Code No: 155BT

R18

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
B. Tech III Year I Semester Examinations, January/February - 2023
IMAGE PROCESSING
(Common to CSE, IT, CSE(AIML), CSE(DS))

Time: 3 Hours **Max.Marks: 75**

Note: i) Question paper consists of Part A, Part B.
ii) Part A is compulsory, which carries 25 marks. In Part A, Answer all questions.
iii) In Part B, Answer any one question from each unit. Each question carries 10 marks and may have a, b as sub questions.

PART – A

(25 Marks)

1. a) What is 'digital image processing'? [2]
b) List the properties of the 2-D DFT method. [3]
c) What are gamma transformations? [2]
d) What is a special correlation? [3]
e) State the expression for the geometric mean filter. [2]
f) Draw the model of image degradation-restoration process. [3]
g) List the advantages of canny edge detector. [2]
h) Write the mask for sobel edge detector and prewitt edge detector prewitt [3]
i) List different types of Redundancies. [2]
j) Summarize noiseless coding theorem. [3]

PART – B

(50 Marks)

2. Illustrate 'Gray level digital image processing' in detail. [10]

OR

3. Discuss the 'Origins of digital image processing'. [10]

4. Outline the mechanism for 'Spatial filtering' in detail. [10]

OR

5. Write the details about 'Histogram Processing' for image enhancement with example. [10]

6. Describe the concept of 'Algebraic approach to restoration' with examples. [10]

OR

7. Compare and contrast 'Enhancement and Restoration'. [10]

8. "The image threshold enjoys a central position in allocation of image segmentation" Prove the statement with suitable case study. [10]

OR

9. Illustrate "Region growing" with an example. [10]

10. a) Discuss 'Fidelity criterion' in image compression.

    b) Draw and explain the functional block diagram for the image compression system. [5+5]

OR

11. Elaborate the techniques for "Lossy compression". [10]

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ANSWER KEY

PART - A

1.a) What is ‘digital image processing’?
Digital image processing involves using algorithms to manipulate digital images to improve their quality or extract useful information for analysis or interpretation.

1.b) List the properties of the 2-D DFT method.
1. Translation Invariant: DFT coefficients remain unchanged under image translation.
2. Linearity: DFT is a linear transformation.
3. Complex Conjugate Symmetry: For real-valued images, DFT coefficients exhibit symmetry.

1.c) What are gamma transformations?
Gamma transformations adjust the brightness and contrast of an image using a power-law function, enhancing details in dark or bright areas based on the value of gamma.

1.d) What is a special correlation?
Special correlation involves matching a template or pattern within an image using correlation techniques, useful for tasks like template matching and pattern recognition.

1.e) State the expression for the geometric mean filter.
The geometric mean filter computes the mean of pixel intensities in a neighborhood to smooth an image, without relying on complex mathematical formulas.

1.f) Draw the model of image degradation-restoration process.
Image → Degradation → Degraded Image → Restoration → Restored Image

1.g) List the advantages of a Canny edge detector.
1. Accurate Localization: Precisely locates edges with minimal error.
2. Low Error Rate: High probability of detecting true edges while minimizing false detections.
3. Multi-stage Process: Includes noise reduction and thresholding for robust edge detection.

1.h) Write the mask for Sobel edge detector and Prewitt edge detector.

- Sobel Edge Detector: Uses a convolution mask for horizontal and vertical edge detection without specific mathematical notation.
- Prewitt Edge Detector: Similarly uses convolution masks for edge detection, focusing on simplicity and effectiveness.

1.i) List different types of Redundancies.
1. Coding Redundancy: Inefficient coding leading to redundant bits.
2. Spatial Redundancy: Redundancy within the spatial layout of pixels.
3. Temporal Redundancy: Redundancy in successive frames of video or sequences.

1.j) Summarize noiseless coding theorem.
The noiseless coding theorem states that the average length of code words per source symbol in a noiseless coding scheme must be at least equal to the entropy of the source. It defines the fundamental limit of how efficiently data can be compressed without any loss of information.

PART - B

2. Illustrate 'Gray level digital image processing' in detail.
1. Definition: Involves manipulation of intensity levels (gray levels) in an image without changing its color format.
2. Operations: Includes contrast enhancement, histogram equalization, and edge detection specific to gray intensity.
3. Applications: Common in medical imaging, where subtle variations in gray levels indicate tissue differences.
4. Challenges: Requires careful handling to avoid loss of details due to limited intensity resolution.
5. Techniques: Involves adaptive thresholding, where thresholds adjust dynamically based on local image characteristics.
6. Benefits: Enhances visual clarity and improves the interpretability of grayscale images.
7. Examples: Used in facial recognition systems to detect subtle facial features based on gray level variations.
8. Processing Steps: Typically involves filtering operations like median filtering to remove noise while preserving gray level details.
9. Comparison: Contrasts with color image processing, which manipulates RGB or CMYK channels instead of grayscale intensity.
10. Future Trends: Increasingly integrated with deep learning algorithms for enhanced feature extraction in computer vision tasks.

3. Discuss the 'Origins of digital image processing'.

1. Early Beginnings: Emerged during the mid-20th century with the development of digital computers and imaging technologies.
2. Military Applications: Initially driven by military needs for aerial reconnaissance and intelligence gathering.
3. Scientific Research: Extended into scientific fields such as astronomy for processing astronomical images.
4. Medical Imaging: Pioneered applications in medical diagnostics, such as X-ray image enhancement and analysis.
5. Technological Advances: Benefited from advancements in semiconductor technology and digital sensor development.
6. Academic Evolution: Evolved as a multidisciplinary field combining mathematics, computer science, and physics.
7. Commercialization: Became commercially viable with the advent of personal computing and digital cameras.
8. Standardization: Led to the development of image file formats and compression algorithms for efficient storage and transmission.
9. Modern Applications: Widely used in diverse fields including entertainment, geology, and forensic analysis.
10. Future Directions: Continues to evolve with innovations in artificial intelligence and machine learning for automated image analysis.

4. Outline the mechanism for 'Spatial filtering' in detail.
1. Definition: Involves manipulating pixel values in an image based on their spatial arrangement.
2. Types: Includes low-pass, high-pass, and band-pass filters for smoothing, edge detection, and noise reduction.
3. Operations: Convolution process where a filter kernel slides over the image, computing new pixel values based on neighboring pixels.
4. Mathematical Basis: Utilizes convolution matrix operations to apply filter masks to the image matrix.
5. Applications: Used in image preprocessing tasks like blurring for image smoothing or sharpening for enhancing edges.
6. Effectiveness: Depends on the size and shape of the filter kernel, impacting the strength of spatial filtering effects.
7. Implementation: Often implemented using techniques like Gaussian smoothing or Laplacian sharpening.
8. Challenges: Balancing between noise reduction and preservation of image details during spatial filtering.
9. Real-time Processing: Requires efficient algorithms for rapid computation in applications like video processing.
10. Advanced Techniques: Includes adaptive spatial filtering where filter parameters adjust dynamically based on image content.

5. Write the details about 'Histogram Processing' for image enhancement with example.

1. Purpose: Adjusts pixel intensities across an image to improve contrast or brightness distribution.
2. Techniques: Include histogram equalization, stretching, and matching for specific enhancement goals.
3. Histogram Equalization: Spreads out pixel intensity values evenly across the histogram range to enhance contrast.
4. Histogram Stretching: Adjusts image intensity levels to span the full dynamic range for improved visualization.
5. Example: Enhancing a low-contrast medical image by stretching its histogram to utilize the full intensity spectrum.
6. Applications: Used in satellite imaging to enhance terrain features or in microscopy for clearer cellular structures.
7. Benefits: Enhances image details that are otherwise obscured by poor lighting or sensor limitations.
8. Limitations: Can amplify noise or artifacts if not applied carefully, affecting image quality.
9. Advanced Methods: Include adaptive histogram equalization, where regions of an image are processed independently.
10. Future Trends: Integrating histogram processing with deep learning algorithms for automated enhancement tasks.

6. Describe the concept of 'Algebraic approach to restoration' with examples.

1. Concept: Involves formulating image restoration as an optimization problem using algebraic equations.
2. Methods: Include iterative algorithms like Richardson-Lucy deconvolution for recovering sharp images from blurred versions.
3. Example: Restoring a degraded astronomical image using maximum likelihood estimation to reconstruct missing details.
4. Applications: Applied in medical imaging for removing noise or in forensic science for enhancing surveillance footage.
5. Mathematical Models: Use matrix operations and system equations to represent degradation and restoration processes.
6. Benefits: Offers precise control over restoration parameters and convergence to optimal image quality.
7. Challenges: Requires computational resources and accurate modeling of degradation processes.
8. Comparisons: Contrasts with statistical methods by focusing on deterministic modeling and solution strategies.
9. Future Directions: Incorporates machine learning to adaptively adjust restoration parameters based on image content.

10. Integration: Links with digital signal processing techniques for advanced image reconstruction in complex scenarios.

7. Compare and contrast 'Enhancement and Restoration'.

1. Purpose: Enhancement aims to improve image appearance for better visual interpretation, while restoration aims to recover original details from degraded images.
2. Techniques: Enhancement uses operations like sharpening or contrast adjustment, whereas restoration involves deblurring or denoising algorithms.
3. Input Requirements: Enhancement starts with a good-quality image, while restoration deals with degraded or corrupted images.
4. Effects: Enhancement may introduce artifacts or alter image content, whereas restoration aims for fidelity to the original scene.
5. Applications: Enhancement is used in photography or video processing for aesthetic improvements, while restoration is critical in medical imaging or forensic analysis.
6. Complexity: Restoration typically requires more computational resources and advanced algorithms compared to enhancement.
7. Objective Measures: Enhancement success is subjective based on visual appeal, whereas restoration success can be objectively measured by fidelity metrics.
8. Integration: Both processes can complement each other in image processing pipelines, with enhancement often preceding restoration.
9. Future Trends: Advances in AI and deep learning are enhancing capabilities in both enhancement and restoration tasks.
10. Ethical Considerations: Both processes require careful consideration to preserve the integrity of image content and avoid misleading representations.

8. "The image threshold enjoys a central position in the allocation of image segmentation" Prove the statement with a suitable case study.

1. Importance: Thresholding is crucial for segmenting organs or tissues in medical images like MRI or CT scans.
2. Method: Adaptive thresholding adjusts thresholds dynamically based on local image characteristics to segment complex tissues accurately.
3. Benefits: Enables precise delineation of organs for surgical planning or disease diagnosis, improving patient treatment outcomes.
4. Challenges: Variations in image quality or noise can affect segmentation accuracy, requiring robust thresholding techniques.
5. Example: Segmenting brain tumors using thresholding to isolate abnormal tissue regions from healthy brain structures.
6. Validation: Comparing segmented results with ground truth annotations or expert manual segmentation to validate accuracy.

7. Applications: Extends to other medical fields like cardiology for analyzing heart structures or oncology for tumor detection.
8. Future Directions: Integrating machine learning for adaptive thresholding algorithms to enhance segmentation accuracy and efficiency.
9. Ethical Considerations: Ensuring patient privacy and confidentiality in handling sensitive medical image data.
10. Conclusion: Demonstrates how thresholding plays a pivotal role in precise image segmentation, influencing critical medical decisions and treatments.

9. Illustrate “Region growing” with an example.
1. Concept: Region growing starts from seed points and expands based on predefined criteria to form homogeneous regions.
2. Process: Seeds are pixels or small regions selected based on intensity or spatial proximity to grow into larger regions.
3. Criteria: Growth stops when pixels outside the region don't meet specified similarity conditions, like intensity or texture.
4. Example: Segmenting a forest area in satellite imagery by growing regions from initial seed points of known forest regions.
5. Advantages: Automatically adapts to local image characteristics, suitable for irregular shapes or complex textures.
6. Disadvantages: Sensitive to seed selection and parameter settings, requiring careful tuning for accurate segmentation.
7. Applications: Used in geospatial analysis for land cover classification or in medical imaging for tumor delineation.
8. Techniques: Includes connectivity-based region growing for linking neighboring pixels with similar attributes.
9. Validation: Comparing segmented regions with ground truth data or expert annotations to assess segmentation accuracy.
10. Future Developments: Integrating machine learning for adaptive region growing algorithms to handle diverse image types and complexities.

10. a) Discuss ‘Fidelity criterion’ in image compression.
1. Definition: Fidelity criterion measures how accurately a compressed image represents the original image without perceptible loss.
2. Objective Metrics: Utilizes metrics like Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSI), or Mean Squared Error (MSE) to quantitatively assess fidelity.
3. Applications: Critical in medical imaging for preserving diagnostic details and in archival systems for maintaining document integrity.
4. Evaluation: Compares compressed images against originals to ensure fidelity standards meet specific application requirements.
5. Trade-offs: Balances fidelity against compression efficiency, as higher fidelity often requires larger file sizes or more complex compression algorithms.

10. b) Draw and explain the functional block diagram for the image compression system.

1. Pre-processing: Initial adjustments such as color space conversion or filtering to prepare the image for compression.
2. Transform Coding: Utilizes techniques like Discrete Cosine Transform (DCT) to convert spatial image data into frequency components.
3. Quantization: Reduces the precision of transformed coefficients based on perceptual relevance or compression ratio targets.
4. Entropy Coding: Applies efficient coding methods (e.g., Huffman coding or Arithmetic coding) to compress quantized data.
5. Bitstream Formatting: Organizes compressed data into a structured format suitable for transmission or storage, often including headers and metadata.

11. Elaborate the techniques for "Lossy compression".

1. Concept: Lossy compression selectively discards data that is less perceptually significant to achieve higher compression ratios.
2. Transform Coding: Utilizes transforms like Discrete Cosine Transform (DCT) or Wavelet Transform to convert spatial data into frequency domain, where high-frequency components (less perceptible) are quantized or discarded.
3. Quantization: Reduces the precision of transformed coefficients based on perceptual models or psychovisual principles, minimizing information loss that is least noticeable to human vision.
4. Subsampling: In color images, reduces redundancy by discarding color information in less critical channels (e.g., chrominance) or at lower resolutions.
5. Predictive Coding: Estimates pixel values based on neighboring pixels or previous decoded values, allowing compression of residual errors rather than exact pixel values.
6. Entropy Coding: Applies efficient coding techniques like Huffman coding or Arithmetic coding to further compress quantized data by assigning shorter codes to more frequent symbols.
7. Error Metrics: Uses perceptual metrics such as Peak Signal-to-Noise Ratio (PSNR) or Structural Similarity Index (SSI) to measure the quality of reconstructed images against originals.
8. Applications: Widely used in multimedia applications like streaming video (e.g., MPEG), digital photography (e.g., JPEG), and audio compression (e.g., MP3), balancing between storage efficiency and acceptable perceptual quality.
9. Artifacts: Introduces compression artifacts such as blockiness (in JPEG), ringing (in JPEG2000), or blurring (in video codecs), which are perceptible distortions resulting from irreversible data loss.
10. Trade-offs: Optimizes between compression ratio and perceptual quality, with different algorithms and settings suitable for specific applications ranging from internet streaming to archival storage.