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Digital Image Processing

2nd Edition

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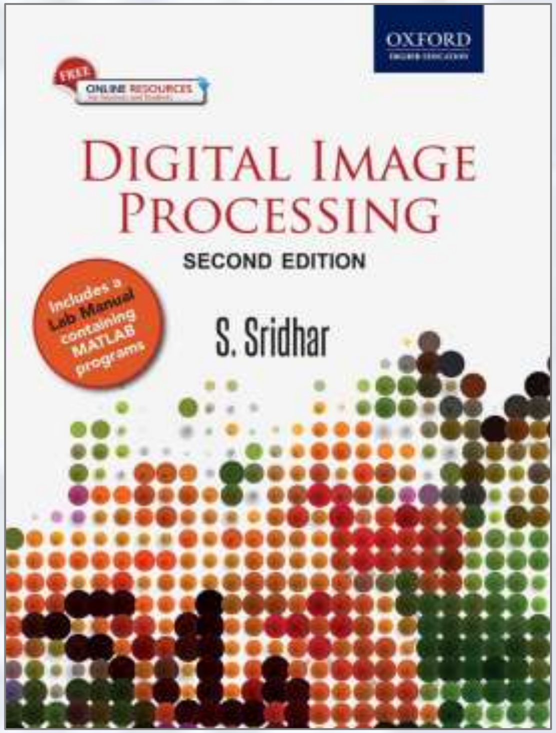


Chapter 1

Introduction to Image Processing

Nature of Image Processing

- Images are everywhere! Sources of Images are paintings, photographs in magazines, Journals, Image galleries, digital Libraries, newspapers, advertisement boards, television and Internet.

- Images are imitations of Images.

- In image processing, the term ‘image’ is used to denote the image data that is sampled, quantized, and readily available in a form suitable for further processing by digital computers.

IMAGE PROCESSING ENVIRONMENT

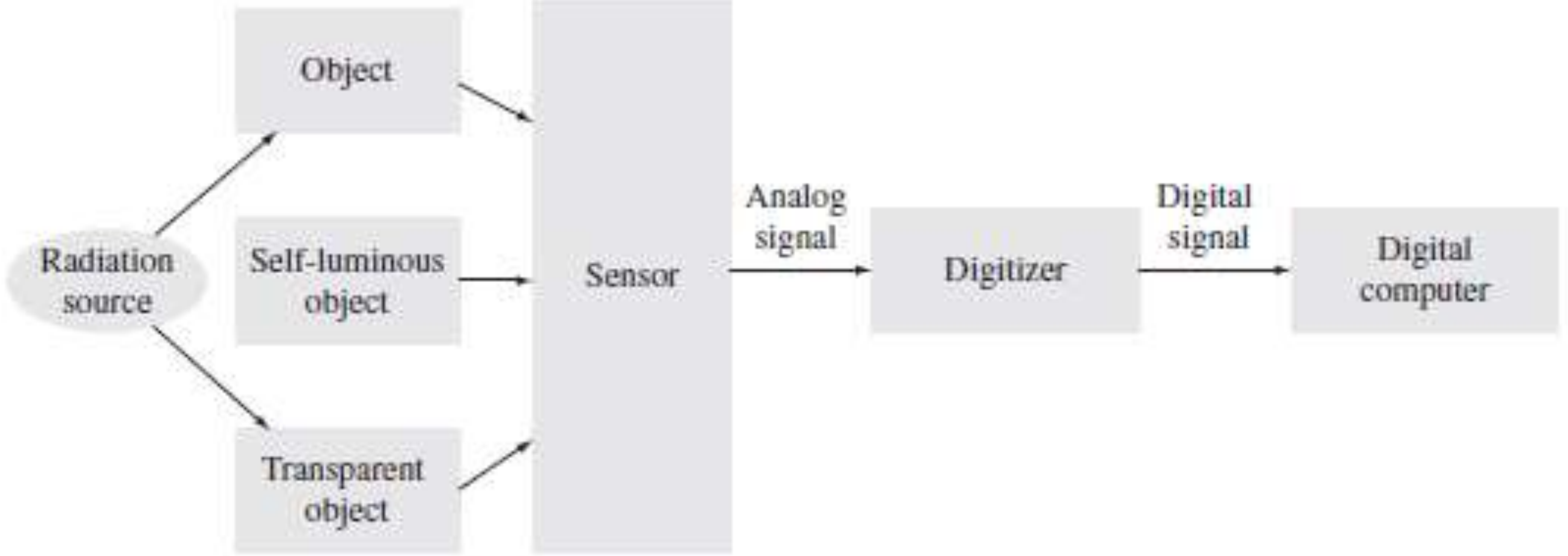


Fig. 1.1 Image processing environment

Reflective mode Imaging

- *Reflective mode imaging* represents the simplest form of imaging and uses a sensor to acquire the digital image. All video cameras, digital cameras, and scanners use some types of sensors for capturing the image.

Emissive type imaging

- *Emissive type imaging* is the second type, where the images are acquired from self-luminous objects without the help of a radiation source. In emissive type imaging, the objects are self-luminous. The radiation emitted by the object is directly captured by the sensor to form an image. Thermal imaging is an example of emissive type imaging.

Transmissive imaging

- *Transmissive imaging* is the third type, where the radiation source illuminates the object. The absorption of radiation by the objects depends upon the nature of the material. Some of the radiation passes through the objects. The attenuated radiation is sensed into an image.

Image Processing

- *Optical image processing* is an area that deals with the object, optics, and how processes are applied to an image that is available in the form of reflected or transmitted
- *Analog image processing* is an area that deals with the processing of analog electrical signals using analog circuits. The imaging systems that use film for recording images are also known as analog imaging systems.

What is Digital Image Processing?

- *Digital image processing* is an area that uses digital circuits, systems, and software algorithms to carry out the image processing operations. The image processing operations may include quality enhancement of an image, counting of objects, and image analysis.

Reasons for Popularity of DIP

1. It is easy to post-process the image. Small corrections can be made in the captured image using software.
2. It is easy to store the image in the digital memory.
3. It is possible to transmit the image over networks. So sharing an image is quite easy.
4. A digital image does not require any chemical process. So it is very environment friendly, as harmful film chemicals are not required or used.
5. It is easy to operate a digital camera.

IMAGE PROCESSING AND RELATED FIELDS

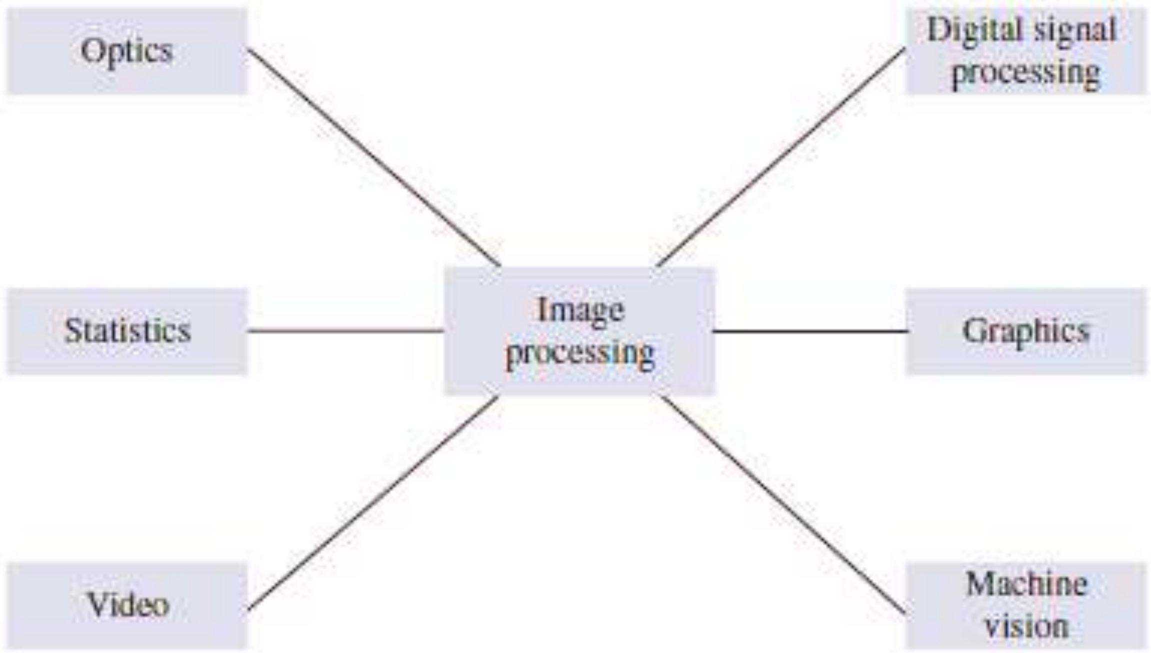


Fig. 1.2 Image processing and other closely related fields

Relations with other branches

- Image processing deals with raster data or bitmaps, whereas computer graphics primarily deals with vector data.
- In digital signal processing, one often deals with the processing of a one-dimensional signal. In the domain of image processing, one deals with visual information that is often in two or more dimensions.

Relations with other branches

- The main goal of machine vision is to interpret the image and to extract its physical, geometric, or topological properties. Thus, the output of image processing operations can be subjected to more techniques, to produce additional information for interpretation.

Relations with other branches

- Image processing is about still images. Thus, video processing is an extension of image processing. In addition, images are strongly related to multimedia, as the field of multimedia broadly includes the study of audio, video, images, graphics, and animation.

Relations with other branches

- Optical image processing deals with lenses, light, lighting conditions, and associated optical circuits. The study of lenses and lighting conditions has an important role in the study of image processing.

Relations with other branches

- Image analysis is an area that concerns the extraction and analysis of object information from the image. Imaging applications involve both simple statistics such as counting and mensuration and complex statistics such as advanced statistical inference. So statistics play an important role in imaging applications.

Digital Image

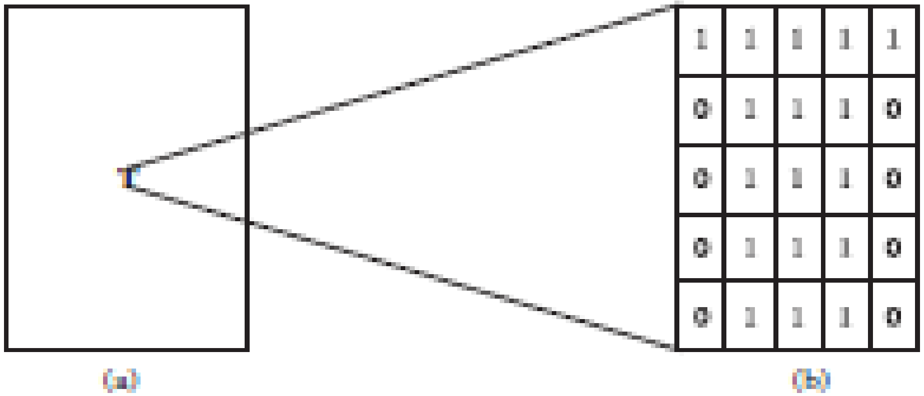


Fig. 1.3 Digital image representation (a) Small binary digital image (b) Equivalent image contents in matrix form

An image can be defined as a 2D signal that varies over the spatial coordinates *x* and *y*, and can be written mathematically as $f(x, y)$.

Digital Image

- The value of the function *f* (*x*, *y*) at every point indexed by a row and a column is called *grey value* or *intensity* of the image.
- Resolution is an important characteristic of an imaging system. It is the ability of the imaging system to produce the smallest discernable details, i.e., the smallest sized object clearly, and differentiate it from the neighbouring small objects that are present in the image.

Useful definitions

- Image resolution depends on two factors—optical resolution of the lens and spatial resolution.
- A useful way to define resolution is the smallest number of line pairs per unit distance.
- Spatial resolution depends on two parameters—

  1. The number of pixels of the image

  2. The number of bits necessary for adequate intensity resolution, referred to as the bit depth.

Useful definitions

- The number of bits necessary to encode the pixel value is called *bit depth*. Bit depth is a power of two; it can be written as powers of 2.
- So the total number of bits necessary to represent the image is
- Number of rows = Number of columns * Bit depth

Classification of Images

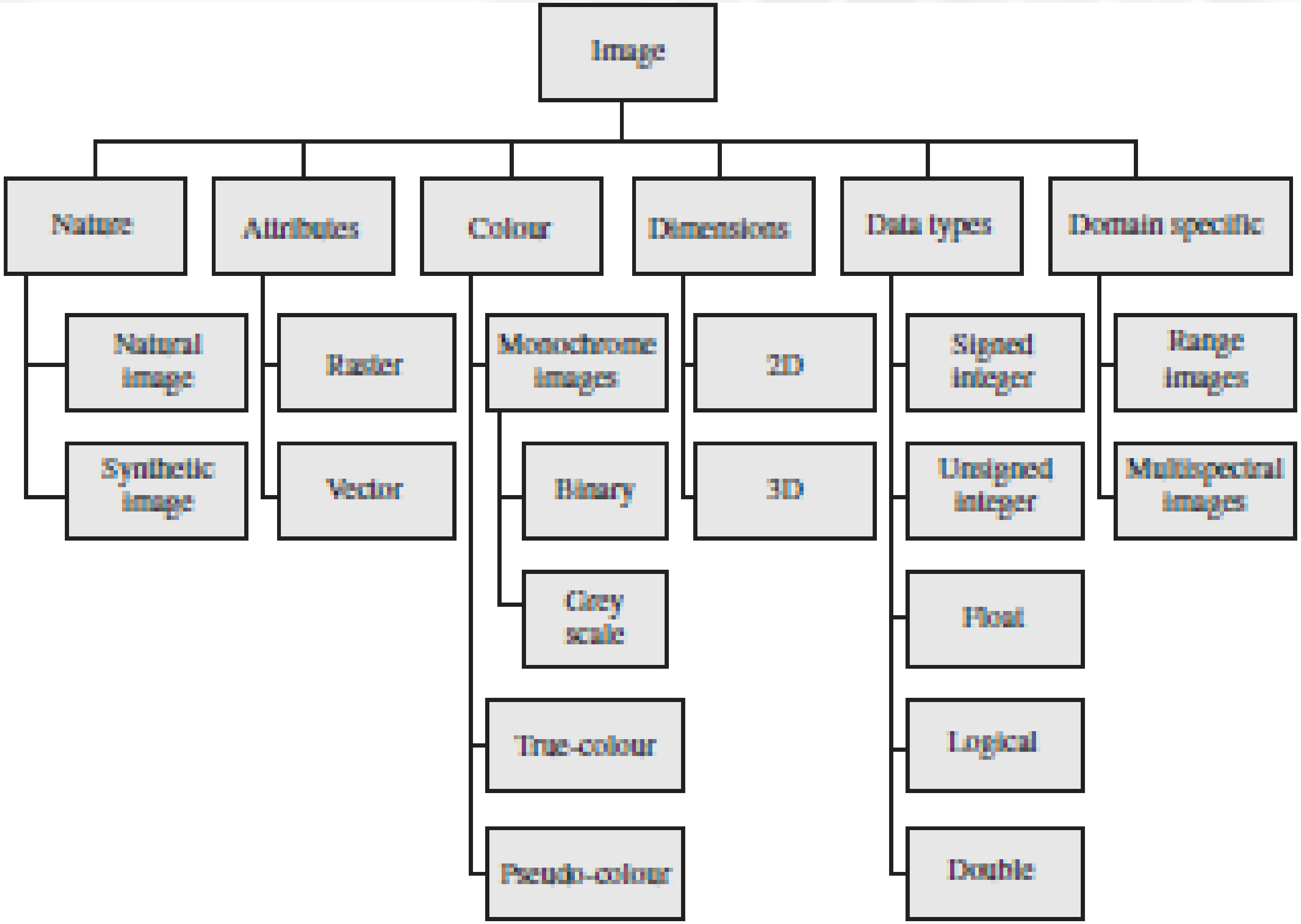


Fig. 1.4 Classification of images

Based on Nature

- Natural Images

  Produced by Cameras and Scanners
- Synthetic Images

  Produced by Computer Programs

Based on Attributes

- Raster Images

  Pixel based Images
- Vector Images

  Produced by Geometrical attributes like Lines, circles etc

Types of Images Based on Colour

Grey scale images are different from binary images as they have many shades of grey between black and white. These images are also called monochromatic as there is no colour component in the image, like in binary images. *Grey scale* is the term that refers to the range of shades between white and black or vice versa.

Types of Images

- In binary images, the pixels assume a value of 0 or 1. So one bit is sufficient to represent the pixel value. Binary images are also called bi-level images.

- In true colour images, the pixel has a colour that is obtained by mixing the primary colours red, green, and blue. Each colour component is represented like a grey scale image using eight bits. Mostly, true colour images use 24 bits to represent all the colours.

Indexed Image

- A special category of colour images is the indexed image. In most images, the full range of colours is not used. So it is better to reduce the number of bits by maintaining a colour map, gamut, or palette with the image.

Storage Structure

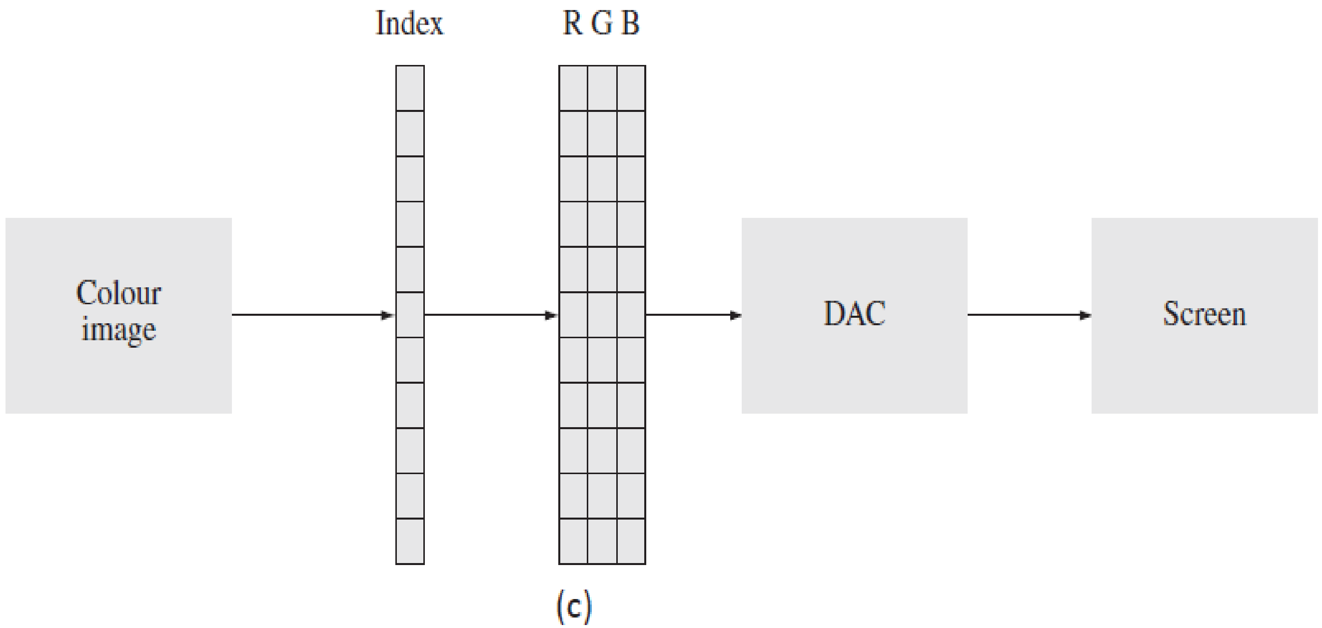


Fig. 1.6 (b) Storage structure of colour images (c) Storage structure of an indexed image
[Refer to Oxford University Press (OUPI) website for colour images]

Pseudocolour Image

- Like true colour images, Pseudocolour images are also used widely in image processing. True colour images are called three-band images. However, in remote sensing applications, multi-band images or multi-spectral images are generally used. These images, which are captured by satellites, contain many bands.

Example Problems

Example 1.1 What is the storage requirement for a 1024×1024 binary image?

Solution For a binary image, one bit is sufficient for representing the pixel value. So the number of bits required will be $1024 \times 1024 \times 1 = 10{,}48{,}576$ bits $= 1{,}31{,}072$ bytes = 131.072 Kb (Assume 1 Kb = 1000 bytes).

Example Problems

Example 1.2 What is the storage requirement for a 1024×1024 24-bit colour image?

Solution Since colour images are three-band images (red, green, and blue components), the storage requirement is $1024 \times 1024 \times 3$ bytes = 31,45,728 bytes. If it is assumed that 1 Kb is 1000 bytes, the storage requirement is 3,145.728 Kb.

Example Problems

Example 1.3 A picture of physical size 2.5 inches by 2 inches is scanned at 150 dpi. How many pixels would be there in the image?

Solution The relation between the physical dimensions and the spatial resolution is simple. The pixel dimensions are obtained by multiplying the physical width and height by the scanned resolution. Therefore, the pixel dimension is as follows.

$$(2.5 \times 150) \times (2 \times 150)$$

$$= 375 \times 300 = 112500 \text{ pixels would be present}$$

Example Problems

Example 1.4 If a 375 × 300 grey-scale image needs to be sent across the channel of capacity 28 kbps, then how much transmission time is required?

Solution If the picture is grey scale, then 8 bits are used. Therefore, transmission time would be

$$= \frac{375 \times 300 \times 8}{28 \times 1000} = \frac{112500 \times 8}{28000} = 32.143 \text{ sec}$$

Example Problems

Example 1.5 Given a grey-scale image of size 5 inches by 6 inches scanned at the rate of 300 dpi, answer the following:

(a) How many bits are required to represent the image?
(b) How much time is required to transmit the image if the modem is 28 kbps?
(c) Repeat the aforementioned if it were a binary image.

Solution

(a) Number of bits required to represent grey-scale image (uses 8 bits)

$$= 5 \times 300 \times 6 \times 300 \times 8 = 1500 \times 1800 \times 8 = 21600000 \text{ bits}$$

(b) Total time taken to transmit image

$$= \frac{\text{Total number of bits in image}}{\text{Transmission Speed}} = \frac{21600000}{28000} = 771.43 \text{ sec}$$

(c) If it is binary image, then the number of bits required to represent binary image

$$= 5 \times 300 \times 6 \times 300 \times 1 = 1500 \times 1800 \times 1 = 2700000 \text{ bits}$$

The total transmission time would be $= \frac{\text{Total number of bits}}{\text{Transmission speed}} = \frac{2700000}{28000} = 96.429 \text{ sec}$

Types of Images based on Dimensions

- **Types of Images Based on Dimensions**

  2D and 3D
- **Types of Images Based on Data Types**
- Single, double, Signed or unsigned.

Types of Images based on Data types

- Single, float, double, Signed , Logical or unsigned.

Types of Images based on Domain Specific Images

- Range Images
- Pixel value denotes the distance between
- camera and object
- Multispectral Images
- Many band images encountered in remote
- sensing

DIGITAL IMAGE PROCESSING OPERATIONS

Fig. 1.7 Image processing operation

Image Analysis

Fig. 1.8 Image analysis operation

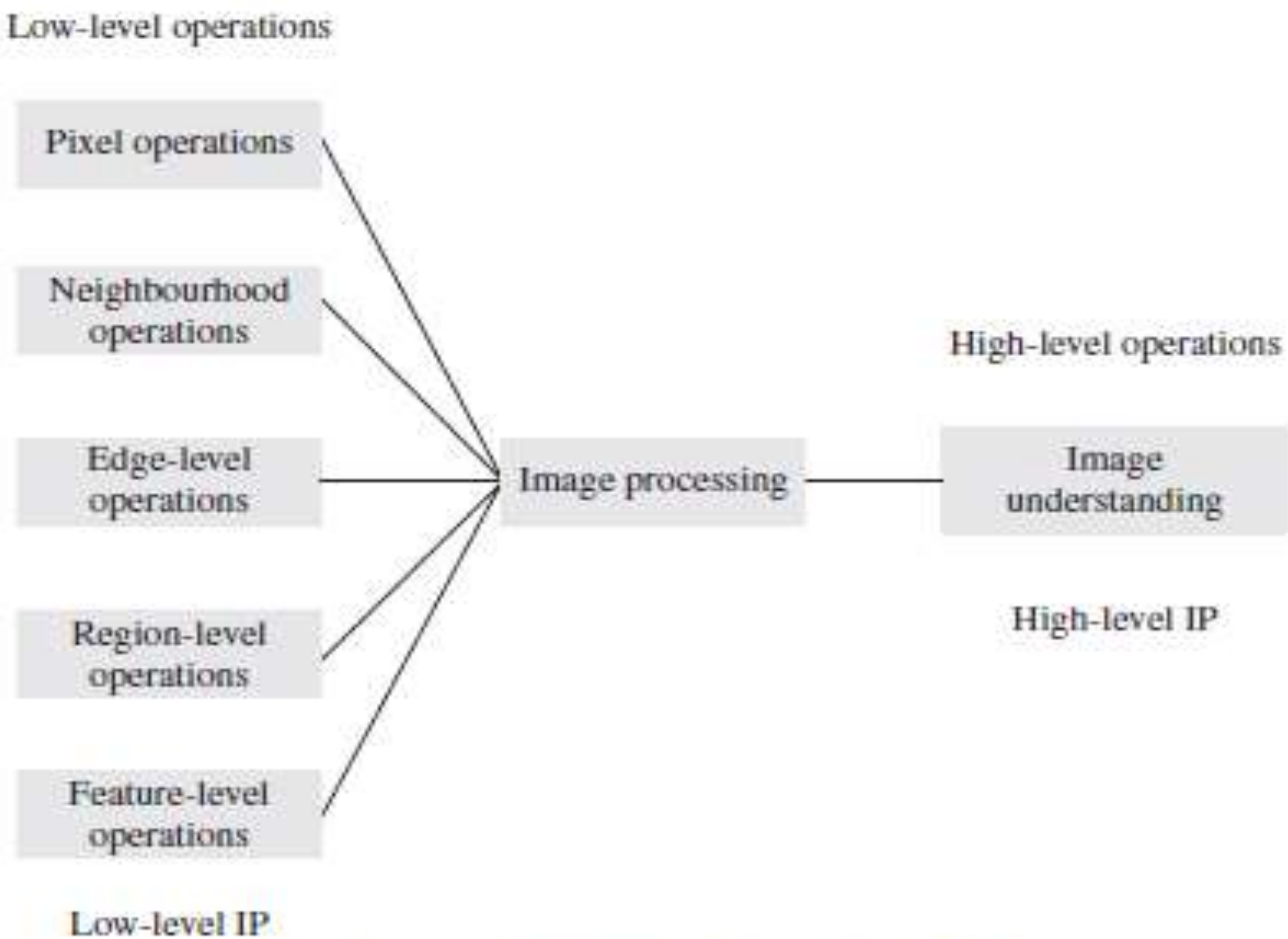


Fig. 1.9 Levels of image processing operations

Table 1.1 Comparison of computer-based and manual interpretation

Computer-based interpretation	Manual interpretation
Computers are very accurate in performing numerical calculations, but less skilled in recognition compared to human beings.	Human beings are highly skilled in recognition, but slow in performing numerical calculations.
Computers are very fast.	Human beings are affected by many factors such as fatigue and boredom. Human errors are inevitable.
Computers are robust.	Human analysis is subjective. Often experts themselves differ from one another in interpretation. There are intra- and inter-operator differences.
Computers are flexible. They are easily configurable and easily deployable.	Human expertise is costly and less flexible.
Computer interpretation is reliable.	Human interpretation is subjective and variable. This affects reliability.

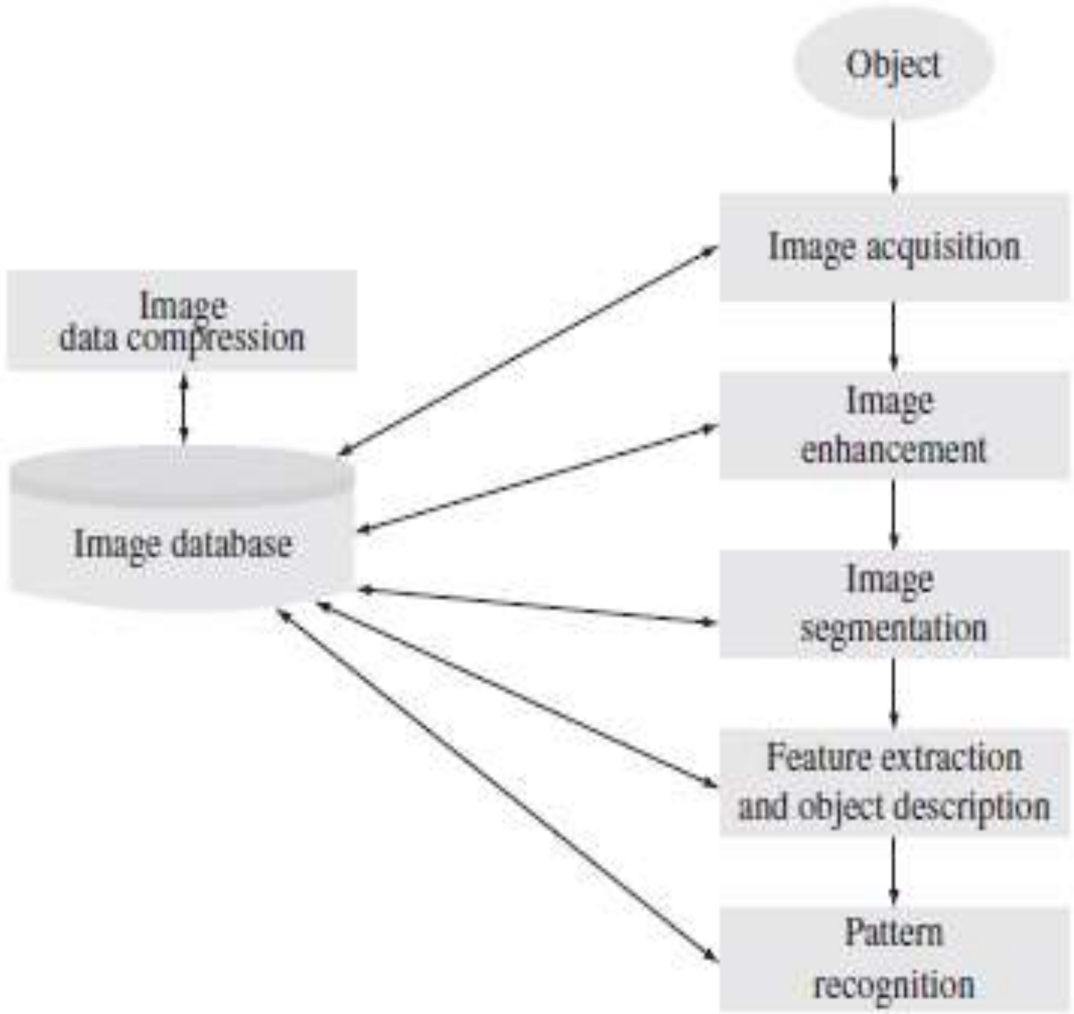


Fig. 1.10 Steps in image processing

Image acquisition This step aims to obtain the digital image of the object.

Image enhancement This step aims to improve the quality of the image so that the analysis of the images is reliable.

Image segmentation This step divides the image into many sub-regions and extracts the regions that are necessary for further analysis. The portions of the image that are not necessary, such as image backgrounds (dictated by the imaging requirement), are discarded.

Feature extraction and object description Imaging applications use many routines for extraction of image features that are necessary for recognition. This is called image feature extraction step. The extracted object features are represented in meaningful data structures and the objects are described.

Pattern recognition This step is for identifying and recognizing the object that is present in the image, using the features generated in the earlier step and pattern recognition algorithms such as classification or clustering.

Image data compression and image database are the other important steps in image processing. Image databases are used to store the acquired images and the temporary images that are created during processing. The data compression step is crucial as it

Image Enhancement

Fig. 1.11 Image enhancement (a) Dark image (b) Enhanced image

Image Restoration

(a) (b)

Fig. 1.12 Image restoration (a) Blurred image (b) Restored image

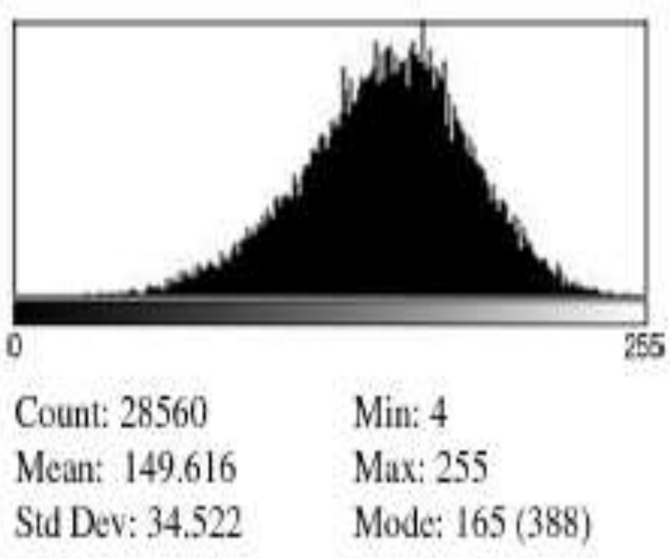
Image Compression

(a) (b) (c)

Fig. 1.13 Image compression (a) Original image (b) Image quality at 95% (c) Image quality at 5%

Image Analysis

(a)



(b)

Fig. 1.14 Image analysis (a) Original image (b) Histogram and its statistics

Image Synthesis

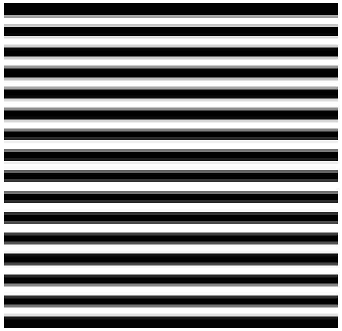


Fig. 1.15 Sample synthetic grating

Image Processing Applications

Table 1.2 Select parts of the electromagnetic spectrum

Types of radiation	Frequency range (in Hertz)	Wave length (in cm)	Nature of imaging and its relevance for image processing
Radio waves	10^5–10^{10}	$> 10^9$	AM/FM radio
Microwave	10^{10}–10^{12}	10^9–10^6	Radar imaging
Infrared	10^{12}–10^{14}	10^9–7000	Thermal imaging
Visible light	4–7.5×10^{14}	7000–4000	Optical
Ultraviolet	10^{15}–10^{17}	4000–10	Optical
X-rays	10^{17}–10^{20}	10–0.1	Medical and industrial
Gamma rays	10^{20}–10^{24}	< 0.1	Medical

Based on Electromagnetic Spectrum

- Radio Waves
  Magnetic Resonance Imaging
- Microwave
  Radar Imaging (Radio Detection and Ranging)
  SAR Imaging (Synthetic Aperture Imaging)
- Infrared Waves
- Visible Light
- Ultraviolet ray
- Gamma Rays
- Ultrasound Imaging

Survey Based on Application

- Pattern Recognition
  Fingerprint, face, Iris, DNA

Medical Imaging

- Visualization and Rendering

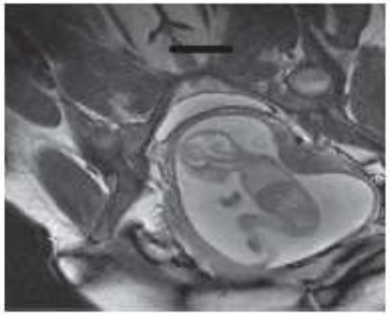


Fig. 1.18 Foetal MRI image

Fig. 1.19 CT skull image

More Domains

- Remote Sensing
- Image communication
- Image Security and Copyright Protection

(a)

Fig. 1.20 Watermarking (a) Original image

(b)

Fig. 1.20 (b) Image with watermark—'Visible Watermark Demo'

More Domains

- Video Processing
- Image Understanding
- Military Applications
- Computational Photography and Photography
- Image and Video Analytics
- Image Security and Copyright Protection

Image Effects

Fig. 1.21 Polar transformation (a) Original image (b) Polar transform

Image Mosaicking

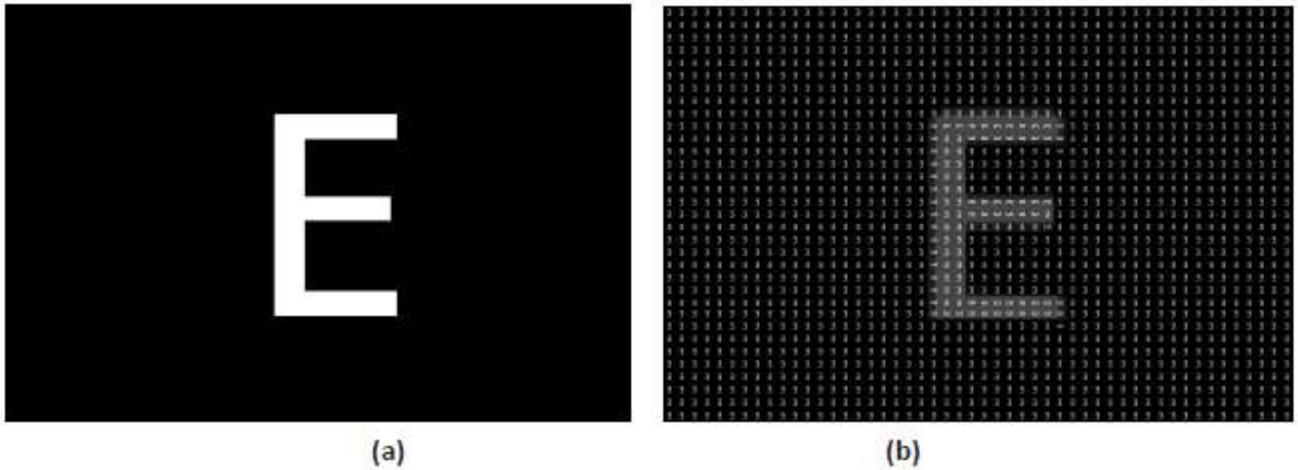


Fig. 1.22 Image mosaic (a) Tile mosaic (b) Photo mosaic

More Domains

- Entertainment
- Image retrieval Systems

SUMMARY

- Images are sampled and discretized mathematical functions.
- The objective of digital image processing is to improve the quality of the pictorial information and to facilitate automatic machine interpretation.
- Image processing is a complex task because of difficulties such as illusion, loss of information, extensive knowledge requirement for interpretation, presence of noise, and artefacts.
- Images can be classified based on nature, attributes, colour, dimensions, data types, and domain of imaging applications.
- Image processing applications are present in all domains.