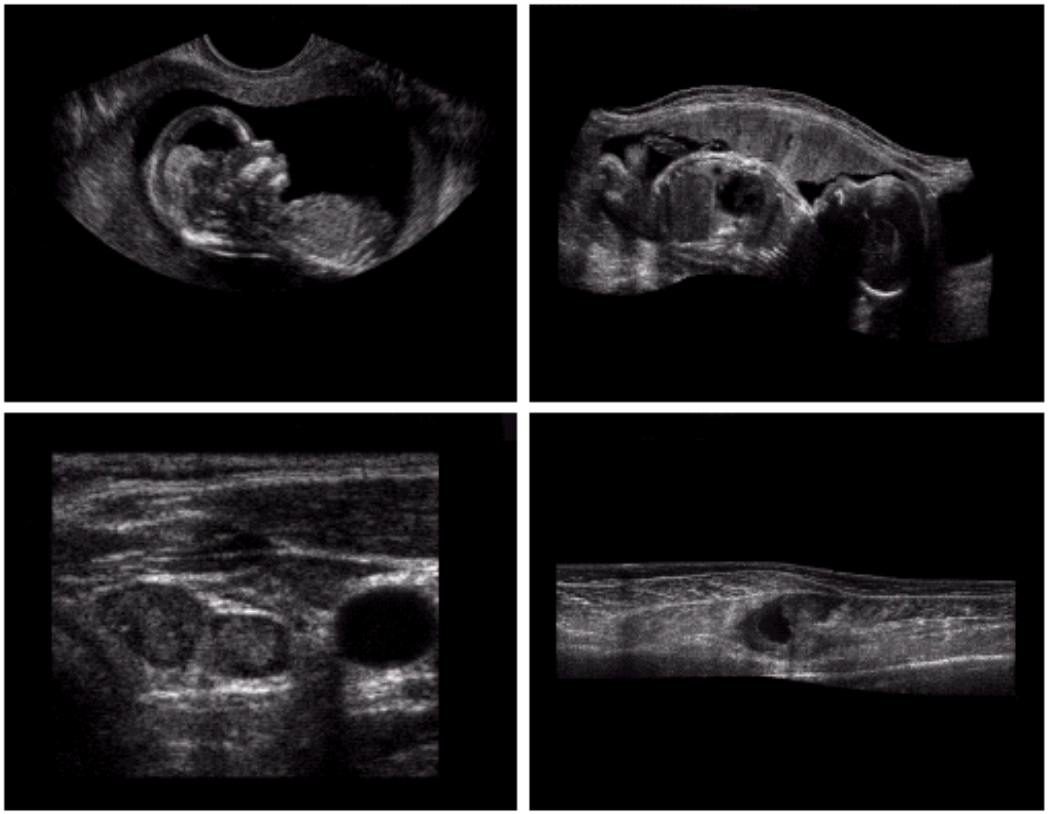


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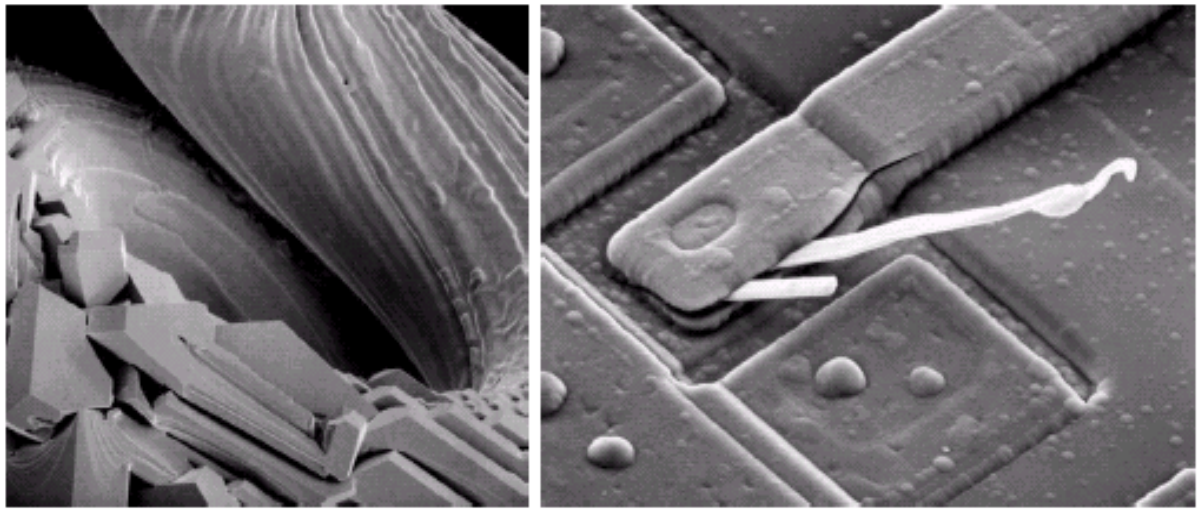
FIGURE 1.20
Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Electron microscope imaging

- Electron microscopy
  - TEM (transmission electron microscope) for bulky objects
  - SEM (scanning electron microscope) for very thin samples



a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

Computer generated image

- Computer graphic

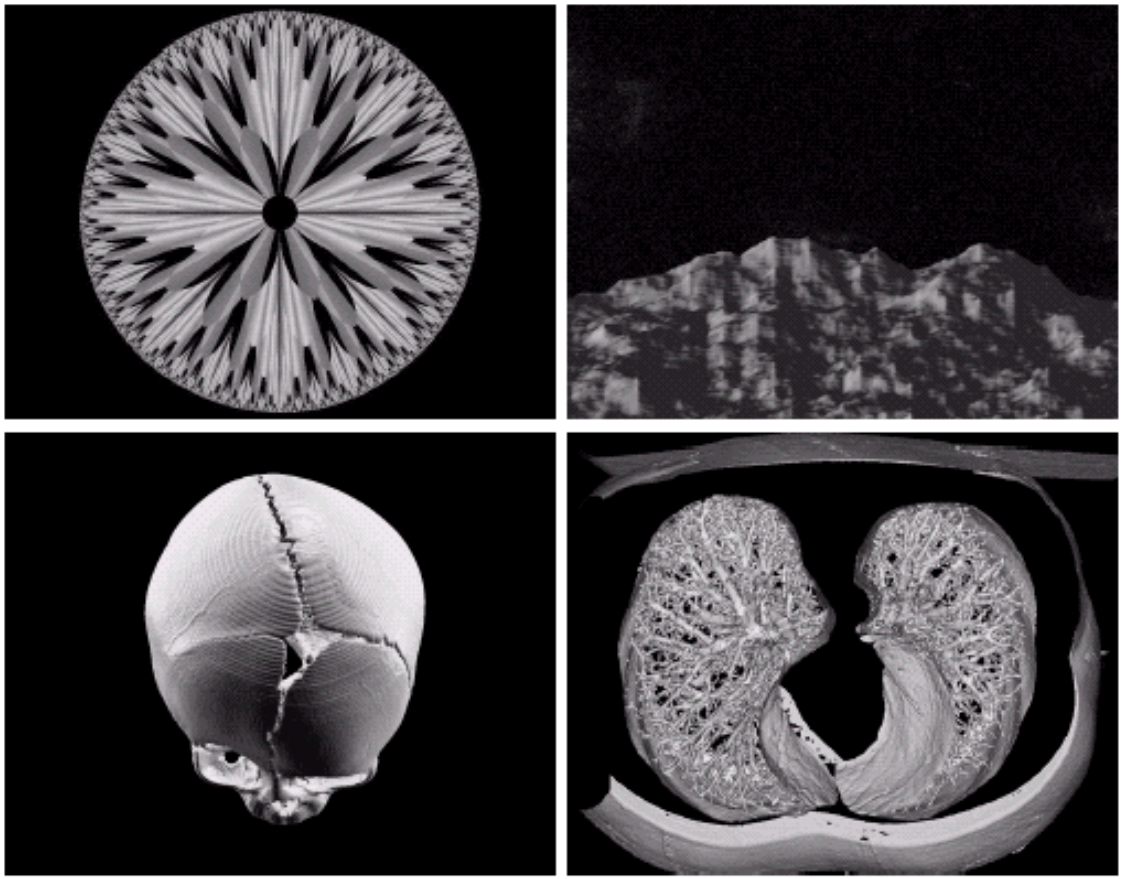


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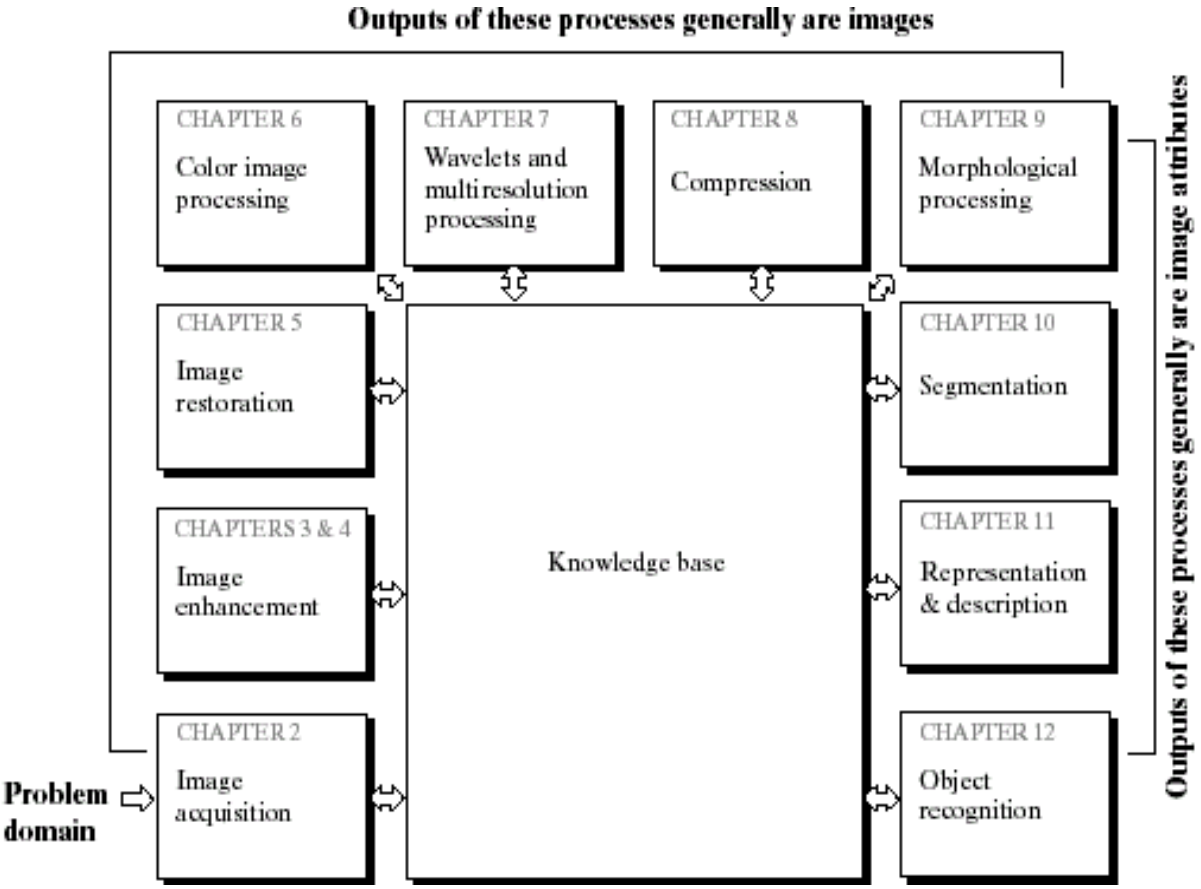
FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)

Topics of DIP (1)

- Fundamental steps in DIP



Topics of DIP (2)

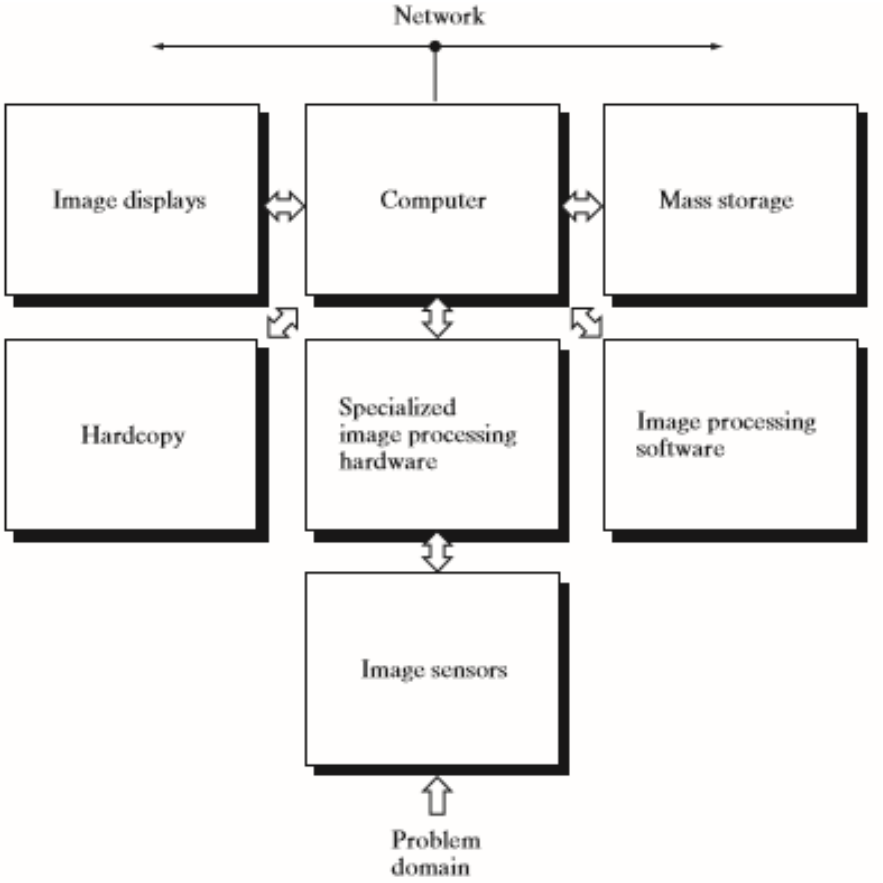
- Image acquisition
  - 빛이나 다른 signal을 digital signal로 변환
  - Image digitizer, or image grabber
- Image enhancement
  - 보다 보기 좋은 형태로 변환
- Image restoration
  - Noisy한 영상으로부터 본래의 영상을 복원
- Color image processing
- Wavelets
  - New mathematical foundation for signal processing, especially multi-resolutional image representation

Topics of DIP (3)

- Image compression
  - 영상에 존재하는 중복성을 제거하여 데이터 양을 감축
  - 정지영상압축, 동영상압축
- Morphological processing
  - Tools for extracting image components
- Image segmentation
  - Partition an image into meaningful subimages
- Representation and description
  - Represent image of raw pixels into a set of features
- Recognition
  - Assign a label to an object based on its descriptors

Components of image processing system (1)

- Components of general-purpose image processing system



Components of image processing system (2)

- Sensing unit
  - Sensor: converts energy into desired form
  - Digitizer: converts analog signal into digital signal
- Specialized image processing hardware
  - Primitive operations such as AL operations
  - Front-end subsystem
- Computer
  - General-purpose computer from a PC to a supercomputer
  - Dedicated computer such as MPP(massively parallel processor)
  - CUDA processors

Components of image processing system (3)

- Software
  - Specialized modules that perform specific tasks
- Mass storage
  - Short-term storage for use during processing
  - On-line storage for fast recall
  - Archival storage with infrequent access
- Image displays
  - Eg. Color monitor, head gear for stereo vision
- Hardcopy
  - Eg. Laser printer, film camera, ink-jet printer, CD ROM, etc.
- Networking