DIGITAL IMAGE PROCESSING

Lecture1: Course Plan and Introduction

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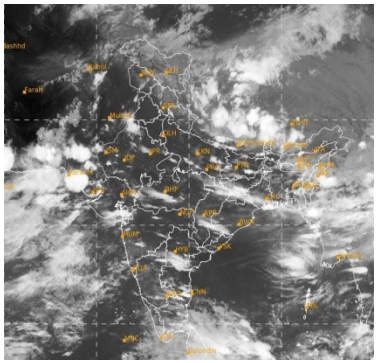
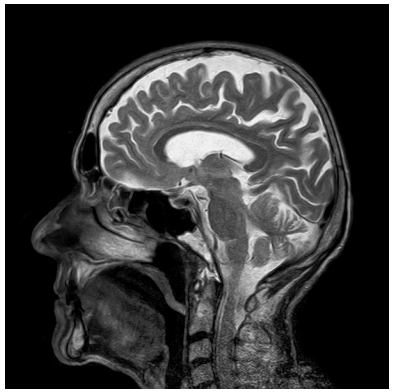
Welcome to DIP Class



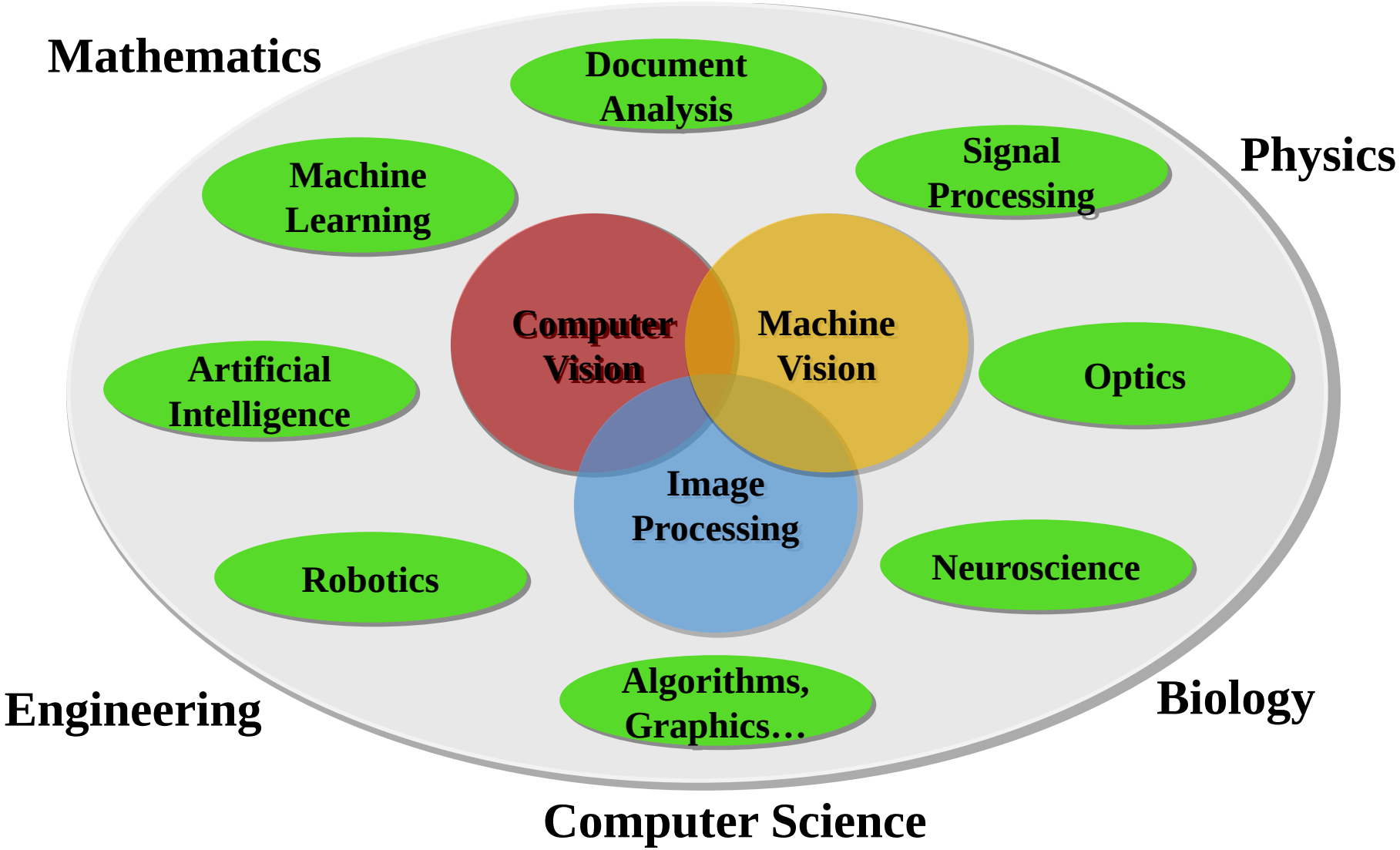






Relation with Other Fields



Prerequisites

- **Knowledge of Signals and Systems**
- **Linear Algebra:**
  1. Matrices, Matrix Operations
  2. Determinants, System of Linear Equations
  3. Eigen Values, Eigen Vectors
- **Probability and Statistics:**
  1. Probability density function, Probability distribution
  2. Mean, variance, co-variance, correlation
  3. Priors, Posteriors, Likelihoods
  4. Gaussian Distribution
- **Good programming skills**

Course Outcomes

- Learn different types of image transformations and their properties.
- Learn different techniques employed for the enhancement of images.
- Learn different causes for image degradation and overview of image restoration techniques.
- Understand the need for image compression and to learn the techniques of image compression.
- Learn different feature extraction techniques for image analysis and recognition.
- Develop any image processing application.

Course Topics

- **Introduction:** Steps in Digital Image Processing (DIP)
- **Digital Image Fundamental:** Digital Image Formation
- **Image Enhancement in Spatial Domain:** Filtering
- **Image Enhancement in Frequency Domain:** Filtering
- **Image Restoration:** Noise Reduction
- **Color Image Processing:** Models, Transformation, Smoothing

Course Topics

- **Wavelet and Multi-resolution Processing:** Scales
- **Image Compression:** Models, Lossy, Lossless, Standards
- **Morphological Image Processing:** Structure Detection
- **Image Segmentation:** Pixel & Region based, Thresholding
- **Representation and Description:** Feature Extraction
- **Object Recognition:** Identifying Objects by Extracted Feature

Grading Policy

1) Mid-Exam-1 10%
2) Mid-Exam-2 10%
3) End-Exam 20%
4) Assignments 30%
5) Term Project 30%

Assignments / Projects

- **Programming Language:** Python, C, C++, Matlab
- **Programming Platform:** Google Colab, Google Cloud Platform, Numpy, Matlab Toolbox
- **Submission Deadline:** Must be submitted before the deadline specified for the assignment/project.
- **Penalty:** You will get three additional days for submission with 25% of penalty, any submission after that will not be considered for evaluation.
- **Good / Bad Practices:** Students are encouraged to complete the home works / assignments / projects by their own. Any type of plagiarism may lead to heavy penalty.

Text / Reference Books

I. R. C. Gonzalez and R. E. Woods, ***Digital Image Processing***, Prentice Hall, 4th edition, 2018.

II. A. K. Jain, ***Fundamentals of Digital Image Processing***, Prentice Hall, 1995.

III. R. C. Gonzalez and R. E. Woods, ***Digital Image Processing with MATLAB***, Prentice Hall, 2003.

Introduction

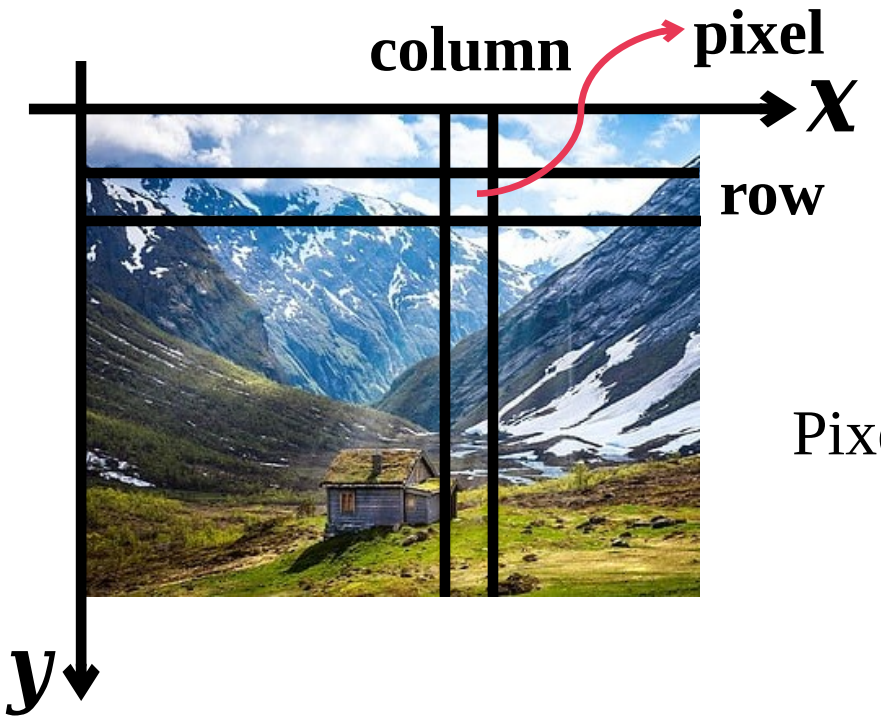
- **This lecture will cover:**
  - What is a digital image?
  - What is digital image processing?
  - Why do we process images?
  - Source of digital imaging
  - A few examples of digital image processing
  - Key steps in digital image processing

What is an image?

- **Image:** A visual representation in form of a function where is related to brightness (or color) at spatial coordinate point
- The **amplitude** of is called the **intensity** or **gray level.**
- Images are **continuous** in amplitude and space**.**

What is a digital image?

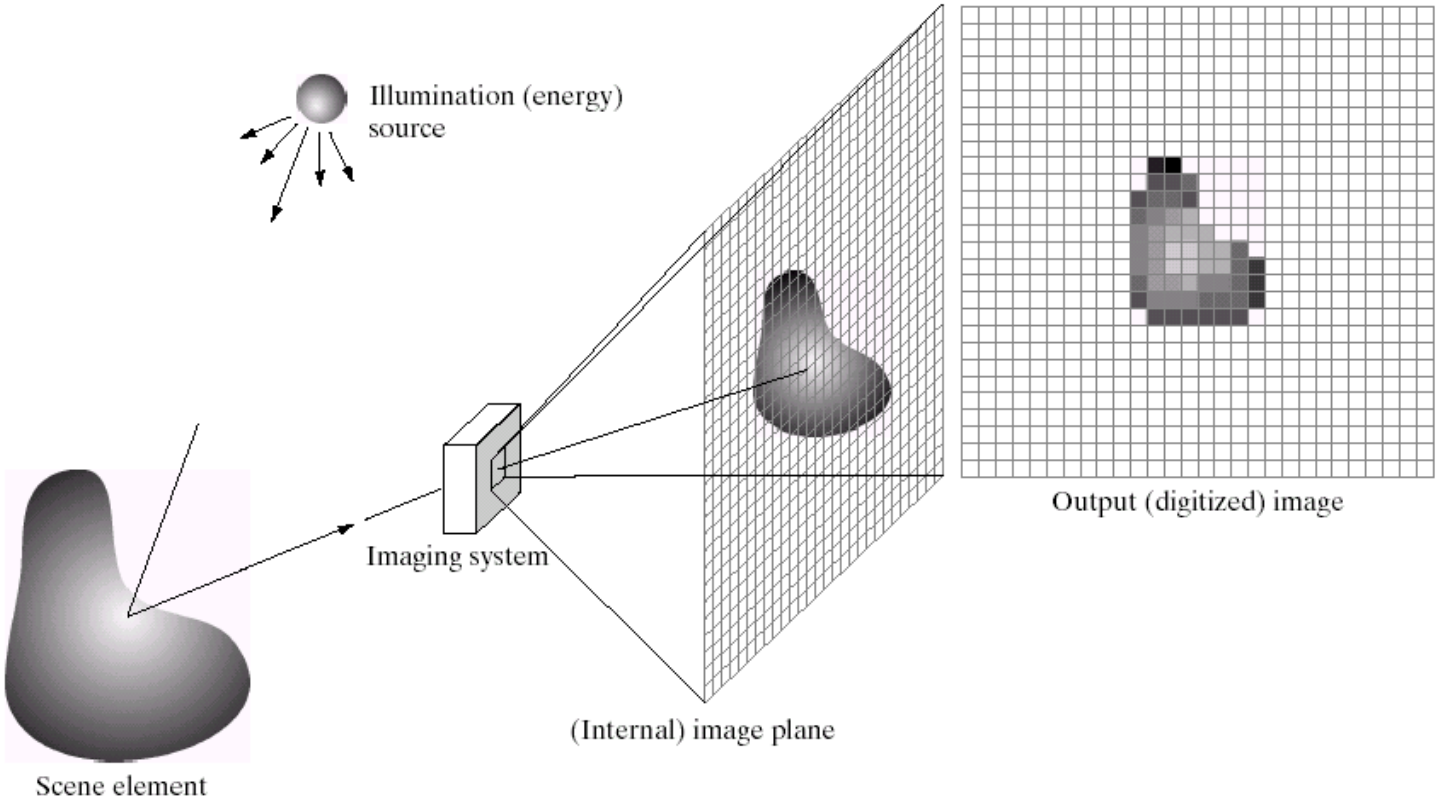
- **Digital Image:** Discrete samples representing continuous image
- Each element of the 2-d array is called a **pixel** or **pel.**



$$Image ¿ max\ x \times max\ y$$

Pixel intensity

Imaging System



a
b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

What is digital image processing?

- **DIP mainly focuses on**
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception
- **DIP includes the following steps**
  - Importing an image via image acquisition tools
  - Analyzing and manipulating the image
  - Extract information useful for the image analysis and computer vision tasks.
- **Any DIP system takes an image as an input and produce a processed image as an output.**

Digital Image Processing System

3D World

Camera

Input Image

Problem Specific Algorithm

Processed Image

Input Image

Sobel Filter

Processed Image

Why do we process images?

- **Acquire an image**
  - Correct aperture and balance
  - Reconstruct image from projections
- **Prepare for display and printing**
  - Adjust image size
  - Color mapping, gamma-correction, half-toning
- **Storage and transmission**
  - Efficiently store an image in a digital camera
  - Send an image from space
- **Enhance and restore images**
  - Improve visibility and color enhancement
  - Reduce noise in the capture image
- **Extract information from image**
  - Read 2-d bar codes
  - Character recognition








Origins of DIP

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

Sent by submarine cable between London and New York, the transportation time was reduced to less than three hours from more than a week

Origins of DIP

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.)

Image Sources

- **Electromagnetic (EM) energy spectrum**
- **Acoustic**
- **Ultrasonic**
- **Electronic**
- **Synthetic images produced by computer**

Electromagnetic Energy Spectrum

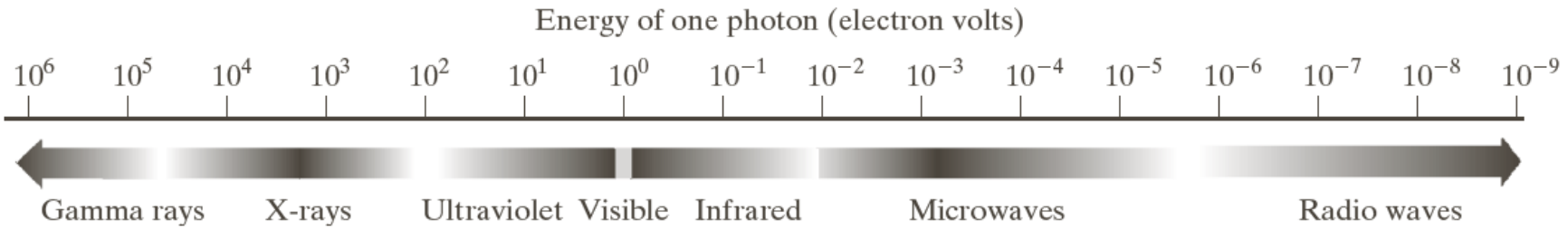
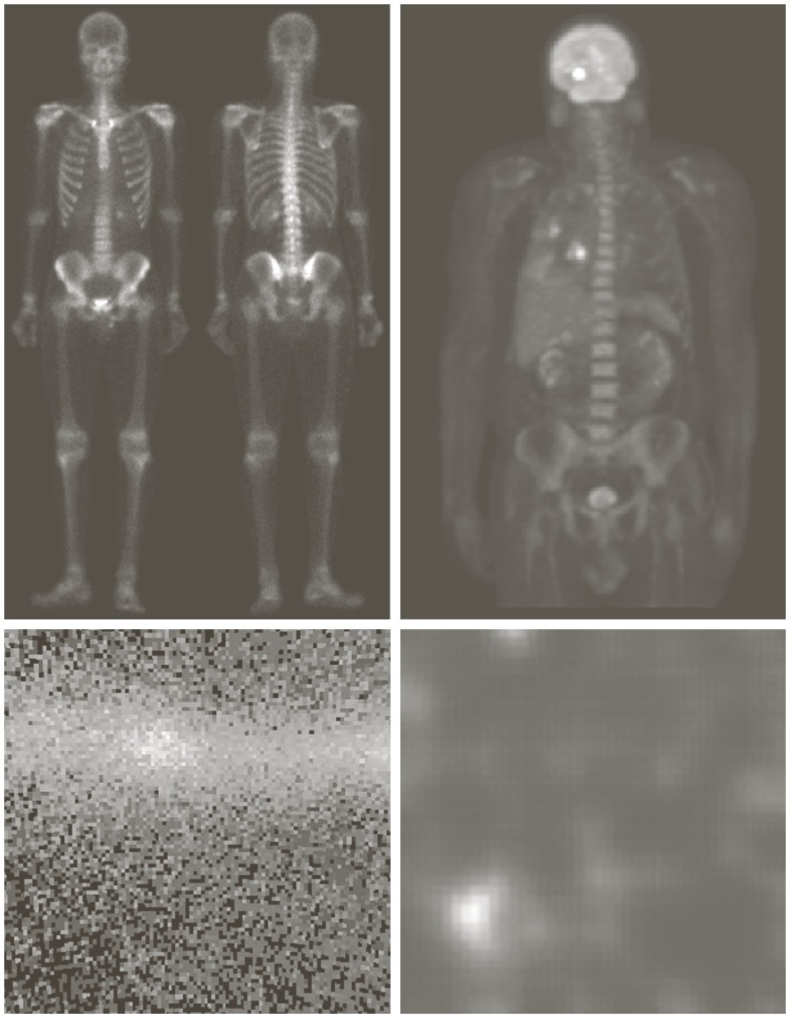


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

- **Gamma-ray imaging**: nuclear medicine and astronomical observations
- **X-rays**: medical diagnostics, industry, and astronomy, etc.
- **Ultraviolet**: lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations
- **Visible and infrared bands**: light microscopy, astronomy, remote sensing, industry, and law enforcement
- **Microwave band**: radar
- **Radio band**: medicine (such as MRI) and astronomy

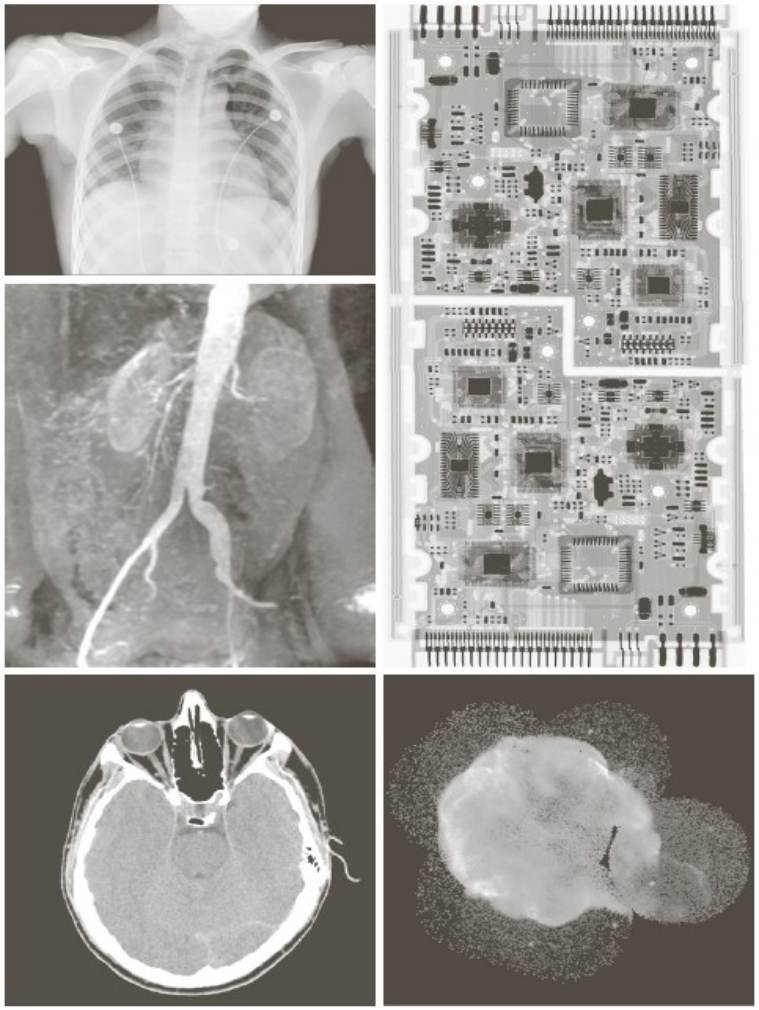
Gamma-Ray Imaging



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.)

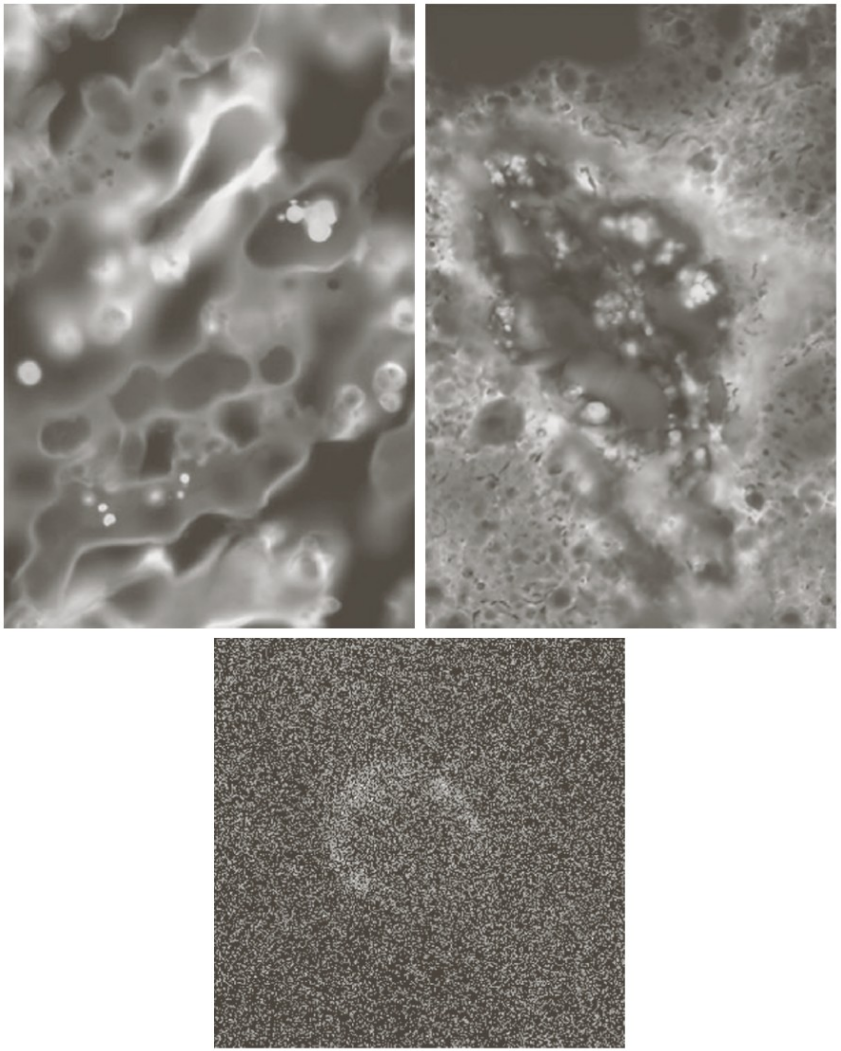
X-Ray Imaging



a d
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.)

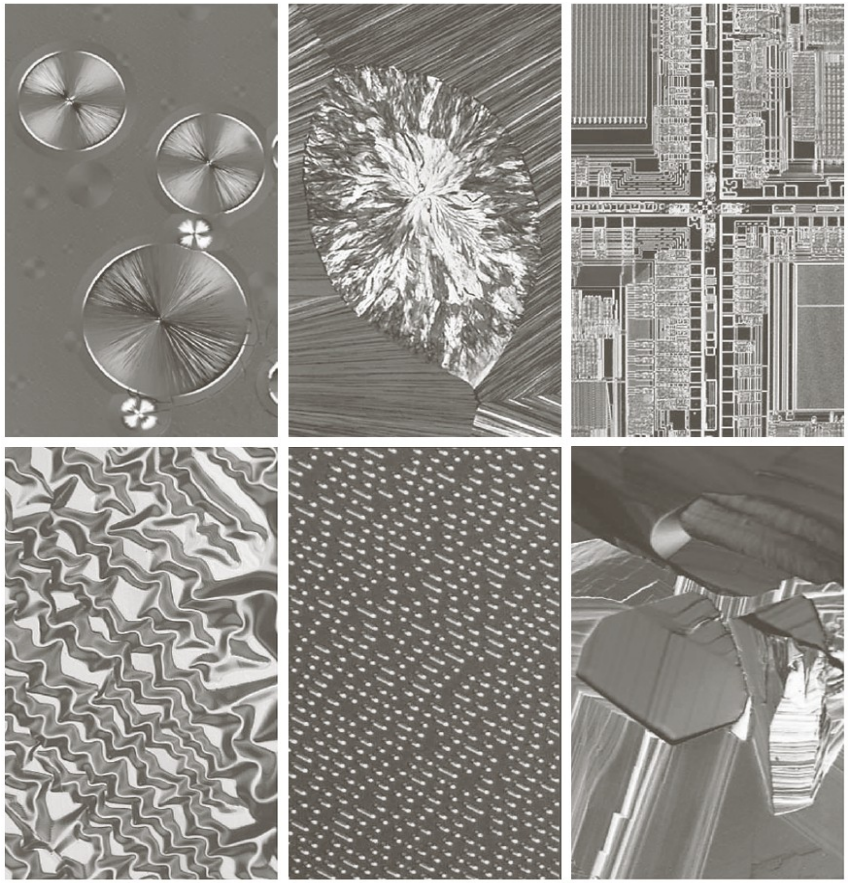
Ultraviolet Imaging



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.)

Light Microscopy Imaging



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.)

Visual and Infrared 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

Visual and Infrared Imaging

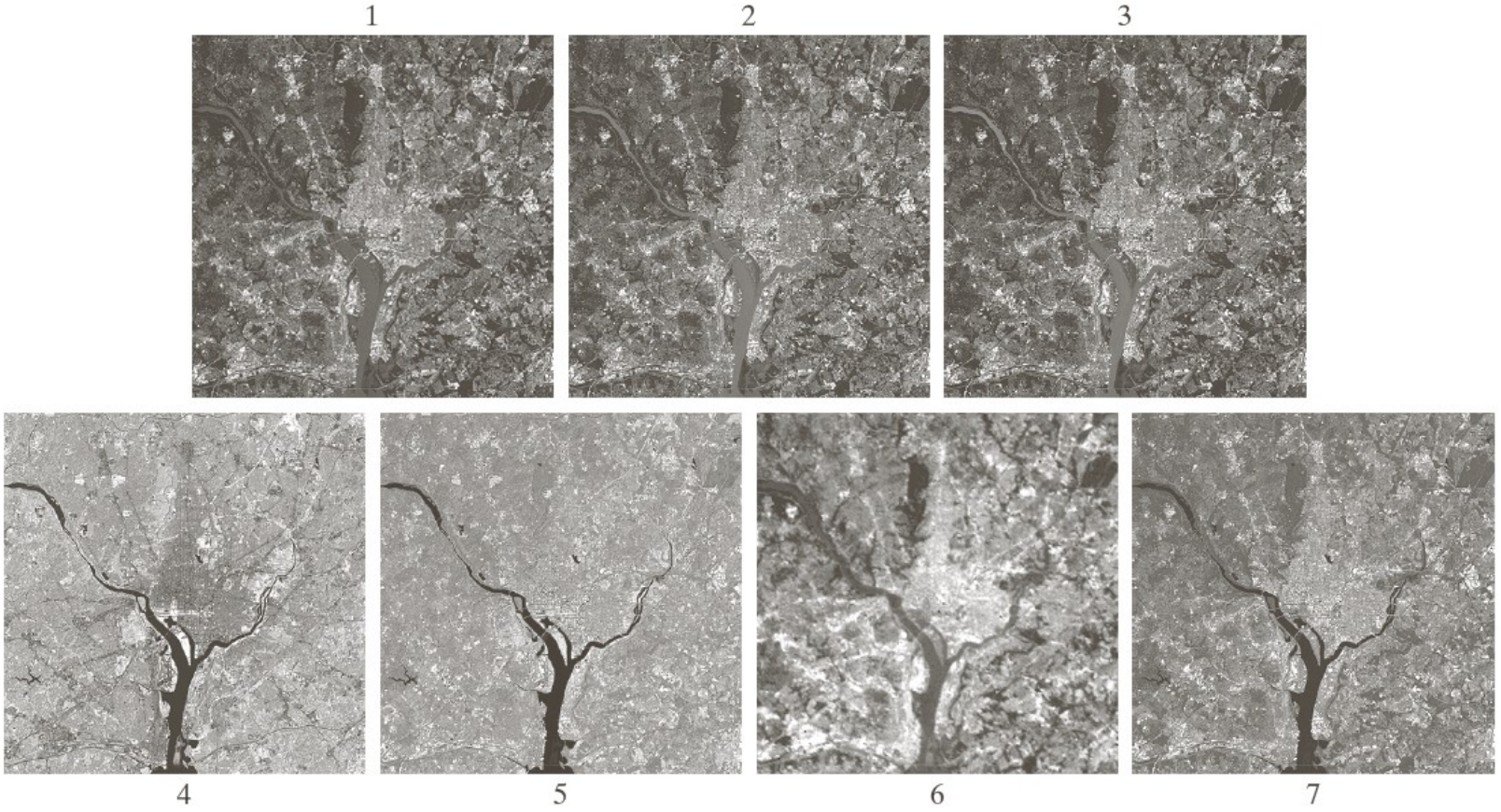
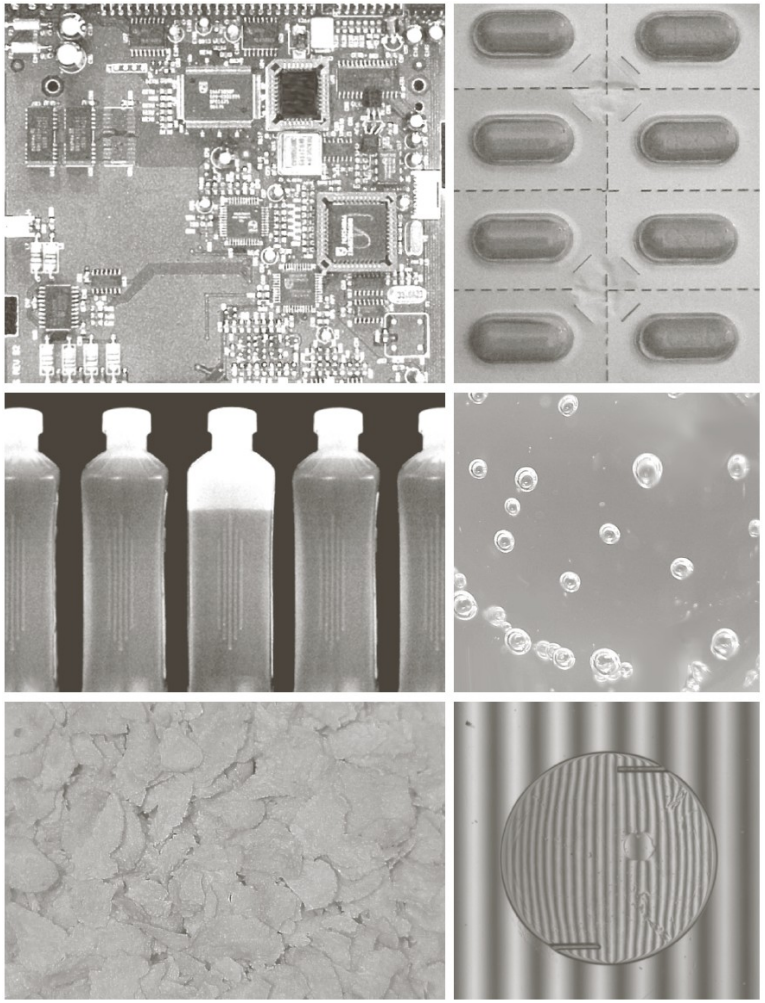


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Infrared Satellite Image

Automated Visual Inspection



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) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

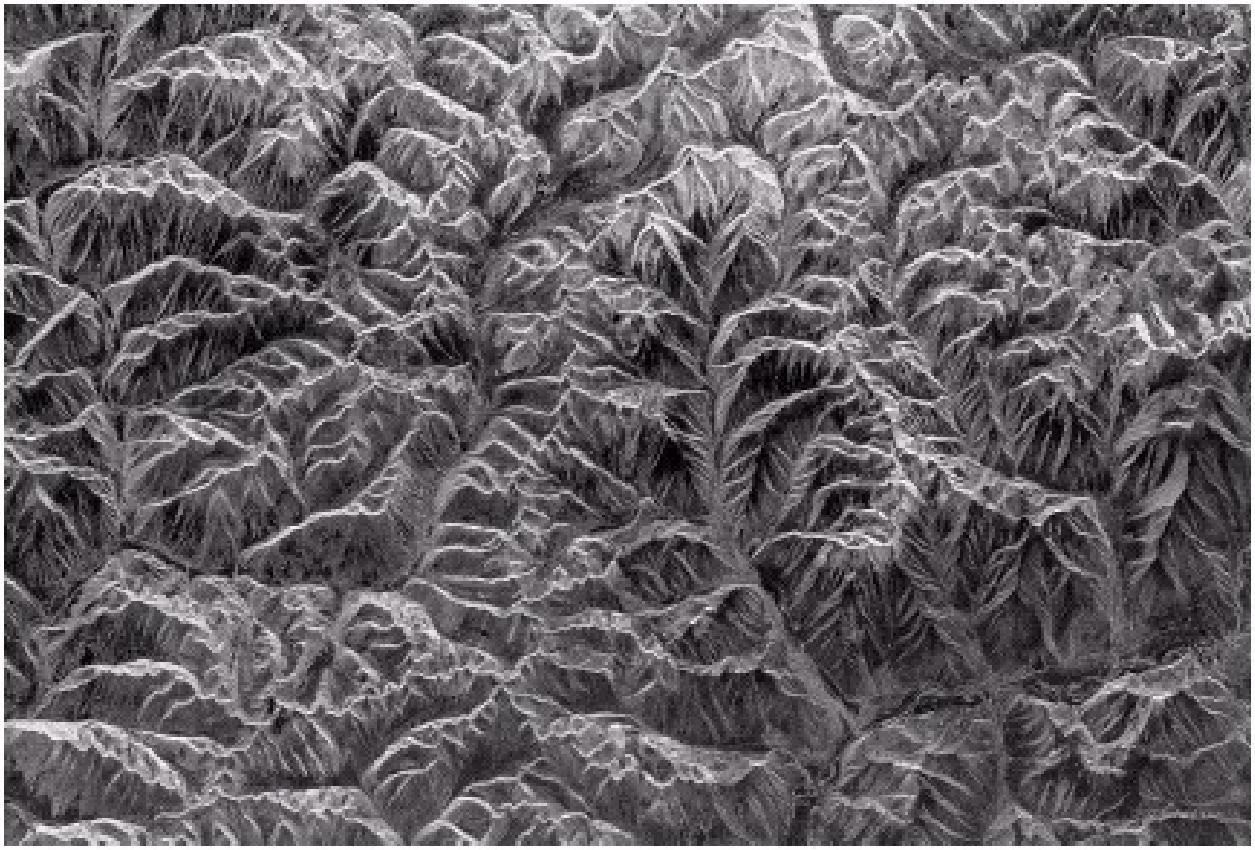
Automated Visual Inspection

a b
c
d

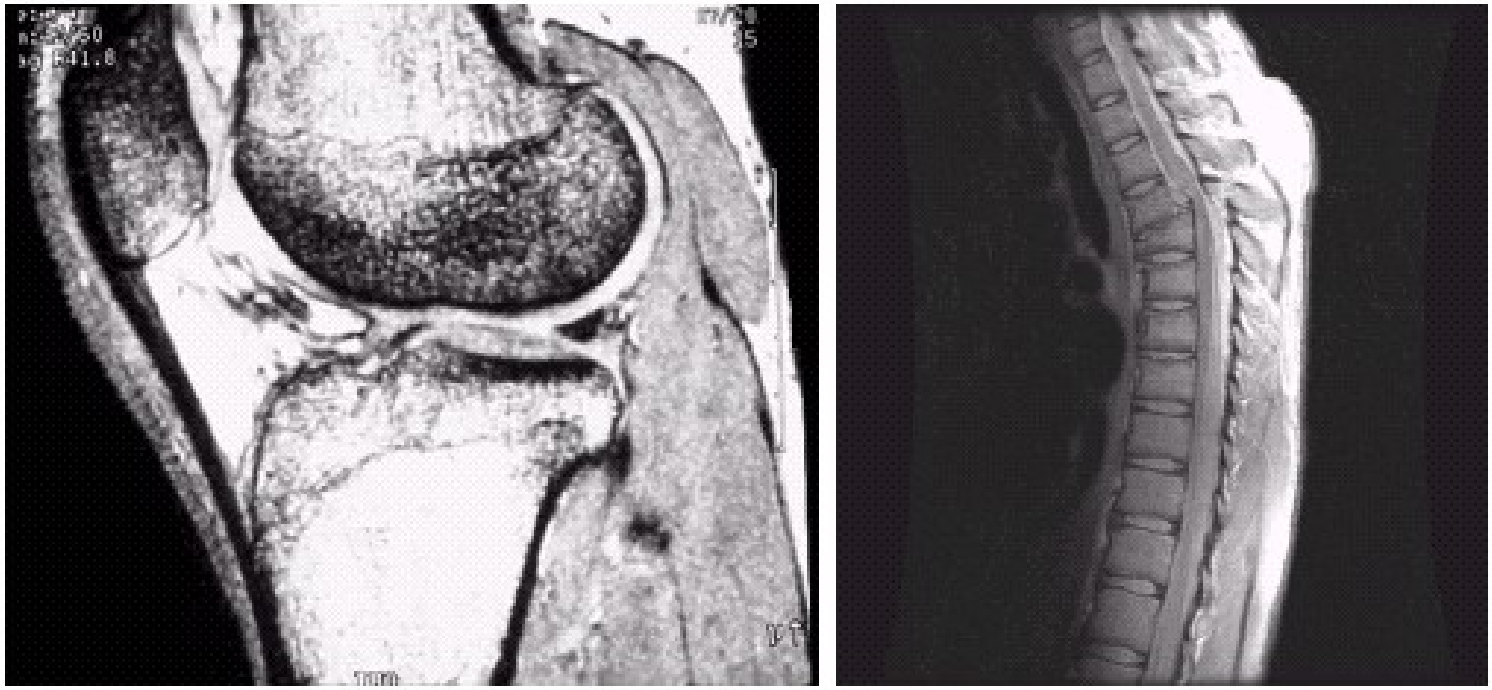
FIGURE 1.15
Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

Microwave Band: Radar Image

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



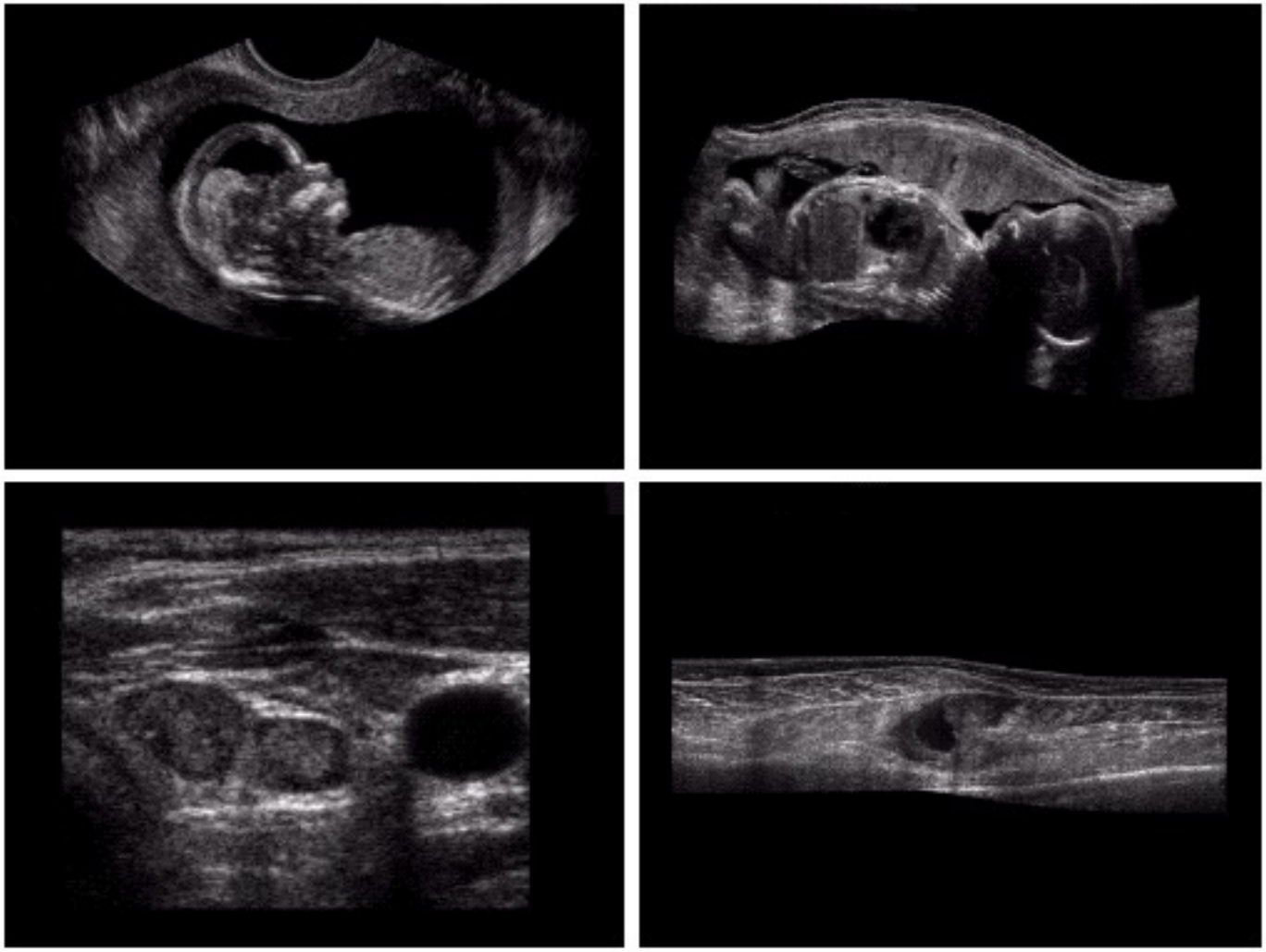
Radio Band



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.)

Ultrasound Imaging



a b
c d

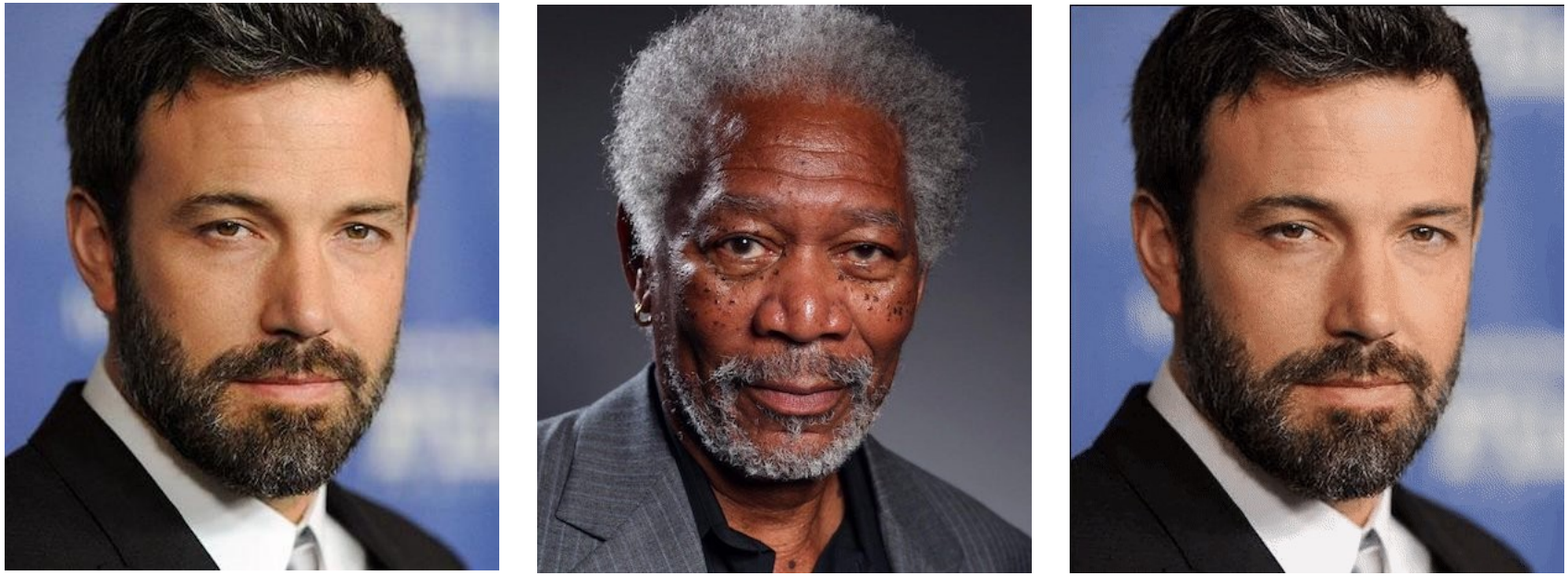
FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Image Processing Example

Image Stitching

Source: **Vaibhav Vaish,** Stanford CS223B Computer Vision, Winter 2007

Image Processing Example



Face Morphing

Source: https://github.com/cirbuk/face-morphing

Image Processing Example

Face Blurring for Privacy Protection

Image Processing Example

Image Inpainting

Source: http://graphics.cs.cmu.edu/projects/scene-completion/

Image Processing Example

Image Dehazing

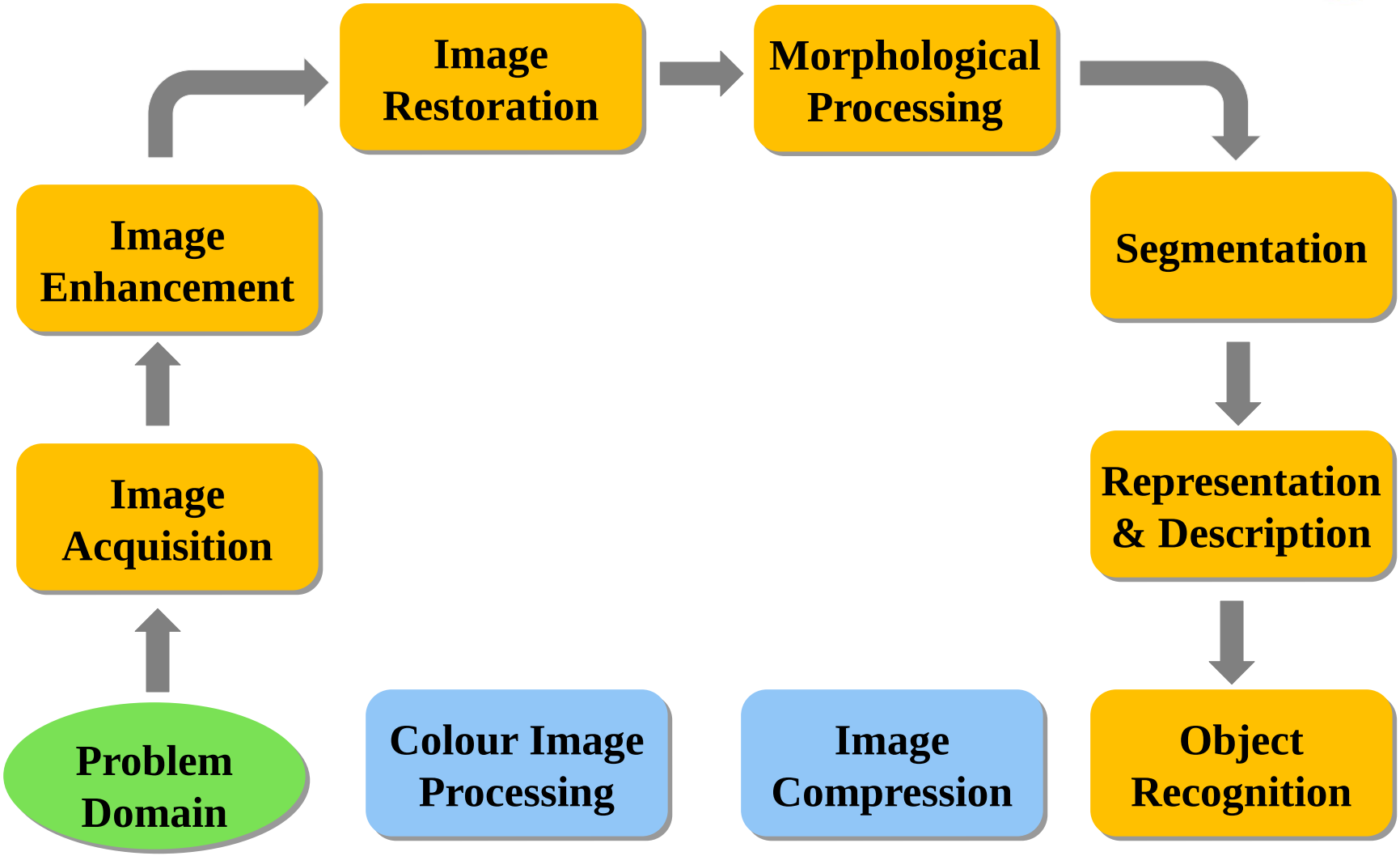
Source: http://san-santra.github.io/comp_t18/

Image Processing Example

Image Retargeting

Source: https://github.com/davidirobinson/image-retargeting

Key Steps in DIP



Key Steps in DIP: Image Acquisition

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

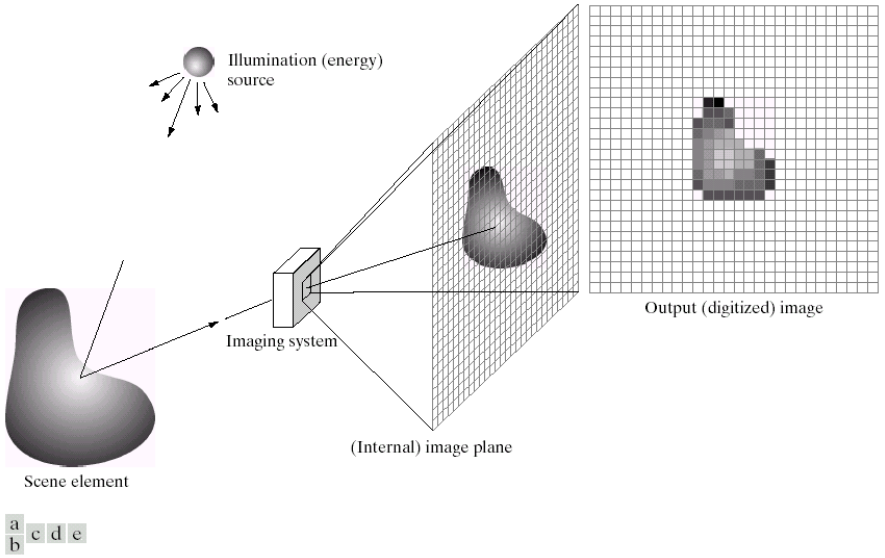
Segmentation

Representation & Description

Object Recognition

Image Compression

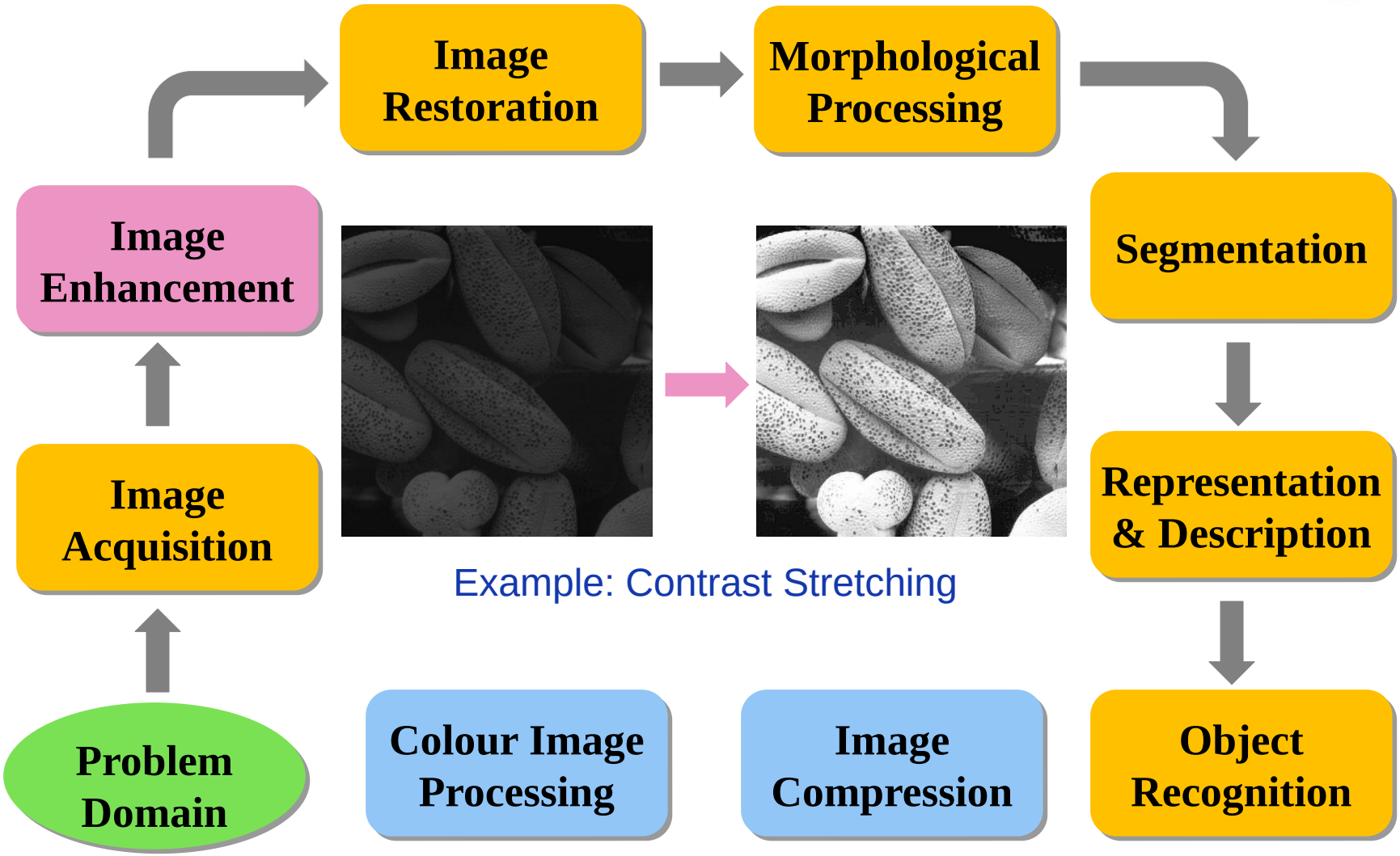
Colour Image Processing



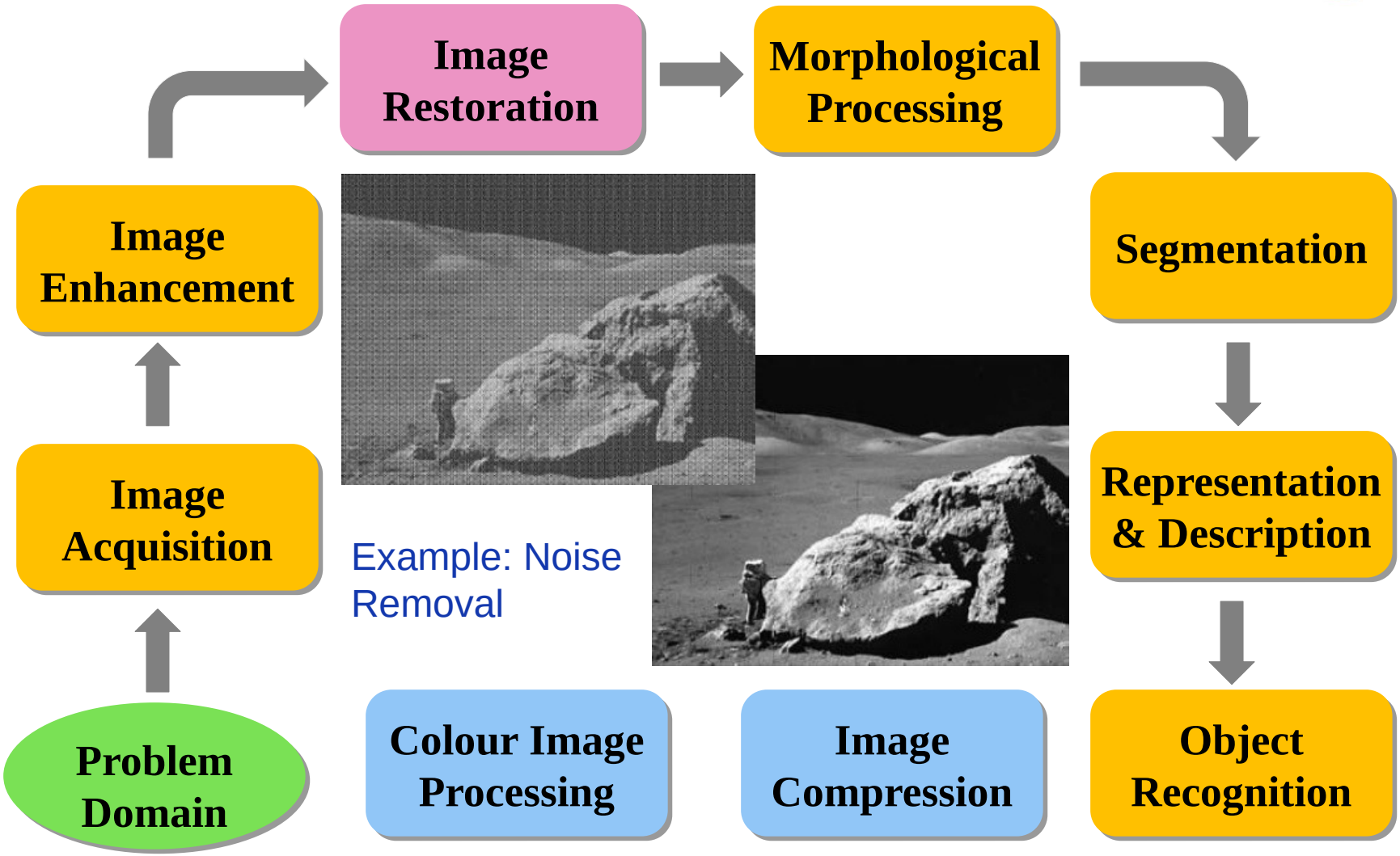
a b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

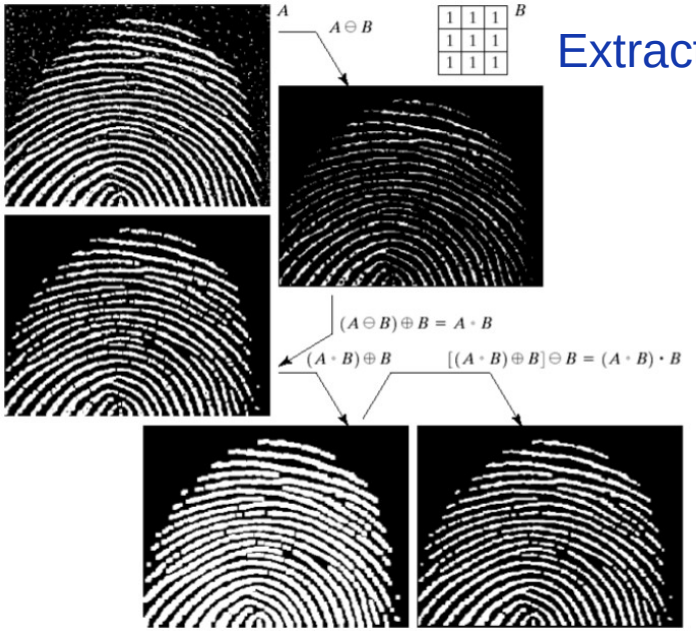
Key Steps in DIP: Image Enhancement



Key Steps in DIP: Image Restoration



Key Steps in DIP: Morphological Processing



Extract attributes

Image Restoration

Morphological Processing

Segmentation

Representation & Description

Object Recognition

Image Compression

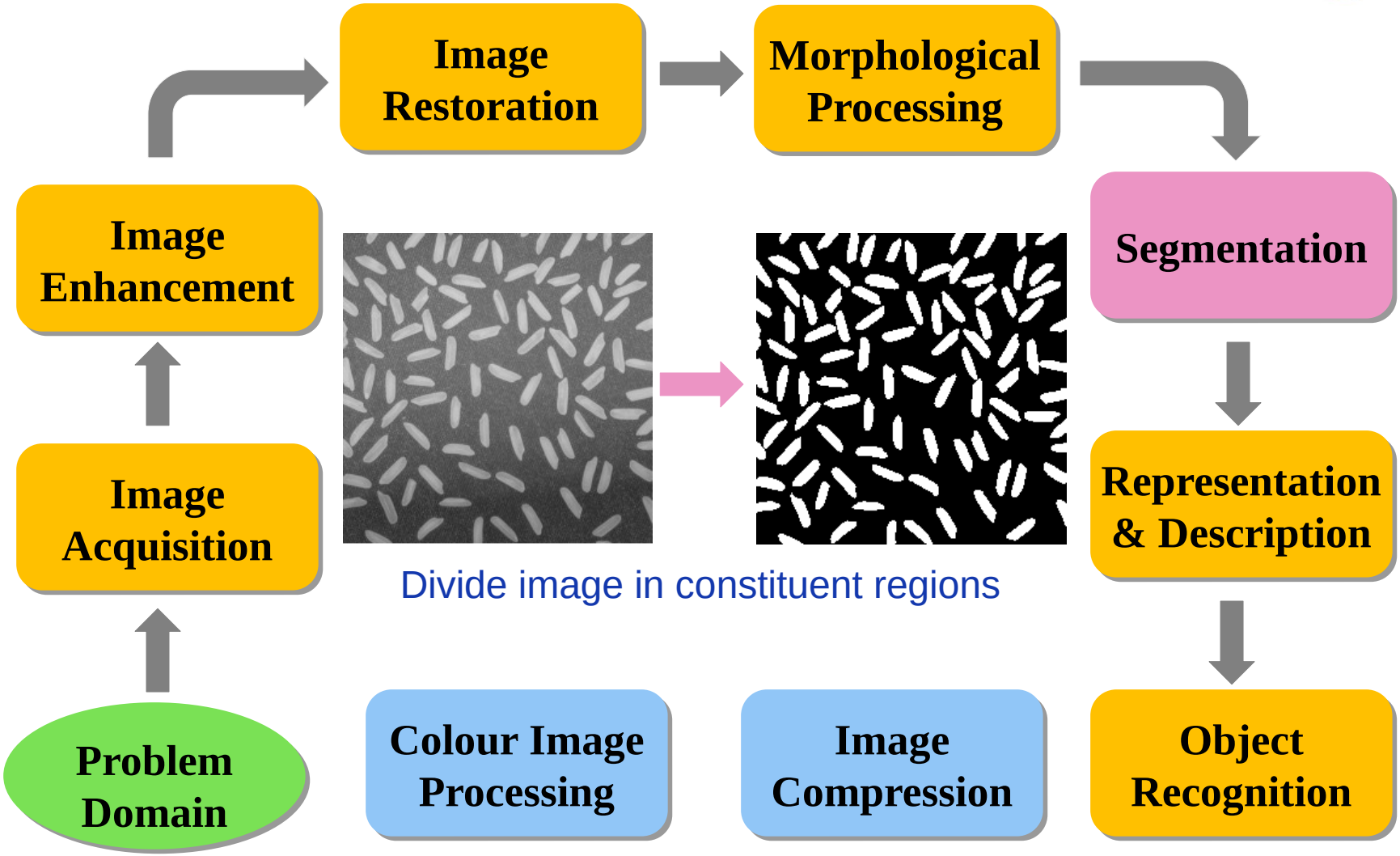
Colour Image Processing

Problem Domain

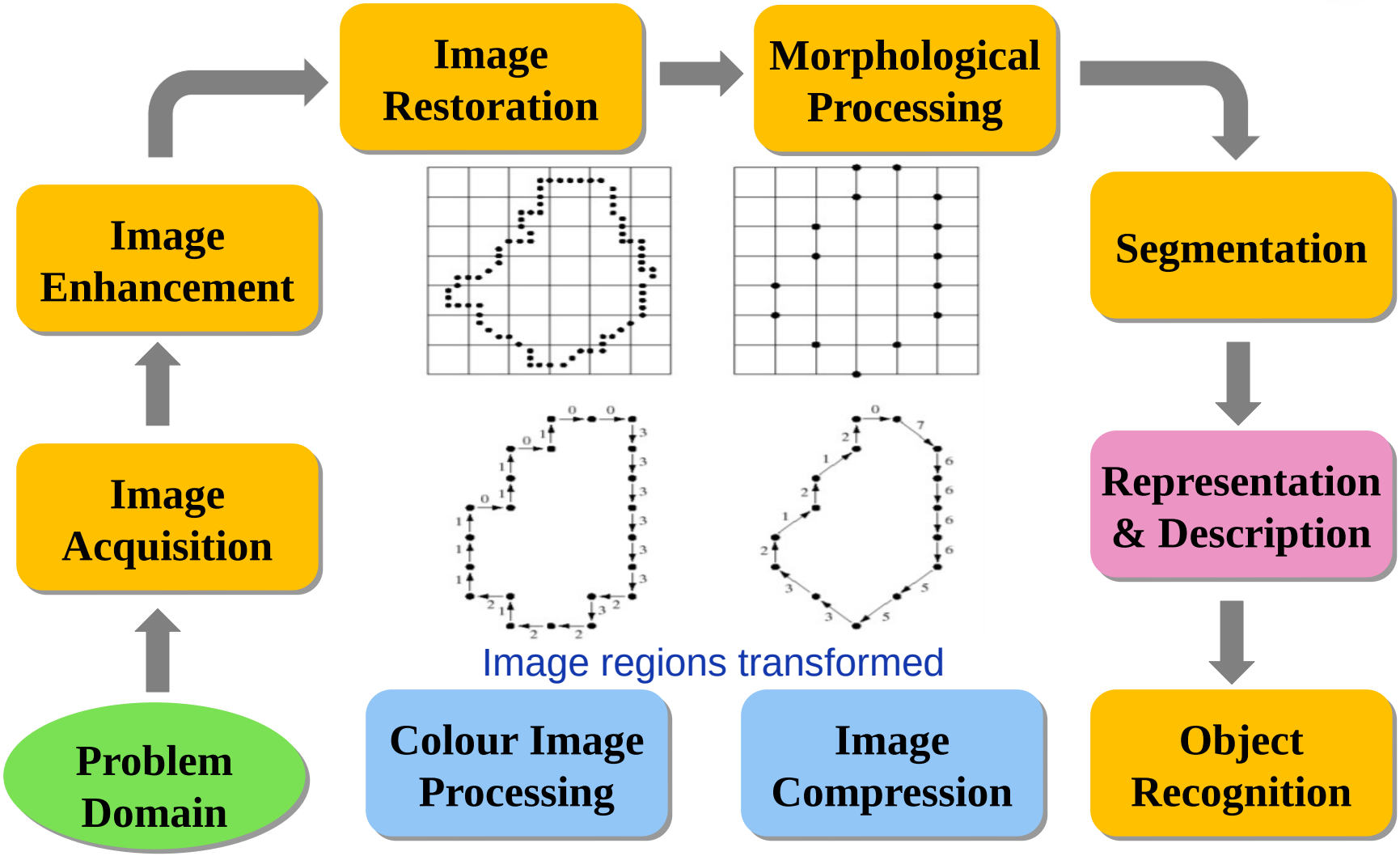
Image Acquisition

Image Enhancement

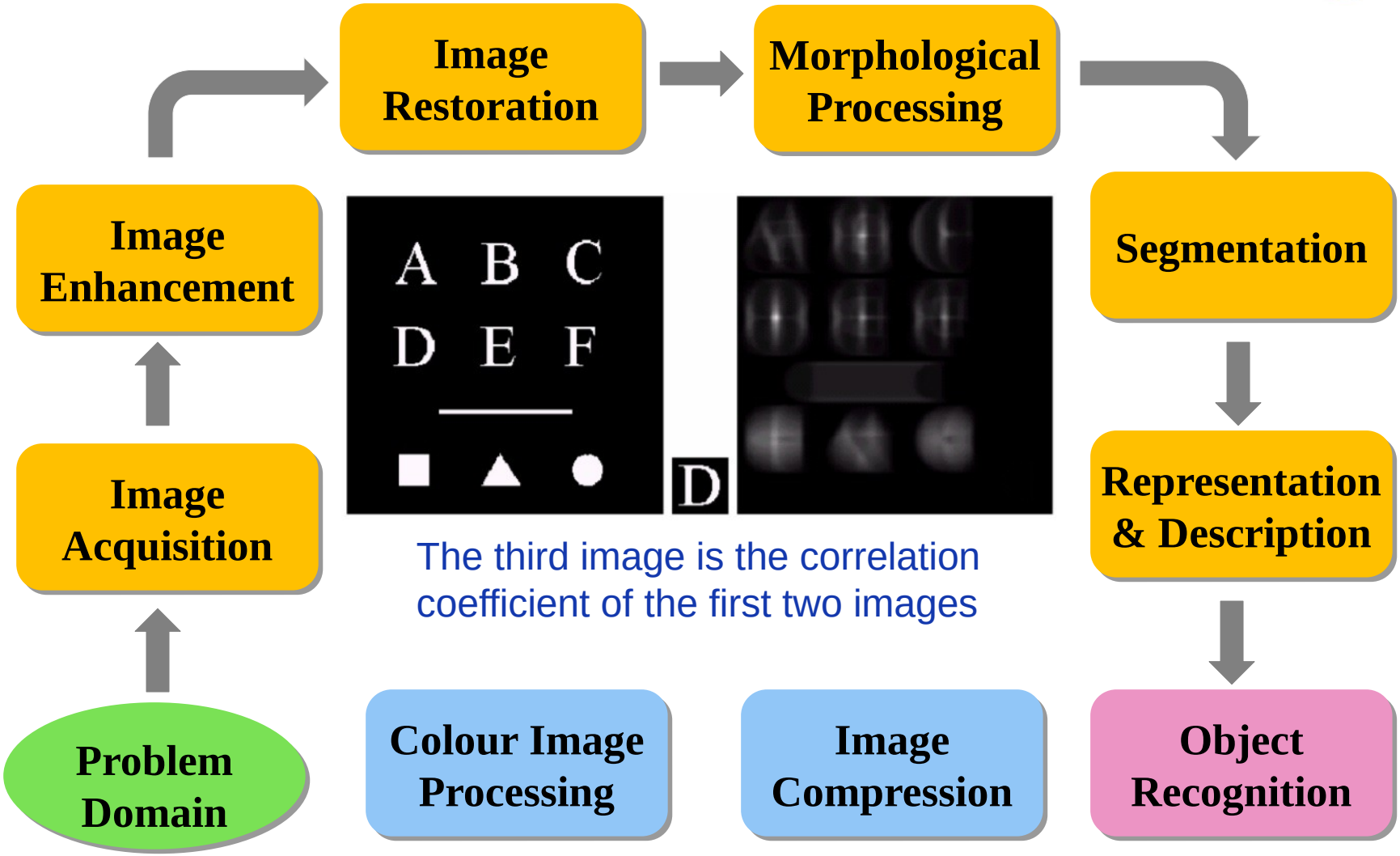
Key Steps in DIP: Segmentation



Key Steps in DIP: Rep. & Des.



Key Steps in DIP: Object Recognition



Key Steps in DIP: Image Compression

Two JPEG compression and reconstruction, difference with original image, and a zoomed portion of the reconstructed image

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

Segmentation

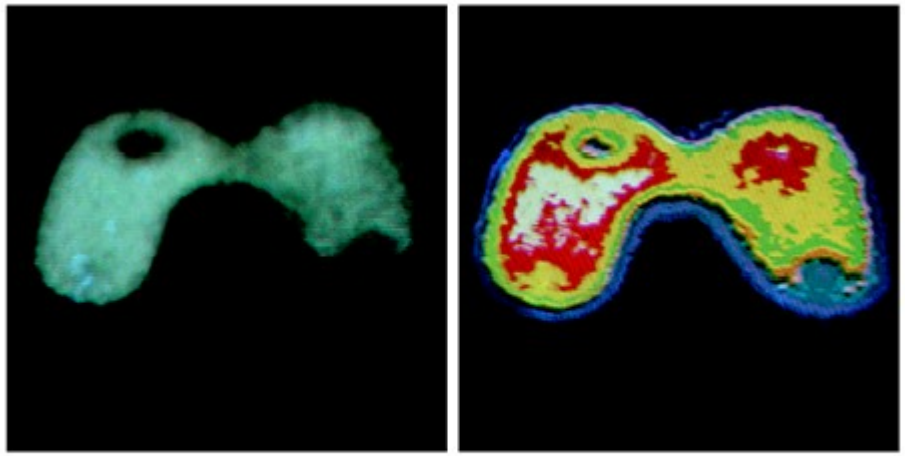
Representation & Description

Object Recognition

Image Compression

Colour Image Processing

Key Steps in DIP: Colour Image Processing



a b

FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

Segmentation

Representation & Description

Object Recognition

Image Compression

Colour Image Processing

Next Class

- **Digital Image Fundamentals**
  - Elements of visual perception
  - Image sensing and acquisition
  - Image sampling and quantization
  - Relationship between pixels

Thank you: Question?