Lecture 1
Introduction

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Self Introduction

• B.Eng., Tongji University, 2000
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• PhD., Computer Science, University of Eastern Finland, 2012
• Assistant Professor, SSE, Tongji University, 2008~2010
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Self Introduction

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Course information can be found at
http://sse.tongji.edu.cn/hyli/DIP/DIP15.htm
Materials

• Textbook

• Reference Books

• My slides
• Some papers
Examination

• Homework 45%: 3 times, and each time 15%.
• Final examination 50%
• Attendance 5% (being absent >=5 times, you will fail this course)

Bonus:
• Class activity 5%: being active in class and answering my questions correctly
“One picture is worth more than ten thousand words”

Anonymous
Contents

• What is a digital image?
• What is digital image processing?
• Why do we need to learn DIP?
• History of digital image processing
• Different sources to generate images
• Key stages in digital image processing
What is a Digital Image?

A digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels.
What is a Digital Image? (cont...)

Pixel values typically represent gray levels, colours, heights, opacities etc

**Remember** *digitization* implies that a digital image is an *approximation* of a real scene
What is a Digital Image? (cont…)

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)

For most of this course we will focus on grey-scale images
What is a Digital Image? (cont...)

An image can be regarded as a function

$$f : \mathbb{R}^2 \rightarrow \mathbb{R}$$

- $f(x, y)$ gives the intensity at the position $(x, y)$
- Defined over a rectangle, with a finite range:

$$f : [a, b] \times [c, d] \rightarrow [0, 255]$$
What is a Digital Image? (cont…)

An image can be regarded as a function

\[ f: \mathbb{R}^2 \rightarrow \mathbb{R} \]

- \( f(x, y) \) gives the intensity at the position \((x, y)\)
- Defined over a rectangle, with a finite range:

\[ f: [a, b] \times [c, d] \rightarrow [0, 255] \]

A color image is just three functions pasted together. We can write this as a “vector-valued” function:

\[
\begin{bmatrix}
    r(x, y) \\
    g(x, y) \\
    b(x, y)
\end{bmatrix}
\]
%sample matlab code

img = imread('3.jpg');
imgR = img(:,:,1);
imgG = img(:,:,2);
imgB = img(:,:,3);

figure;imshow(imgR,[]);
figure;imshow(imgG,[]);
figure;imshow(imgB,[]);
What is a Digital Image? (cont...)
What is a Digital Image? (cont…)

- Images are usually discrete
- Represented as a matrix of integer values

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What is Digital Image Processing?

Digital image processing focuses on two major tasks

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission and representation for autonomous machine perception

Some argument about where image processing ends and fields such as image analysis and computer vision start
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**
- **Input:** Image
- **Output:** Image
- **Examples:** Noise removal, image sharpening

**Mid Level Process**
- **Input:** Image
- **Output:** Attributes
- **Examples:** Object recognition, segmentation

**High Level Process**
- **Input:** Attributes
- **Output:** Understanding
- **Examples:** Scene understanding, autonomous navigation

In this course we will stop here
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Why do we need to learn DIP?

• Simply because it is useful and has many potential applications

• DIP has many applications
  • Medicine
  • Astronomy
  • Biology
  • Meteorology
  • Agriculture
  • Entertainment
  • Industrial inspection
  • Law enforcement
  • ......
Why do we need to learn DIP?

- Applications in medicine

X-ray  OCT  Ultrasound

MRI  CT
Why do we need to learn DIP?

• Applications in medicine

Image enhancement for medical applications
Why do we need to learn DIP?

- Applications in medicine
  - Take slice from MRI scan of canine heart, and find boundaries between types of tissue; image with gray levels representing tissue density

![Original MRI image of a dog heart](image1.png)  ![Edge detection image](image2.png)

Original MRI image of a dog heart  Edge detection image
Why do we need to learn DIP?

• Applications in astronomy

The first picture of the moon by a US spacecraft, Jul. 31, 1964, AM 9:09

Sombrero Galaxy in infrared light
Why do we need to learn DIP?

• Applications in astronomy
  • Launched in 1990 the Hubble telescope can take images of very distant objects
  • However, an incorrect mirror made many of Hubble’s images useless
  • Image processing techniques were used to fix this
Why do we need to learn DIP?

- Applications in biology

  Cholesterol under a microscopy

  Red blood cells under the microscope
Why do we need to learn DIP?

• Applications in agriculture

Dark and medium red areas are the conifers, white spruce and red pine respectively. Lighter pink areas are aspen, maple and oak.
Why do we need to learn DIP?

- Applications in meteorology

Satellite image of Hurricane Katrina taken on Aug. 29, 2005. The image was taken by a NOAA satellite using sensors in the visible and infrared bands.
Why do we need to learn DIP?

• Applications in entertainment
  • Artistic effects are used to make images more visually appealing, to add special effects and to make composite images
Why do we need to learn DIP?

- Applications in entertainment
  - HCI: try to make human computer interfaces more natural

Hand gesture recognition

Motion-sensing games
Why do we need to learn DIP?

- Applications in entertainment
  - Panorama stitching by Xinyue WANG & Enjing WU (Media&Arts, 2009)
Why do we need to learn DIP?

• Applications in entertainment
  • Kinect Effects

**DEMO:**
http://v.youku.com/v_show/id_XMzE4MzM5OTA0.html
http://v.youku.com/v_show/id_XNTg0MDk4ODIw.html

**Kinect Gesture Dataset, Microsoft Research Cambridge**
Why do we need to learn DIP?

• Applications in industrial inspection
  • Human operators are expensive, slow and unreliable
  • Make machines do the job instead
  • Industrial vision systems are used in all kinds of industries

areas with defects
Why do we need to learn DIP?

• Applications in industrial inspection—PCB inspection
  • Machine inspection is used to determine that all components are present and that all solder joints are acceptable
  • Both conventional imaging and x-ray imaging are used
Why do we need to learn DIP?

• Applications in law enforcement
  • Number plate recognition for automated toll systems
  • Biometrics
  • Enhancement of CCTV images
Why do we need to learn DIP?

• Applications in law enforcement—biometric identifiers
Why do we need to learn DIP?

- Applications in law enforcement
  - Ex: high resolution fingerprint recognition, HK PolyU
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History of Digital Image Processing

**Early 1920s:** One of the first applications of digital imaging was in the newspaper industry

- The Bartlane cable picture transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

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Early digital image
Mid to late 1920s: Improvements to the Bartlane system resulted in higher quality images

- New reproduction processes based on photographic techniques
- Increased number of tones in reproduced images
History of DIP (cont...)

1960s: Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing

- **1964**: Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe
- Such techniques were used in other space missions including the Apollo landings

A picture of the moon taken by the *Ranger 7* probe
History of DIP (cont...) 

1970s: Digital image processing begins to be used in medical applications

- **1979:** Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans

Typical head slice CAT image
1980s - Today: The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas

- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces
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Different Sources to Generate Images

• Two major factors for image creation
  • Energy generator
  • Energy receiver (sensor)

• Energy sources include
  • Electromagnetic energy spectrum
  • Acoustic
  • Ultrasonic
  • Electronic
Different Sources to Generate Images

- Electromagnetic spectrum

<table>
<thead>
<tr>
<th>Energy of one photon (electron volts)</th>
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<tbody>
<tr>
<td>$10^6$</td>
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<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
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<tbody>
<tr>
<td>$10^{21}$</td>
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<table>
<thead>
<tr>
<th>Wavelength (meters)</th>
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<tbody>
<tr>
<td>$10^{-12}$</td>
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</table>

- Gamma rays
- X-rays
- Ultraviolet
- Infrared
- Microwaves
- Radio waves

Visible spectrum

<table>
<thead>
<tr>
<th>Ultraviolet</th>
<th>Violet</th>
<th>Blue</th>
<th>Green</th>
<th>Yellow</th>
<th>Orange</th>
<th>Red</th>
<th>Infrared</th>
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<tbody>
<tr>
<td>$0.4 \times 10^{-6}$</td>
<td>$0.5 \times 10^{-6}$</td>
<td>$0.6 \times 10^{-6}$</td>
<td>$0.7 \times 10^{-6}$</td>
<td></td>
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</tbody>
</table>
Different Sources to Generate Images

• Gamma-Ray Imaging
  • Used for nuclear medicine and astronomical observations
  • 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

Image of a complete bone obtained by using gamma-ray imaging
Different Sources to Generate Images

• X-Ray Imaging
  • Used for medical diagnosis and also for industrial inspection
  • The object is placed between a X-ray source and a film sensitive to X-ray energy
  • The intensity of the X-rays is modified by absorption as they pass through the object
Different Sources to Generate Images

• X-Ray Imaging

Illustration for the working scheme of a typical X-ray imaging system
Different Sources to Generate Images

- X-Ray Imaging

A chest X-ray image
Different Sources to Generate Images

• Ultraviolet Imaging
  • Used for lithography, industrial inspection, microscopy, biological imaging, and astronomical observations
  • Ultraviolet light is used in fluorescence microscopy

Examples of ultraviolet imaging

Normal corn

Smut corn
Different Sources to Generate Images

• Visible and Infrared Bands Imaging
  • Most of the images you see in daily life are captured in these bands
  • Used in light microscopy, astronomy, remote sensing, industry, and law enforcement

Visible lighting  Infrared lighting
Different Sources to Generate Images

- Visible and Infrared Bands Imaging
  - Ex: NASA’s LANDSAT satellite gets multispectral images of the earth in order to monitoring environmental conditions on our planet

<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 shoreline 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>2.08–2.35</td>
<td>Mineral mapping</td>
</tr>
</tbody>
</table>

Thematic bands in NASA’s LANDSAT satellite
Different Sources to Generate Images

- Visible and Infrared Bands Imaging
  - Ex: NASA’s LANDSAT satellite gets multispectral images of the earth in order to monitoring environmental conditions on our planet

 LANDSAT satellite images of the Washington, D.C. area
Different Sources to Generate Images

- Visible and Infrared Bands Imaging
  - Ex: spectral image segmentation, Color Lab, UEF
Different Sources to Generate Images

• Visible and Infrared Bands Imaging
  • Ex: multispectral palmprint recognition, HK PolyU [1]

Palmprint images captured under (a) blue, (b) green, (c) red, and (d) NIR.

Different Sources to Generate Images

• Imaging in the microwave band
  • The dominant application of imaging in the microwave band is radar; radar can get image regardless of weather or ambient lighting conditions. Radar waves can penetrate clouds, see through vegetation, ice, and dry sand.

Radar image of mountains in southeast Tibet (provided by NASA)
Different Sources to Generate Images

- Imaging in the radio band
  - Used in medicine and astronomy (consider gamma-rays)
  - In medicine, radio waves are used in MRI

3D MRI of a brain
Different Sources to Generate Images

- Other Imaging Modalities
  - Acoustic imaging
  - Electronic microscopy
  - Synthetic (computer-generated) imaging

Cross-sectional image of a seismic model

Computer generated fractal image
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Key Stages in Digital Image Processing

Image Acquisition → Image Enhancement → Image Restoration → Morphological Processing → Segmentation → Representation & Description → Object Recognition

Problem Domain

- Colour Image Processing
- Image Compression
Key Stages in DIP: Image Acquisition

1. Image Acquisition
2. Image Enhancement
3. Image Restoration
4. Morphological Processing
5. Segmentation
6. Representation & Description
7. Object Recognition
8. Colour Image Processing
9. Image Compression
Key Stages in DIP: Image Enhancement

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

Segmentation

Representation & Description

Object Recognition

Colour Image Processing

Image Compression
Key Stages in DIP: Image Restoration

- Image Acquisition
- Image Enhancement
- Image Restoration
- Morphological Processing
- Segmentation
- Representation & Description
- Object Recognition

Problem Domain

- Colour Image Processing
- Image Compression
Key Stages in DIP: Morphological Processing

- Image Acquisition
- Image Enhancement
- Problem Domain
- Colour Image Processing

Procedures:

1. Image Restoration
2. Morphological Processing
3. Segmentation
4. Representation & Description
5. Object Recognition

Mathematical Formulas:

- $(A \ominus B) \circ B = A \cdot B$
- $((A \cdot B) \ominus B) \circ B = (A \cdot B) \cdot B$

In the context of image processing, these operations help in enhancing, restoring, segmenting, representing, and recognizing objects within images.
Key Stages in DIP: Segmentation

- Image Acquisition
- Image Enhancement
- Problem Domain

- Image Restoration
- Morphological Processing

- Segmentation
- Representation & Description
- Object Recognition

- Colour Image Processing
- Image Compression
Key Stages in DIP: Representation & Description

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

Segmentation

Representation & Description

Object Recognition

Colour Image Processing

Image Compression
Key Stages in DIP: Object Recognition

- Image Acquisition
- Image Enhancement
- Image Restoration
- Morphological Processing
- Segmentation
- Representation & Description
- Object Recognition

Problem Domain

- Colour Image Processing
- Image Compression

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2015
Key Stages in DIP: Image Compression

Image Acquisition → Image Restoration → Morphological Processing

- Image Enhancement
- Image Restoration
- Morphological Processing

Problem Domain → Colour Image Processing

Object Recognition → Representation & Description → Segmentation
Key Stages in DIP: Colour Image Processing

1. Image Acquisition
2. Image Enhancement
3. Image Restoration
4. Morphological Processing
5. Segmentation
6. Representation & Description
7. Object Recognition
8. Colour Image Processing
9. Image Compression
Summary

We have looked at:

- What is a digital image?
- What is digital image processing?
- Why do we need to learn DIP?
- History of digital image processing
- Different sources to generate images
- Key stages in digital image processing

Next time we will start to see how it all works...
Thanks for your attention