Ψηφιακή Επεξεργασία Εικόνας
Εισαγωγή
Διδάσκων: Αναπληρωτής Καθηγητής Νίκου Χριστόφορος

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Digital Image Processing

Introduction

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Images taken from:
Digital Image Processing course by Brian Mac Namee, Dublin Institute of Technology.
**Miscellanea**

**Prerequisites**
- Signals and systems
- Matlab

**Course Grading**
- Assignments (50%, at least 5/10)
- Final examination (50%)

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**Bibliography (cont...)**

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C. Nikou – Digital Image Processing (E12)
This lecture will cover:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

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

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 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
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
- An image was transferred by submarine cable between London and New York in 3 hours
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer with halftoning


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**History of DIP (cont...)**

**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

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

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
History of DIP (cont...)

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

Imaging modalities

![Energy of one photon (electron volts)]

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

- Positron Emission Tomography (PET)
- Cygnus Loop natural radiation of the star (exploded 15k years ago)
- Valve of a nuclear reactor

X-ray imaging

- Chest X-ray
  - Absorption of energy
- Angiography
  - Catheter with contrast medium
- Computed Axial Tomography (CAT)
- Manufacturing errors in electronic circuits
- Cygnus Loop
Ultraviolet imaging

- Fluorescence microscopy
  - Normal corn
  - Corn infected by smut disease
- Cygnus Loop

Visible and infrared imaging

- Light microscopy
  - Taxol (anticancer agent) 250x
  - Cholesterol 40x
  - Microprocessor 60x
  - Nickel oxide thin film 600x
  - Surface of audio CD 1750x
  - Organic superconductor 450x
Visible and infrared imaging (cont.)

Remote sensing
- Terrain classification (LANDSAT)
- Meteorology (NOAA)


LANDSAT thematic bands of Washington DC area

Hurricane Katrina, 2005

Visible and infrared imaging (cont.)

- Night-time lights of the world
  - Infrared band
  - Useful for estimating the percent of total electrical energy
Visible and infrared imaging (cont.)

- Night-time lights of the world
  - Infrared band
  - Useful for estimating the percent of total electrical energy


Visible and infrared imaging (cont.)

- Industrial inspection
  - Circuit board controller
  - Pill container
  - Bottle filling
  - Air pockets in plastic parts
  - Burned flakes
  - Intraocular implant
    - Structured light for detecting lens deformations (damages at 1 and 5 o’clock)
Visible and infrared imaging (cont.)

- Law enforcement
  - Fingerprint for database search
  - Automated counting
  - Bill identification
  - Licence plate detection and reading

Imaging in the microwave

- Radar is the dominant application
  - It emits pulses and receives them back at its antenna

FIGURE 1.36
Spacborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)
Imaging in the radio band

- Magnetic Resonance Imaging (MRI)
  - Patient placed in a magnet and radio wave pulses are emitted through the body
  - Resonance takes place with tissues (e.g. water molecules)

![MRI images](image1.jpg)

**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)

Imaging in the radio band

- Astronomy

![Images of the Crab Pulsar](image2.jpg)

**Figure 1.18** Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA)
Other imaging modalities

- Ultrasound imaging

![Ultrasound images](image)

**FIGURE 3.20** Examples of ultrasound imaging:
(a) Baby
(b) Another view of baby
(c) Thyroid line
(d) Muscle layers showing lesion
(Courtesy of Siemens Medical Systems Inc.: Ultrasound Group)

Other imaging modalities (cont.)

- Electron Microscopy (EM)
  - Works like a slide projector emitting a beam of electrons instead of light
  - The transmitted beam is projected on a phosphor screen
  - The interaction of the beam with the slide produces light which is recorded
    - Scanning Electron Microscopy (SEM)
    - Transmission Electron Microscopy (TEM)
  - Very high magnification (10000x)
Other imaging modalities (cont.)

![Images taken from Gonzalez & Woods, Digital Image Processing (2002)]

**FIGURE 1.21** (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left); (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

Applications: Image Enhancement

One of the most common uses of DIP techniques: improve quality, remove noise etc

![Images taken from Gonzalez & Woods, Digital Image Processing (2002)]

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Applications: The Hubble Telescope

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.

Applications: Artistic Effects

Artistic effects are used to make images more visually appealing, to add special effects and to make composite images.
Applications: Medicine

3D tomography and rendering with transparencies

Applications: HCI

Try to make human computer interfaces more natural
- Face recognition
- Gesture recognition

Does anyone remember the user interface from “Minority Report”? These tasks can be extremely difficult
Key Stages in Digital Image Processing

- Image Acquisition
- Image Restoration
- Morphological Processing
- Segmentation
- Object Recognition
- Representation & Description
- Image Enhancement
- Colour Image Processing
- Image Compression
- Problem Domain

Key Stages in Digital Image Processing: Image Enhancement

Image Enhancement

Image Acquisition

Morphological Processing

Segmentation

Object Recognition

Representation & Description

Problem Domain

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Image Restoration

Image Enhancement

Image Acquisition

Morphological Processing

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Problem Domain

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing:
Morphological Processing

Key Stages in Digital Image Processing:
Segmentation
Key Stages in Digital Image Processing:

**Object Recognition**

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Key Stages in Digital Image Processing:

**Representation & Description**

- Image Restoration
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Key Stages in Digital Image Processing:

Image Compression

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

Problem Domain: Colour Image Processing

Image Compression

Key Stages in Digital Image Processing:

Colour Image Processing

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

Problem Domain: Colour Image Processing

Image Compression
## Summary

We have looked at:

- What is a digital image?
- What is digital image processing?
- History of digital image processing
- State of the art examples of digital image processing
- Key stages in digital image processing

Important: Acquire some experience with Matlab.
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