Technical University of Cluj - Napoca
Computer Science Department

Image Processing

(Year III, 2-nd semester)

Lecture 1: Introduction

What is Computer Vision?

Computer vision is the discipline that uses **statistical methods to disentangle data using models constructed with the aid of geometry, physics and learning theory.**

Computer vision relies on a solid understanding of cameras and of the physical process of image formation:

- to obtain simple inferences from individual pixel values and combine the information available in multiple images into a coherent whole,

- impose some order on groups of pixels to separate them from each other or infer shape information, and recognize objects using geometric information.

Some related disciplines

- **artificial intelligence**
- **robotics**
- **signal processing**
- **pattern recognition**
- **control theory**
- **psychology**
- **neuroscience**

Computer Vision also known as

- **image analysis**
- **scene analysis**
- **image understanding**

Introduction

Image Processing

Concerned with *image properties* and *image-to-image transformations*

Most computer vision algorithms require image processing

Examples of image processing

- image enhancement (improving image quality through transforms, bring out detail that is obscured, highlight features of interest in an image)
- compression (compact representation of images for transmission)
- restoration (elimination of known degredations)
- feature extraction (locating specific image patterns like edges)

Are image processing techniques related to “high-level” image understanding? Can these be understood independently?

Introduction

Pattern Recognition

Concerned with the **recognition and classification of objects using digital images**.

Has a long research history originating with early associative memory work in the 60s.

Many classic approaches only worked under very constrained views and led to the development of computer vision as a field.

Machine Learning is a field of computer science that gives computer systems the ability to "learn" from data, without being explicitly programmed.

Deep Learning the hottest topic of the last 4 years.

Introduction

Photogrammetry

Concerned with obtaining **reliable, accurate measurements from noncontact imaging**.

Higher-levels of accuracy are traditionally required for photogrammetric applications than computer vision.

Not all of computer vision is related to the act of

measuring (perception is not necessarily measurement).

More info: see *International Society of Photogrammetry and Remote Sensing*.

(http://www.p.igp.ethz.ch/isprs/isprs.html)

Introduction

Example Research Areas:

- Feature Detection
- Contour Representation
- Color vision
- Active/Purposive vision
- Invariants
- Object detection
- Vision architectures
- Stereo vision
- Range image analysis
- Shape reconstruction from image cues
- Shape modeling and representation
- Motion analysis
- 3D object recognition

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Introduction

Example Application Areas

- Industrial inspection/quality control
- Reverse engineering
- Surveillance and security
- Face recognition
- Gesture recognition
- Road monitoring
- Space applications
- Medical image analysis
- Virtual reality, telepresence, and telerobotics
- Autonomous vehicles
- Automated map making, model acquisition

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Examples of fields that use digital image processing

- **The principal energy source for images is the electromagnetic energy spectrum.**
- **Other important sources include acoustic and ultrasonic spectrum**.
- Electromagnetic radiation is a phenomenon that takes the form of self-propagating waves in a vacuum or in matter. It consists of electric and magnetic field components which oscillate in phase perpendicular to each other and perpendicular to the direction of energy propagation.
- **Electromagnetic waves can be conceptualized as** propagating sinusoidal waves of varying wavelengths, or they can be thought of as **a stream of massless particles**, **each traveling in wavelike pattern and moving at the speed of light**.
- **Each massless particle contains a certain amount of energy – called photon**.
- The electromagnetic waves are described by any of the following three physical properties: **the frequency f, wavelength λ, or photon energy E**.

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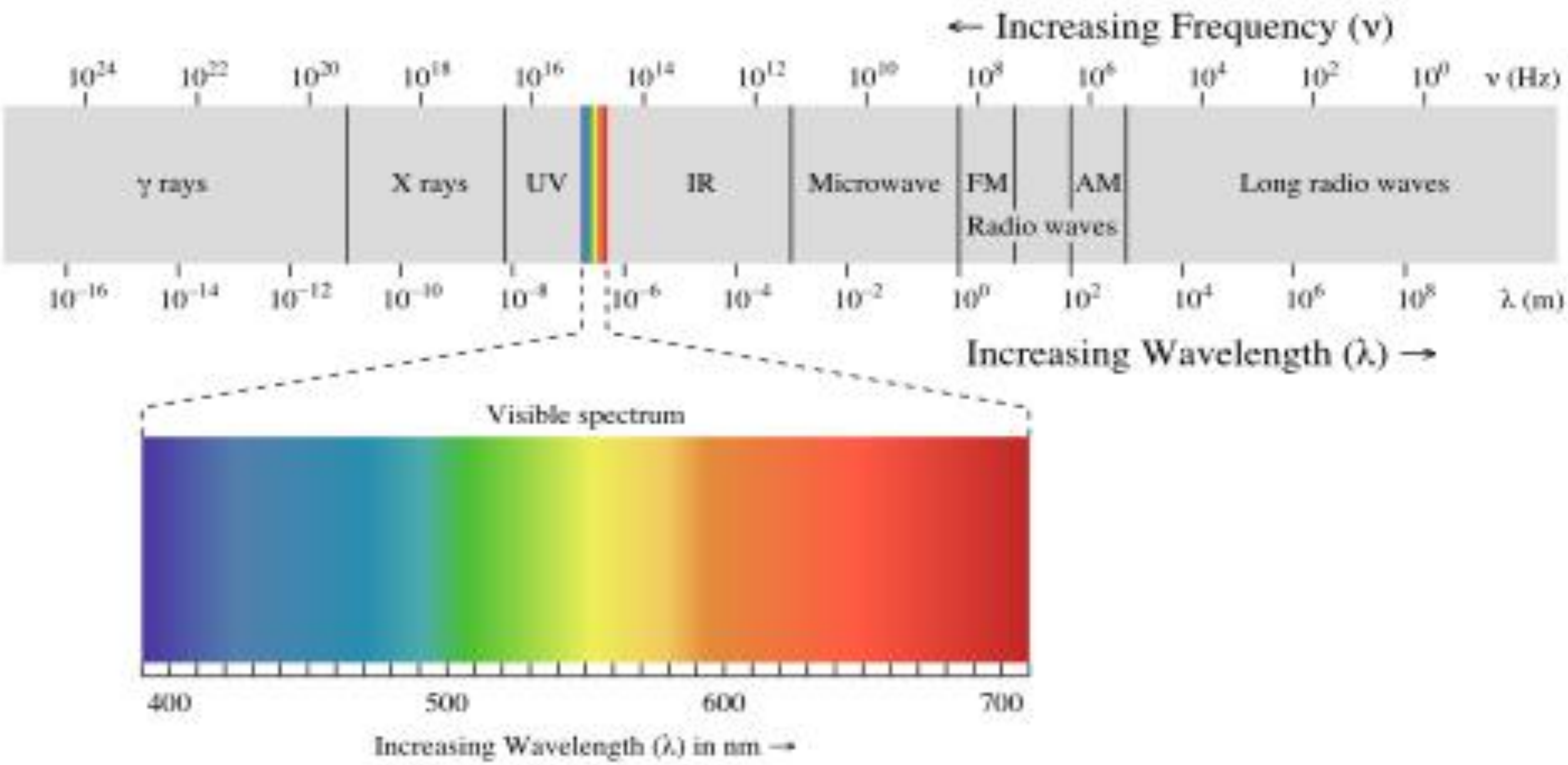
Examples of fields that use digital image processing

Electromagnetic radiation is classified into several types according to the frequency of its wave: **radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.** Wavelengths of electromagnetic radiation, no matter what medium they are traveling through, are usually quoted in terms of vacuum wavelength. Whenever electromagnetic waves exist in a medium with matter, their wavelength is decreased.

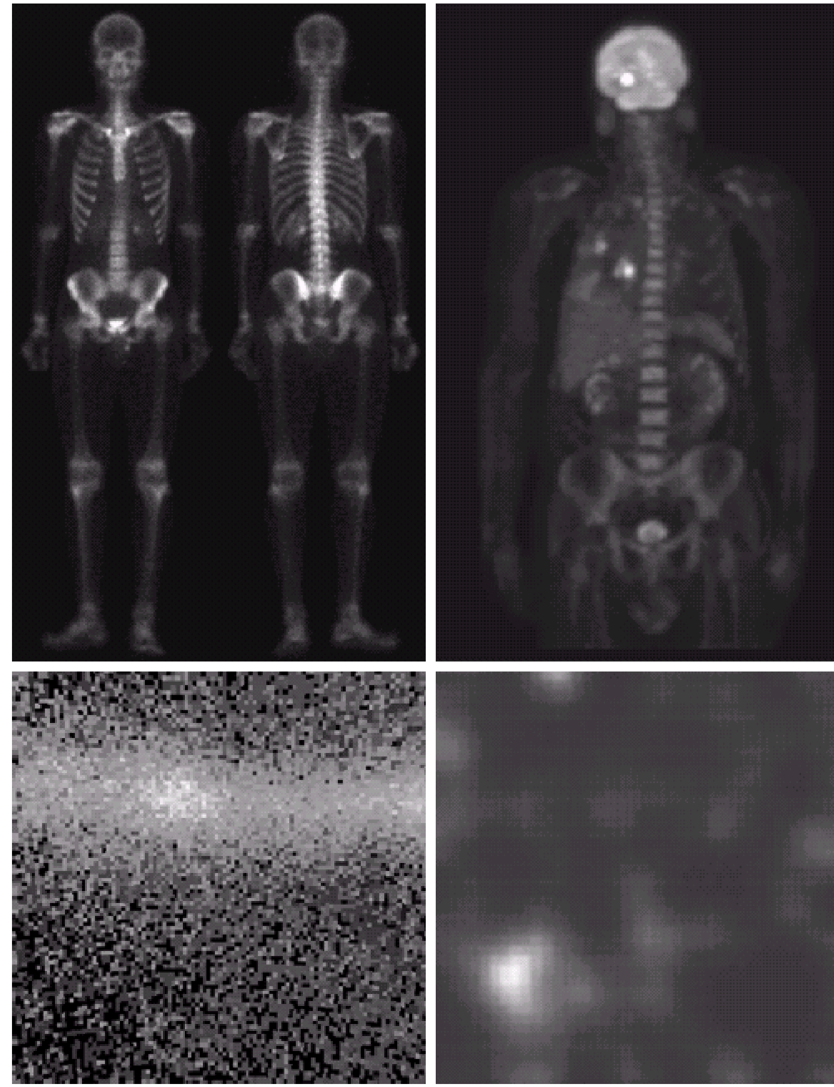


Gamma-ray imaging

Gamma-ray imaging – nuclear medicine and astronomical observations
-inject radioactive isotope that emits gamma rays as it decays.
-images are produced from the emissions collected by gamma ray detectors.
-positron emission tomography (radioactive isotope that emits positrons – when a positron meets an electron two gamma rays are given off)

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.)



From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

X-ray imaging

X-ray imaging is used in medicine, industry, astronomy

-X-ray tube generates in a controlled way X-ray radiations

-the intensity of the X-rays is modified by absorption as they pass through the patient or object , and the resulting energy falling on the film develops it

-used in radiography, angiography, X-ray tomography

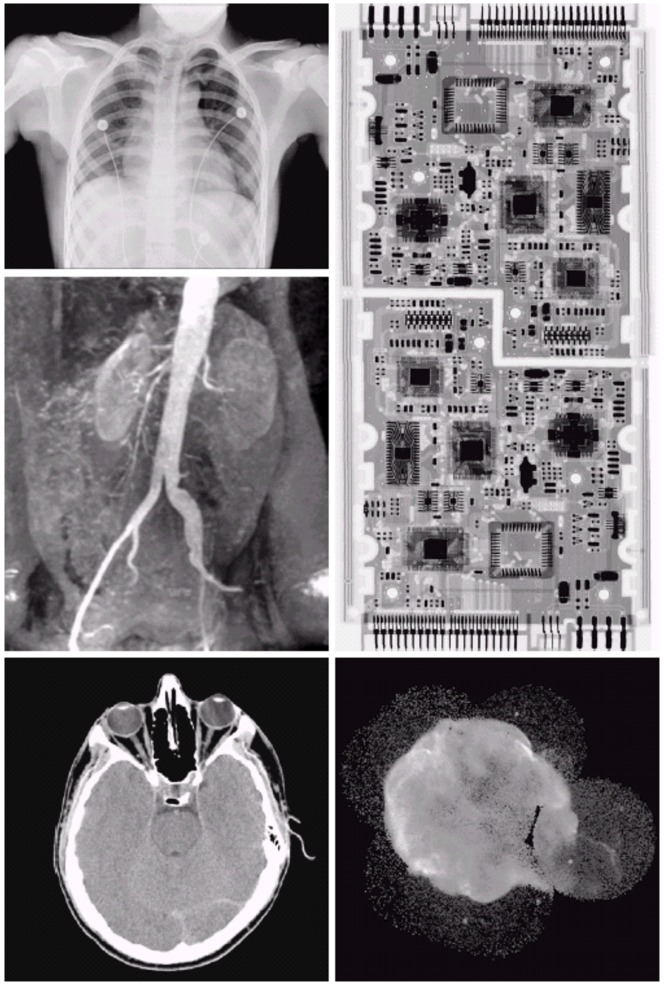


FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical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

From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Imaging in the Ultraviolet Band

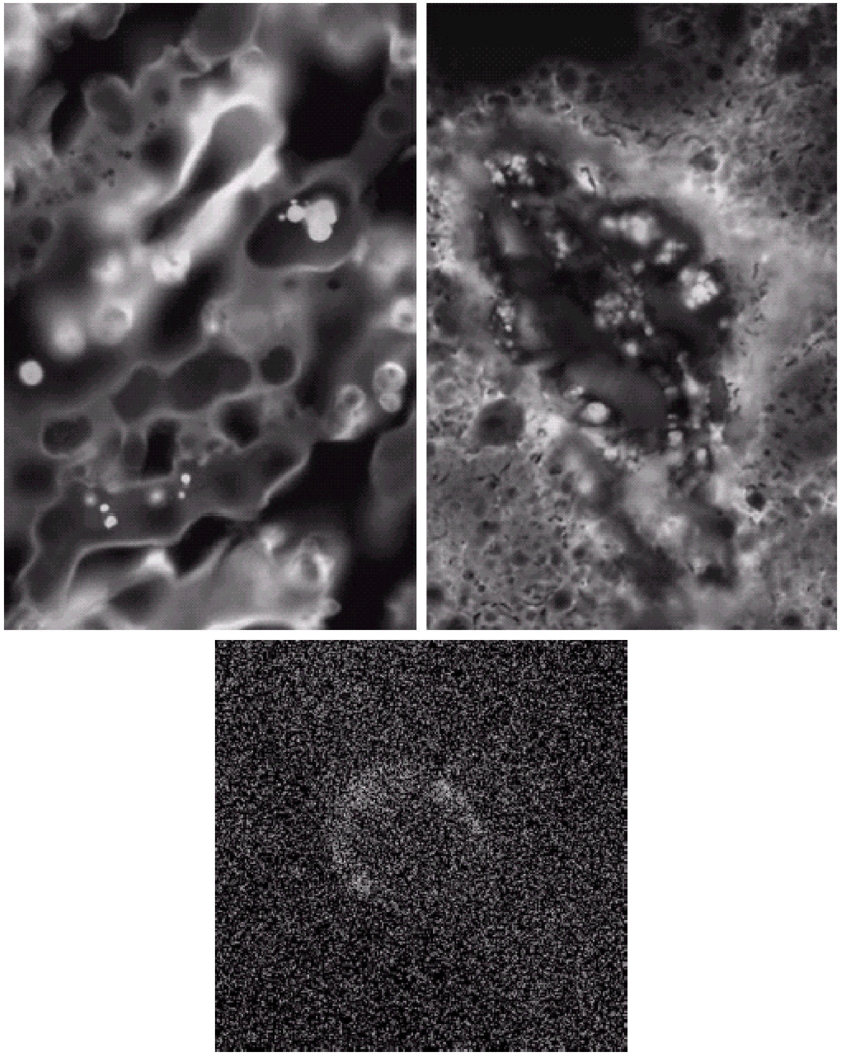
Industrial inspection, microscopy, biological imaging, astronomy.

Ultraviolet light is used in fluorescence Microscopy.

Is a method for studying materials that can be made fluoresce, either in their natural form or when treated with chemicals.

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.)



From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Imaging in the Visible and Infrared Bands

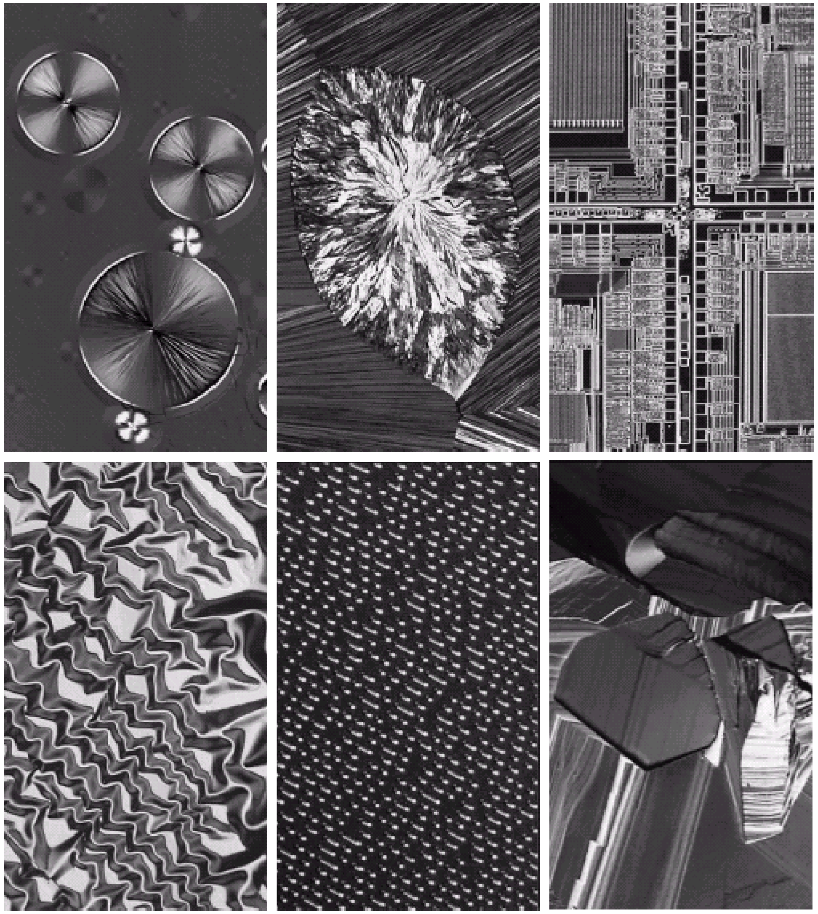


FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Imaging in the Visible and Infrared Bands

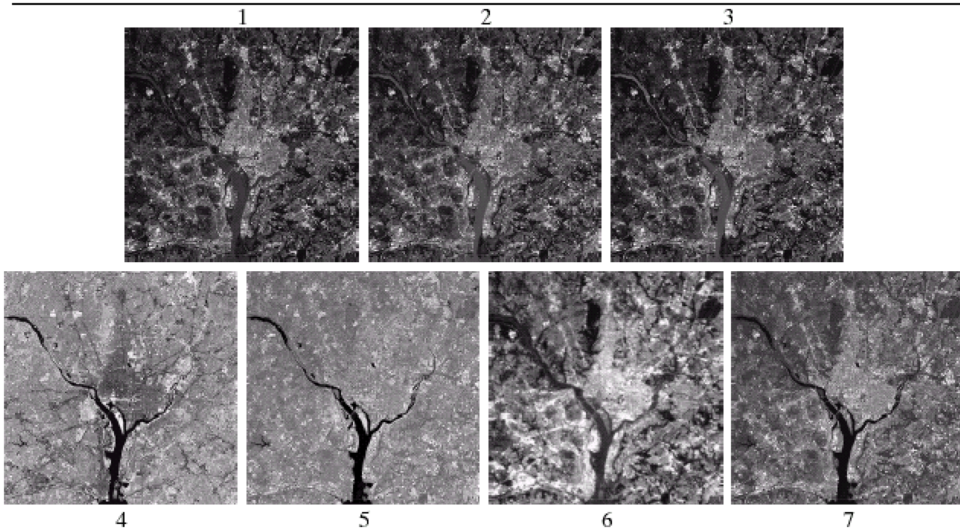


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

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

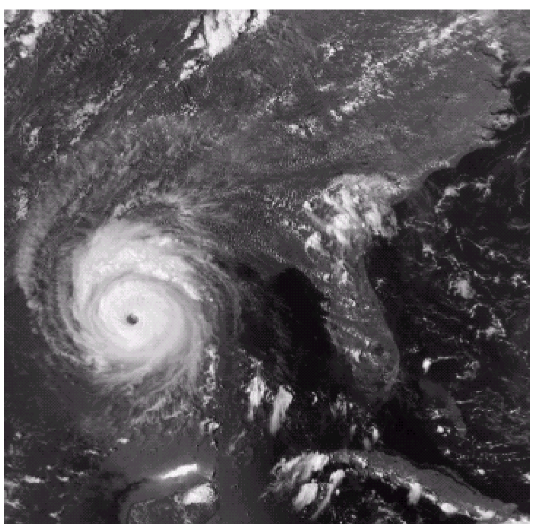


FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

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Imaging in the Visible and Infrared Bands

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

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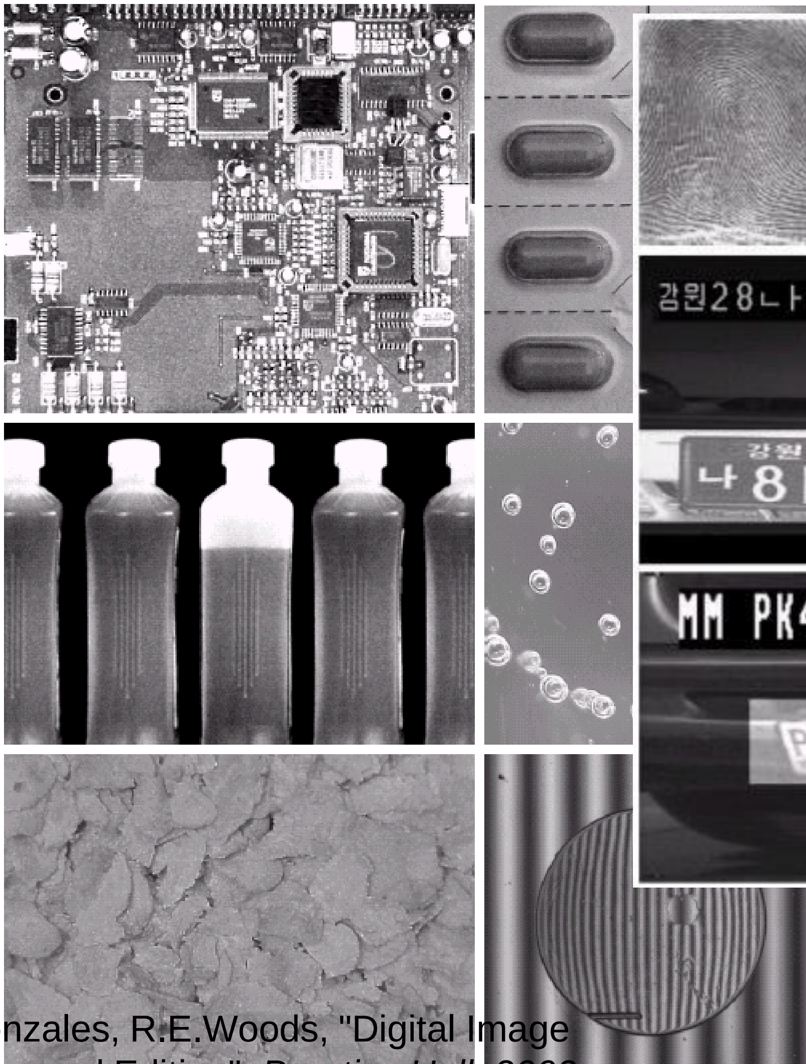
Imaging in the Visible and Infrared Bands

a b
c d
e f

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.)



a b
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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.)

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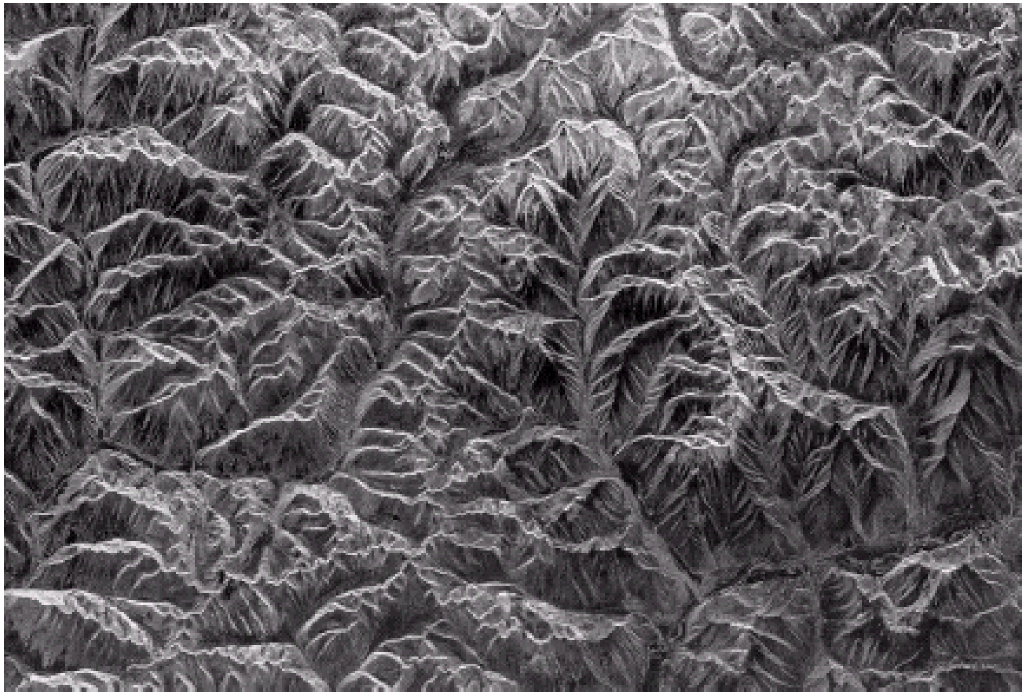
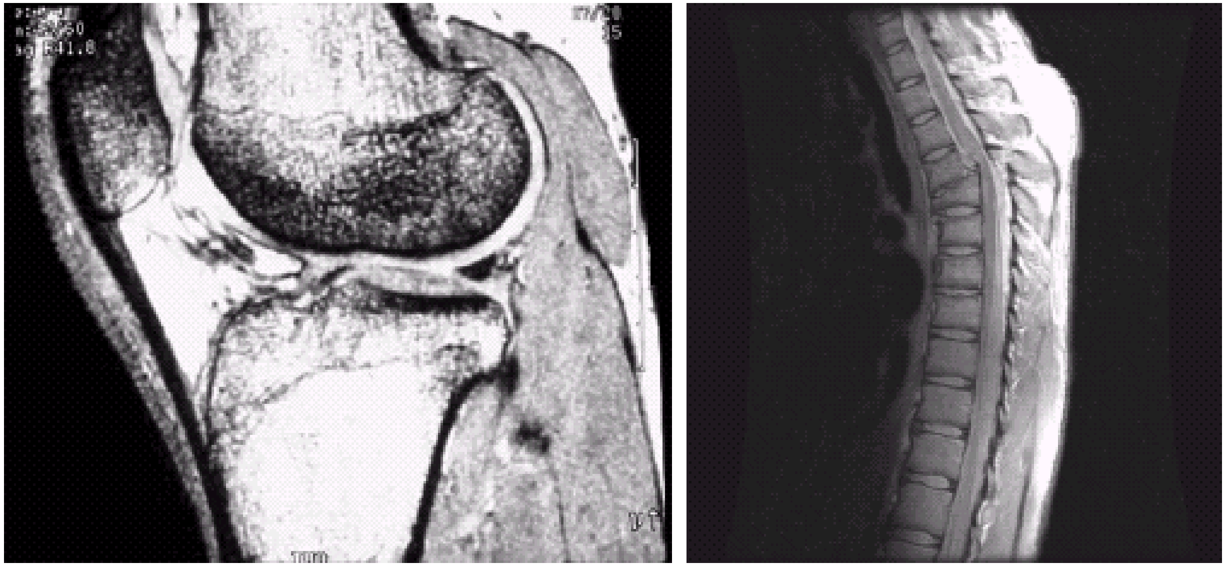
Imaging in the Microwave Band

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



From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Imaging in the Radio Band

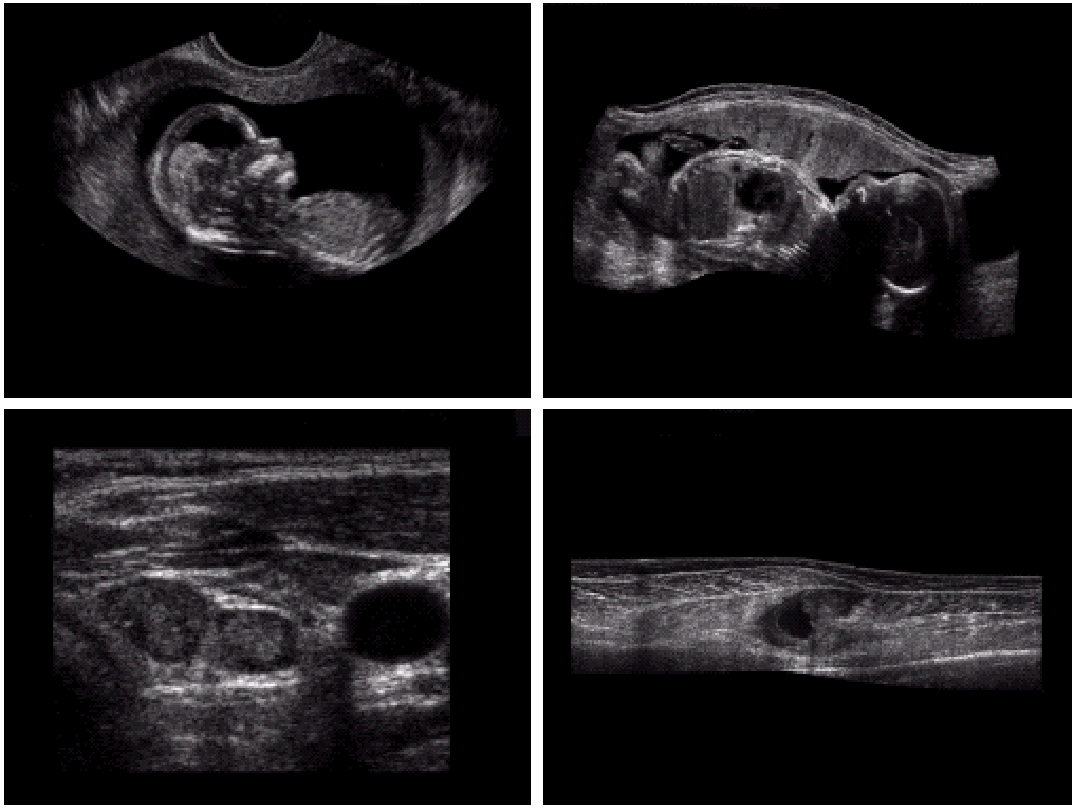


a b

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.)

From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Imaging with Ultrasounds



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.)

From R.C.Gonzales, R.E.Woods, "Digital Image Processing-Second Edition", *Prentice Hall, 2002*

Fundamental steps in digital image processing

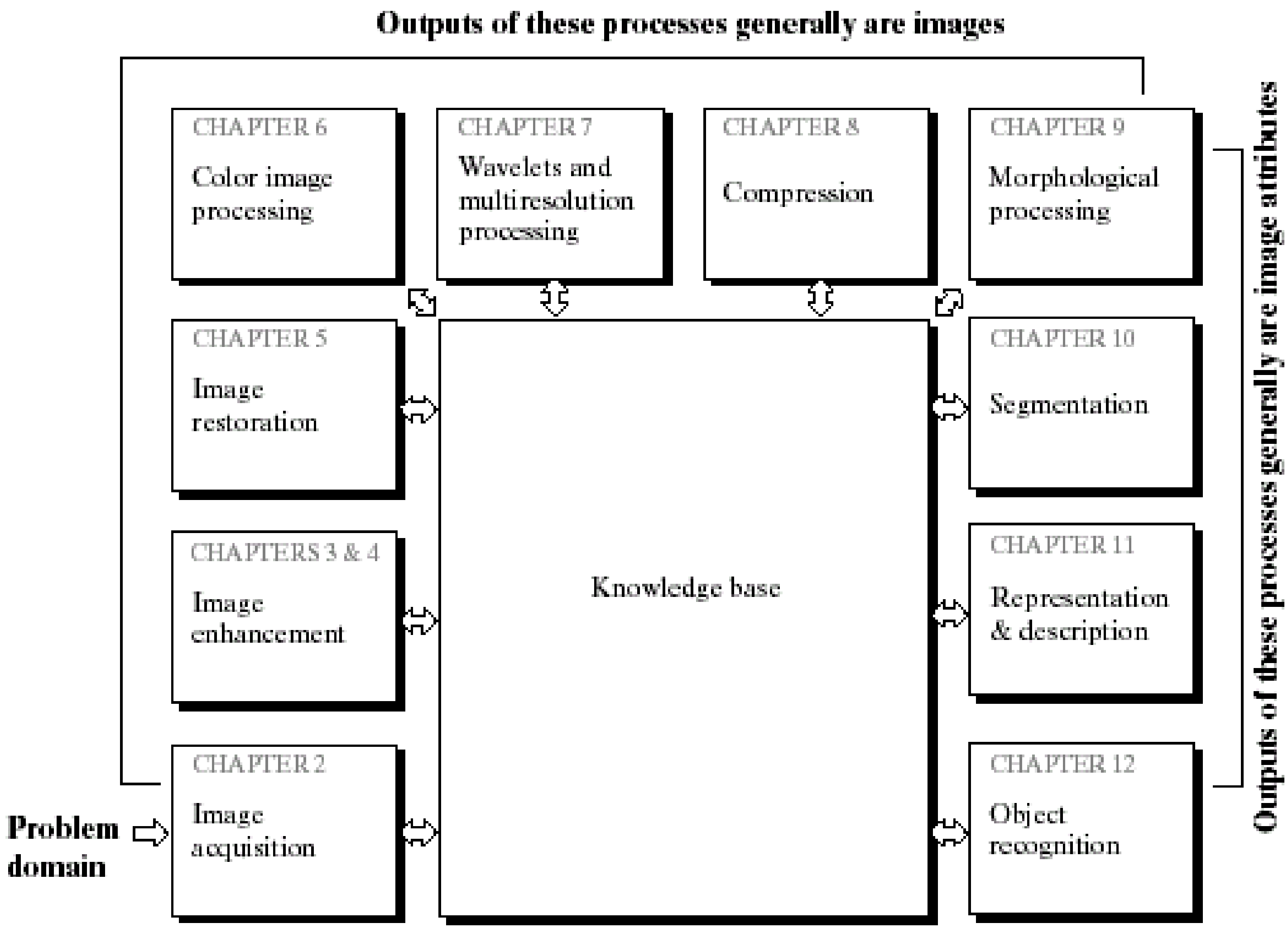


FIGURE 1.23 Fundamental steps in digital image processing.

Objectives

Lecture objectives

- Introduction to theoretical concepts and practical issues associated with image processing.
- Problem solving skills and engineering intuition in the subject area.
- Knowledge and competence in applying the specific concepts
- Capability to read advanced textbooks and research literature in the field.

Topics

- image preprocessing
- image enhancement
- image segmentation and analysis
- computer vision

Key words

Digital image processing, enhancement, preprocessing, segmentation and analysis, computer vision.

Lecture Content (2C+1S+2L)

01. Computer vision and applications. Vision system structure and functions. Image acquisition systems.
02. Image formation and sensing. Camera model
03. Binary image processing: Simple Geometric Properties.
04. Binary image processing: Labeling, Contour Tracing, Polygonal Approximation
05. Binary image processing: Mathematical Morphology
06. Grayscale image processing: Mathematical methods for grayscale image processing, Statistic features of the grayscale images, Histogram processing, Point Processing
07. Grayscale image processing: Convolution and Fourier Transform
08. Grayscale image processing: Noise in images
09. Grayscale image processing: Digital Filtering
10. Grayscale image segmentation: Edge based segmentation (first order differential methods).
11. Grayscale image segmentation: Edge based segmentation (second order differential methods, edge linking, contour closing,).
12. Stereo-vision basics. Epipolar geometry. Depth computation.
13. Color images: Color models. Color based segmentation.

Lab content

1. Introduction to the Open CV library
2. Color spaces
3. The histogram of image intensity levels
4. Geometrical features of binary images
5. Connected-components labeling
6. Border tracing algorithm
7. Morphologic operations on binary images.
8. Statistical properties of grayscale images
9. Image filtering in the spatial and frequency domains.
10. Noise modeling and noise elimination.
11. Edge detection (1)
12. Edge detection (2)
13. Evaluation

Assessment

- **Assessment:**
- - Written examination (E),
- - Lab activity assessment (LA),
- - Project (P)
- Grade = 0,5*E+0,3*P + 0.2*LA
- The pass condition is $E \geq 5$ & $LA \geq 5$ & $P \geq 5$;

Textbooks and references

1. Rafael C. Gonzalez and Richard E. Woods, “Digital Image Processing”, 4th Edition, *Pearson,* March 30, 2017.
2. Rafael C. Gonzalez, Richard E. Woods and Steven L. Eddins , “Digital Image Processing Using MATLAB”, 2nd ed., *Mc Graw Hill,* 2010.
3. Richard Szeliski, Computer Vision: Algorithms and Applications, *Springer*, 2011
4. David. A. Forsyth, Jean Ponce, Computer Vision: A Modern Approach, Pearson, 2011
5. E. Trucco, A. Verri, “Introductory Techniques for 3-D Computer Vision”, *Prentice Hall, 1998.*
6. S. Nedevschi, R. Danescu, F. Oniga, T. Marita, Tehnici de viziune artificiala in conducerea automata a autovehiculelor, *Editura UT Press,* 2012
7. *S. Nedevschi, T. Marita, R. Danescu, F. Oniga, R. Brehar, I. Giosan, S. Bota, A. Ciurte, A. Vatavu, Image Processing - Laboratory Guide, UT Press, 2016*