UNIT–1 : Digital Image Fundamentals (PYQ Solution)

AKTU · Image Processing (BCS057) · Solutions by **Chirag Jain**, Ycotes

SECTION A Answers (≈70 Words Each)

Q1. What is Digital Image Processing? (2023)

Digital Image Processing (DIP) is the use of computer algorithms to process digital images, which are 2-D functions f(x, y) of discrete pixel values. Its aims are to improve image quality for human viewing and to extract information for machine perception. It covers enhancement, restoration, compression, segmentation and recognition.

Q2. What do you mean by reflectance? (2023)

An image is modelled as f(x, y) = i(x, y) · r(x, y). Reflectance r(x, y) is the fraction of incident light that a surface reflects, between 0 (total absorption) and 1 (total reflection). It depends on the object's material, while illumination i(x, y) depends on the light source. Homomorphic filtering separates the two components.

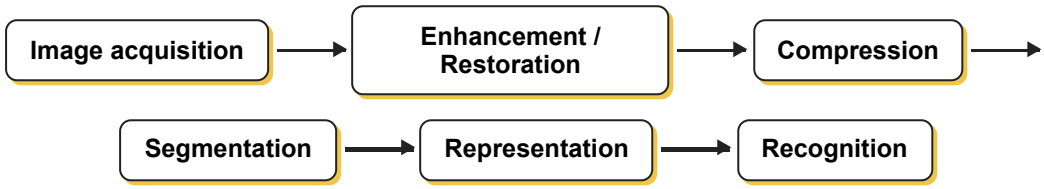
Q3. Define image sampling and quantization. (2019)

Sampling digitises the coordinate values (x, y) of an image, selecting a grid of M × N points; it fixes spatial resolution. Quantization digitises the amplitude (intensity) values into a finite number of levels L = 2^k; it fixes gray-level resolution. Together they convert a continuous image into a digital one.

SECTION B Answers (≈250 Words Each)

Q1. What is image processing? Explain the fundamental steps of digital image processing with a block diagram. (2023, 2019)

Image processing means performing operations on an image to enhance it or to extract useful information. A digital image is a finite array of pixels, f(x, y), whose spatial coordinates and intensity are discrete.



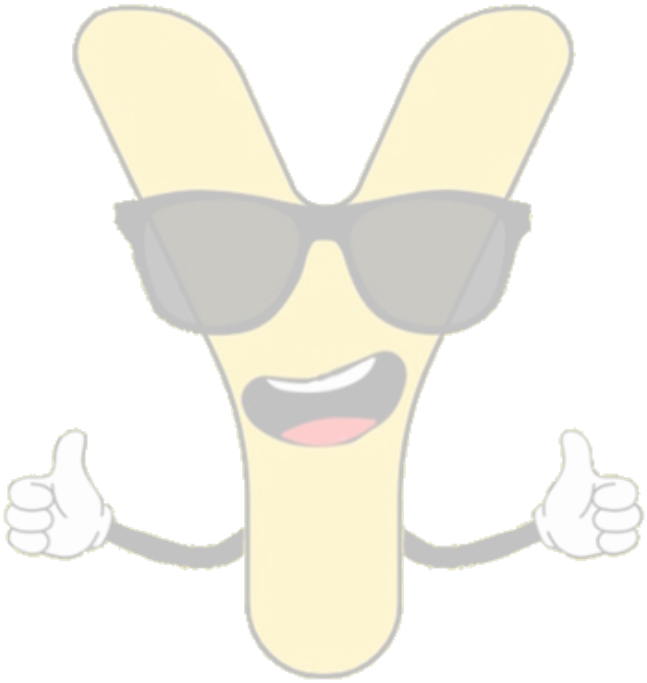
Steps of digital image processing

Fundamental steps:

1. **Image acquisition:** capturing the image with a sensor (camera, scanner) and digitising it; includes pre-processing such as scaling.
2. **Image enhancement:** improving visual quality for a specific purpose, e.g. contrast stretching, histogram equalisation. It is subjective.
3. **Image restoration:** recovering the original image from degradation (blur, noise) using a mathematical degradation model; it is objective.
4. **Colour image processing:** handling colour models (RGB, HSI, CMY) and colour enhancement.
5. **Wavelets and multiresolution processing:** representing images at several resolutions (pyramids).
6. **Compression:** reducing storage and bandwidth (JPEG, run length, Huffman).
7. **Morphological processing:** extracting shape components (erosion, dilation) from binary images.
8. **Segmentation:** partitioning the image into objects and background (thresholding, edges, regions).
9. **Representation and description:** converting segmented data to boundary or region form and extracting features.
10. **Object recognition:** labelling objects from their descriptors.

All steps use a **knowledge base** that holds prior information about the problem domain.

Conclusion: the steps move from low-level (input is an image, output is an image) to high-level (input is an image, output is attributes or meaning).

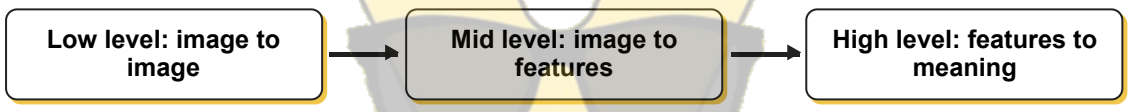


SECTION C Answers (≈500 Words Each)

Q1. Explain low-level, mid-level and high-level image processing. Also explain the sampling and quantization process. (2023)

Levels of image processing:

1. **Low-level processing:** both input and output are images. Operations are primitive: noise reduction, contrast enhancement, sharpening, smoothing, histogram operations.
2. **Mid-level processing:** input is an image, output is **attributes extracted from it**: edges, contours, regions and object identities. Examples: segmentation, classification of regions, description.
3. **High-level processing:** "making sense" of recognised objects, performing cognitive functions associated with vision: scene understanding, image analysis and computer vision.



Levels of image processing

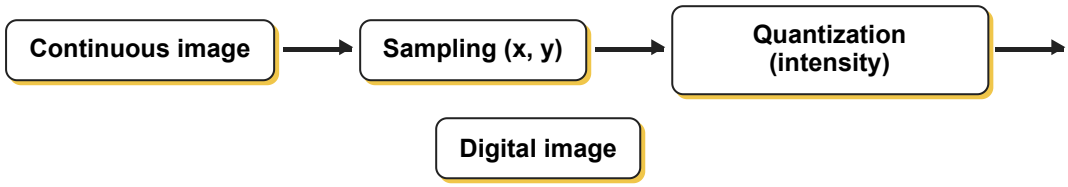
Image sampling and quantization: a continuous image f(x, y) must be digitised both in coordinates and amplitude.

Sampling is the digitisation of the spatial coordinates. The image plane is divided into an M × N grid and the value at each grid point is taken. Higher sampling rate means more pixels, finer spatial resolution and larger file; too low a rate causes **aliasing** and a checkerboard effect. The Nyquist criterion says the sampling frequency must be at least twice the highest frequency in the image.

Quantization is the digitisation of the amplitude. The continuous range of intensity is divided into L = 2^k discrete **gray levels**, each sample being rounded to the nearest level. More levels (larger k) give smoother tonal gradation; too few levels cause **false contouring**.

Number of bits needed to store an image: b = M × N × k. Example: a 256 × 256 image with 8 bits per pixel needs 256 × 256 × 8 = 524,288 bits = 64 KB.

Basis	Sampling	Quantization
Digitises	Coordinates (x, y)	Amplitude (intensity)
Determines	Spatial resolution	Gray-level resolution
Defect if low	Aliasing, blockiness	False contours
Result	M × N pixel grid	L = 2^k levels



Digitisation process

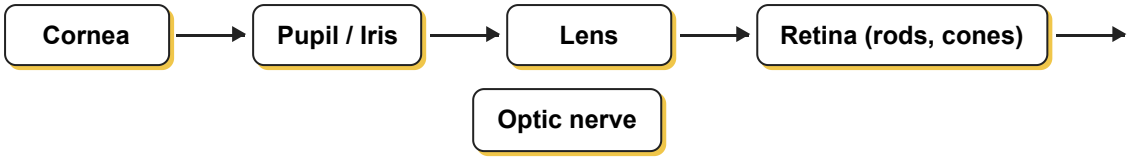
Conclusion: sampling and quantization together produce the digital image; the choice of M, N and k balances quality against storage.

Q2. Explain the elements of visual perception. Discuss the structure of the human eye and its role in image formation. (2019)

Visual perception studies how the human visual system forms, interprets and judges images; it helps decide how to design processing methods.

Structure of the human eye: a nearly spherical organ about 20 mm in diameter.

- **Cornea:** transparent front covering that refracts light.
- **Sclera:** tough white outer cover that protects the eye.
- **Iris and pupil:** the iris controls pupil diameter (2 to 8 mm) and so the amount of light.
- **Lens:** flexible lens focuses light; **ciliary muscles** change its shape (focal length about 14 to 17 mm).
- **Choroid:** pigmented layer with blood vessels that absorbs stray light.
- **Retina:** the inner light-sensitive layer where the image is formed. It has **cones** (6-7 million, mostly in the **fovea**, colour and bright light, photopic vision) and **rods** (75-150 million, spread over the retina, low light, scotopic vision).
- **Blind spot:** where the optic nerve leaves, with no receptors.



Path of light in the eye

Image formation: light from an object passes through the cornea and pupil, and the lens focuses it on the retina as a small, inverted image. For a distant object, the lens is flat (focal length about 17 mm); for near objects it is thicker. Example: a 15 m tall tree seen from 100 m gives retinal image height h from 15/100 = h/17, so h = 2.55 mm. Receptors convert light into electrical impulses and the optic nerve carries them to the brain.

Elements of perception:

- **Brightness adaptation:** the eye adapts to a huge range of intensities (about 10^10) but only a small range at one time.
- **Subjective brightness** is a logarithmic function of intensity.
- **Mach bands:** perceived brightness overshoots at edges.
- **Simultaneous contrast:** a patch looks darker on a bright background.
- **Optical illusions** show perception is not simple measurement.

Conclusion: knowing the eye's limits helps design enhancement and display methods.
