Introduction to Digital Image Processing

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Outline

- What is Digital Image Processing?
- The origins of Digital Image Processing
- Examples of fields that use Digital Image Processing
- Fundamental steps in Digital Image Processing
- Components of an Image Processing System
“One picture is worth more than ten thousand words”

Anonymous
Section 1.1

WHAT IS DIGITAL IMAGE PROCESSING?
What is an image?

- An **image** is defined as a two-dimensional function, $f(x, y)$.
  - where $x$ and $y$ are spatial (plane) coordinates
- The amplitude of $f$ at any pair of coordinates $(x, y)$ is called the **intensity** or **gray level** of the image at that point.
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 are pixels?

- Pixel values typically represent gray levels, colours, heights, opacities, etc.
- *Digitization* implies that a digital image is an *approximation* of a real scene.
Common image formats

- 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
Digital image processing refers to processing digital images by means of a digital computer.

Two major tasks are focused

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission and representation for autonomous machine perception
Digital image processing covers almost the entire electromagnetic spectrum.

- It encompasses a wide and varied field of applications.
What is digital image processing?
The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes.

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Image processing | Image analysis | Computer vision

This course will stop here
Section 1.2

THE ORIGINS OF DIGITAL IMAGE PROCESSING
History of Digital Image Processing

1920s

- **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.

A digital picture produced in 1921
History of Digital Image Processing

1920s

- 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

An improved image made in 1922

Early 15-tone digital image
History of Digital Image Processing

- **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

A picture of the moon taken by the Ranger 7 probe minutes before landing
History of Digital Image Processing

- **1970s**: Medical applications of digital image processing arises.
  - 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.
  - Also used in remote Earth resources observations, and astronomy.

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

- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

Restoration of historical documents in archeology (EG2014)
Section 1.3

EXAMPLES OF DIGITAL IMAGE PROCESSING APPLICATION
Image enhancement

- One of the most common uses of digital image processing techniques.
- Improve quality, remove noise, etc.
Astronomy: The Hubble Telescope

- Launched in 1990, the Hubble telescope can take images of very distant objects.
- However, many Hubble’s images are useless due to an incorrect mirror.
Artistic effects

- Images are modified to be more visually appealing.
- Add special effects and make composite image
Take slice from MRI scan of canine heart, and find boundaries between types of tissue

- Image with gray levels representing tissue density
- Use a suitable filter to highlight edges
Geographic Information Systems (GIS)

- Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification, meteorology
Geographic Information Systems (GIS)

- Night-Time Lights of the World data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data
Human operators are expensive, slow and unreliable

Make machines do the job instead

Industrial vision systems are used in all kinds of industries

Can we trust them?
Industrial inspection

- Printed Circuit Board (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.
Law enforcement

- Used extensively by law enforcers
- Number plate recognition for speed cameras/automated toll systems
- Fingerprint recognition
- Enhancement of CCTV images
Human – computer interactions (HCI)

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- These tasks can be extremely difficult.
Section 1.4

FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING
Outputs of these processes generally are images

- **CHAPTER 6**: Color image processing
- **CHAPTER 7**: Wavelets and multiresolution processing
- **CHAPTER 8**: Compression
- **CHAPTER 9**: Morphological processing
- **CHAPTER 5**: Image restoration
- **CHAPTERS 3 & 4**: Image enhancement
- **CHAPTER 2**: Image acquisition
- **Knowledge base**
- **Output of these processes generally are image attributes**
  - **CHAPTER 10**: Segmentation
  - **CHAPTER 11**: Representation & description
  - **CHAPTER 12**: Object recognition
A number of basic digital image concepts
• Involve preprocessing, e.g. sampling, quantization, scaling, etc.
• Manipulate an image so that the result is more suitable than the original for a specific application
• Enhancement techniques are problem-oriented
Image restoration

- Improve the appearance of an image
- Objective, techniques based on mathematical or probabilistic models of image degradation
• Fundamental concepts in color models and basic color processing in a digital domain
• Also be the basis for extracting features of interest in an image
Wavelet and multiresolution processing

- Represent images in various degrees of resolution
- Pyramidal representation
• Reduce the storage required to save an image, or the bandwidth required to transmit it
• Storage technology has improved significantly over the past decade, the same cannot be said for transmission capacity
• Extracting image components that are useful in the representation and description of shape.
• Partition an image into its constituent parts or objects
• Autonomous segmentation is one of the most difficult tasks in digital image processing.
• Representation: whether the data should be represented as a boundary or as a complete region
• Descriptions: attributes are extracted, resulting in some quantitative information of interest
• Almost always follow the output of a segmentation stage
• Assigns a label (e.g., “vehicle”) to an object based on its descriptors.
Section 1.5

COMPONENTS OF AN IMAGE PROCESSING SYSTEM
General-purpose image processing system

- Image displays
- Computer
- Mass storage
- Hardcopy
- Specialized image processing hardware
- Image processing software
- Image sensors

Problem domain
Image sensors

- One of the two elements required to acquire digital images
  - **Sensor**: a physical device that is sensitive to the energy radiated by the object we wish to image.
  - **Digitizer**: a device for converting the output of the physical sensing device into digital form.

- For instance, in a digital video camera:
  - Sensors produce an electrical output proportional to light intensity
  - Digitizer converts these outputs to digital data
Specialized image processing hardware

- Usually consists of the digitizer, plus hardware that performs other primitive operations.
  - E.g. arithmetic logic unit (ALU), performing arithmetic and logical operations in parallel on entire images.
- Front-end subsystem
- The most distinguishing characteristic is **speed**.
  - This unit performs functions that require fast data throughputs (e.g., digitizing and averaging video images at 30 frames/s)
  - Typical main computers cannot handle
A general-purpose computer may range from a PC to a supercomputer.

Software for image processing consists of specialized modules that perform specific tasks.
A must in image processing applications

Digital storage for image processing applications falls into three principal categories:

- Short-term storage for use during processing
  - Computer memory, frame buffers
- On-line storage for relatively fast recall
  - Magnetic disks or optical-media storage
- Archival storage, characterized by infrequent access
Image displays

- Mainly color (preferably flat screen) TV monitors
- Stereo displays: head-gear containing two small displays embedded in goggles worn by the user
Hardcopy devices

- Laser printers, film cameras, heat-sensitive devices, inkjet units, and digital units, such as optical and CD-ROM disks
- Film provides the highest possible resolution, but paper is the obvious medium of choice for written material.
- For presentations, images are displayed on film transparencies or in a digital medium.
A default function in any computer system in use today

The key consideration in image transmission is bandwidth.

- Large amount of data inherent in image processing applications
- Communications with remote sites via the Internet are not always as efficient.
  - Optical fiber and other broadband technologies.
Reference

- Dr. Brian Mac Namee’s lecture:
  
- Images are obtained from the above materials and Google