📘 Computer Vision Exam Notes

🧠 Introduction to Computer Vision

Definition:
Computer Vision is a field of AI that enables machines to interpret and make decisions based on visual data (images or videos), similar to human sight.

❓ What is Computer Vision?

- It's a multidisciplinary field combining **AI**, **image processing**, **ML**, and **deep learning**.
- The goal is to **automate tasks** the human visual system can do.

🚀 Applications of Computer Vision

1. Healthcare

- Tumor detection (MRI/CT scans)
- Automated X-ray analysis
- Retinal disease diagnosis (fundus images)

2. Autonomous Vehicles

- Object detection (pedestrians, vehicles, traffic signs)
- Lane detection
- Real-time scene understanding

3. Face Recognition

- Surveillance systems
- Device unlocking (Face ID)
- Emotion detection

4. Others

- Augmented reality (AR)

- Industrial inspection
- OCR (Optical Character Recognition)

🕰 History and Evolution of Computer Vision

- **1960s**: Early research focused on interpreting simple shapes and edges.
- **1970s–80s**: Shift towards geometry, edge detection, and object recognition.
- **1990s**: Emergence of real-time video processing, feature extraction.
- **2000s–2010s**: ML + feature-based systems (SIFT, SURF, HOG).
- **Post-2012**: Deep Learning (CNNs) revolutionized the field (e.g., AlexNet).

🧾 Overview of Image Processing vs. Computer Vision

Aspect	Image Processing	Computer Vision
Purpose	Enhancing image quality	Understanding the image
Focus	Pixel manipulation	Object detection, scene understanding
Techniques	Filtering, transformation	Feature extraction, classification

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🧩 Image Processing Basics

🖼 Digital Image Representation

- **Pixel**: Smallest unit of an image with intensity value.
- **Resolution**: Total number of pixels (e.g., 1920×1080).
- **Color Models**:
  - **RGB**: Red, Green, Blue (standard for color images).
  - **HSV**: Hue, Saturation, Value (better for color detection).
  - **Grayscale**: 1 channel (intensity from 0 to 255).

🧹 Image Filtering

1. Smoothing (Blurring)
Reduces noise and detail.

- **Average Filter**:

$$I'(x, y) = \frac{1}{N} \sum_{i,j} I(x+i, y+j)$$

- **Gaussian Filter** (weighted average with Gaussian kernel)

2. Sharpening
Enhances edges by emphasizing pixel differences.

- Uses **Laplacian operator**:

$$\text{Laplacian} = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

3. Edge Detection

- **Sobel Operator**: Detects gradients in x and y directions.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$\text{Edge Magnitude} = \sqrt{G_x^2 + G_y^2}$$

- **Canny Edge Detection**: Multi-stage algorithm (smoothing → gradient → non-max suppression → hysteresis thresholding)

🔄 Image Transformation

1. Scaling

- Changes image size.
- **Nearest Neighbor / Bilinear Interpolation**.

2. Rotation

- Rotates image about a point.
- Uses rotation matrix:

[x'y']=[cosθ−sinθsinθcosθ][xy]\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}

3. Affine Transformations

- Linear transformation preserving points and parallel lines.
- Matrix form:

[x'y']=A[xy]+[txty]\begin{bmatrix} x' \\ y' \end{bmatrix} = A \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}

🌈 Histogram Equalization and Contrast Adjustment

Histogram

- Shows pixel intensity distribution.

Histogram Equalization

- Improves global contrast of an image.

Steps:

1. Compute histogram.
2. Compute **Cumulative Distribution Function (CDF)**.
3. Normalize the CDF to 0–255.
4. Map old values to new values using normalized CDF.

Mathematical Formula:

New Pixel=round(CDF(x)−CDFmin(M×N)−CDFmin×(L−1))\text{New Pixel} = \text{round} \left(\frac{\text{CDF}(x) - \text{CDF}_{min}}{(M \times N) - \text{CDF}_{min}} \times (L - 1) \right)

Where:

- M×NM \times N: Total number of pixels
- LL: Number of intensity levels (usually 256)