UNIT–1 : Fundamentals and Intensity Transformations (PYQ Solution)

AKTU · Image Analytics (BCDS061) · Solutions by **Chirag Jain**, Ycotes

SECTION A Answers (≈70 Words Each)

Q1. What is Digital Image Processing? (Jun 2023)

Digital image processing (DIP) is the use of computer algorithms to process a digital image, which is a 2-D array of pixels f(x, y). It covers acquisition, enhancement, restoration, compression, segmentation and recognition. Its aim is to improve the image for human viewing or to extract information for machine analysis.

Q2. Name some applications of digital image processing. (Jun 2023)

- **Medical imaging: X-ray, CT, MRI, ultrasound analysis**
- **Remote sensing: satellite and weather images**
- **Biometrics: fingerprint, face and iris recognition**
- **Industrial inspection and robot vision**
- **Character recognition (OCR) and document scanning**
- **Surveillance, forensics, entertainment and compression**

Q3. Define point detection process. (Jun 2023)

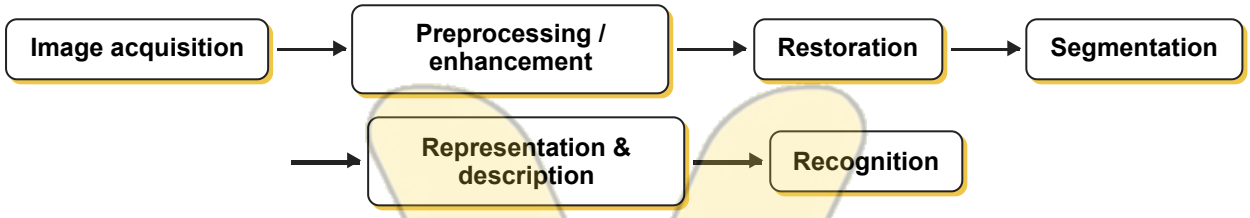
Point detection finds isolated points whose gray level differs sharply from their neighbours. A Laplacian-type mask is used (centre 8, all eight neighbours −1). The response $R = \Sigma w_i z_i$ is computed at each pixel; a point is detected where $|R| \geq T$, a non-negative threshold.

SECTION B Answers (≈250 Words Each)

Q1. Define digital image. Explain fundamental steps in image processing system with the help of suitable diagram. (Jun 2023)

A **digital image** is a two-dimensional function f(x, y) in which x and y are spatial coordinates and the amplitude f is the intensity (gray level) at that point, with x, y and f all finite and discrete. It is a matrix of M × N picture elements (**pixels**), each stored in k bits, giving 2^k gray levels.

Fundamental steps



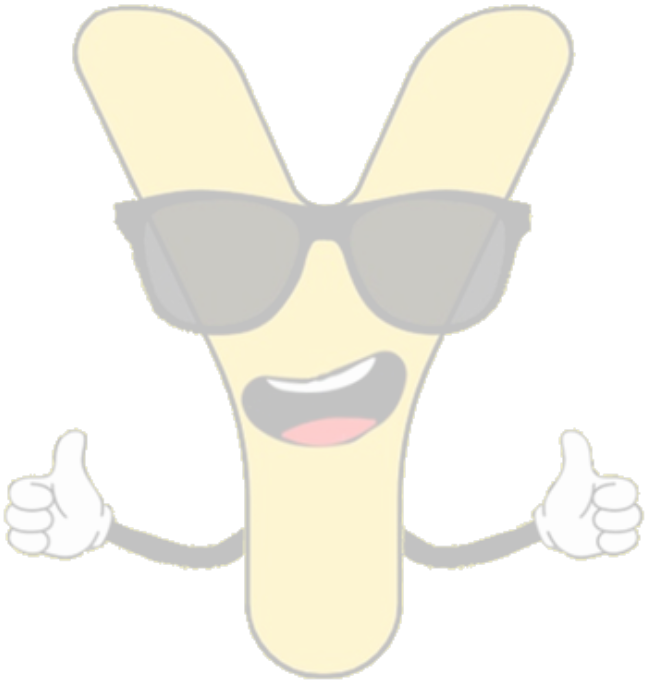
Fundamental steps of digital image processing

1. **Image acquisition:** capturing the image with a sensor and converting it to digital form (sampling and quantisation).
2. **Image enhancement:** improving visual quality, e.g. contrast stretching, histogram equalisation, filtering. It is subjective.
3. **Image restoration:** removing known degradation such as blur or noise using mathematical models. It is objective.
4. **Colour image processing:** processing RGB, HSI and other colour models.
5. **Wavelets and multiresolution processing:** representing images at several resolutions.
6. **Compression:** reducing storage and bandwidth (JPEG).
7. **Morphological processing:** extracting shape components using erosion, dilation.
8. **Segmentation:** partitioning the image into regions or objects (edges, thresholds).
9. **Representation and description:** converting segmented data into boundary or region form and extracting features.
10. **Object recognition:** assigning a label (e.g. "vehicle") based on descriptors.

All steps use a **knowledge base** that holds information about the problem domain and guides each module.

Output type	Steps
Image in, image out	Enhancement, restoration, compression, morphology
Image in, attributes out	Segmentation, description, recognition

In conclusion, these steps convert a captured scene into meaningful information.



SECTION C Answers (≈500 Words Each)

Q1. Explain image acquisition in detail with the help of diagram. (Jun 2023)

Image acquisition is the first step of image processing: converting the energy reflected or transmitted by a scene into a digital image. It has two stages: **sensing** (illumination energy to electrical signal) and **digitisation** (sampling and quantisation).

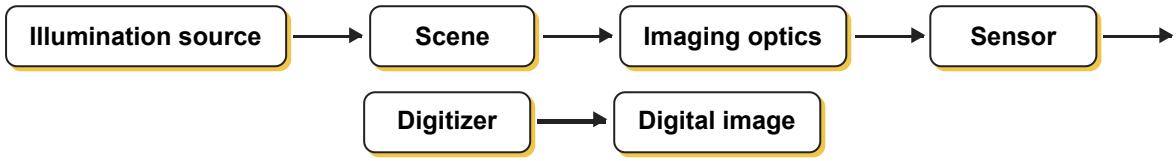


Image acquisition chain

Process

1. An **illumination source** (light, X-ray, radar, ultrasound) falls on the scene.
2. The scene **reflects or transmits** energy; the lens focuses it onto the sensor.
3. The **sensor** produces a voltage proportional to the incident energy.
4. A **digitiser** (ADC) turns the continuous signal into numbers.

Sensor arrangements

- **Single sensor:** one photodiode with filters; the sensor and object are moved mechanically in x and y (slow but high-resolution, e.g. flat-bed scanners).
- **Line (strip) sensor:** a row of sensors scans in one direction while the object moves in the other; used in scanners, CT.
- **Array (matrix) sensor:** CCD or CMOS grid in cameras, capturing the whole image at once; no motion needed.

Image formation model: $f(x, y) = i(x, y) \cdot r(x, y)$, where i is illumination ($0 < i < \infty$) and r is reflectance ($0 < r < 1$). Gray level $L = f$ lies in $[L_{min}, L_{max}]$.

Sampling and quantisation

- **Sampling** digitises the spatial coordinates (number of pixels M × N).
- **Quantisation** digitises amplitude into $L = 2^k$ levels. An image of M × N pixels with k bits needs $b = M \times N \times k$ bits; e.g. 1024 × 1024 at 8 bits = 8,388,608 bits = 1 MB.

Parameter	Effect
More samples	Higher spatial resolution
More bits k	Better gray-level resolution, less false contouring

In conclusion, acquisition determines the quality of every later processing step.

Q2. Differentiate between smoothing and sharpening spatial filters in detail. (Jun 2023)

Spatial filtering modifies each pixel using the values in a neighbourhood defined by a mask (kernel) moved over the image: $g(x, y) = \Sigma\, w(s, t)\, f(x+s, y+t)$.

Smoothing (low-pass) filters reduce sharp transitions, noise and detail; they blur the image.

- **Averaging (box) filter:** all weights equal, 3 × 3 mask = (1/9) × all ones.
- **Weighted average / Gaussian:** centre has higher weight, e.g. (1/16)[1 2 1; 2 4 2; 1 2 1].
- **Median filter (non-linear):** replaces pixel by the median of the neighbourhood; excellent for salt-and-pepper noise.
- Used for noise reduction, bridging small gaps, preprocessing.

Sharpening (high-pass) filters highlight edges and fine detail.

- **First derivative:** gradient (Sobel, Prewitt), magnitude ≈ $|gx| + |gy|$; thick edges.
- **Second derivative: Laplacian** $\nabla^2 f = f(x+1,y)+f(x-1,y)+f(x,y+1)+f(x,y-1) - 4f(x,y)$; mask [0 1 0; 1 −4 1; 0 1 0]; strong response to fine detail; sharpened $g = f - \nabla^2 f$.
- **Unsharp masking / high-boost:** $g = f + k(f - \bar{f})$, where $\bar{f}$ is the blurred image.

Point	Smoothing	Sharpening
Based on	Averaging (integration)	Differentiation
Mask coefficients	All positive, sum = 1	Positive and negative, sum = 0
Effect	Blurs, removes noise	Enhances edges, detail
Frequency domain	Low-pass	High-pass
Side effect	Loss of edges	Amplifies noise
Examples	Box, Gaussian, median	Laplacian, Sobel, unsharp



Role of the two filter types

In conclusion, smoothing suppresses noise at the cost of detail, while sharpening restores detail at the cost of noise.

