Chapter 1: Introduction

Textbook:
**Course Content**

Chapter 1: Introduction  
Chapter 2: Digital Image Fundamentals  
Chapter 3: Image Enhancement in the Spatial Domain  
Chapter 4: Image Enhancement in the Frequency Domain  
Chapter 6: Color image processing  
Chapter 8: Image Compression (introduction)  
Chapter 9: Morphological Image Processing  
Chapter 11: Representation and Description  
Chapter 12: Object Recognition (introduction)

**Grading System**

- First Exam 20%  
- Second Exam 20%  
- Assignment/Quiz/Report 20%  
- Final Exam 40%
Overview

- Early days of computing, data was numerical and textual.
- Today, many other forms of data: voice, music, speech, images, computer graphics, etc.
- Each of these types of data are signals.
- Loosely defined, a signal is a function that conveys information.

Relationship of Signal Processing to other fields

- As long as people have tried to send or receive through electronic media: telegraphs, telephones, television, radar, etc. there has been the realization that these signals may be affected by the system used to acquire, transmit, or process them.
- Sometimes, these systems are imperfect and introduce noise, distortion, or other artifacts.
• Understanding the effects of these systems and finding ways to correct them is the fundamental of signal processing.

• Sometimes, these signals are specific messages that we create and send to someone else (e.g., telegraph, telephone, television, digital networking, etc.).

• That is, we specifically introduce the information content into the signal and hope to extract it out later.

• Sometimes, these man-made signals are encoding of natural phenomena (audio signal, acquired image, etc.),

• but sometimes we can create them from scratch (speech generation, computer generated music, computer graphics).

• Finally, we can sometimes merge these technologies together by acquiring a natural signal, processing it, and then transmitting it in some fashion.
Concerned fields:

- Digital Communication
- Compression
- Speech Synthesis and Recognition
- Computer Graphics
- Image Processing
- Computer Vision
What is Image Processing?

- Image processing is a subclass of signal processing concerned specifically with pictures.
- Improve image quality for human perception and/or computer interpretation.

Several fields deal with images

- Computer Graphics: the creation of images.
- Image Processing: the enhancement or other manipulation of the image – the result of which is usually another images.
- Computer Vision: the analysis of image content.
Several fields deal with images

<table>
<thead>
<tr>
<th>Input/Output</th>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image</td>
<td>Image</td>
<td>Computer Vision</td>
</tr>
<tr>
<td>Description</td>
<td>Computer Graphics</td>
<td>AI</td>
</tr>
</tbody>
</table>

2 Principal application areas

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission, and representation for autonomous machine perception
Ex. of fields that use DIP

- Categorize by image sources
  - Radiation from the Electromagnetic spectrum
  - Acoustic
  - Ultrasonic
  - Electronic (in the form of electron beams used in electron microscopy)
  - Computer (synthetic images used for modeling and visualization)

Radiation from EM spectrum

- Spectral bands are grouped by energy per photon
  - Gamma rays, X-rays, Ultraviolet, Visible, Infrared, Microwaves, Radio waves

**FIGURE 1.5** The electromagnetic spectrum arranged according to energy per photon.
Gamma-Ray Imaging

- Nuclear Image
  - (a) Bone scan
  - (b) PET (Positron emission tomography) image
- (c) Astronomical Observations.
- Nuclear Reaction
  - (d) Gamma radiation from a reactor valve

X-ray Imaging

- Medical diagnostics
  - (a) chest X-ray (familiar)
  - (b) aortic angiogram
  - (c) head CT
- Industrial imaging
  - (d) Circuit board
- (e) Astronomy
Imaging in Ultraviolet Band

- Industrial inspection
- Microscopy (fluorescence)
  - (a) Normal corn
  - (b) Smut corn
- Lasers
- Biological imaging
- (c) Astronomical observations

Imaging in Visible and Infrared Bands

- Astronomy
- Light microscopy
  - pharmaceuticals
    - (a). taxol (anticancer agent)
    - (b). cholesterol
  - Microinspection to materials characterization
    - (c). Microprocessor
    - (d). Nickel oxide thin film
    - (e). Surface of audio CD
    - (f). Organic superconductor
Remote sensing

To monitor the environmental conditions on the planet.

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Name</th>
<th>Wavelength (μm)</th>
<th>Characteristics and Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Visible blue</td>
<td>0.45-0.52</td>
<td>Maximum water penetration</td>
</tr>
<tr>
<td>2</td>
<td>Visible green</td>
<td>0.52-0.60</td>
<td>Good for measuring plant vigor</td>
</tr>
<tr>
<td>3</td>
<td>Visible red</td>
<td>0.63-0.69</td>
<td>Vegetation discrimination</td>
</tr>
<tr>
<td>4</td>
<td>Near infrared</td>
<td>0.76-0.90</td>
<td>Biomass and biomass mapping</td>
</tr>
<tr>
<td>5</td>
<td>Middle infrared</td>
<td>1.55-1.75</td>
<td>Moisture content of soil and vegetation</td>
</tr>
<tr>
<td>6</td>
<td>Thermal infrared</td>
<td>10.4-12.5</td>
<td>Soil moisture; thermal mapping</td>
</tr>
<tr>
<td>7</td>
<td>Middle infrared</td>
<td>2.06-2.35</td>
<td>Mineral mapping</td>
</tr>
</tbody>
</table>

NASA’s LANDSAT: Washington DC

**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.)

Remote sensing: Weather observation and prediction

Multispectral image from satellites using sensors in the visible and infrared bands.
Remote sensing: Nighttime Lights of the World
(provides a global inventory of human settlements)

Infrared satellite images of the Americas.

Infrared satellite images of the remaining populated part of the world

Industry: visual spectrum
(automated visual inspection of manufactured goods)

(a). A circuit board: inspect them for missing parts
(b). Pill container: look for missing pills
(c). Bottles: look for bottles that are not filled up to an acceptable level
(d). Bubbles in clear-plastic product: detect unacceptable number of air pockets
(e). Cereal: inspection for color and the presence of anomalies such as burned flake.
(f). Inspection of damaged or incorrectly manufactured implants
Law enforcement: visual spectrum

(a). Thumb print: automated search of a database for a potential matches
(b). Paper currency: automated counting/reading of the serial number for tracking and identifying bills
(c) and (d) Automated license plate reading

Imaging in Microwave Band

- Imaging radar: the only way to explore inaccessible regions of the Earth’s surface
- Radar image of mountains in southeast Tibet
- Note the clarity and detail of the image, unencumbered by clouds or other atmospheric conditions that normally interfere with images in the visual band.
Imaging in Radio Band

- **Medicine**
  - Magnetic resonance image (MRI): 2D picture of a section of the patient (any plane)
  - (a) knee
  - (b) spine

- **Astronomy**

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Acoustic Imaging

- **Geological applications**: use sound in the low end of the sound spectrum (hundred of Hz)
  - Mineral and oil exploration

*Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap (bright spots)*
Ultrasound Imaging

- Manufacturing
- Medicine
  - (a) Baby
  - (b) Another view of baby
  - (c) Thyroids
  - (d) Muscle layers showing lesion

Generated images by computer

- Fractals: an iterative reproduction of a basic pattern according to some mathematical rules
  - (a) and (b)
- 3-D computer modeling
  - (c) and (d)
3 types of computerized process

- **Low-level**: input, output are images
  - Primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening

- **Mid-level**: inputs may be images, outputs are attributes extracted from those images
  - Segmentation
  - Description of objects
  - Classification of individual objects

- **High-level**:
  - Image analysis

Fundamental steps

Output of these processes generally are images

Problem domain

Knowledge base

Chapter 2
Image Acquisition

Chapter 3 & 4
Image Enhancement

Chapter 5
Image Restoration

Chapter 6
Color Image Processing

Chapter 7
Wavelet and Multiresolution Processing

Chapter 8
Compression

Chapter 9
Morphological Processing

Chapter 10
Segmentation

Chapter 11
Representation & Segmentation

Chapter 12
Object Recognition
Image Acquisition:

- An image is captured by a sensor (such as a monochrome or color TV camera) and digitized.
- If the output of the camera or sensor is not already in digital form, an analog-to-digital converter digitizes it.

Camera

- Camera consists of 2 parts
  - A lens that collects the appropriate type of radiation emitted from the object of interest and that forms an image of the real object
  - A semiconductor device – so called charged coupled device or CCD which converts the image into an electrical signal.
Frame Grabber

- Frame grabber only needs circuits to digitize the electrical signal from the imaging sensor to store the image in the memory (RAM) of the computer.

Image Enhancement

- To highlight certain features of interest in an image.

Example:
Image Restoration

- Improving the appearance of an image
- Tend to be based on mathematical or probabilistic models of image degradation

Example:

Distorted image $\rightarrow$ Restored image

Color Image Processing

- Gaining in importance because of the significant increase in the use of digital images over the Internet
Wavelets

- Foundation for representing images in various degrees of resolution.
- Used in image data compression and pyramidal representation.

Compression

- Reducing the storage required to save an image or the bandwidth required to transmit it.
- Ex. JPEG (Joint Photographic Experts Group) image compression standard.
Morphological processing

- Tools for extracting image components that are useful in the representation and description of shape.

**FIGURE 9.7** (a) Image of squares of size 1, 3, 5, 7, 9, and 15 pixels on the side. (b) Erosion of (a) with a square structuring element of 1x13 pixels on the side. (c) Dilation of (b) with the same structuring element.

Image Segmentation

- The computer tries to separate objects from the image background.
- It is one of the most difficult tasks in DIP.
- Output of the segmentation stage is raw pixel data, constituting either the boundary of a region or all the points in the region itself.
Representation & Description

- Representation \( \Rightarrow \) make a decision whether the data should be represented as a boundary or as a complete region.
  - Boundary representation \( \Rightarrow \) focus on external shape characteristics, such as corners and inflections.
  - Region representation \( \Rightarrow \) focus on internal properties, such as texture or skeleton shape.

Representation + Description

1 connected component, 1 hole

1 connected component, 2 holes

transform raw data

a form suitable for the Recognition processing
**Recognition & Interpretation**

- **Recognition** ⇒ the process that assigns a label to an object based on the information provided by its descriptors.
- **Interpretation** ⇒ assigning meaning to an ensemble of recognized objects.

**Knowledge base**

- **a problem domain** ⇒ detailing regions of an image where the information of interest is known to be located.
- **Help to limit the search**
Not all the processes are needed. Ex. Postal Code Problem

Desired output = alphanumeric characters
Digital Image Processing (DIP)

“A picture is worth a thousand words”.

What Is A Digital Image?

- Is composed of a finite number of elements each of which has a particular location and value (pixels, pels, picture elements).
Image Processing: What Is It?

- Processing images by means of a digital computer.
  - Image acquisition.
  - Representing, storing and displaying images.
  - Image transformations.
  - Image filtering, enhancement and restoration.
  - Image compression.

Related Computations

- Image/Video processing: Improving or changing images/video.
- Image/Video analysis (computer vision).
- Acting based on visual information (image understanding).
- Graphics and animation: Generating images and video.
**Image Processing vs. Computer Vision**

- **Low-level processing:** Involves primitive operations.
  - Input: Image
  - Output: Image

- **Mid-level processing:** Involves tasks such as partitioning an image into regions or objects, object description, and classification.
  - Input: Image
  - Output: Attributes

- **High-level processing:** Involves “making sense” of an ensemble of recognized objects (image analysis to computer vision).
  - Input: …
  - Output: …

**History**

- Newspaper industry: 1921
- Space imaging: 1960
- Computer axial tomography (CAT): 1970
DIP: Fundamentals

FIGURE 1.23
Fundamental steps in digital image processing.

Outputs of these processes generally are images

Problem domain

CHAPTER 2
Image acquisition

CHAPTER 3 & 4
Image enhancement

CHAPTER 5
Image restoration

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Color image processing

CHAPTER 7
Wavelets and multiresolution processing

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CHAPTER 11
Representation & description

CHAPTER 12
Object recognition

Knowledge base

DIP: Components

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