Digital Image Processing

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What is a Digital Image Processing?

- The main objective of image processing is **to transform an image into digital form and perform certain operations on it in order to obtain specific models or to extract useful information from the image**.
- An image may be defined as a two-dimensional function, $f(x, y)$, where x and y are *spatial* (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the *intensity* or *gray level* of the image at that point. When x, y, and the intensity values of f are all finite, discrete quantities, we call the image a *digital image*.
- The field of *digital image processing* refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called *picture elements*, *image elements*, and *pixels*.

What is a Digital Image Processing?

- There are no clear-cut boundaries in the continuum from image processing at one end to computer vision at the other. However, one useful paradigm is to consider three types of computerized processes in this continuum: low-, mid-, and high level processes.
- Low-level processes involve primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening. A low level process is characterized by the fact that both its inputs and outputs are images.
- Mid-level processing of images involves tasks such as segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. A mid-level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects).

What is a Digital Image Processing?

- Finally, higher-level processing involves “making sense” of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cognitive functions normally associated with human vision.

What is DIP? (cont…)

The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image **Examples:** Noise removal, image sharpening	**Input:** Image **Output:** Attributes **Examples:** Object recognition, segmentation	**Input:** Attributes **Output:** Understanding **Examples:** Scene understanding etc

Origin of Digital Image Processing?

- One of the earliest applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York. Introduction of the Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours.
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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.]

Applications of DIP

- 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, and astronomy. The invention in the early 1970s of *computerized axial tomography* (CAT), also called *computerized tomography* (CT) for short, is one of the most important events in the application of image processing in medical diagnosis.
- Tomography consists of algorithms that use the sensed data to construct an image that represents a “slice” through the object. Motion of the object in a direction perpendicular to the ring of detectors produces a set of such slices, which constitute a three-dimensional (3-D) rendition of the inside of the object. Tomography was invented independently by Sir Godfrey N. Hounsfield and Professor Allan M. Cormack, who shared the 1979 Nobel Prize in Medicine for their invention.

Applications of DIP

- It is interesting to note that X-rays were discovered in 1895 by Wilhelm Conrad Roentgen, for which he received the 1901 Nobel Prize for Physics. These two inventions, nearly 100 years apart, led to some of the most important applications of image processing today.
- From the 1960s until the present, the field of image processing has grown vigorously. In addition to applications in medicine and the space program, digital image processing techniques are now used in a broad range of applications.
- Computer procedures are used to enhance the contrast or code the intensity levels into color for easier interpretation of X-rays and other images used in industry, medicine, and the biological sciences.

EXAMPLES OF FIELDS THAT USE DIGITAL IMAGE PROCESSING

- Geographers use the same or similar techniques to study pollution patterns from aerial and satellite imagery. Image enhancement and restoration procedures are used to process degraded images of unrecoverable objects, or experimental results too expensive to duplicate.
- In archeology, image processing methods have successfully restored blurred pictures that were the only available records of rare artifacts lost or damaged after being photographed.
- In physics and related fields, computer techniques routinely enhance images of experiments in areas such as high-energy plasmas and electron microscopy.
- Similarly successful applications of image processing concepts can be found in astronomy, biology, nuclear medicine, law enforcement, defense, and industry

EXAMPLES OF FIELDS THAT USE DIGITAL IMAGE PROCESSING

- The second major area of application of digital image processing techniques mentioned at the beginning of this chapter is in solving problems dealing with machine perception. In this case, interest is on procedures for extracting information from an image, in a form suitable for computer processing.

EXAMPLES OF FIELDS THAT USE DIGITAL IMAGE PROCESSING

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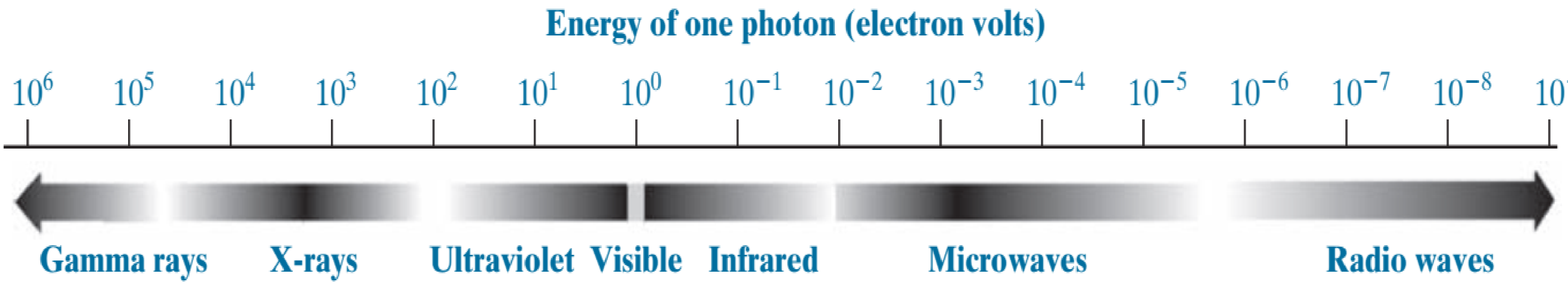


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

GAMMA-RAY IMAGING

- Major uses of imaging based on gamma rays include nuclear medicine and astronomical observations. In nuclear medicine, the approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays. Images are produced from the emissions collected by gamma-ray detectors.
- Images of this sort are used to locate sites of bone pathology, such as infections or tumors.
- Angiography is another major application in an area called contrast enhancement radiography.
- Another important use of X-rays in medical imaging is computerized axial tomography (CAT). Due to their resolution and 3-D capabilities, CAT scans revolutionized medicine from the moment they first became available in the early 1970s.

X-RAY IMAGING

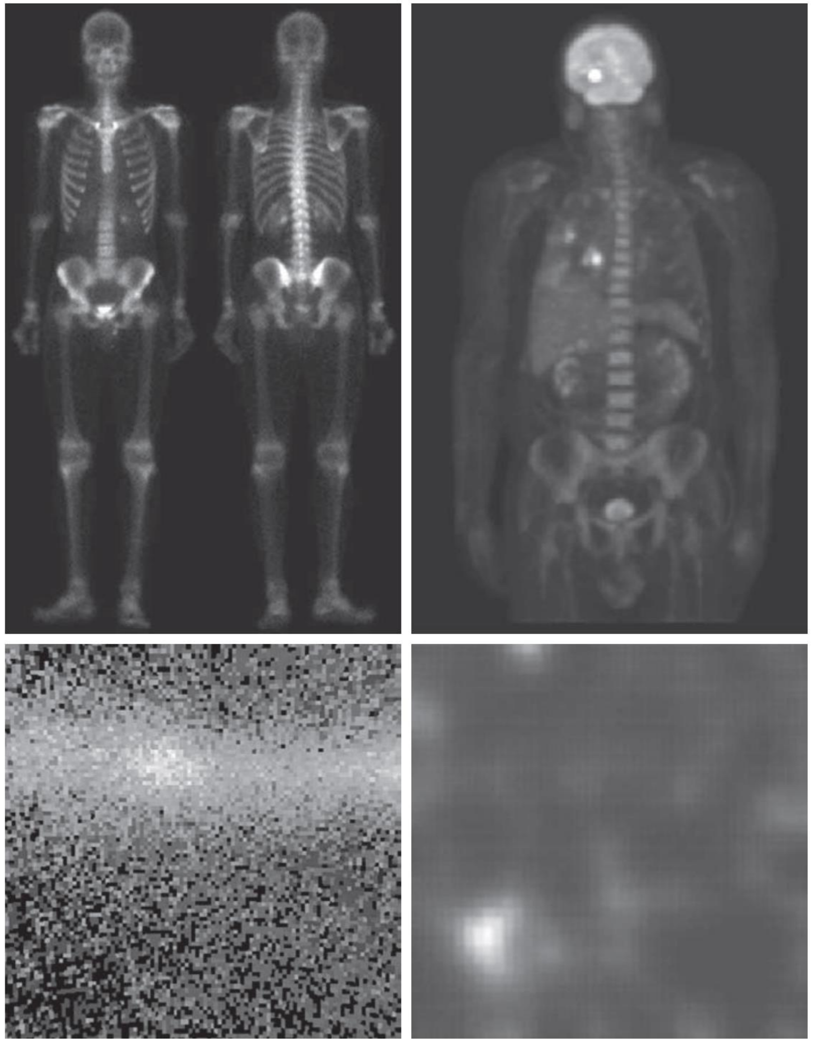


FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems; (b) Dr. Michael E. Casey, CTI PET Systems; (c) NASA; (d) Professors Zhong He and David K. Wehe, University of Michigan.)

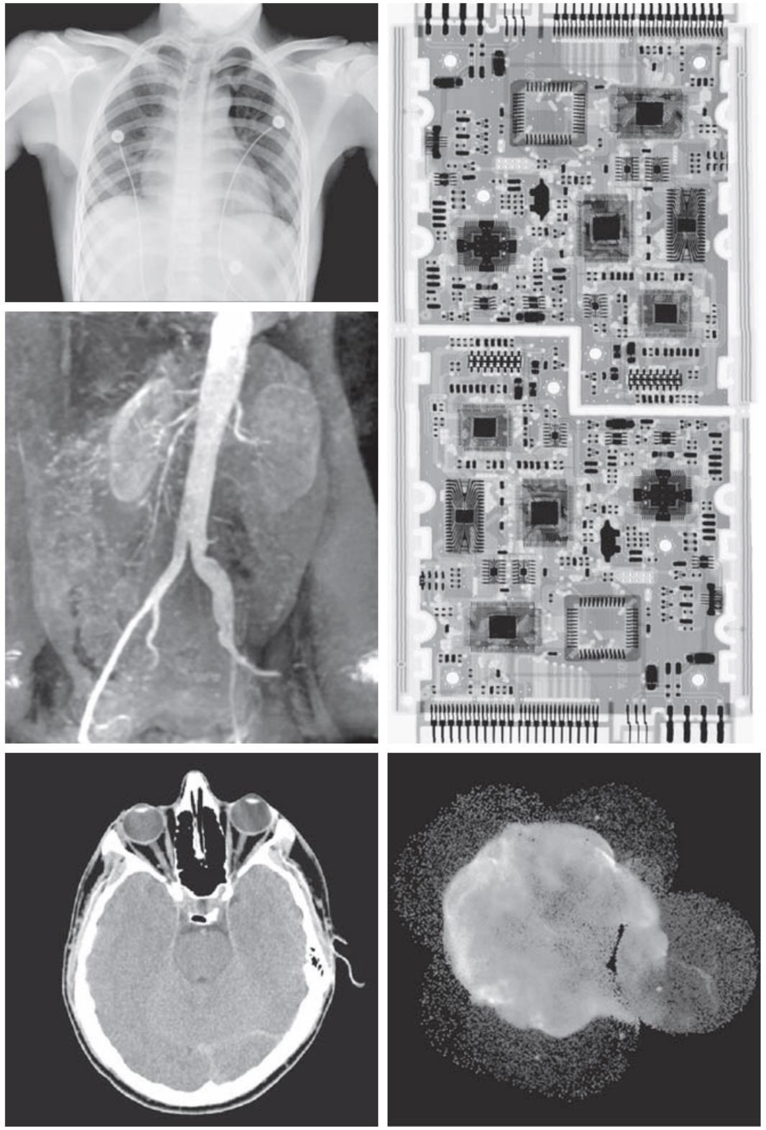


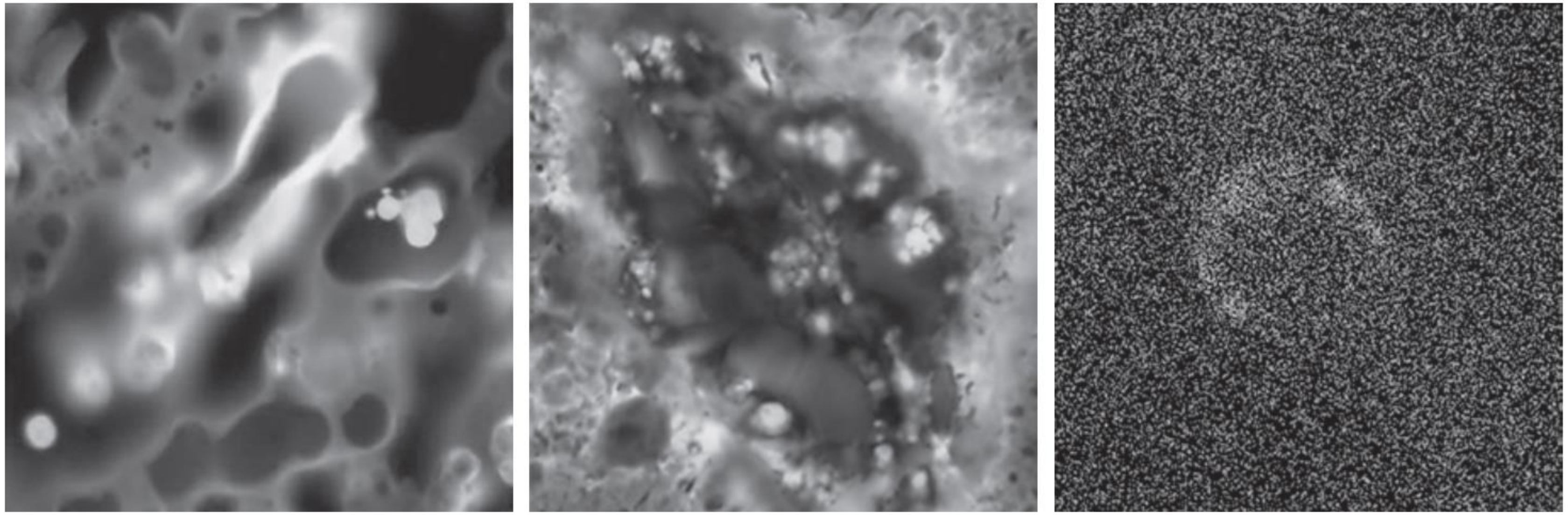
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical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

Positron Emission Tomography (PET)

- A positron emission tomography (PET) scan is **an imaging test that can help reveal the metabolic or biochemical function of your tissues and organs**. The PET scan uses a radioactive drug (tracer) to show both normal and abnormal metabolic activity.
- PET scans may be used **to evaluate organs and/or tissues for the presence of disease or other conditions**. PET may also be used to evaluate the function of organs, such as the heart or brain. The most common use of PET is in the detection of cancer and the evaluation of cancer treatment.

IMAGING IN THE ULTRAVIOLET BAND

- Applications of ultraviolet “light” are varied. They include lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations.



a b c

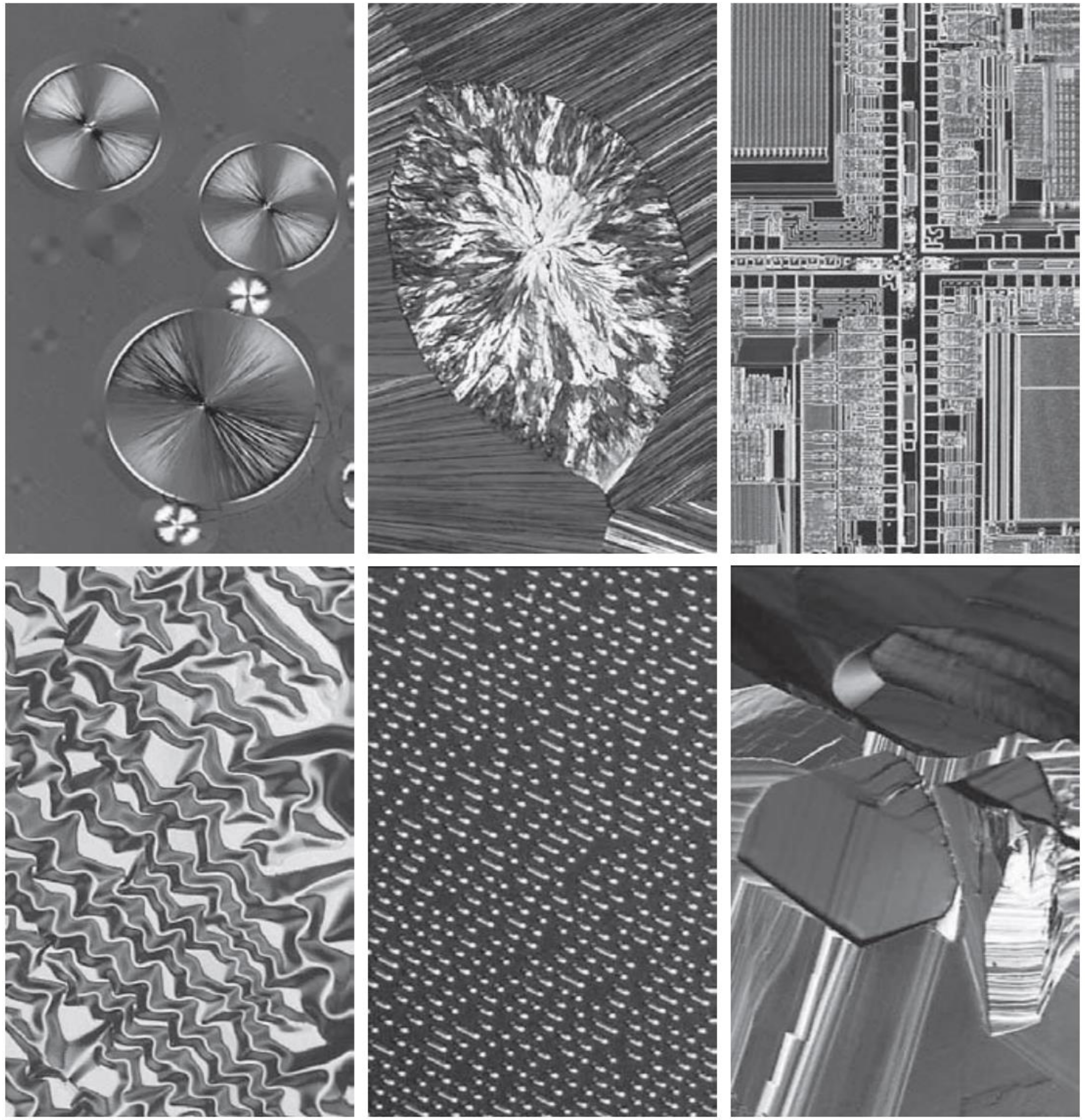
FIGURE 1.8 Examples of ultraviolet imaging. (a) Normal corn. (b) Corn infected by smut. (c) Cygnus Loop. (Images (a) and (b) courtesy of Dr. Michael W. Davidson, Florida State University, (c) NASA.)

IMAGING IN THE VISIBLE AND INFRARED BANDS

- Considering that the visual band of the electromagnetic spectrum is the most familiar in all our activities, it is not surprising that imaging in this band outweighs by far all the others in terms of breadth of application.

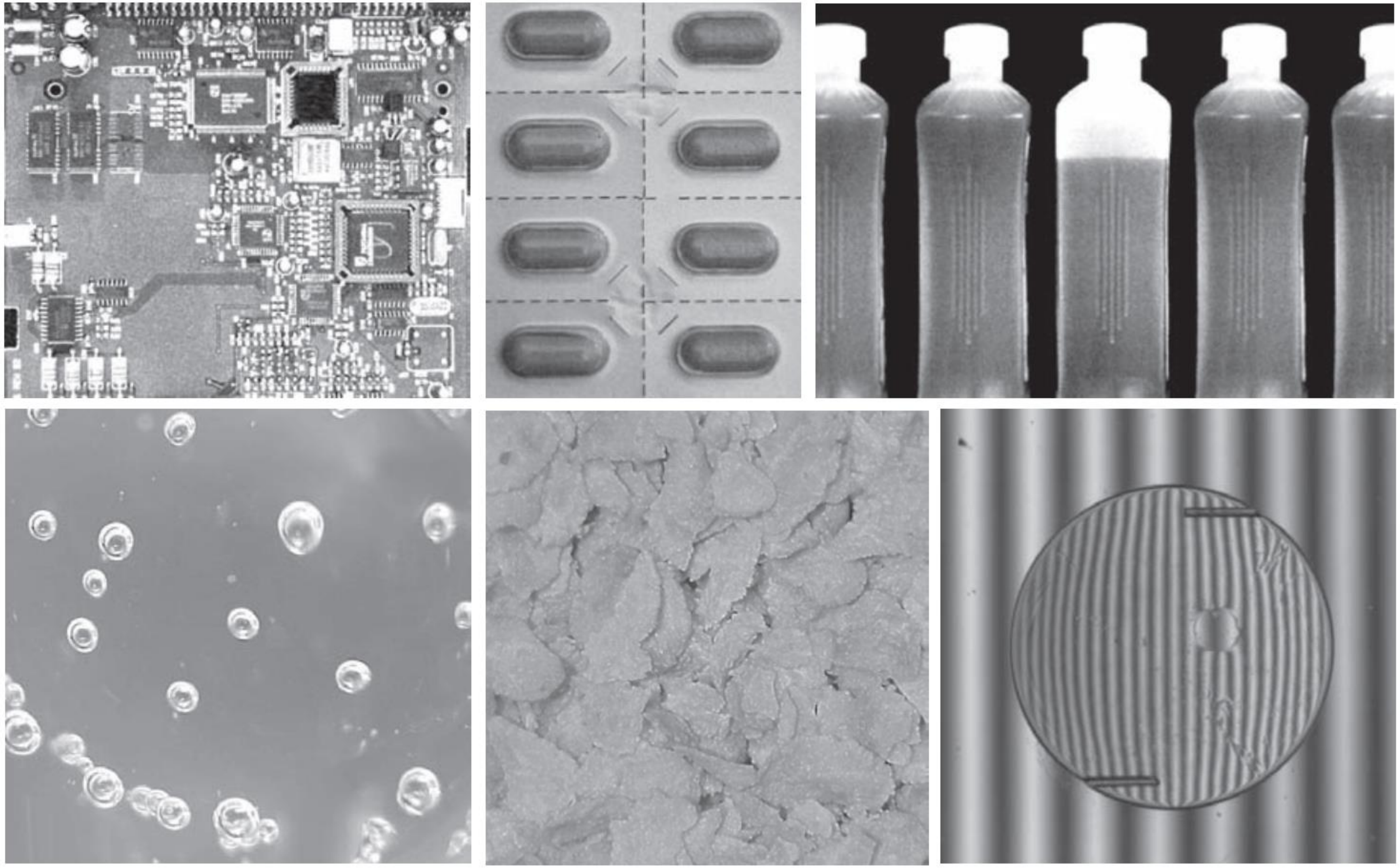
a b c
d e f

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.)



IMAGING IN THE MICROWAVE BAND

- The principal application of imaging in the microwave band is radar. The unique feature of imaging radar is its ability to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions. Some radar waves can penetrate clouds, and under certain conditions, can also see through vegetation, ice, and dry sand.



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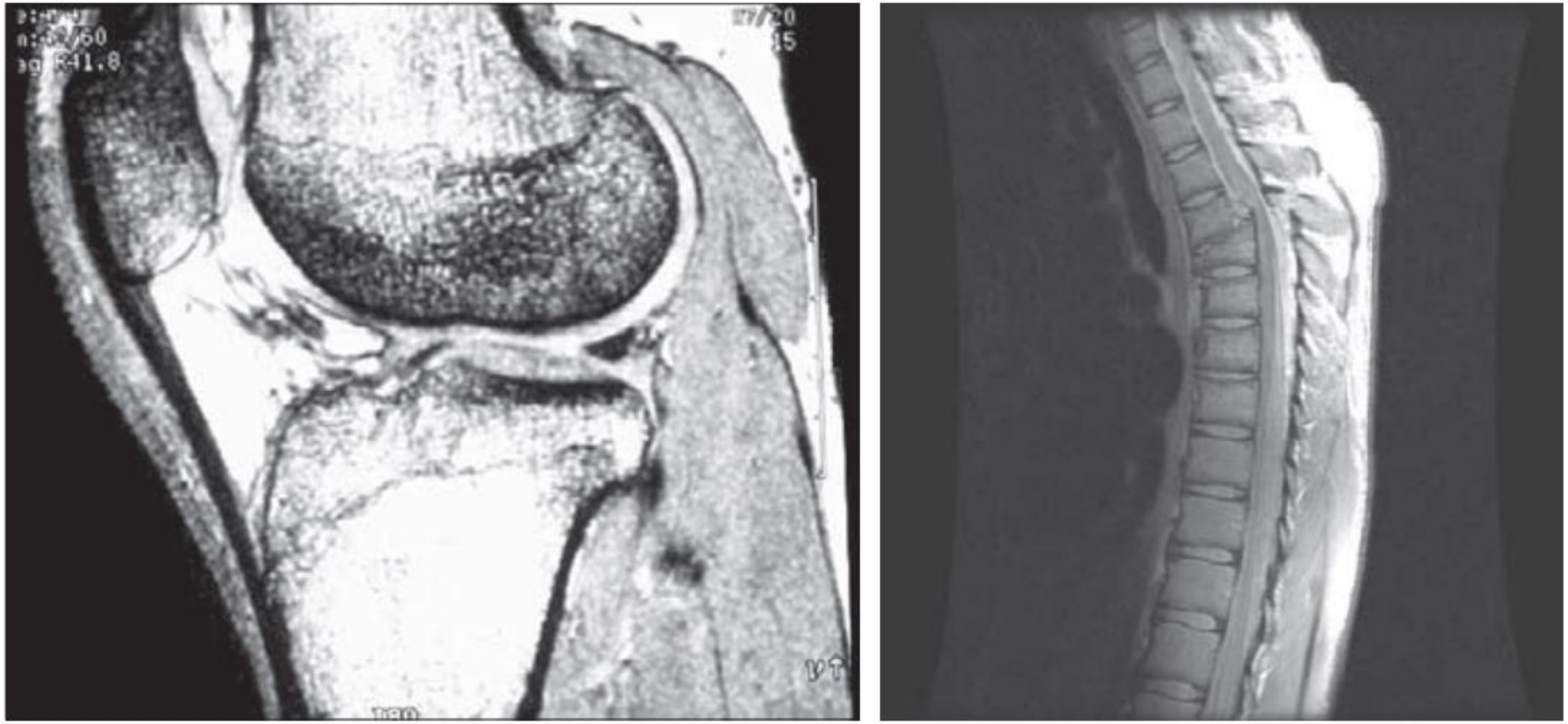
d e f

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.)

IMAGING IN THE RADIO BAND

- As in the case of imaging at the other end of the spectrum (gamma rays), the major applications of imaging in the radio band are in medicine and astronomy. In medicine, radio waves are used in magnetic resonance imaging (MRI). patient in a powerful magnet and passes radio waves through the individual’s body in short pulses. Each pulse causes a responding pulse of radio waves to be emitted by the patient’s tissues. The location from which these signals originate and their strength are determined by a computer, which produces a two-dimensional image of a section of the patient. MRI can produce images in any plane.



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.)

FUNDAMENTAL STEPS 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.

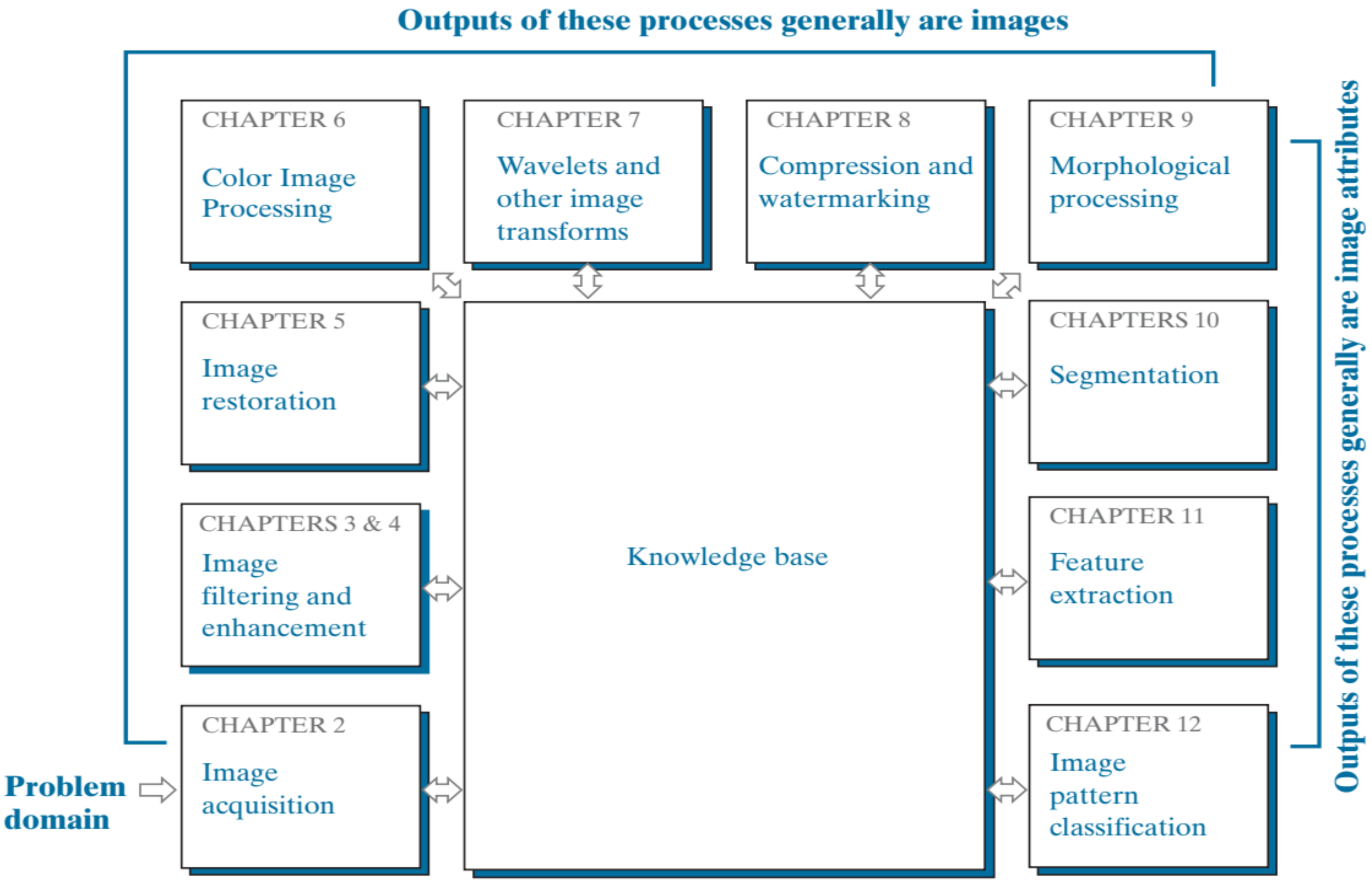


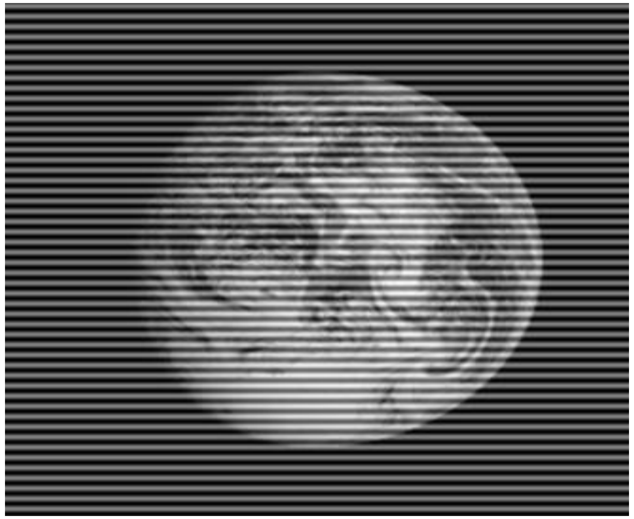
Image Acquisition

- Image acquisition can be defined as **the act of procuring an image from sources**. This can be done via hardware systems such as cameras, encoders, sensors, etc. Irrefutably, it is the most crucial step in the MV workflow because an inaccurate image will render the entire workflow useless.

Image enhancement

- Filtering
- Low pass filters
- High pass filters

Image Restoration - Examples



Distorted image

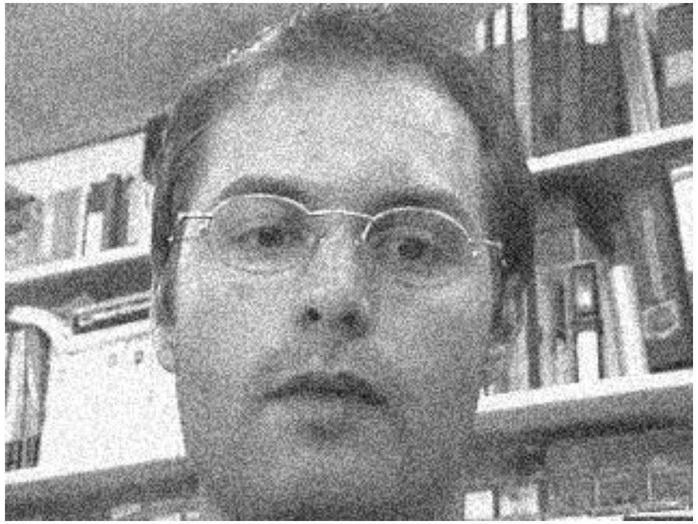
Restored image

Geometrically distorted image

Restored image

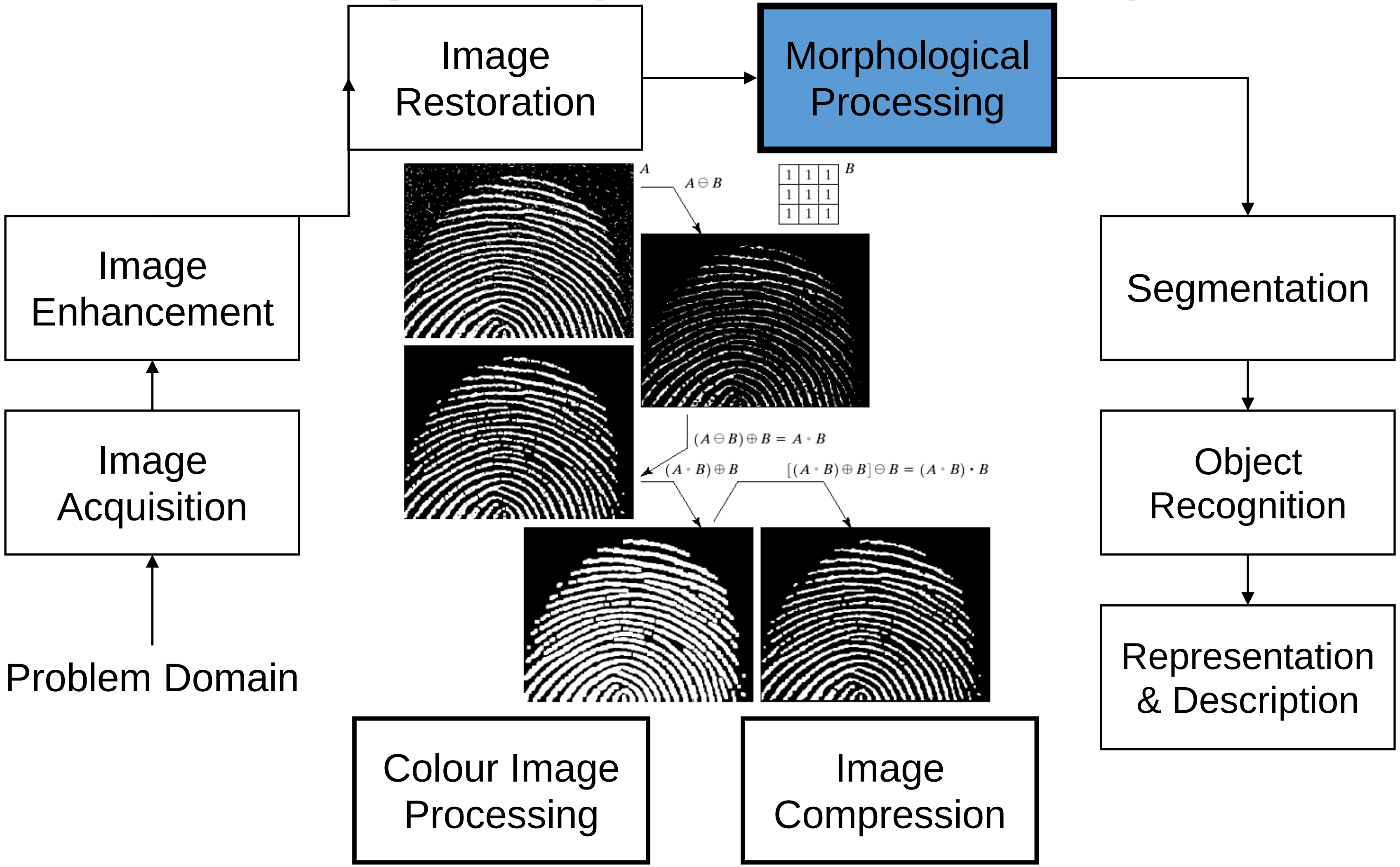
Image Restoration – De-noising

Noisy images

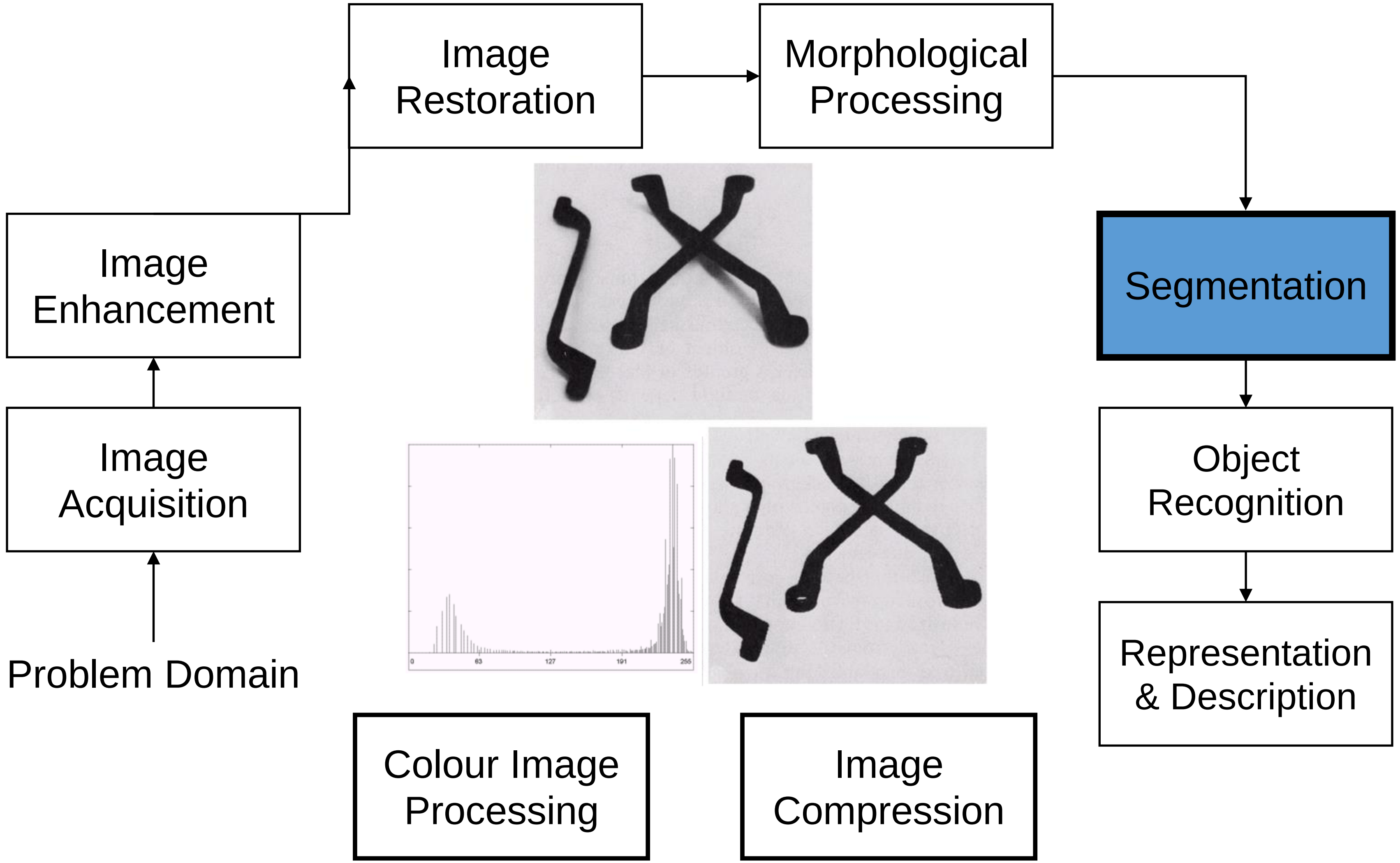


Restored “Clean” images

Key Stages in Digital Image Processing: Morphological Processing



Key Stages in Digital Image Processing: Segmentation



Key Stages in Digital Image Processing: Object Recognition

Image Restoration

Morphological Processing

Image Enhancement

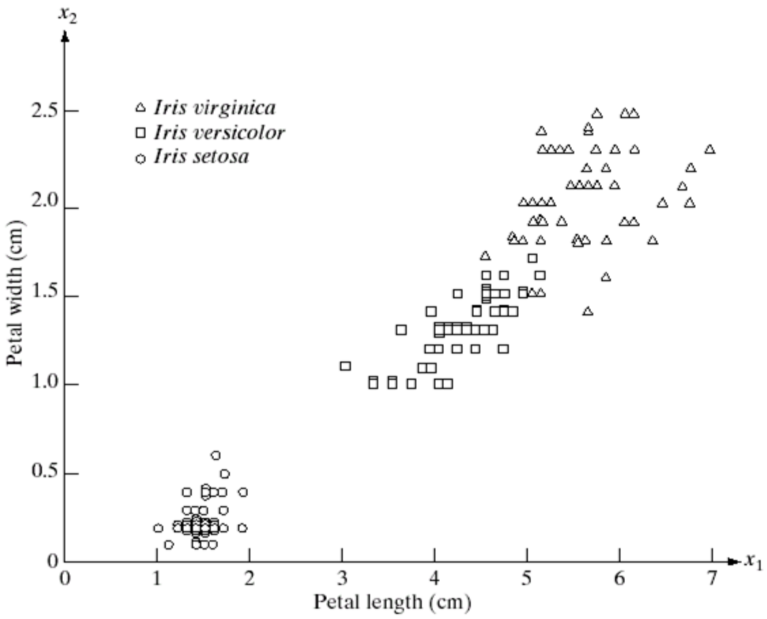
Segmentation

Image Acquisition

Object Recognition

Problem Domain

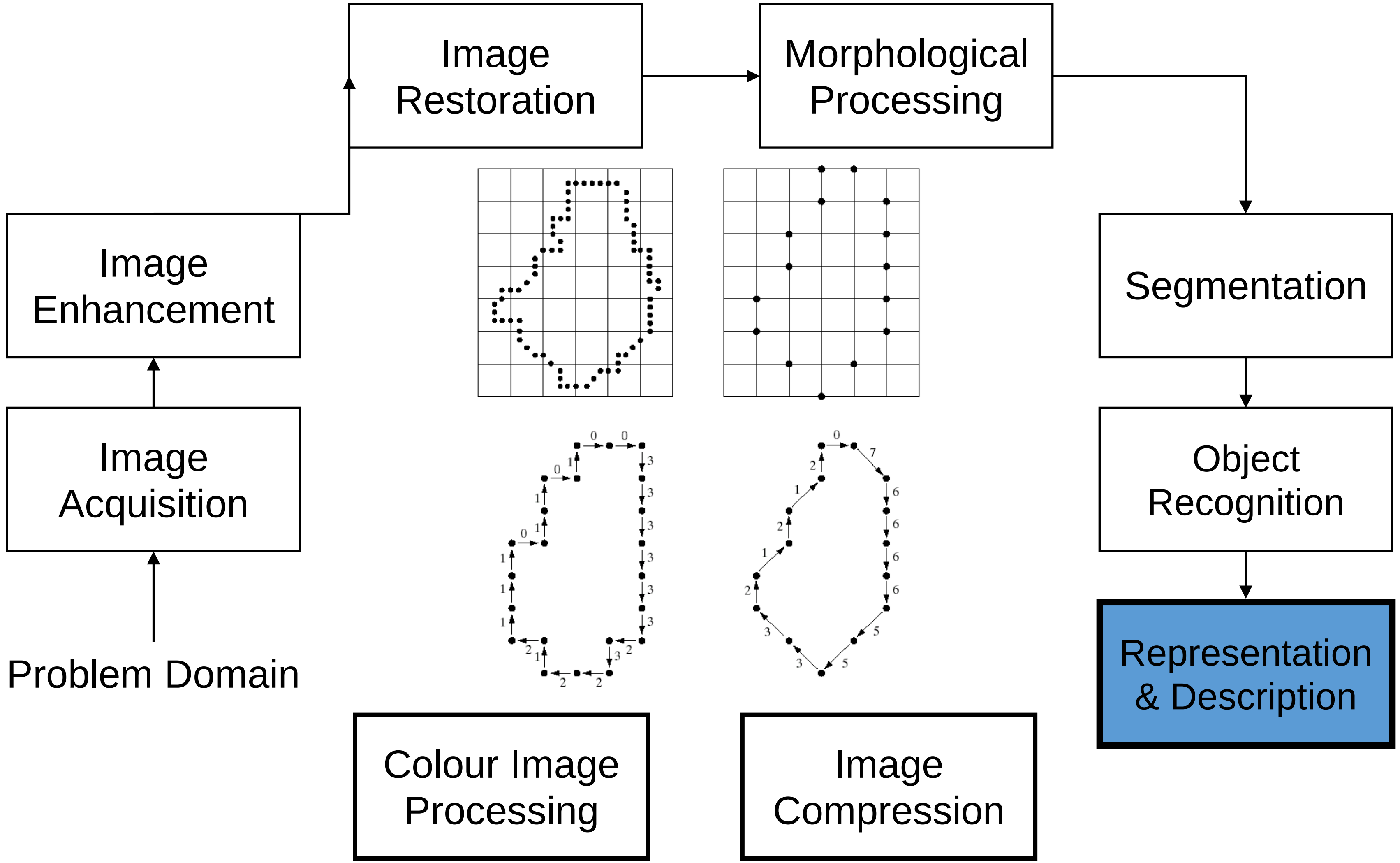
Representation & Description



Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing: Representation & Description

- **Representation deals with the image's characteristics and regional properties**. Description deals with extracting quantitative information that helps differentiate one class of objects from the other.

Key Stages in Digital Image Processing: Image Compression

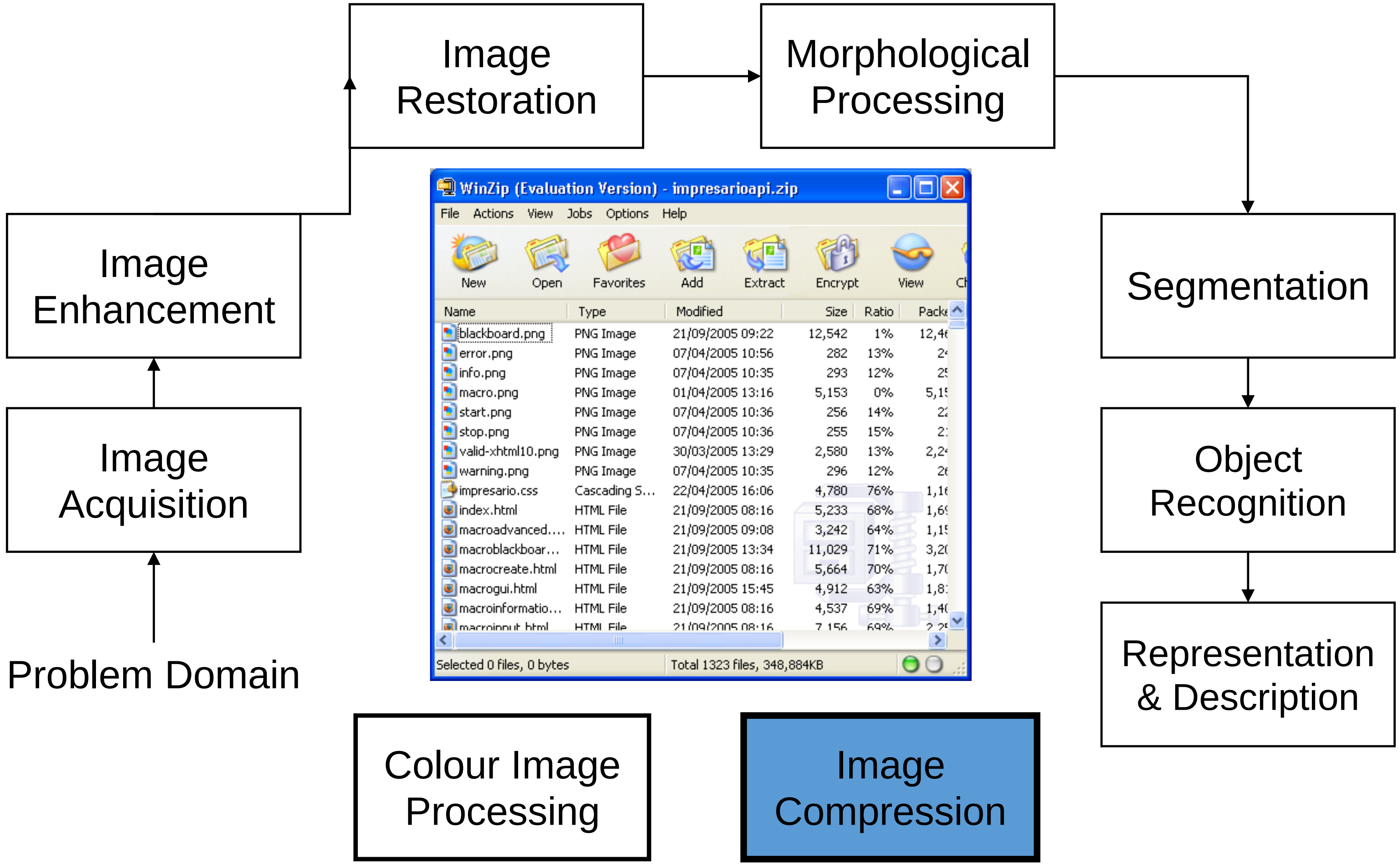
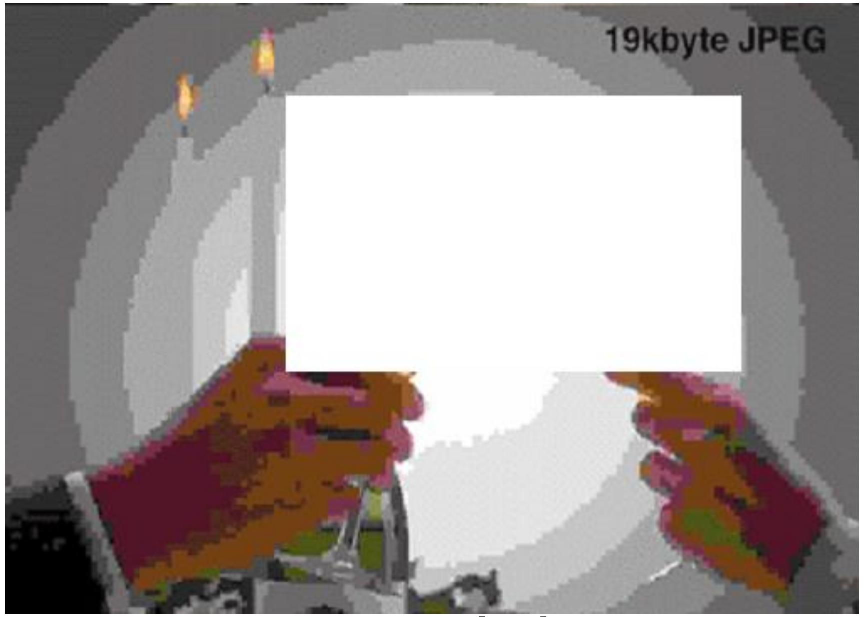
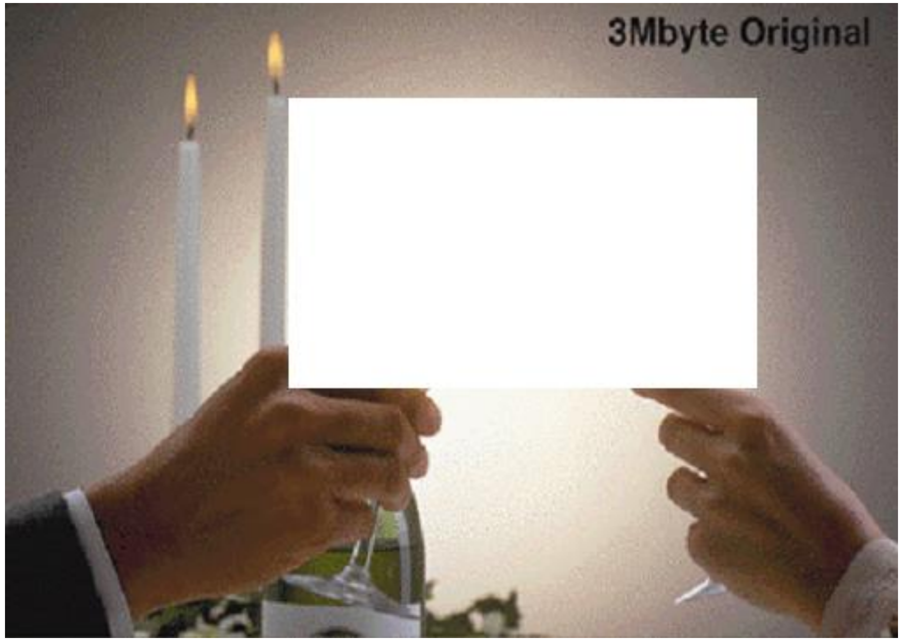


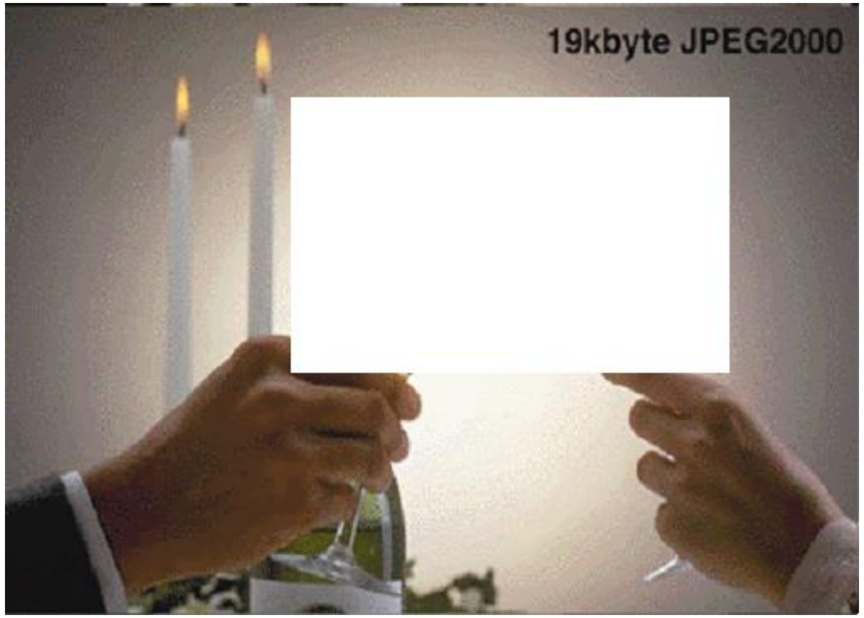
Image Compression



JPEG Compression)



Original image



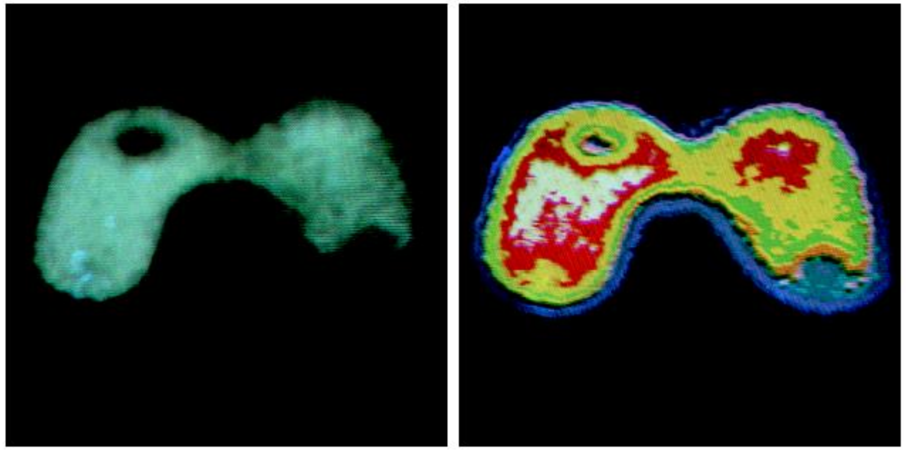
JPEG2000 Compression

Key Stages in Digital Image Processing: Color Image Processing

Image Restoration

Morphological Processing

Image Enhancement



Segmentation

Image Acquisition

Object Recognition

Problem Domain

Representation & Description

Colour Image Processing

Image Compression

Color image processing

- Color image processing is the analysis, transformation, and interpretation of visual data presented in color.