Summary

I. Introduction
   - DIP ?, Examples, Fundamental steps, components

II. Digital Image Fundamentals
    - Visual perception, light
    - Image sensing, acquisition, sampling, quantization
    - Linear, and non linear operation

III. Discrete 2D Processing
    - Vector space, Convolution
    - Unitary Transform

IV. Image Improvement
    - Enhancement, restoration, geometrical modifications
Introduction

- What is Digital Image Processing?
- Examples of fields that use DIP
- Fundamental steps in DIP
- Components of an image processing system

→ Book

*Digital Image Processing, Gonzales, Prentice Hall (3Ed.)*

What is a **DIP**?

- Image definition
  - An image may be defined as a two-dimensional function, \( f(x,y) \)
    - \( x \) and \( y \) are spatial (plane) coordinates
    - the amplitude of \( f \) at any pair of coordinates \((x,y)\) is called **intensity** or **gray level** of the image at that point
What is a DIP?

- **Image definition**
  - When $f$, $x$ and $y$ are all finite and discrete quantities, the image is called a *digital image*.

- **Image definition**
  - The definition of $f$ may be extended:
    - as a $n$-dimensional function,
      - i.e. 3D: $f(x,y,z)$ or image sequence $f(x,y,t)$
    - with amplitudes composed as a vector of data,
      - i.e. Color image: 3 components at each point, Complex number

- **Gray level digital image**
  - $f(x_1,y_1) = 179$

- **RGB image**
  - $f(x_1,y_1) = \{217, 182, 167\}$
    - $= \{\text{gray}, \text{gray}, \text{gray}\}$
    - $= \{\text{red}, \text{green}, \text{blue}\}_\text{RGB}$
What is a **DIP**?

- **Pixel**
  - A digital image is composed of a finite number of elements, each of which has a particular location and value
  - These elements are referred to as *picture elements, image elements, pels, and pixels*
  - *Pixel* is the term most widely used to denote the elements of a digital image

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What is a **DIP**?

- **Digital Image Processing & related areas**
  - *Image processing*
    - Low-level processes
      - noise reducing, contrast enhancement, …
  - *Image analysis*
    - Mid-level processes
      - segmentation (partitioning an image into regions or objects)
      - classification (recognition) of objects, …
  - *Computer vision*
    - Ultimate goal: emulate human vision
    - High-level processes
      - learning, inferences making, actions taking
      - giving a sense to a set of recognized objects
      - perform the cognitive functions normally associated with vision
  - no clear-cut boundaries…
What is a **DIP**?

- Digital Image Processing and human vision
  - The field of DIP refers to processing digital images by means of a digital computer

<table>
<thead>
<tr>
<th></th>
<th>humans</th>
<th>imaging machines &amp; DIP +CV</th>
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</thead>
<tbody>
<tr>
<td>electromagnetic spectrum of images</td>
<td>visible band</td>
<td>Full spectrum</td>
</tr>
<tr>
<td>sources of images</td>
<td>accustomed to be associated with image</td>
<td>all (Ultrasound, electron microscopy, ...)</td>
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<tr>
<td>processing by</td>
<td><strong>brain</strong></td>
<td>computer(s)</td>
</tr>
<tr>
<td>analysis</td>
<td><strong>hand (manually)</strong></td>
<td>computer(s)</td>
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</tbody>
</table>

Examples of fields that use DIP

- Many applications…
  - **Industrial inspection** (anomalies detection, measuring (bench), tracking, monitoring…)
  - Medical imaging (visualization, tumor detection, reconstruction, artifact correction, diseases quantification, …)
  - **Satellite Imaging** (weather, environmental conditions monitoring,..)
  - microscopy (pharmaceutical, micro inspection, materials characterization,....)
  - Telecommunication (transmission, compression,...)
  - Cinema, image synthesis, scientific visualization
  - Law enforcement (license plate reading, speed, finger print…)
  - …
Examples of fields that use DIP

- Images based on radiation from electromagnetic spectrum

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Examples

*Landsat* images after the tsunami in Indonesia 2004,

**Left:** in natural color (Landsat ETM+ bands 1,2,3 RGB)

**Right:** in false-color composite (Landsat ETM+ bands 4[near infrared],3,2 RGB). In this image vegetation appears in red, pink, and maroon; water appears in blue to black; urban and non-vegetated areas (including the tsunami damage regions) appear in bluish-greens and grays.
Examples

$Landsat$ images before the tsunami in Indonesia 2004,

Before
(14/05/02)

In false-color composite (Landsat ETM+ bands 4,3,2 RGB). In this image vegetation appears in red, pink, and maroon; water appears in blue to black; urban and non-vegetated areas (including the tsunami damage regions) appear in bluish-greens and grays.

Examples

$Landsat$ images after the tsunami in Indonesia 2004,

After
(29/12/04)

In false-color composite (Landsat ETM+ bands 4,3,2 RGB). In this image vegetation appears in red, pink, and maroon; water appears in blue to black; urban and non-vegetated areas (including the tsunami damage regions) appear in bluish-greens and grays.
Examples of fields that use DIP

- Industrial inspection, computer vision

![Diagram showing the integration of DIP in industrial processes](image)

Computer vision constrains

- Robust in respect of
  - snapshot conditions
    - Lighting, camera settings...
  - (tolerated) variations of the product to control or monitor
    - Shape, position, color....
  - environment
    - Temperature, dust, moisture, place ...
  - Human being
    - User-friendly, efficiency, ...
Computer vision constraints

- Real Time processing
  - Rate of the objects to control

\[ T_o = \text{time between two objects} \]
\[ T_t = \text{Processing time} \]
\[ T_t < T_o \]

Technical solutions

- A good lighting, a good snapshot are better than an elaborate processing
  - Image analysis can not bring any information that are not present in the image

- For elaborate processing, you may use parallel processing

- Or you may use pipelines
Fundamental steps in DIP

- **Acquisition**
  - Sensors
  - Lighting
  - Image formation
- **Pre-processing**
  - Low- and mid-level
- **Processing**
  - Mid- and high-level
- **Extracted attributes**
  - Reconstruction
    - Image restoration
    - Image filtering and enhancement
    - Image compression
    - Multiresolution processing
    - Morphological processing
- **Segmentation**
  - Morphological processing
  - Representation and description
  - Measurements
  - Object recognition

Components of an image processing system

- **Problem domain**
- **Image sensors**
- **Specialized image processing hardware**
- **Image processing software**
- **Processor**
  - DSP, computer
- **Image displays**
- **Mass Storage**
- **Network**
And you?

- Technical skills needed in computer vision *(including DIP)*
  - Optics, physics
  - Mechanics
  - Electronics
  - Control theory
  - Image processing
  - Artificial intelligence
  - Computer science
  - Interpersonal relationship
  - ...

*Mars Rover*