Chapter-1

Introduction to Image Processing

WRIGHT STATE UNIVERSITY

Aims and Objectives of Chapter 1

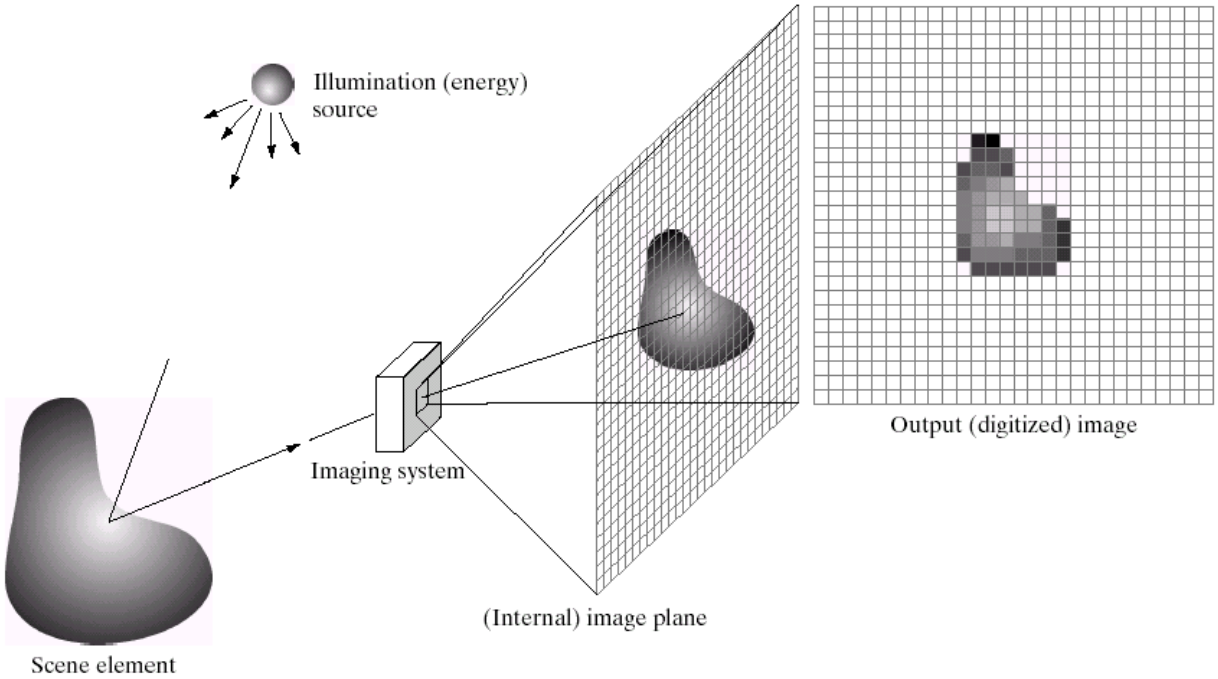
Introduction to common image processing techniques

- What is a digital image?
- What is Digital Image Processing (DIP) ?
- Brief history of Digital Image Processing
- Examples of Digital Image Processing
- Key stages in Digital Image Processing

What is a Digital Image?

Digital Image

- Representation of a two-dimensional image as a finite set of digital values
- Image: $f(x, y)$
- x, y: Spatial Coordinates
- Value of $f(x, y)$: Proportional to the brightness of image at (x, y)
- Pixel: Picture Element



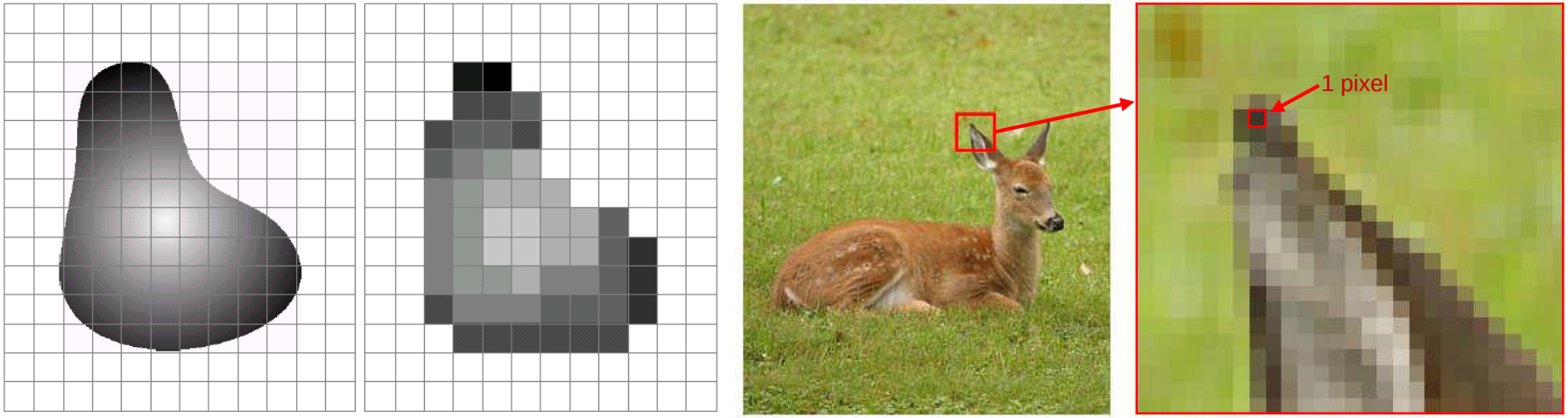
What is a Digital Image? (cont…)

Pixel values

- Gray levels, colors, heights, opacities, etc.

Digitization

- An *approximation* of a real scene with a digital image



What is a Digital Image? (cont…)

Common image formats

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and "Alpha", a.k.a. Opacity)

Most of EE-7150 will focus on gray-scale images

What is Digital Image Processing (DIP)?

Digital image processing focuses on two major tasks

- Improvement of pictorial information for human interpretation
- Image data Processing for
  - Storage
  - Transmission
  - Representation
- Goal: Autonomous machine perception

Image Analysis and Computer Vision start where Image Processing ends

What is Digital Image Processing? (cont…)

From Image Processing to Computer Vision

- Low-Level Process Produces → "Better" or more desirable Image
- Mid-Level Process Produces → Scene Attributes or Features
- High-Level Process Produces → Understanding what is in the Image

This course will stop here

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image	**Input:** Image **Output:** Attributes (features)	**Input:** Attributes **Output:** Understanding
Examples: • Noise Removal • Contrast Enhancement • Image Sharpening	**Examples:** • Segmentation • Edges • Description	**Examples:** • Scene Understanding • Autonomous Navigation • Making Sense of Recognized Objects

Digital Image Processing

Machine Learning, Computer Vision, Pattern Recognition

History of Digital Image Processing

Early 1920s: One of the first applications of digital imaging was in the newspaper industry

- The Bartlane cable picture transmission service
- Images transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer
- Transporting Time Reduction: A week traveling by ship >>> Three hours!

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special typefaces. (McFarlane.) [References in the bibliography at the end of the book are listed in alphabetical order by authors' last names.]

History of DIP (cont…)

Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

- New reproduction processes based on photographic techniques
- Increased number of tones in reproduced images

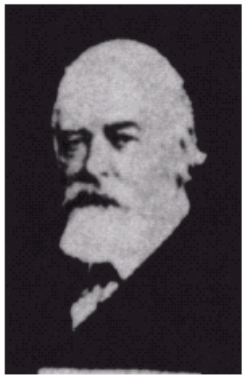


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

Improved digital image

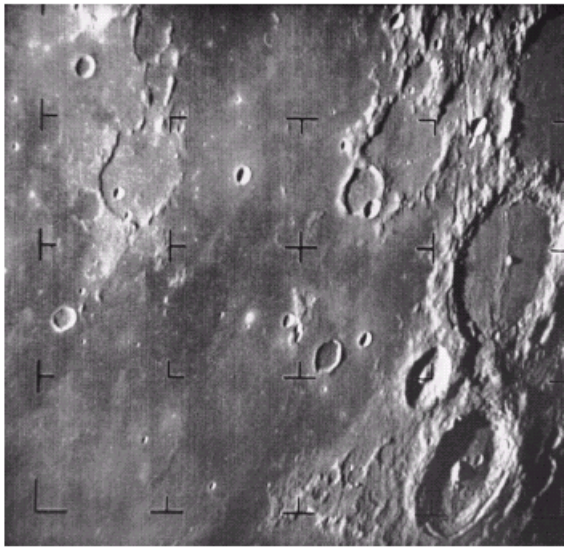
FIGURE 1.3 Unretouched cable picture of Generals Pershing (right) and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

Early 15-tone digital image

History of DIP (cont…)

1960s: Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing

- **1964:** Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe
- Such techniques were used in other space missions including the Apollo landings



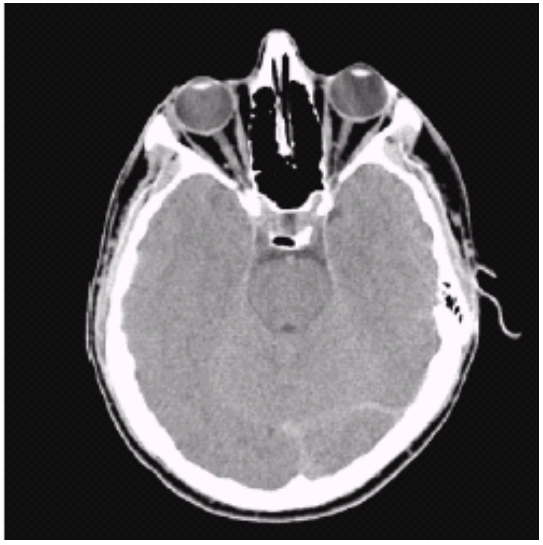
A picture of the moon taken by the Ranger 7 probe minutes before landing

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.)

History of DIP (cont…)

1970s: DIP begins to be used in medical applications

- **1979:** Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerized Axial Tomography (CAT) scans



Typical head slice CAT image

History of DIP (cont…)

1980s - Today:

- Explosion in usage of digital image processing techniques
  - Image enhancement/restoration (BW → Color movies)
  - Artistic effects
  - Medical visualization
  - Industrial inspection
  - Law enforcement
  - Human computer interfaces
  - Geo-Spatial Image Processing (Google Maps)
  - Hyperspectral Image Processing
  - Virtual Reality → POKEMON!

Energy and Wavelengths of Electromagnetic Waves

- Spectrum of Electromagnetic waves: In terms of Energy per Photon

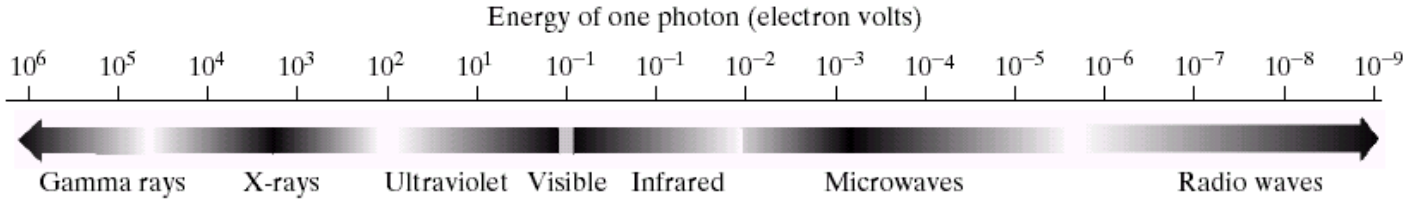
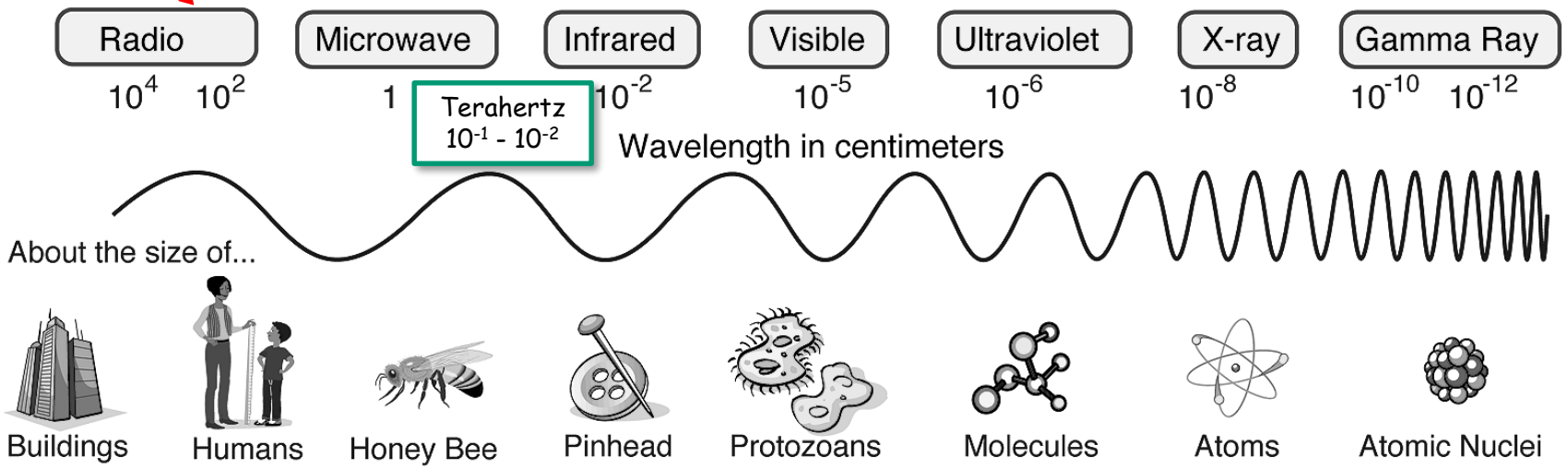


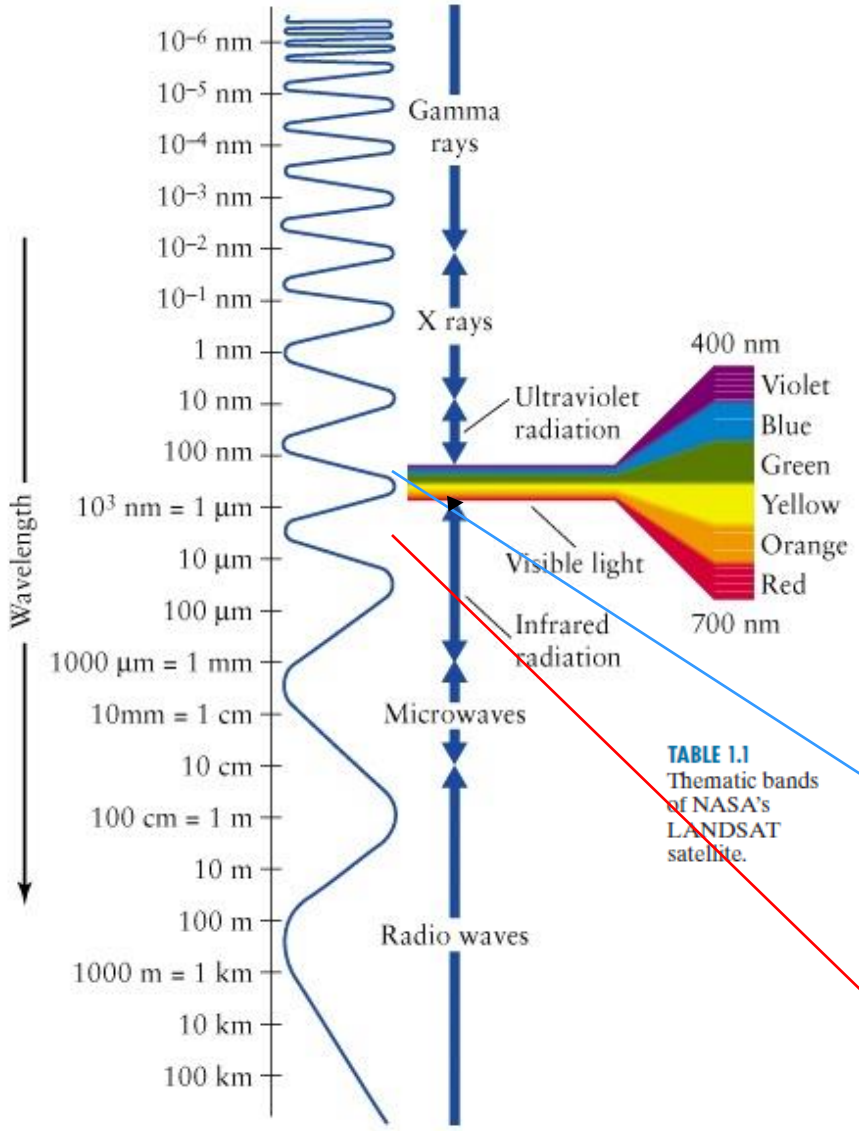
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

- Spectrum of electromagnetic waves: In terms of wavelengths (in cm)



http://www.nasa.gov

Wavelengths of Electromagnetic Waves



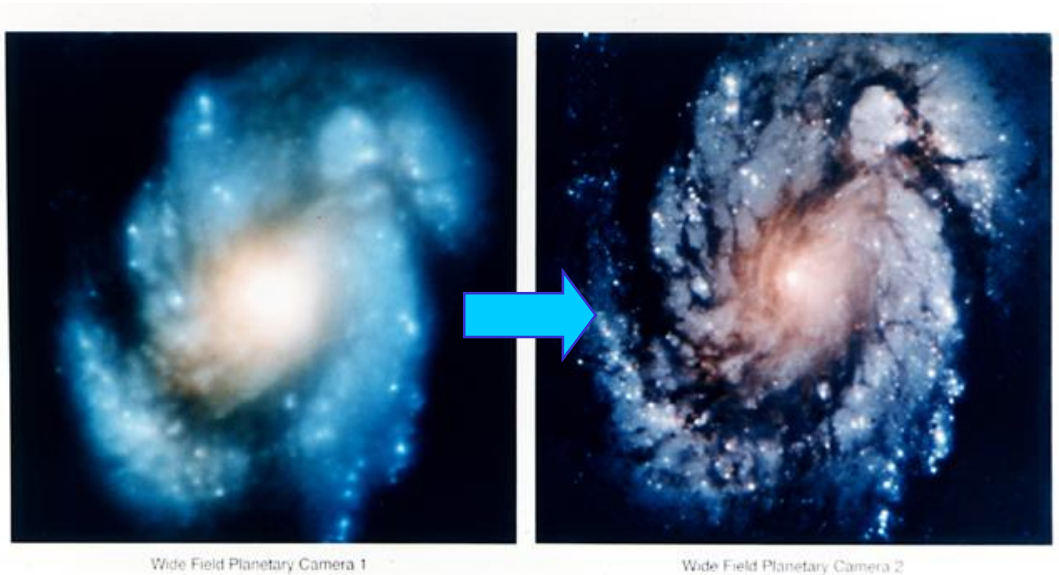
NASA-LANDSAT:
Utility of Visible bands to Infrared bands

TABLE 1.1 Thematic bands of 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	0.53–0.61	Measures plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.78–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content: soil/vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Short-wave infrared	2.09–2.35	Mineral mapping

Example: Hubble Telescope

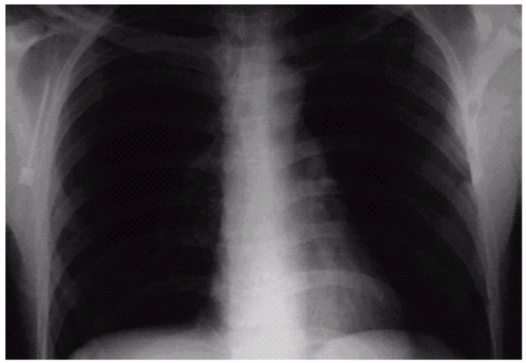
- Launched in 1990, the Hubble telescope can take images of very distant objects
- However, an incorrect mirror made many of Hubble's images useless (out of focus)
- Image processing techniques were used to fix this

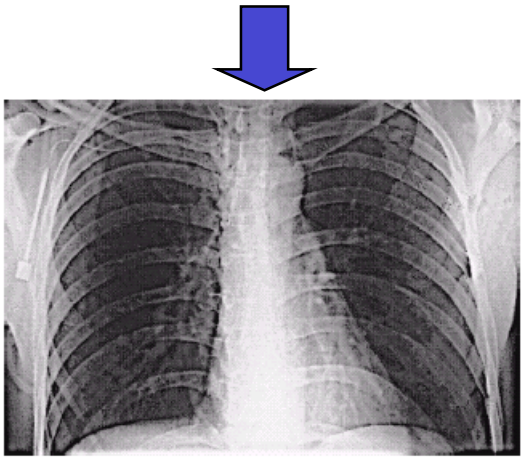


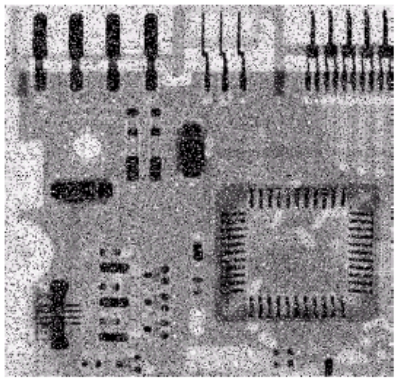
Example: Image Enhancement

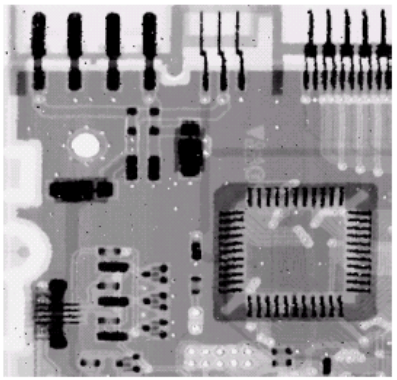
Most common uses of DIP techniques:

- Improve quality
- Remove noise etc.





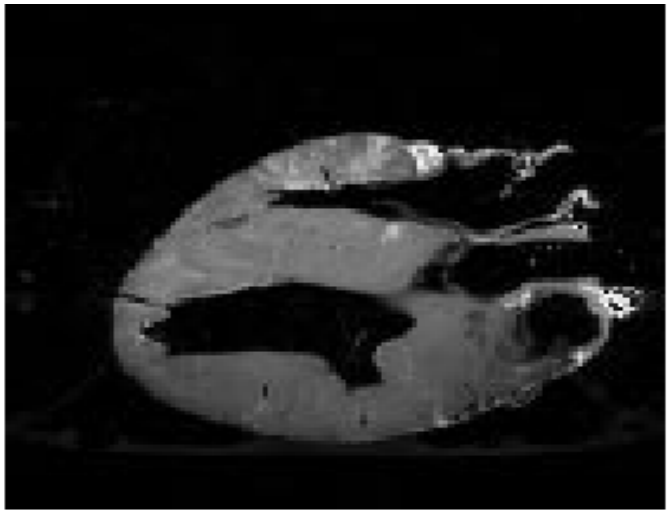




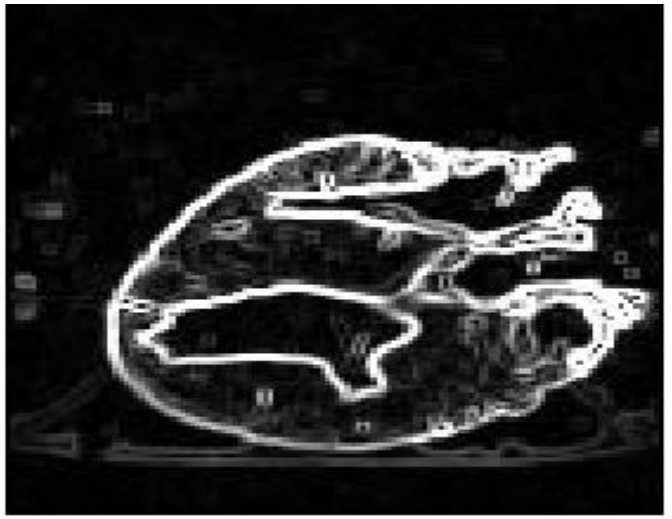
Example: Medicine

Take slice from MRI scan of canine heart, and find boundaries between types of tissue

- Image with gray levels represent tissue density
- Use a suitable filter to highlight edges

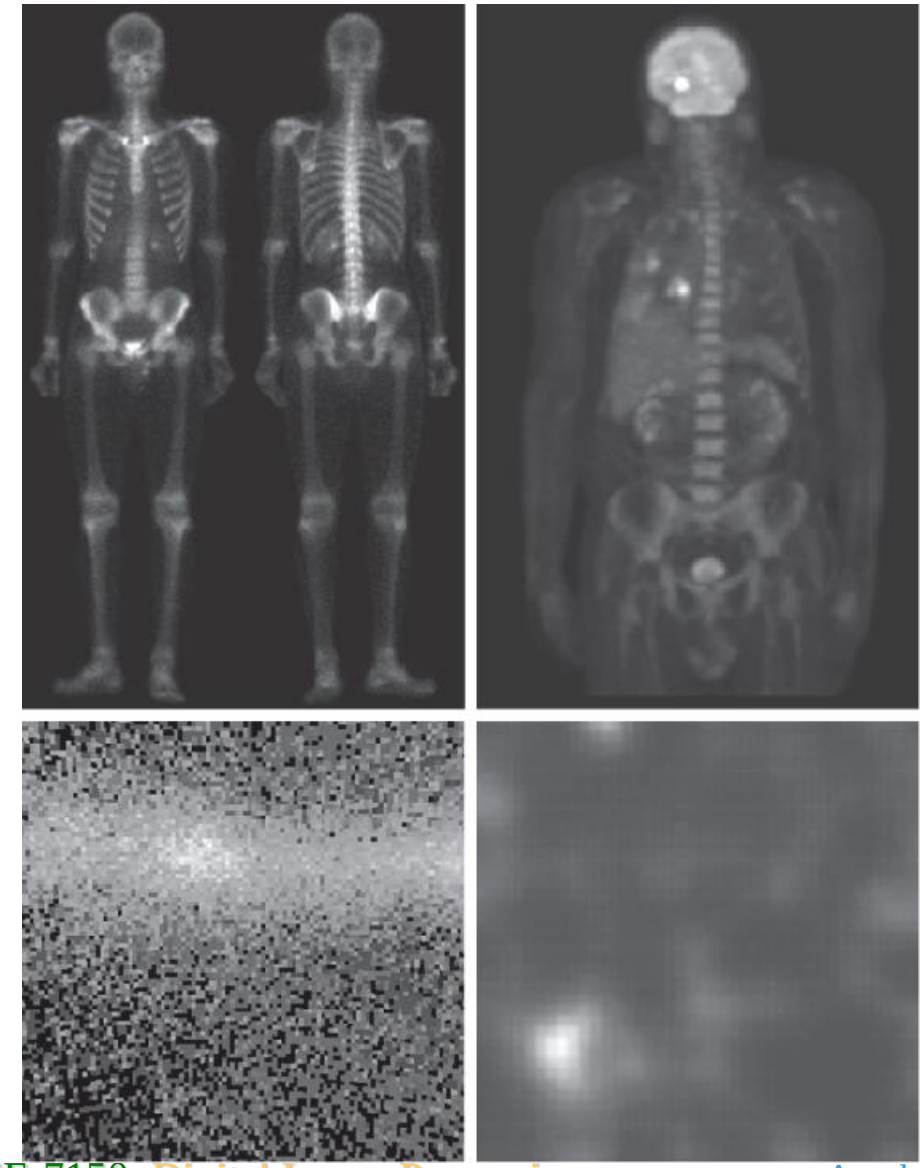


Original MRI Image of a Dog Heart



Edge Detected Image

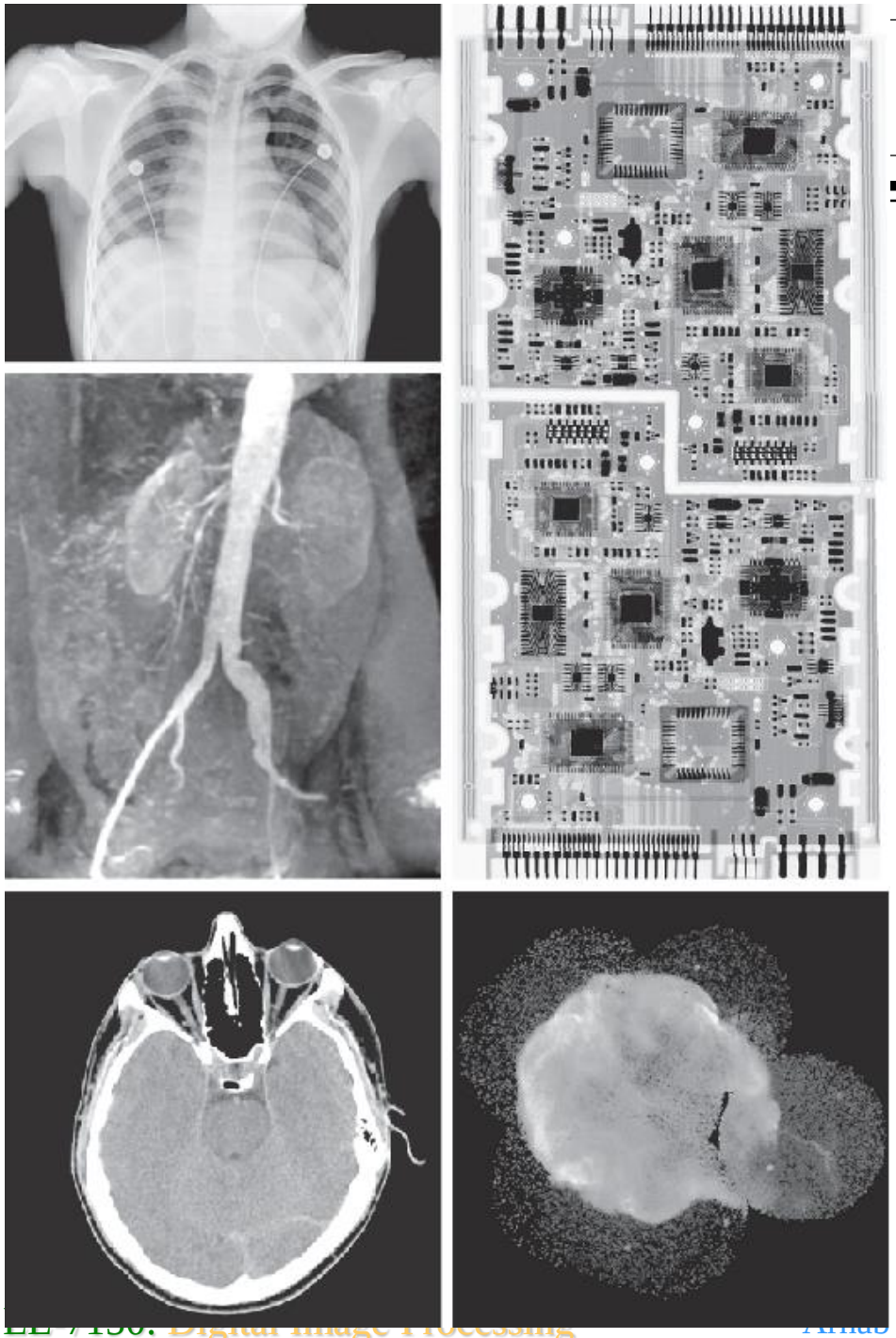
Gamma-Ray Imaging



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.)

X-Ray Imaging

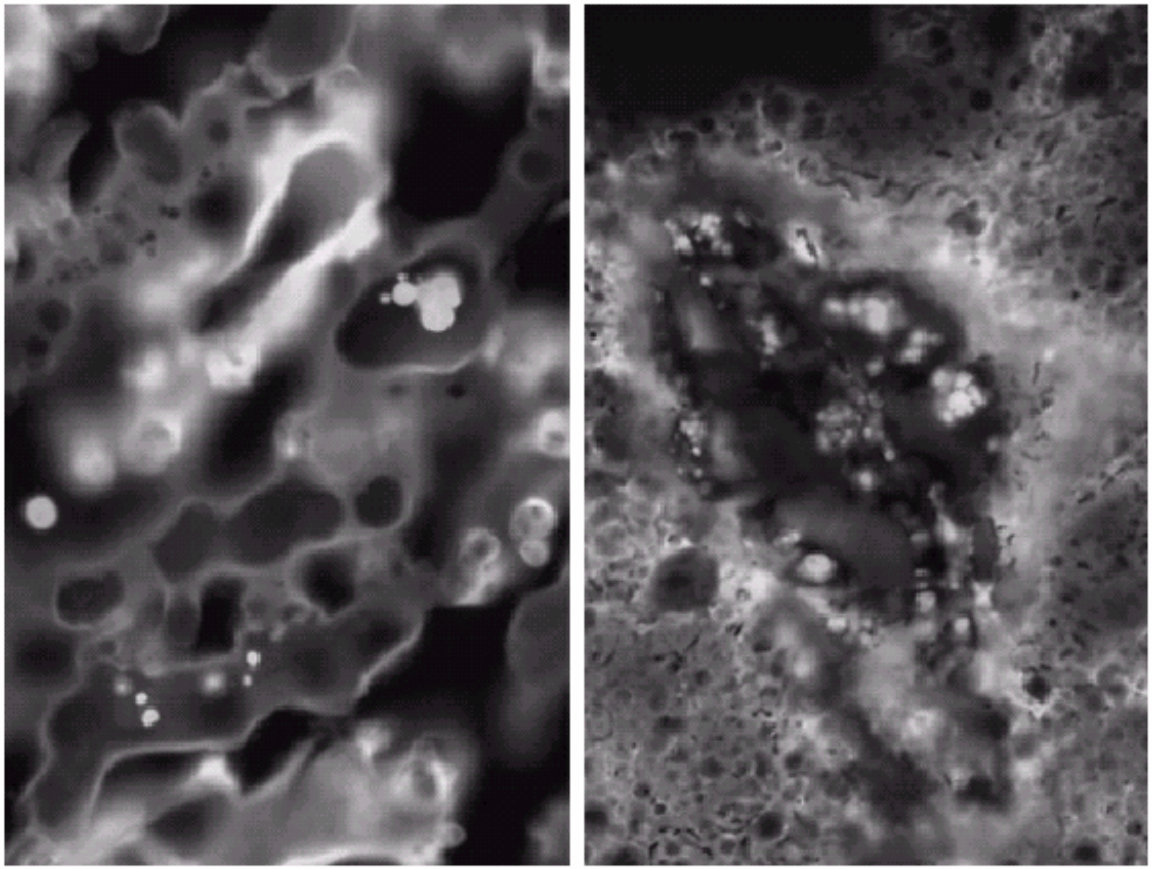


a d
c
b e

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.)

Fluorescence Microscopy

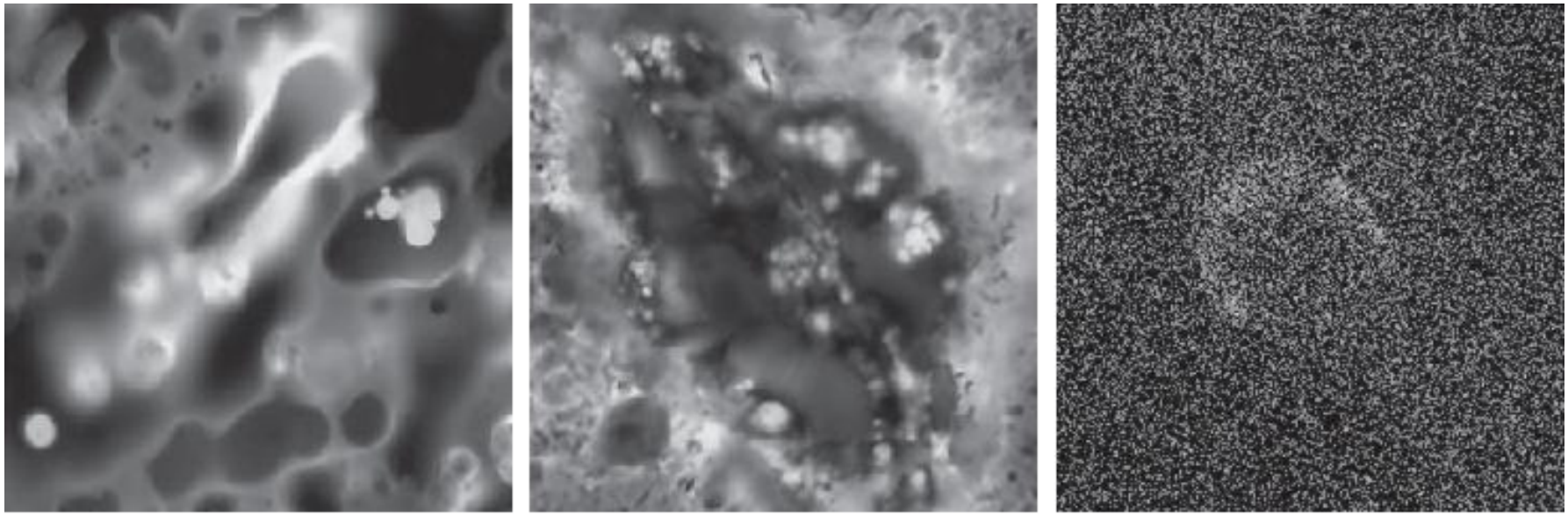
- Operate in the ultraviolet band



Normal Corn

Smut Corn

Ultraviolet Imaging

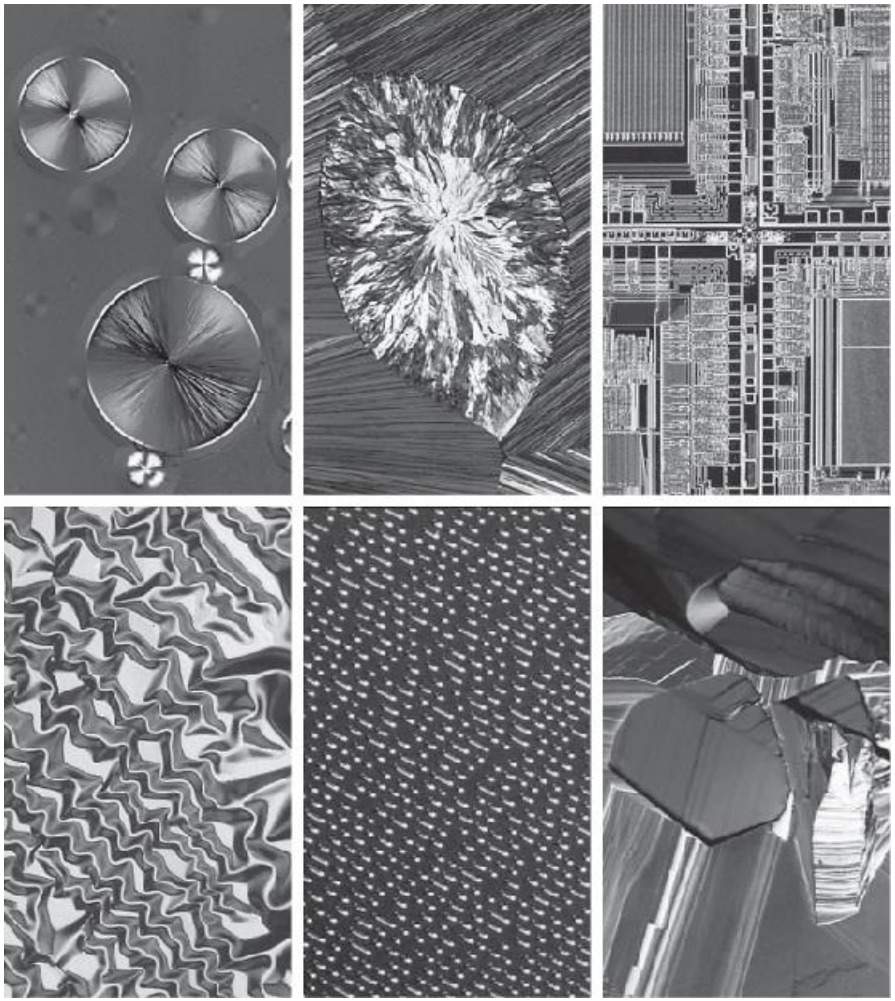


a b c

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

- Operate in the visible band
  - Pharmaceuticals and Microinspection



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.)

Example: GIS

Geographic Information Systems (GIS)

- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology

TABLE 1.1 Thematic bands of NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
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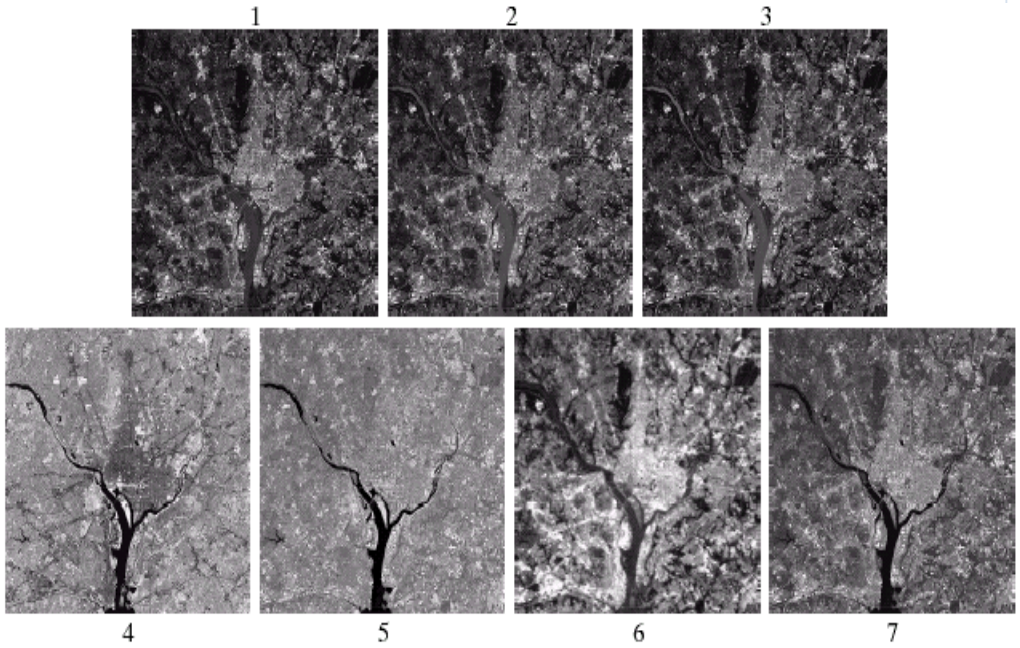


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Example: GIS

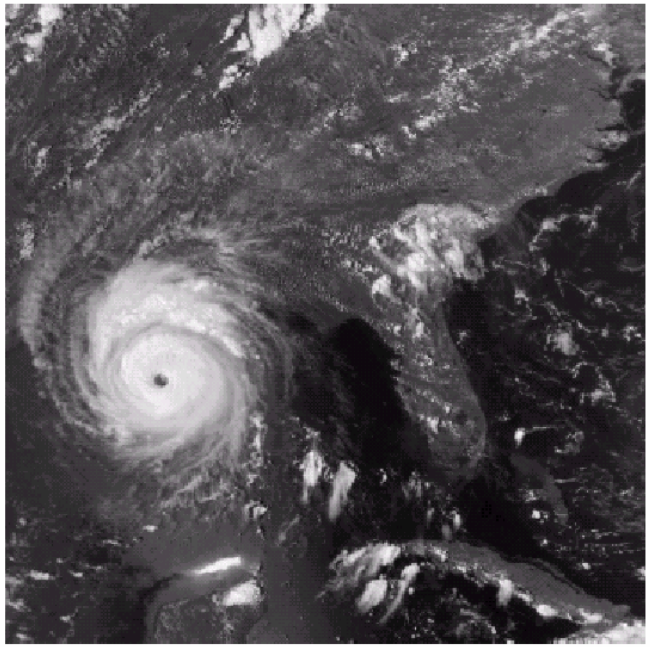
Geographic Information Systems

- Digital image processing techniques are used extensively to manipulate satellite imagery
- Terrain classification
- Meteorology

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

Remote Sensing

- Operate in the visible and infrared bands
  - Weather and Environmental observation



Hurricane Andrew (Aug 1992)
-Taken by NOAA GEOS

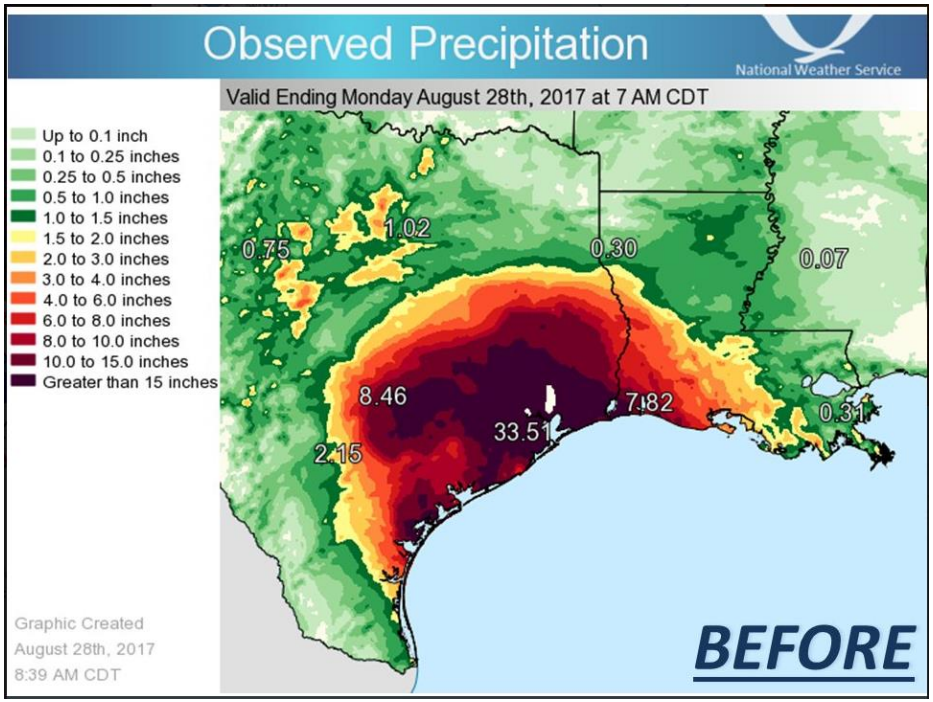
Americas at Night
(Nov. 27, 2000)

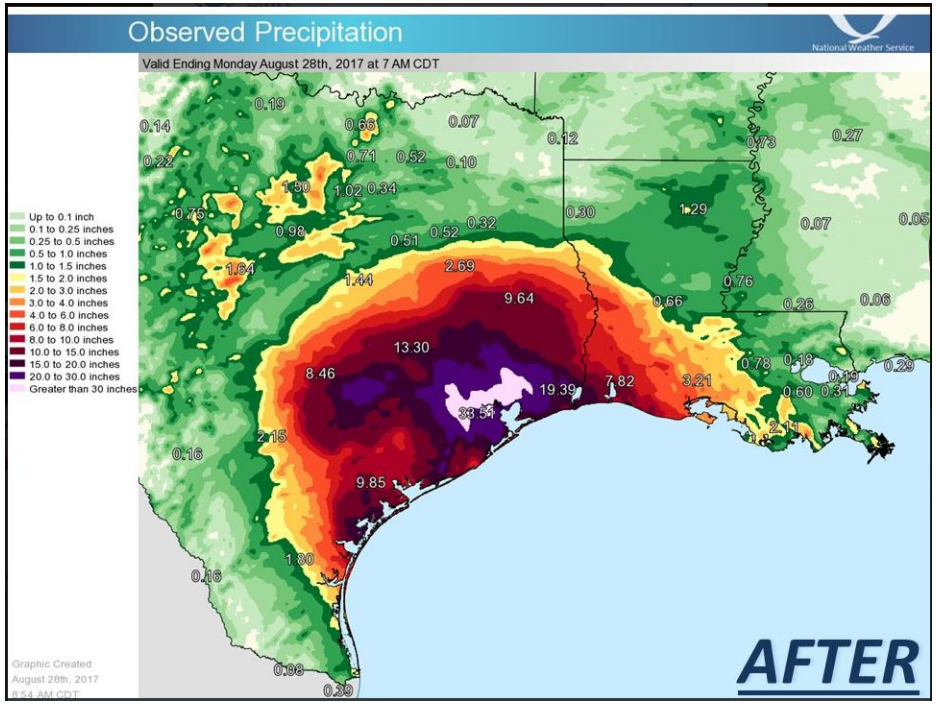
NWS Tweet after Harvey (Aug 2017)

NWS
@NWS

Follow

#Harvey in perspective. So much rain has fallen, we've had to update the color charts on our graphics in order to effectively map it.

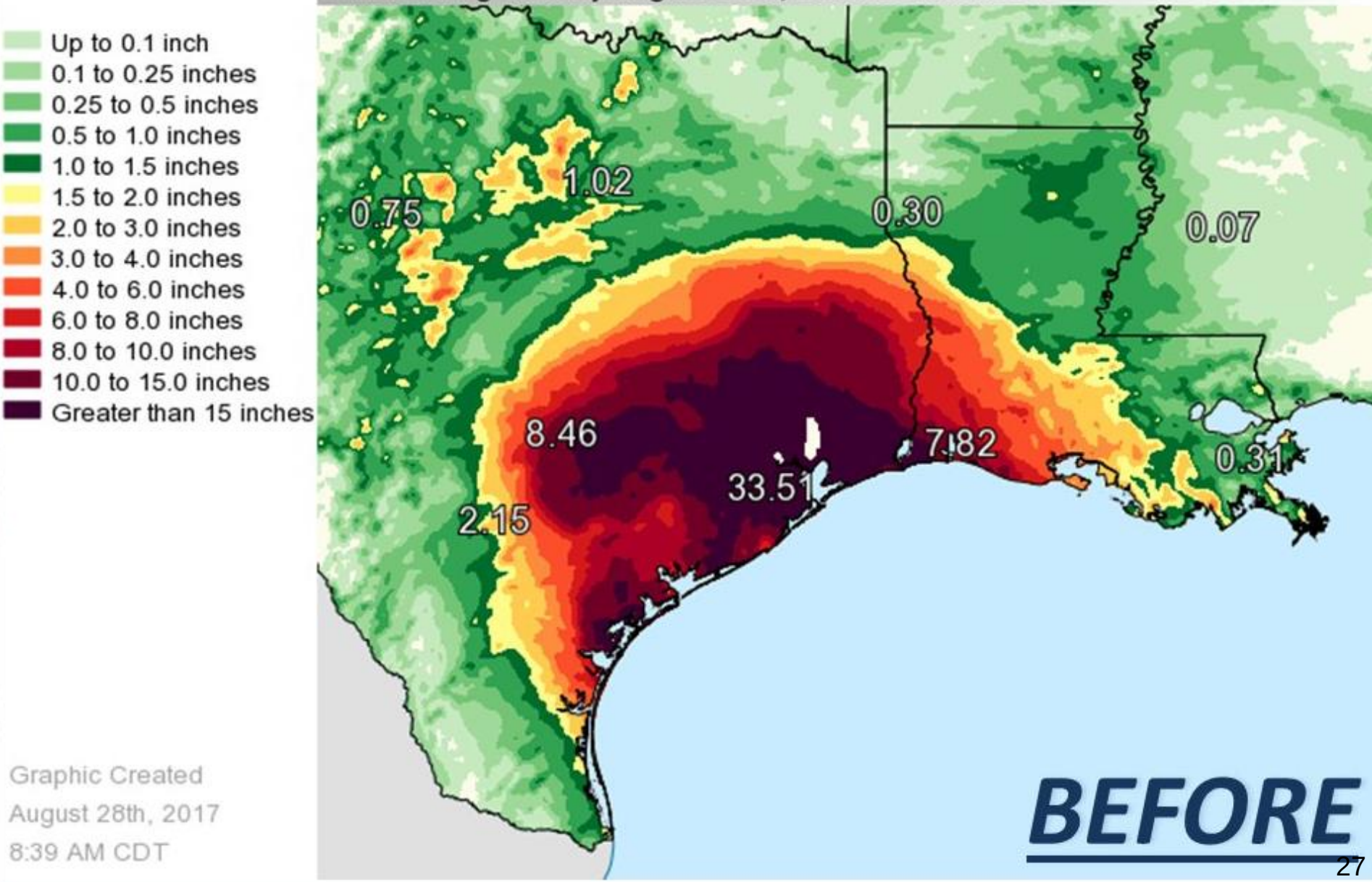




Observed Precipitation

National Weather Service

Valid Ending Monday August 28th, 2017 at 7 AM CDT



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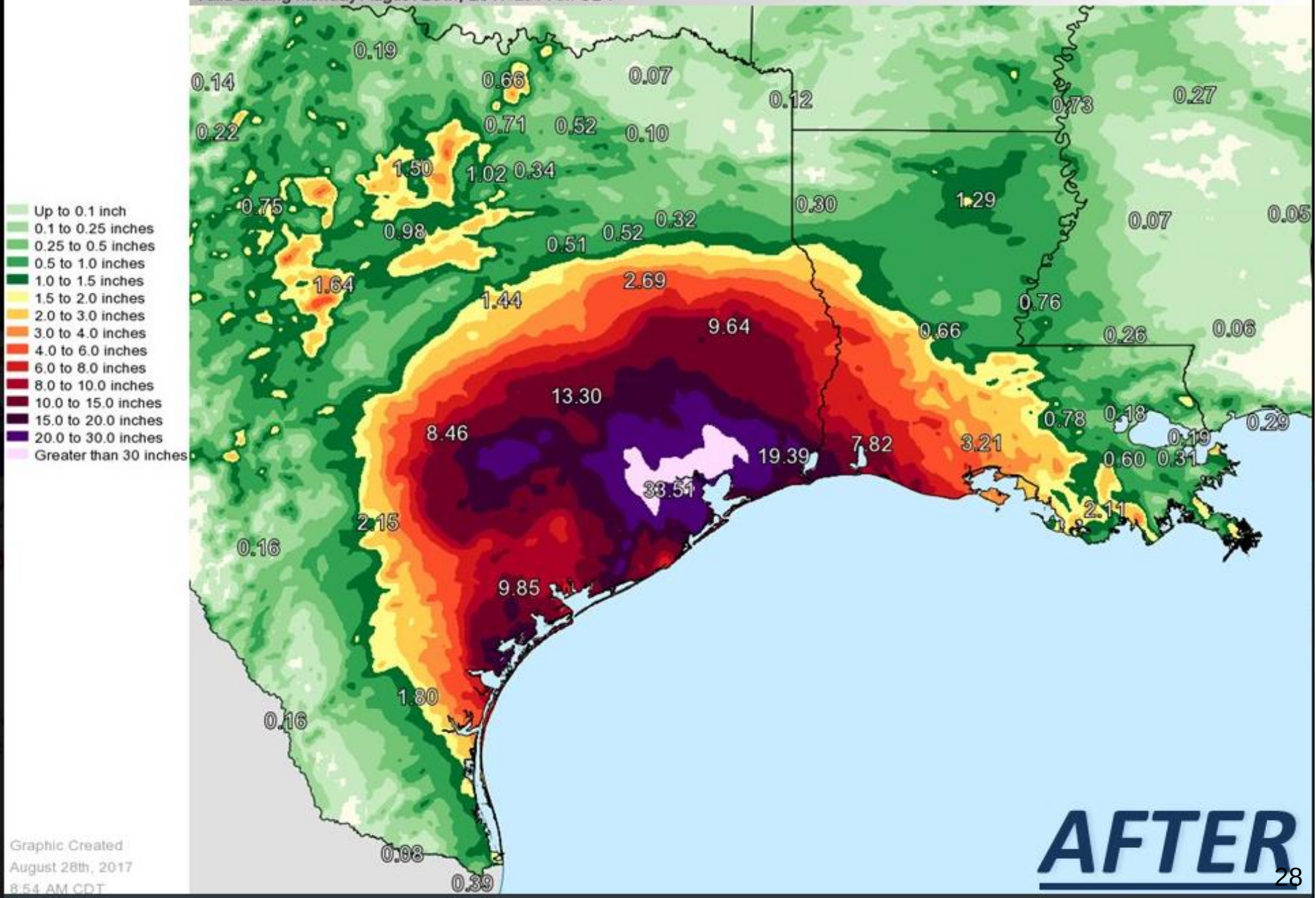


AFTER

Example: GIS (cont…)

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

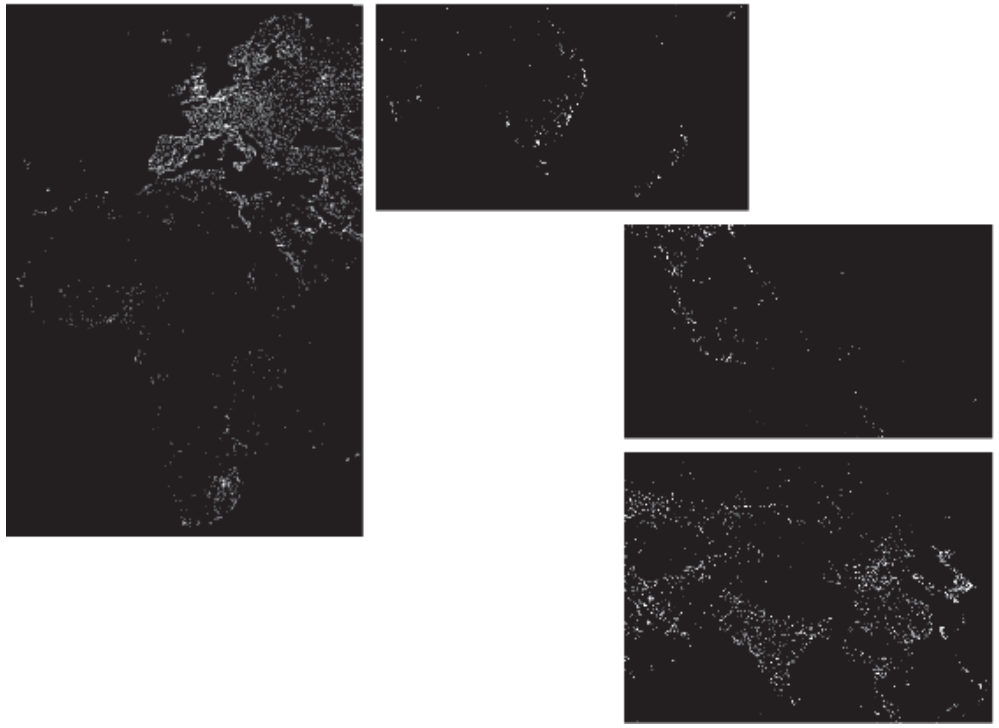
Night-Time Lights of the World data set

- Global inventory of human settlement
- Power usage at different parts of the world
- Rich vs. Poor countries
- Population Density

Example: GIS (cont…)

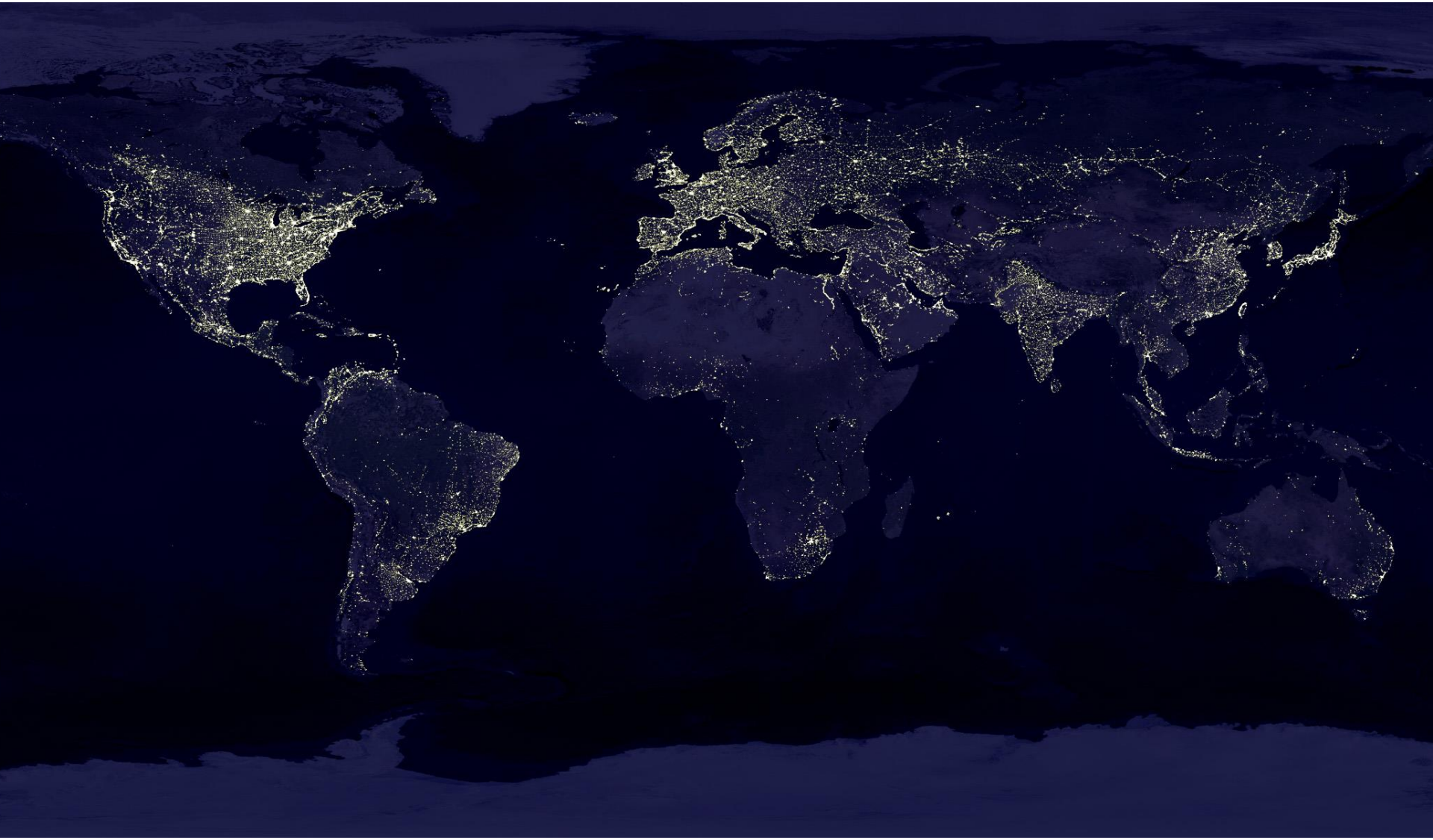
FIGURE 1.13
Infrared satellite images of the remaining populated parts of the world. The small shaded map is provided for reference. (Courtesy of NOAA.)

Night-Time Lights of the World data set



- Global inventory of human settlement
- Power usage at different parts of the world
- Rich vs. Poor countries
- Population Density

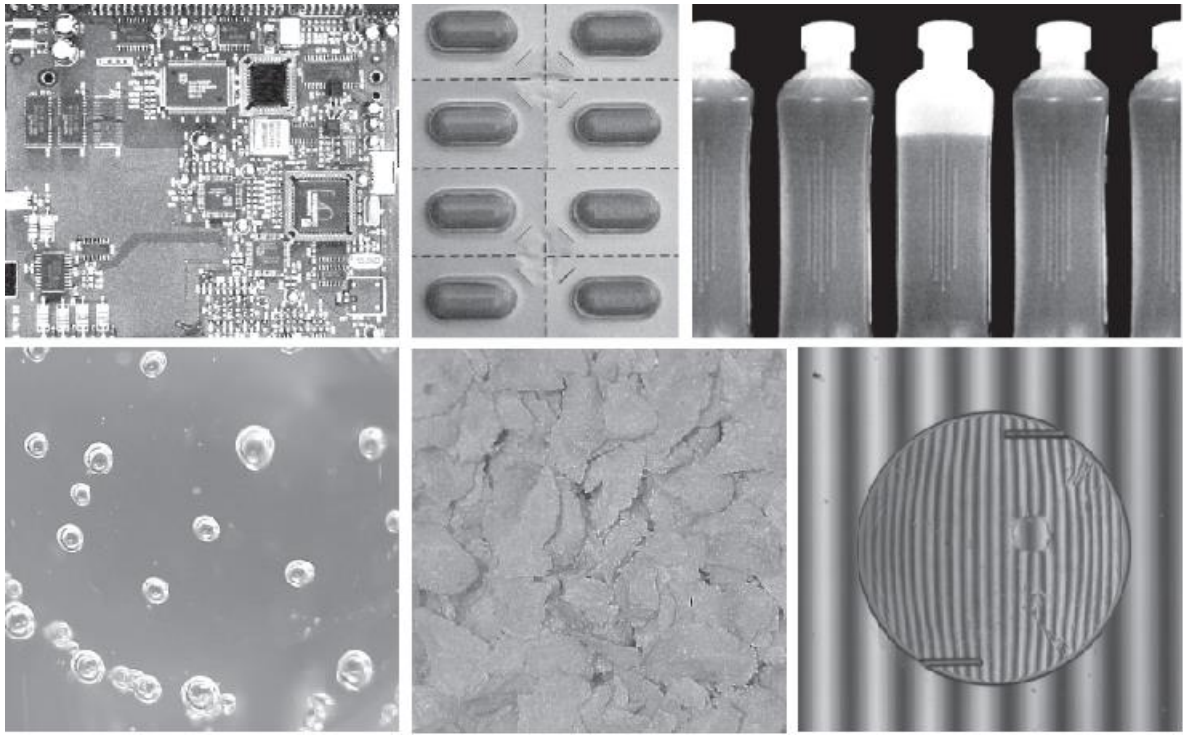
"Visible Earth" (1994-1995)



http://visibleearth.nasa.gov/view.php?id=55167 **Data Date:** October 1, 1994 - March 31, 1995

Manufacturing/Industrial Inspection

- Human operators
  - Expensive
  - Slow and unreliable
- Let machines do the job instead
- Industrial vision systems are used in many industries
- Are these trustworthy?



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.)

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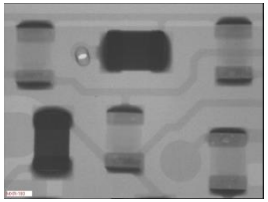
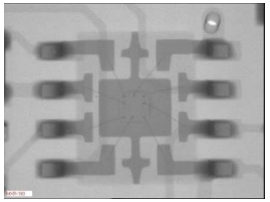
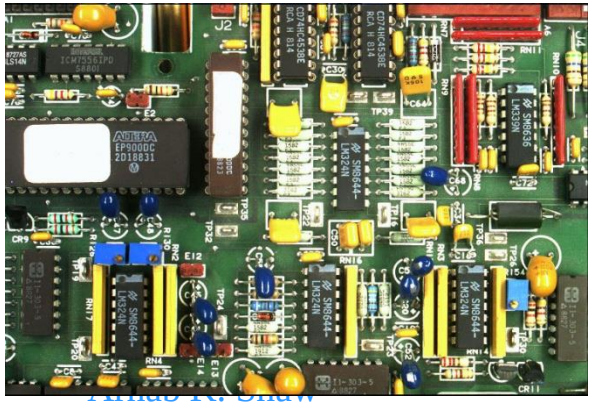
Example: PCB Inspection

Printed Circuit Board (PCB) inspection

- Machine inspection: Determine whether all components are present or all solder joints are acceptable
- Both conventional imaging and x-ray imaging are used



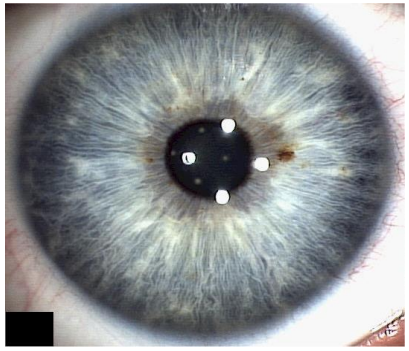


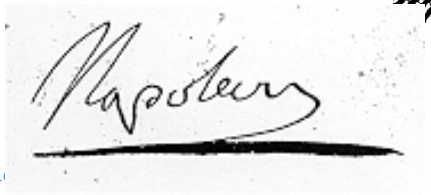


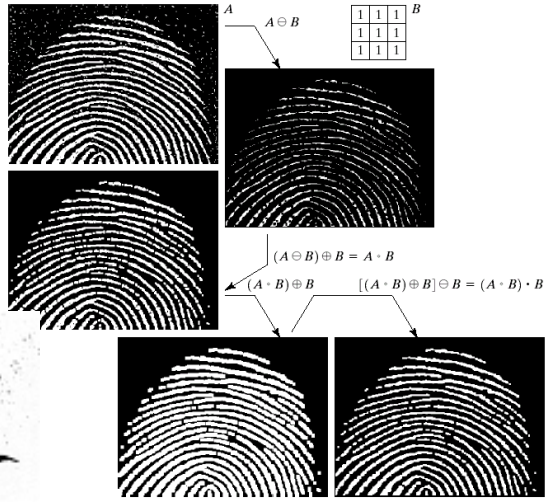
Example: Law Enforcement & Biometrics

Image processing techniques are used extensively by law enforcers

- Signature Recognition
- Number plate recognition for speeding Violations with Cameras
- Automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images
- Iris recognition
- Full body scanners at airports







Radar Images

- Operate in the microwave band

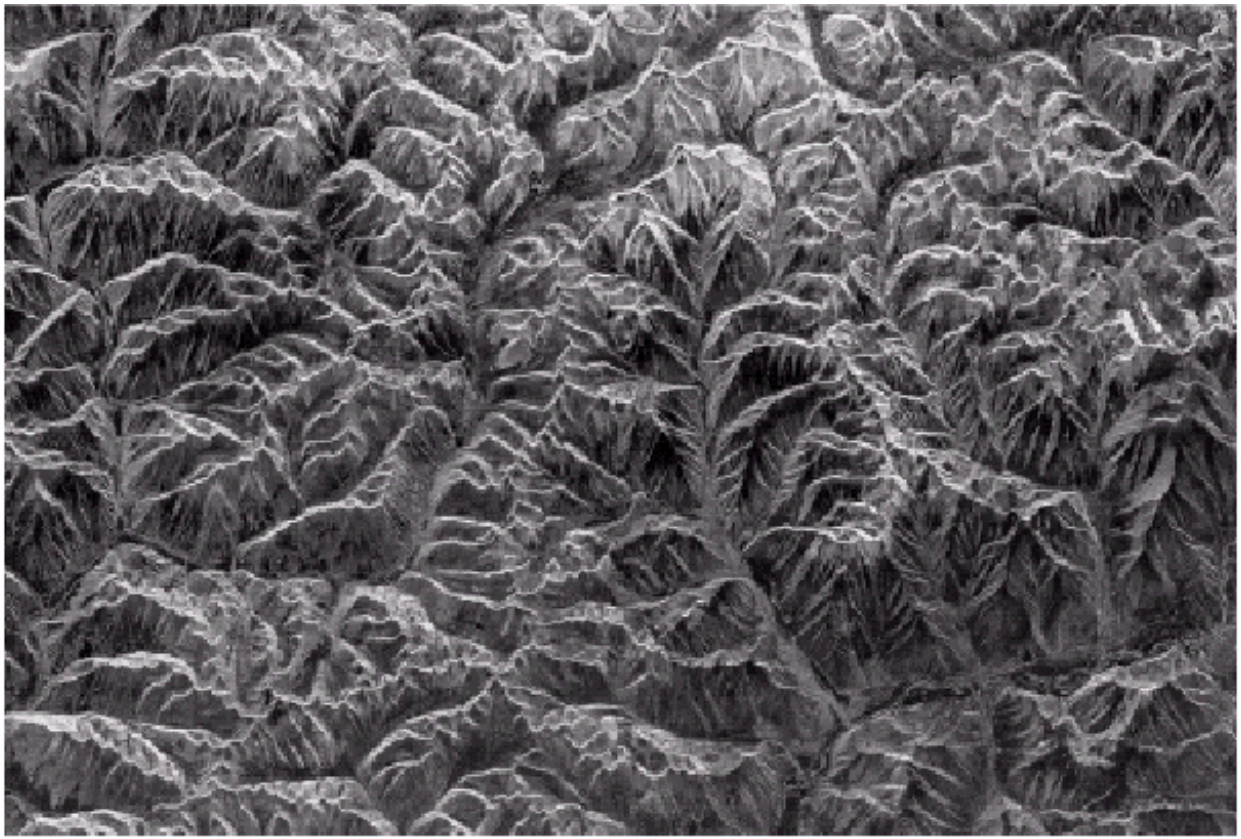


FIGURE 1.16 Spaceborne radar image of mountainous region in southeast Tibet. (Courtesy of NASA.)

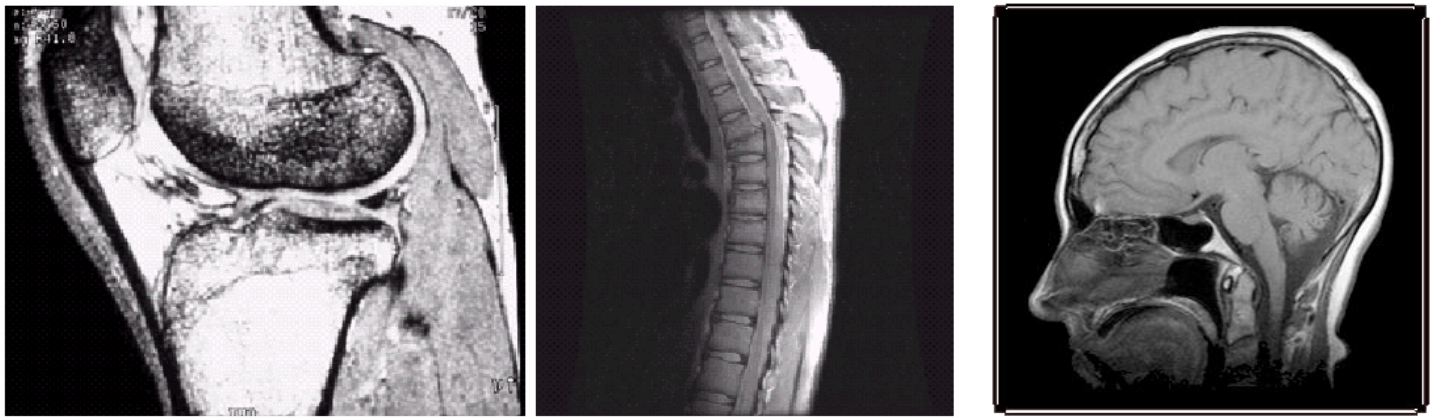
Mountains in Southeast Tibet

MRI Images

- Operate in the radio band
  - Medicine And Astronomy

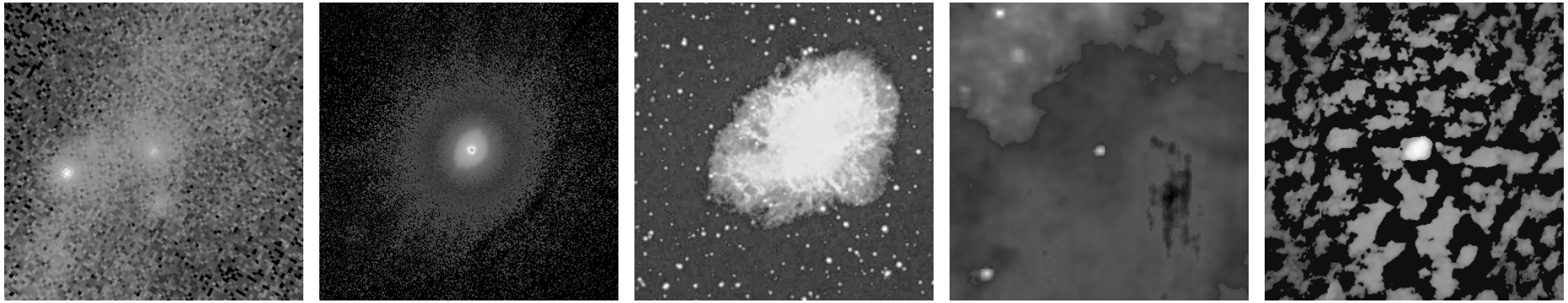
a b

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.)



Knee Spine Head

Crab Pulsar Images At Different Wavelengths in EM Spectrum



Gamma | X-ray | Optical | Infrared | Radio

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

Image of a Seismic Model

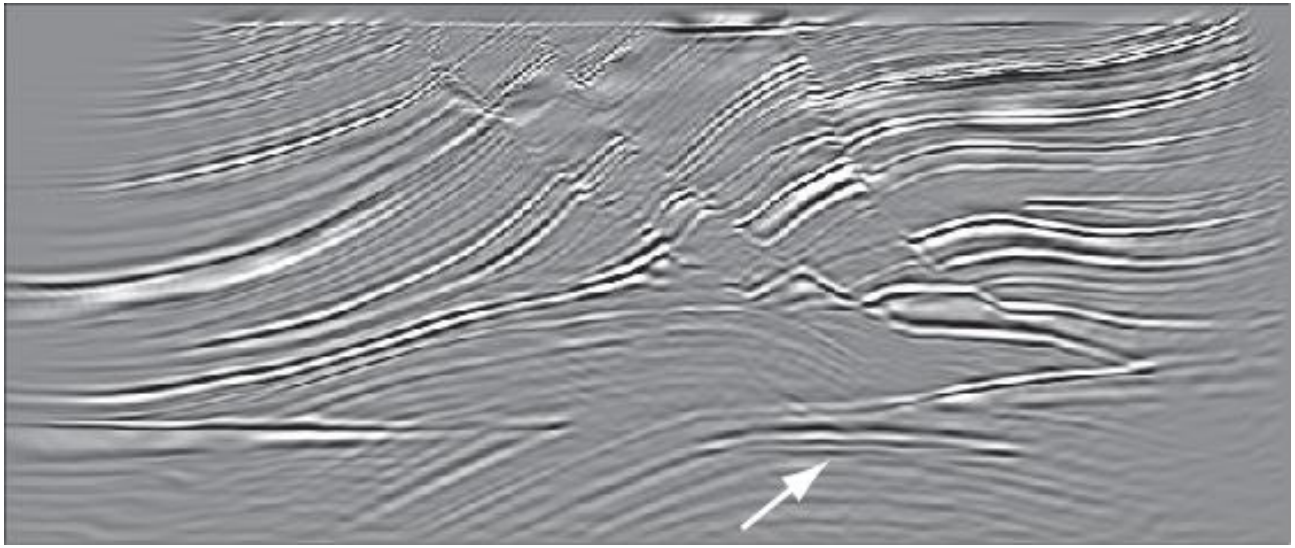


FIGURE 1.19 Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Other Non-Electromagnetic Imaging Modalities

Acoustic Imaging (Ultrasound)

- Translate "sound waves" into image signals (Sonograms)

Scanning Electron Microscopy (SEM)

- Shine a beam of electrons through a specimen

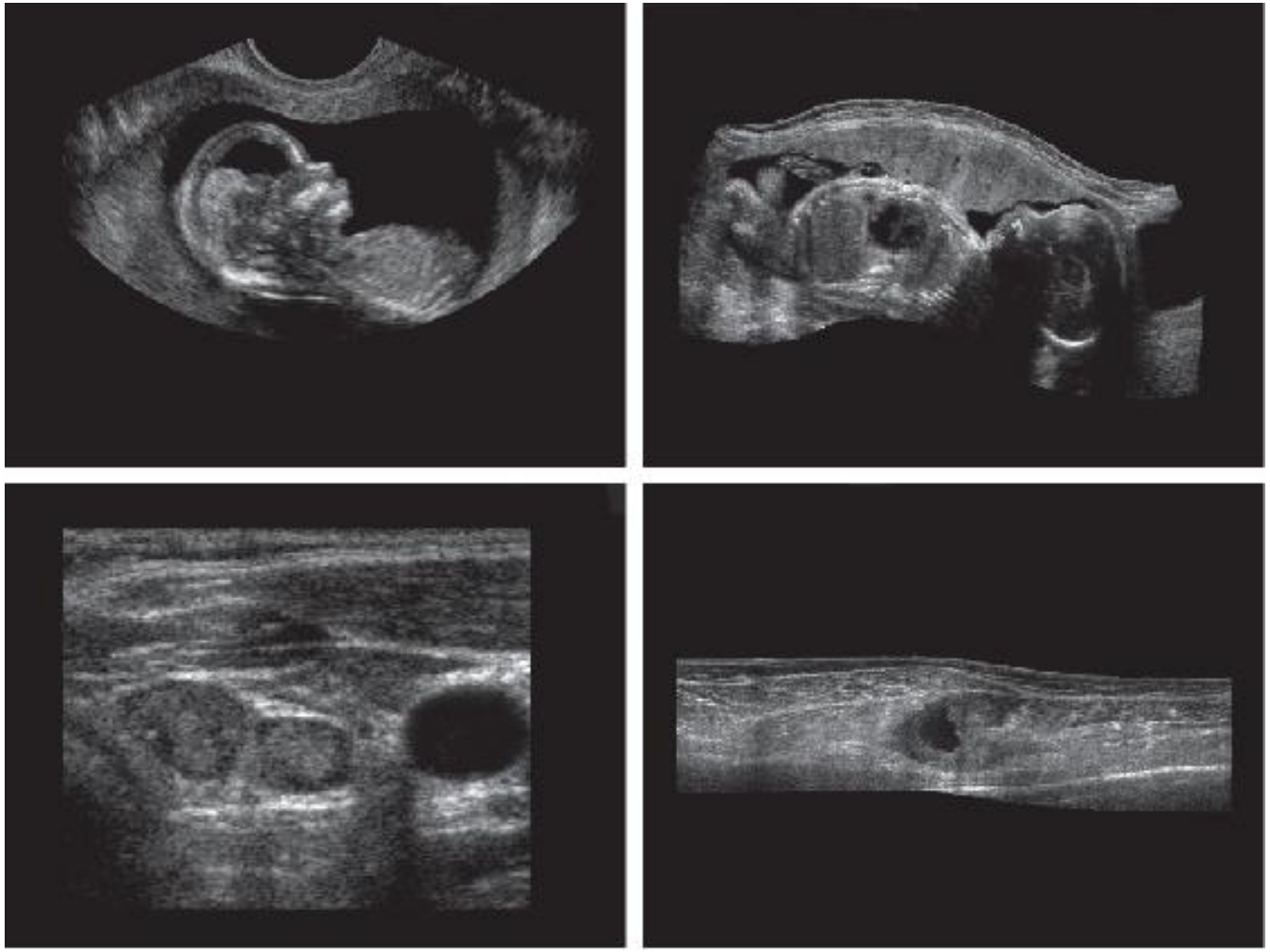
Synthetic Images in Computer Graphics

- Computer generated Animate Movies (non-existent in the real world)

Ultrasound

A Spider Under a Scanning Electron Microscope

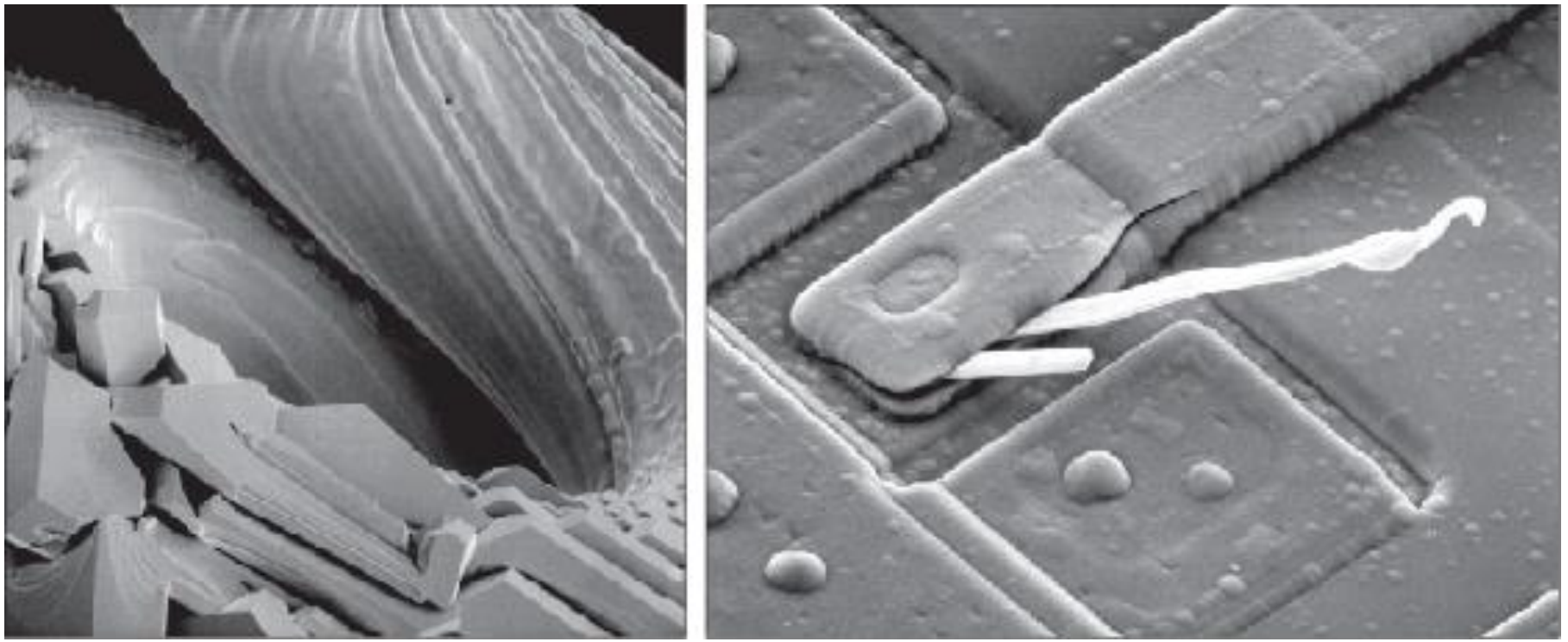
Ultrasound Imaging



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.)

Scanning Electronic Microscopy (SEM)

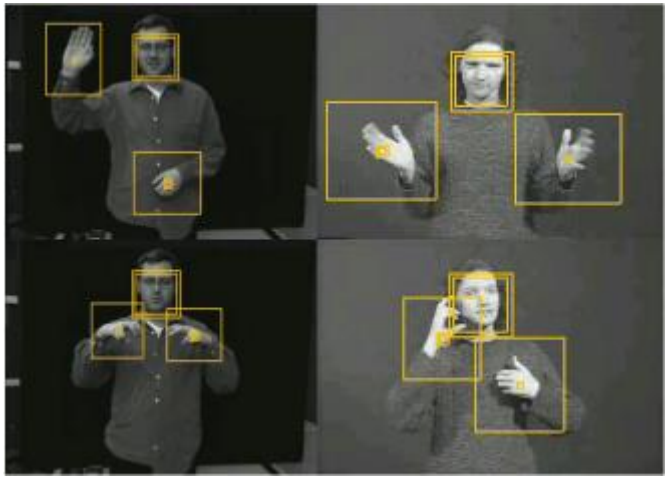


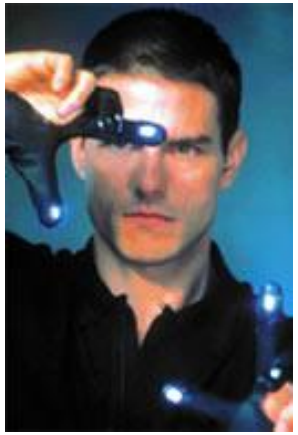
a b

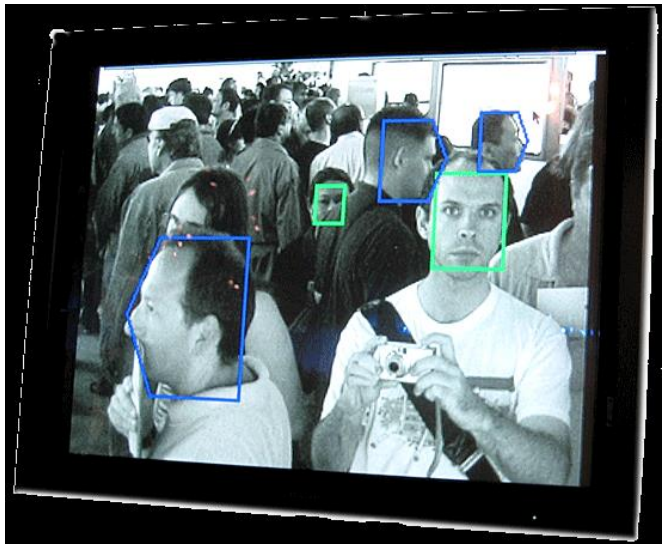
FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) 2500× SEM image of a damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of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

Examples: Human Computer Interface

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition (Xbox)
  - e.g., User interface in "Minority Report"
- These tasks can be extremely difficult







Key Stages in Digital Image Processing

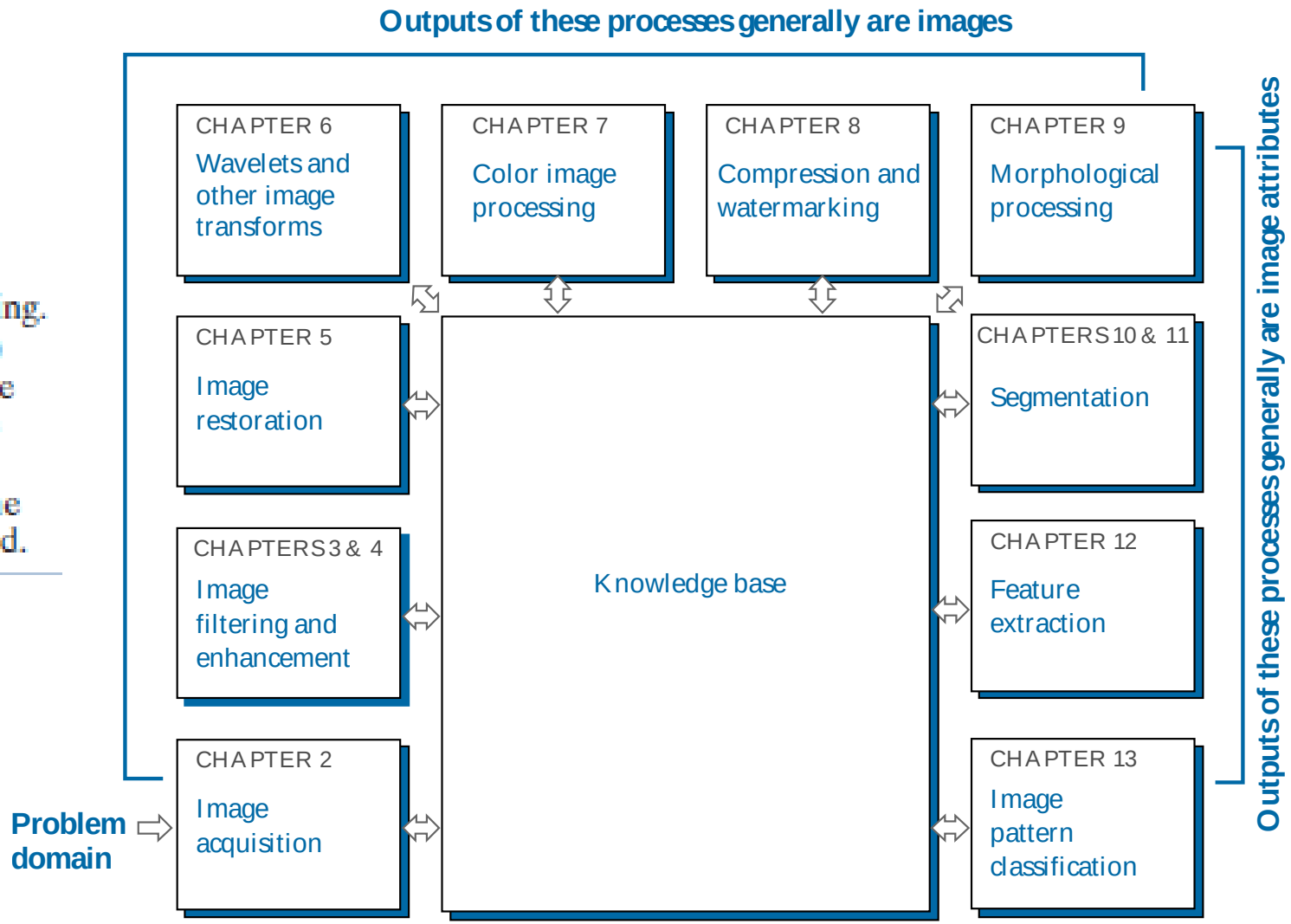
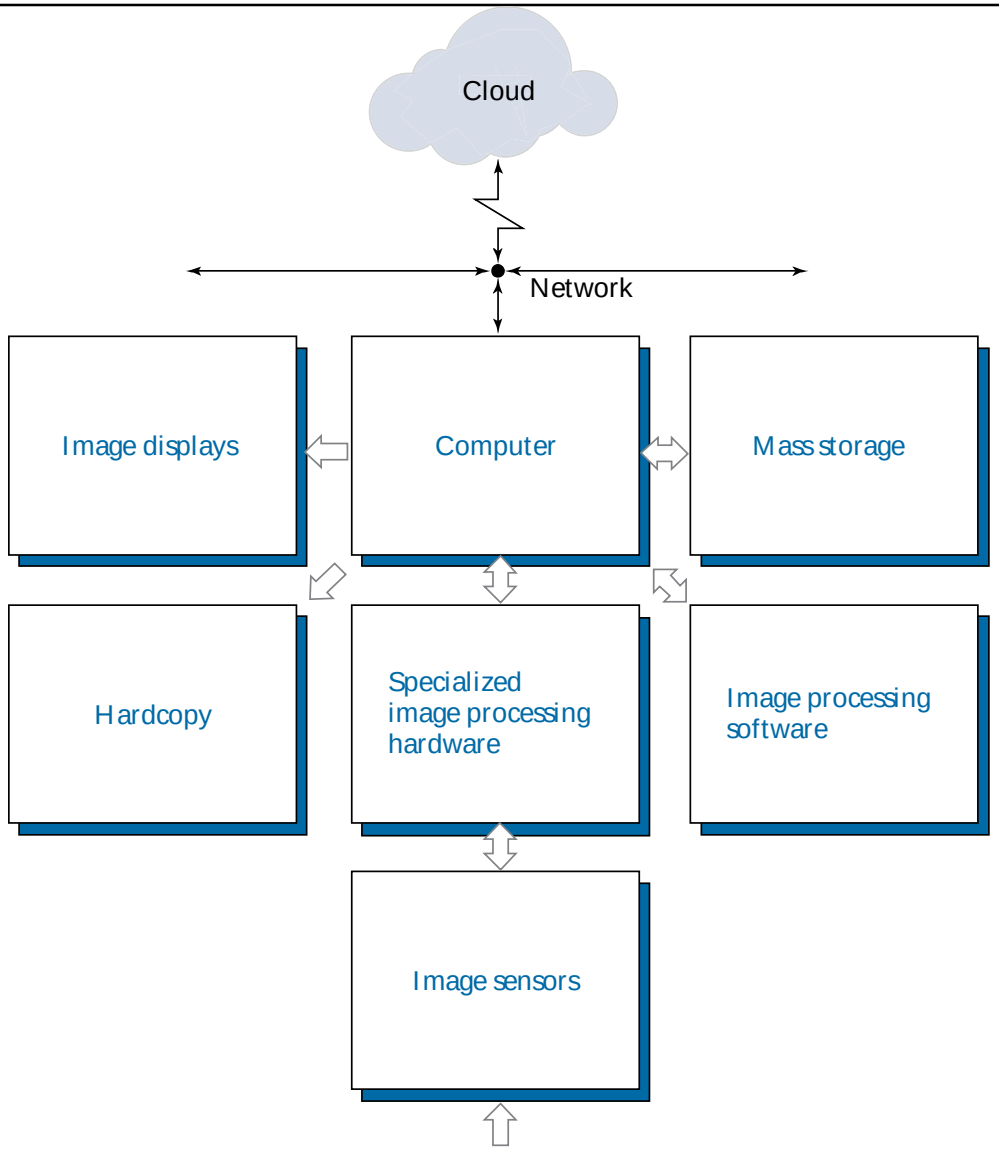


FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

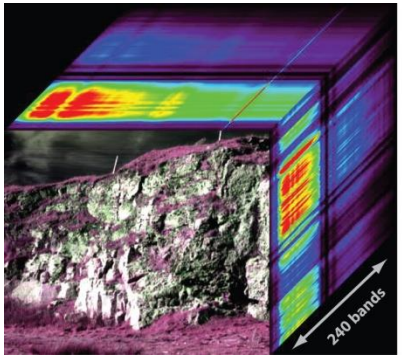
Components of Image Processing Systems

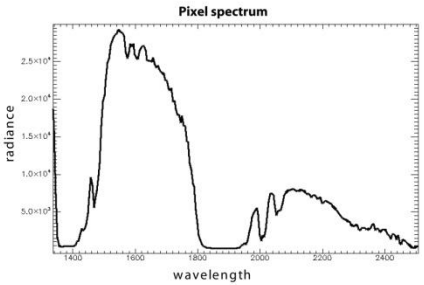
FIGURE 1.24
Components of a general-purpose image processing system.

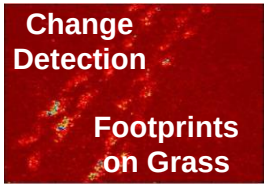


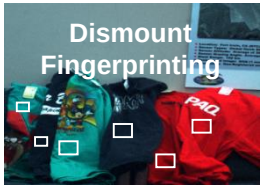
Beyond RGB: Hyperspectral Imaging (HSI)

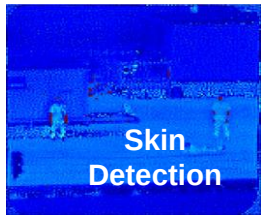
- Hyperspectral (HSI) or Multispectral Images use narrow wavelength bands
- Able to "see" certain objects better than traditional RGB EO data











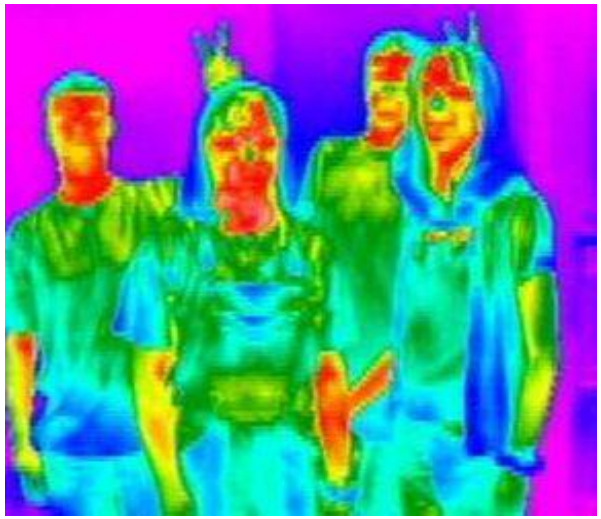
Hyperspectral Detection, ID, Tracking

- **Dismount/Vehicle Detect/ID/Tracking**
- **Fingerprinting**
- **Change/Anomaly Detection**
- **HSI/Video Tracking**
- Hyperspectral Detection of Bio-sensors
  - **Early, non-destructive detection of Chemical/Bio Attacks using Genetically altered Vegetation**

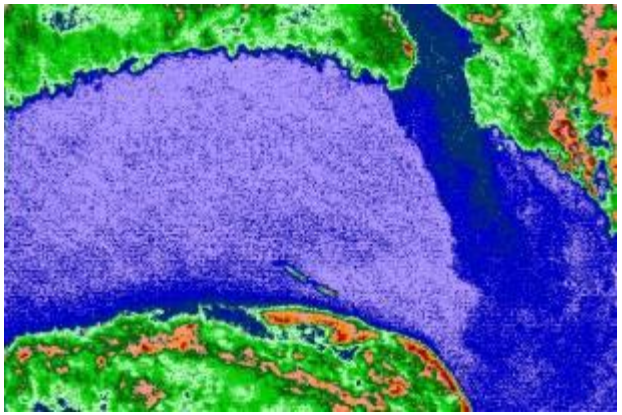
- De-Greened Detected (left)
- Green/Healthy Plants Detected (right)

Thermal Images (Infrared)

- Operate in the infrared band



Human Body Disperses Heat (Red Pixels)



Different Colours Indicate Varying Temperatures

Course Content

Course Topics	Chapters Gonzalez/Woods	Sections 4th Edition
Introduction	1	1.1-1.5
Digital Image Fundamentals	2	2.1 - 2.5 (part)
Spatial Filtering (smoothing - lowpass, sharpening – highpass, other filters)	3	3.1- 3.8
Frequency Domain Filtering	4	4.3 - 4.10
Image Restoration & Reconstruction	5	5.1-5.11 (parts)
Wavelets & Multiresolution	6	6.1- 6.10
Color Image Processing	7	7.1 - 7.8
Image Compression	8	8.1 - 8.11 (parts)
Morphological Image Processing	9	9.1- 9.5
Image Segmentation, Edge Detection, Thresholding & Region Detection	10	10.1 -10.4, 10.7
Feature Extraction	12	12.1 - 12.4 (parts)

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Acknowlegements

The slides are primarily based on the figures and images in the Digital Image Processing textbook by Gonzalez and Woods:

- http://www.imageprocessingplace.com/DIP-3E/dip3e_book_images_downloads.htm

In addition, slides have been adopted and modified from the following useful sources:

- http://www.comp.dit.ie/bmacnamee/gaip.htm
- http://baggins.nottingham.edu.my/~hsooihock/G52IIP/