

Introduction to Image Analysis and Processing

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Key concepts, workflow, and fundamental techniques

1. What Is Image Analysis & Processing?

Term	Definition
Image Processing	Manipulation of raw pixel data to improve visual quality or prepare images for further analysis (e.g., filtering, enhancement).
Image Analysis	Extraction of meaningful information from images (e.g., object detection, measurement, classification).
Computer Vision	The broader field that combines image processing, analysis, and interpretation to enable machines to “see.”

2. Typical Workflow

1. **Image Acquisition** – Capture or retrieve images (cameras, scanners, medical devices, satellites).
2. **Pre-processing** – Noise reduction, illumination correction, geometric alignment.
3. **Feature Extraction** – Compute descriptors (edges, textures, shapes, color histograms).
4. **Segmentation** – Partition image into homogeneous regions or objects.
5. **Object Recognition / Classification** – Assign semantic labels to regions or whole images.
6. **Post-processing & Interpretation** – Refine results, quantify measurements, integrate with higher-level reasoning.

The loop is often iterative: results may feed back to adjust earlier steps.

3. Core Concepts & Techniques

3.1 Pixel Representation

- **Grayscale**: single intensity value per pixel (0–255 for 8-bit).
- **Color**: typically RGB (3 channels) or alternative spaces (HSV, Lab).

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- **Bit depth:** determines dynamic range; higher depth ? finer intensity resolution.

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3.2 Image Geometry

- **Resolution** – Number of pixels (width × height).
- **Aspect ratio** – Width ÷ height.
- **Coordinate system** – Origin usually at top-left; (x, y) denotes column, row.

3.3 Noise & Artifacts

Type	Source	Typical Model
Gaussian	Sensor electronics	Additive white Gaussian noise
Salt&Pepper	Transmission errors	Impulse noise
Speckle	Coherent imaging (e.g., SAR, ultrasound)	Multiplicative noise

3.4 Pre-processing Operations

Operation	Purpose	Common Filters
Smoothing	Reduce noise	Gaussian blur, median filter, bilateral filter
Sharpening	Enhance edges	Laplacian, unsharp masking
Histogram Equalization	Improve contrast	Global (HE), adaptive (CLAHE)
Geometric Transform	Align or resize	Translation, rotation, scaling, perspective warp

3.5 Edge Detection

- **Gradient-based:** Sobel, Prewitt, Scharr (first-order).
- **Zero-crossing:** Laplacian of Gaussian (LoG).
- **Canny:** Multi-stage (noise reduction ? gradient ? non-maximum suppression ? hysteresis threshold).

3.6 Segmentation Methods

Category	Example Techniques
Thresholding	Global, Otsu's method, adaptive
Region-based	Region growing, watershed

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Category	Example Techniques
Clustering	K-means, Gaussian Mixture Models
Edge-based	Active contours (snakes), graph cuts
Deep learning	Fully Convolutional Networks (FCN), U-Net, Mask R-CNN

3.7 Feature Descriptors

- **Statistical:** Mean, variance, skewness of intensity or color channels.