1. Discrete Time Signals and Systems

1.1 Introduction to Digital Signals and Systems, Properties, and Operations on Digital Signals:

Questions:

1. What is the fundamental difference between analog and digital signals?
    - Answer: Analog signals are continuous in nature, while digital signals are discrete.
2. Name and explain three properties of digital signals.
    - Answer: Three properties of digital signals are:
        - Discreteness: Digital signals have values defined only at discrete time instants.
        - Finite Duration: Digital signals exist only over a finite time interval.
        - Quantization: Digital signals have discrete amplitude levels.
3. What are the basic operations performed on digital signals?
    - Answer: Basic operations on digital signals include addition, subtraction, multiplication, and division.

1.2 Classification of Signals, System, LTI System:

Questions:

1. How do you classify signals based on their domain and amplitude?
    - Answer: Signals can be classified into continuous-time or discrete-time based on their domain, and into analog or digital based on their amplitude.
2. Define an LTI (Linear Time-Invariant) system.
    - Answer: An LTI system is a system that satisfies the properties of linearity and time-invariance.
3. Give an example of a system that is not time-invariant.
    - Answer: A system with a time-varying impulse response is an example of a system that is not time-invariant.

1.3 Convolution in Time Domain (Linear & Circular), Correlation:

Questions:

1. Explain the process of convolution in the time domain.
    - Answer: Convolution in the time domain involves sliding one signal over another, multiplying them at each point, and summing the products.
2. Differentiate between linear and circular convolution.
    - Answer: Linear convolution operates on finite-duration signals and produces an output that is also finite in duration, while circular convolution assumes periodicity in signals and produces a periodic output.
3. What is correlation, and how does it differ from convolution?
    - Answer: Correlation measures the similarity between two signals, while convolution combines two signals to produce a third signal.
4. Explain the concept of circular correlation.
    - Answer: Circular correlation is the correlation of two signals assuming periodicity, where one signal is shifted cyclically to find the correlation with another signal.

Self-Learning Topic: Correlation (Circular)

Questions:

1. How is circular correlation different from linear correlation?
    - Answer: Circular correlation assumes periodicity in signals and wraps around the ends, while linear correlation considers signals as finite and non-periodic.
2. In what applications is circular correlation commonly used?
    - Answer: Circular correlation is often used in signal processing applications where signals exhibit periodic behavior, such as in communications and audio processing.
3. What are the advantages of circular correlation over linear correlation in certain scenarios?
    - Answer: Circular correlation can provide better results when dealing with periodic signals or when signals have significant cyclic components.

2. Fundamentals of Digital Image and Spatial Domain Enhancement

2.1 Digital Image Representation, Elements of Digital Image Processing Systems, Sampling and Quantization, Basic Relationships Between Pixels, Mathematical Operations on Images:

Questions:

1. Explain the process of digital image representation.
   - Answer: Digital images are represented as a grid of pixels, with each pixel containing numerical values representing color or intensity.
2. What are the elements of a digital image processing system?
   - Answer: The elements include image acquisition, preprocessing, enhancement, transformation, compression, segmentation, and recognition.
3. Define sampling and quantization in the context of digital images.
   - Answer: Sampling is the process of converting a continuous image into a discrete one by selecting points from the continuous image. Quantization involves assigning discrete amplitude levels to the sampled points.
4. Describe basic mathematical operations that can be performed on images.
   - Answer: Basic mathematical operations on images include addition, subtraction, multiplication, and division of pixel values.

2.2 Spatial Domain Enhancement Techniques: Point Processing, Neighborhood Processing, Spatial Domain Filtering, Zooming:

Questions:

1. What is point processing in image enhancement?
   - Answer: Point processing involves applying a function independently to each pixel in an image, based only on the pixel's intensity value.
2. Differentiate between point processing and neighborhood processing.
   - Answer: Point processing operates on individual pixels, whereas neighborhood processing considers the values of neighboring pixels when enhancing a pixel.
3. Explain the concept of spatial domain filtering.
   - Answer: Spatial domain filtering involves modifying the pixel values of an image based on a defined filter mask or kernel.
4. How does zooming enhance an image in the spatial domain?
   - Answer: Zooming increases the size of an image by interpolating the pixel values to create a higher-resolution output.

2.3 Spatial Enhancement: Global Processing: Histogram Equalization:

Questions:

1. What is histogram equalization?
   - Answer: Histogram equalization is a technique used to enhance the contrast of an image by redistributing pixel intensities to create a more uniform histogram.
2. How does histogram equalization improve the visual quality of an image?
   - Answer: Histogram equalization stretches the intensity range of an image, making both dark and bright regions more distinguishable and enhancing overall image contrast.
3. Discuss the limitations of histogram equalization.
   - Answer: Histogram equalization can sometimes result in unnatural-looking images, especially when the original histogram has sharp peaks or valleys. It may also amplify noise in the image.

Self-Learning Topic: Histogram Specification

Questions:

1. What is histogram specification in image processing?
   - Answer: Histogram specification is a technique used to transform the histogram of an image to match a desired histogram, typically to achieve specific contrast or brightness characteristics.
2. Compare histogram specification with histogram equalization.
   - Answer: Histogram specification allows for more control over the transformation of the histogram compared to histogram equalization, which aims to spread out the intensity values uniformly.
3. How is histogram specification applied in practical image processing scenarios?
   - Answer: Histogram specification can be used in medical imaging, satellite imaging, and other fields where specific contrast or brightness adjustments are required.

3. Image Transform: Frequency Domain Representation and Enhancement

3.1 Introduction, Discrete Fourier Transform (DFT) and Its Properties, Radix-2 Algorithm (2-DFT), Fast Fourier Transform (FFT) Algorithm: Divide and Conquer Approach, Decimation in Time (DIT)-FFT:

Questions:

1. What is the Discrete Fourier Transform (DFT) and why is it used in image processing?
    - Answer: The DFT is a mathematical operation that transforms a signal from its time or spatial domain into its frequency domain representation. In image processing, it helps analyze the frequency content of an image.
2. Explain the radix-2 algorithm for computing the 2-DFT.
    - Answer: The radix-2 algorithm is an efficient method for computing the DFT of a sequence of length that is a power of 2. It involves recursively dividing the sequence into smaller sub-sequences and combining their DFTs.
3. Describe the Fast Fourier Transform (FFT) algorithm and its advantages.
    - Answer: The FFT algorithm is a more efficient implementation of the DFT, based on a divide-and-conquer approach. It reduces the computational complexity of computing the DFT from O(N^2) to O(N log N), making it much faster for large inputs.
4. What is Decimation in Time (DIT)-FFT?
    - Answer: DIT-FFT is a specific implementation of the FFT algorithm where the input sequence is divided into smaller sub-sequences by decimating the time domain. It's one of the common methods used to compute the FFT.

3.2 Discrete Cosine Transform (DCT), Walsh Transform, Hadamard Transform, Haar Transform, Principal Component Analysis (PCA)/Hotelling Transform, Introduction to Wavelet Transform:

Questions:

1. Explain the Discrete Cosine Transform (DCT) and its applications.
    - Answer: The DCT is similar to the DFT but focuses on transforming real-valued data. It's widely used in image and video compression algorithms such as JPEG and MPEG.
2. Compare and contrast the Walsh, Hadamard, and Haar transforms.
    - Answer: These transforms are all used for signal and image processing, but they have different mathematical properties and applications. For example, the Haar transform is particularly well-suited for edge detection due to its ability to capture sharp changes in signal values.

3. What is Principal Component Analysis (PCA), and how is it related to image transformation?
    - Answer: PCA is a statistical technique used for dimensionality reduction by identifying the principal components of a dataset. In image processing, it's used for feature extraction and compression.
4. Briefly introduce the Wavelet Transform and its advantages over other transforms.
    - Answer: The Wavelet Transform decomposes a signal into different frequency components at different resolutions. It's advantageous for representing both high and low-frequency components in a signal efficiently.

3.3 Low Pass and High Pass Frequency Domain Filters: Ideal, Butterworth, Homomorphic Filter:

Questions:

1. What are low-pass and high-pass frequency domain filters, and how do they differ?
    - Answer: Low-pass filters allow low-frequency components to pass through while attenuating high-frequency components. High-pass filters do the opposite.
2. Explain the characteristics and applications of the Ideal, Butterworth, and Homomorphic filters.
    - Answer: The Ideal filter has a sharp cutoff frequency but suffers from ringing artifacts. The Butterworth filter provides a smoother transition between passband and stopband. The Homomorphic filter is used for enhancing images by separating illumination and reflectance components.

Self-Learning Topic: Discrete Sine Transform (DST)

Questions:

1. What is the Discrete Sine Transform (DST), and how does it differ from the Discrete Cosine Transform (DCT)?
    - Answer: The DST is similar to the DCT but focuses on capturing frequency components associated with sine functions. It's commonly used in signal and image processing applications where sine-like patterns are prevalent.
2. What are some practical applications of the DST in image processing?

- Answer: The DST is used in tasks such as texture analysis, edge detection, and image compression, particularly for images containing periodic or oscillatory patterns.

4. Image Segmentation and Representation

4.1 Image Segmentation Based on Discontinuities: Point, Line, and Edge Detection (Laplacian, Canny), Edge Linking, Thresholding (Global, Local, Optimum), Region-Based Segmentation, Edge-Based Segmentation: Hough Transform:

Questions:

1. Explain the concept of image segmentation.
    - Answer: Image segmentation involves partitioning an image into multiple segments or regions based on certain criteria, such as color, intensity, or texture similarity.
2. What are the common techniques used for point, line, and edge detection in image segmentation?
    - Answer: Common techniques include using gradient-based methods like the Laplacian operator for edge detection and the Hough Transform for line detection.
3. Describe the Canny edge detector and its advantages.
    - Answer: The Canny edge detector is a multi-stage algorithm that aims to detect a wide range of edges in an image while minimizing false positives. It includes steps such as noise reduction, edge gradient calculation, non-maximum suppression, and edge tracking by hysteresis.
4. What is thresholding in image segmentation?
    - Answer: Thresholding is a simple segmentation technique where pixels in an image are classified into two groups based on whether their intensity values are above or below a certain threshold.
5. Differentiate between global, local, and optimum thresholding methods.
    - Answer: Global thresholding uses a single threshold value for the entire image, while local thresholding adapts the threshold value based on local image characteristics. Optimum thresholding methods determine the threshold value that optimizes a certain criterion, such as maximizing between-class variance.
6. Explain the concepts of region-based segmentation and edge-based segmentation.

- Answer: Region-based segmentation involves grouping pixels into regions based on their similarity in intensity, color, or texture. Edge-based segmentation focuses on detecting and linking edges in an image using techniques like the Hough Transform.

4.2 Boundary Descriptors: Signature, Chain Code, Shape Number, Moments:

Questions:

1. What are boundary descriptors, and why are they important in image analysis?
    - Answer: Boundary descriptors are features that describe the shape or contour of an object in an image. They are important for tasks such as object recognition, classification, and shape analysis.
2. Describe the signature-based boundary descriptor.
    - Answer: The signature of a boundary is a one-dimensional representation obtained by plotting a characteristic function of the boundary against arc length or angle.
3. Explain the concept of chain code as a boundary descriptor.
    - Answer: Chain code represents the boundary of an object by encoding the direction of each boundary pixel relative to its neighboring pixel. It's useful for compactly representing shapes and contours.
4. What is the shape number, and how is it computed?
    - Answer: The shape number is a compact descriptor that quantifies the shape of an object by measuring its global and local curvatures. It's typically computed from the Fourier descriptors of the boundary.
5. Discuss the use of moments as boundary descriptors.
    - Answer: Moments are statistical measures of the spatial distribution of intensity values in an image. In boundary analysis, moments are often used to characterize the shape, size, and orientation of objects.

5. Introduction to Morphology and Image Compression

5.1 Morphological Operations: Dilation, Erosion, Opening, Closing, Hit or Miss Transform, Boundary Extraction:

Questions:

1. Define morphological operations in image processing.

- Answer: Morphological operations are image processing techniques that manipulate the shape and structure of objects within an image based on predefined structuring elements.

2. Explain the concepts of dilation and erosion.
   - Answer: Dilation expands the boundaries of objects in an image, while erosion shrinks them.
3. What are opening and closing operations, and how do they differ from dilation and erosion?
   - Answer: Opening is an erosion followed by a dilation, used to remove small objects and smooth boundaries. Closing is a dilation followed by an erosion, used to fill small holes and gaps in objects.
4. Describe the Hit or Miss Transform and its applications.
   - Answer: The Hit or Miss Transform is used to detect specific patterns or shapes in binary images by matching a given pattern and its complement with the image.
5. How is boundary extraction performed using morphological operations?
   - Answer: Boundary extraction involves subtracting the result of erosion from the original image, leaving only the boundaries of objects.

5.2 Introduction, Redundancies: Coding, Inter-Pixel, Psycho-Visual, Compression Ratio, Fidelity Criteria:

Questions:

1. What is image compression, and why is it necessary?
   - Answer: Image compression is the process of reducing the size of an image file to save storage space or transmission bandwidth. It's necessary to efficiently store and transmit large amounts of image data.
2. Explain the concept of redundancies in image data.
   - Answer: Redundancies refer to patterns or repetitions in image data that can be exploited to achieve compression. They include coding redundancy, inter-pixel redundancy, and psycho-visual redundancy.
3. Define compression ratio in the context of image compression.
   - Answer: Compression ratio is the ratio of the size of the uncompressed image to the size of the compressed image. It indicates how much the image data has been reduced in size.

4. What are fidelity criteria in image compression?
   - Answer: Fidelity criteria are measures used to evaluate the quality of the reconstructed image compared to the original. Common criteria include peak signal-to-noise ratio (PSNR) and mean squared error (MSE).

Lossless Compression Techniques: Run-Length Coding, Arithmetic Coding, Huffman Coding, Differential Pulse Code Modulation (DPCM):

Questions:

1. Explain the principle behind run-length coding.
   - Answer: Run-length coding replaces sequences of repeated values in an image with a pair of values indicating the value and the length of the run.
2. Describe how arithmetic coding works and its advantages.
   - Answer: Arithmetic coding compresses data by representing entire sequences of symbols with fractional values within a range. It achieves better compression ratios than Huffman coding by using fractions to represent probabilities more accurately.
3. What is Huffman coding, and how is it used in image compression?
   - Answer: Huffman coding is a variable-length prefix coding technique that assigns shorter codes to more frequently occurring symbols in the image data. It's widely used for lossless compression due to its simplicity and effectiveness.
4. Explain the concept of Differential Pulse Code Modulation (DPCM).
   - Answer: DPCM is a predictive coding technique where the difference between the current pixel value and a predicted value is encoded instead of the pixel value itself. It exploits temporal redundancy in image sequences.

5.3 Lossy Compression Techniques: Improved Greyscale Quantization, Vector Quantization, Transform Coding, JPEG:

Questions:

1. What is lossy compression, and how does it differ from lossless compression?
   - Answer: Lossy compression reduces the size of an image by discarding some information that may not be perceptually significant, resulting in some loss of image quality. Lossless compression preserves all the original image data.

2. Describe the process of improved grayscale quantization.
    - Answer: Improved grayscale quantization optimally maps the continuous range of grayscale values to a smaller set of discrete values by minimizing the quantization error.
3. What is vector quantization, and how is it used in image compression?
    - Answer: Vector quantization compresses image data by encoding small blocks of pixels (vectors) with indices pointing to codebook entries representing similar blocks. It's effective for compressing natural images with spatially correlated pixel values.
4. Explain the concept of transform coding and its application in image compression.
    - Answer: Transform coding transforms image data into a different domain, such as frequency or spatial frequency, where most of the energy is concentrated in a few coefficients. It's used in standards like JPEG to achieve high compression ratios while maintaining acceptable image quality.
5. Discuss the JPEG compression standard and its key features.
    - Answer: JPEG (Joint Photographic Experts Group) is a widely used image compression standard that employs a combination of discrete cosine transform (DCT) and quantization to compress image data. It allows for adjustable compression ratios and supports both grayscale and color images.

Self-Learning Topic: Morphological Operation - Thinning and Thickening

Questions:

1. What is morphological thinning, and how is it used in image processing?
    - Answer: Morphological thinning is a technique used to reduce the thickness of objects in a binary image while preserving their topology. It's commonly used for skeletonization and feature extraction.
2. Describe the process of morphological thickening and its applications.
    - Answer: Morphological thickening is the opposite of thinning, where the boundaries of objects are expanded to make them thicker. It's used for image enhancement, object segmentation, and pattern recognition tasks.