Computer Vision

1 Introduction to Computer Vision

1.1 What is Computer Vision?

Computer Vision is a field of artificial intelligence that enables computers to interpret and make decisions based on visual data, such as images and videos. It seeks to automate tasks that the human visual system can perform.

1.2 How is Computer Vision used Today?

Computer Vision is applied in various industries, such as:

- **Healthcare**: Medical image analysis and diagnostics.
- **Automotive**: Autonomous vehicles and driver-assist systems.
- **Retail**: Inventory management and customer analytics.
- **Security**: Facial recognition and surveillance.
- **Agriculture**: Crop monitoring and precision farming.

1.3 Why is the .jpeg Format Popular?

The JPEG format is popular because:

- It uses lossy compression to significantly reduce file size while maintaining acceptable image quality.
- It is widely supported across devices and platforms.
- It is efficient for web use, enabling faster image loading.

1.4 Example of Lossless Compression Technique

PNG (Portable Network Graphics) is an example of lossless compression. It preserves the exact image data, ensuring no loss in quality.

1.5 Challenges of Computer Vision

- Understanding diverse environments and contexts.
- Handling occlusions and distortions in images.
- Computational resource requirements.
- Interpreting subjective aspects, such as emotion or intent in images.

2 Image Processing: Introduction and Fundamentals

2.1 Basic Relationship Between Pixels

- **Neighbors**: Pixels directly adjacent to a given pixel.
- **Adjacency**: Two pixels are adjacent if they share a common edge or vertex.

2.2 Path, Foreground, and Background

- **Path**: A sequence of adjacent pixels.
- **Foreground**: The primary objects of interest in an image.
- **Background**: The surrounding area of the foreground.
- **Boundary**: The edge separating the foreground from the background.

2.3 Distance Measures

- **Euclidean Distance**: Straight-line distance between two points.
- **City Block Distance**: Distance measured along grid lines (Manhattan distance).
- **Chessboard Distance**: Maximum of horizontal and vertical distances.

3 Digital Image: Definition and Representation

A digital image is a numerical representation of a 2D visual pattern. It consists of pixels, each represented by a numeric value corresponding to intensity or color.

4 Electromagnetic Spectrum

Images are formed by capturing specific ranges of the electromagnetic spectrum, including visible light, infrared, and ultraviolet.

5 Image Acquisition Techniques

5.1 Single Sensor

Uses a single photosensitive element, often with a rotating mirror or a moving sensor.

5.2 Sensor Strips

Linear arrays of sensors used in scanners.

5.3 2D Array of Sensors

Used in cameras to capture images in one shot.

6 Sample Image Formation Model

The formation of an image involves:

- **Illumination**: Light falling on an object.
- **Reflectance**: Light reflected by the object.

The image intensity is a function of both illumination and reflectance.

7 Image Sampling and Quantization

Sampling converts a continuous signal into discrete values by selecting intervals, while **Quantization** maps these values to finite levels.

8 Smoothing Spatial Filters

- **Linear Filters**: Use weighted averages for smoothing.
- **Average Filter Masks**: Assign equal weights to neighboring pixels.

9 Order Statistic (Non-linear) Filters

Filters such as the **Median Filter** reorder pixel values to remove noise without blurring edges.

10 Representation of Objects

Objects are represented in terms of boundaries, regions, and key points within an image.

11 Median Filtering for Noise Reduction and Sharpening

Median Filtering reduces noise while preserving edges, useful for tasks such as sharpening.

12 Laplace Operator

A second-order derivative operator used for edge detection by identifying areas of rapid intensity change.

13 Unsharp Masking and High-Boost Filtering

These techniques enhance edges by subtracting a smoothed version of the image from the original.

14 Spatial Correlation and Convolution

- **Spatial Correlation**: Measures similarity between patterns.

- **Convolution**: Applies a filter to an image, combining values in a local neighborhood.

15 Image Segmentation (Concept)

Image segmentation partitions an image into regions or objects based on properties like color, intensity, and texture.

16 Addition of Two Images

Combining pixel values of two images to create a composite image.

17 Spatial and Intensity Resolution

- **Spatial Resolution**: The smallest discernible detail in an image.
- **Intensity Resolution**: The smallest discernible change in intensity.

18 Connected Component Analysis

Identifies and labels connected regions in a binary image.

19 Light-Sensitive Receptors

- **Rods**: Sensitive to low light levels.
- **Cones**: Detect color and function in bright light.

20 Edge Detection Using Prewitt and Sobel Operators

- **Prewitt and Sobel**: First-order derivative operators for edge detection.
- **Marr-Hildreth**: A second-order method using Laplacian of Gaussian.

21 Line and Point Detection

Algorithms designed to identify specific structures such as lines and points in an image.

22 Image Classification

22.1 Problem and Challenges

- Variability in illumination, perspective, and noise.

22.2 Nearest Neighbor Classifier

- **L1 Distance**: Sum of absolute differences.

22.3 Hyperparameters

Values set before the learning process to optimize performance.

22.4 Kth Nearest Neighbor

Considers the majority class among k closest points.

22.5 Linear Classification (Parametric Approach)

Models the decision boundary as a linear function.