

Image Processing and Computer Vision

Introduction to Image Processing and Image Acquisition

Sanath Thilakarathna

BSc Eng (Hons), MSc (Reading)

CINEC Campus

January 28, 2026



What Is an Image?

- An image is a **numerical representation** of a visual scene
- In engineering terms, an image is a **2D discrete function**:

$$f(x, y)$$

- Each value represents the **measured light intensity** at a spatial location
- Images are formed through:
 - Light interacting with objects
 - Optical projection (lens)
 - Photoelectric conversion (sensor)
 - Analog-to-digital conversion

Note

An image is **data**, not a picture. It must be processed and interpreted by algorithms.

How an Image Is Born

- Light is emitted from a source or reflected by objects in the scene
- Reflected light enters the camera through a lens
- The lens focuses light onto the image sensor
- The image sensor (CCD or CMOS) converts light into electrical signals
- Electrical signals are digitized using an Analog-to-Digital Converter (ADC)
- The result is a digital image represented as a matrix of pixel values

Note

Every pixel value originates from a **physical light measurement**. Image quality is determined **before** any image processing.

What is Image Processing?

Definition

Image processing is the manipulation and transformation of digital images using mathematical and algorithmic operations to improve image quality or extract useful low-level information.

- Operates directly on pixel values
- Treats images as numerical data (signals)
- Output is usually another image
- No semantic understanding of the scene

Nature of Image Processing

- Pixel-level and neighborhood-level operations
- Deterministic and explainable algorithms
- Repeatable and computationally efficient
- Foundation for higher-level vision tasks

Images as Engineering Data

- An image is a 2D array of numerical values
- Each pixel represents measured light intensity
- Image acquisition involves:
 - Optics
 - Image sensor (CCD / CMOS)
 - Analog-to-digital conversion

Examples of Image Processing Tasks

Example

- Noise removal
- Contrast enhancement
- Filtering
- Edge detection
- Morphological operations
- Image compression

Purpose of Image Processing

- Improve image quality
- Suppress noise and unwanted variations
- Enhance relevant features
- Prepare data for further analysis

Note

Image processing prepares data for decisions; it does not make decisions.

What is Computer Vision?

Definition

Computer vision is the field that enables computers to interpret, analyze, and understand the content of images and videos.

- Works at a higher abstraction level
- Focuses on objects, features, and meaning
- Output is information or decisions
- Often uses machine learning and deep learning

Image Processing vs Computer Vision

Image Processing	Computer Vision
Pixel-level operations	High-level interpretation
Images treated as signals	Images treated as scenes or objects
Output is a modified image	Output is information or decisions
Deterministic algorithms	Often probabilistic or learning-based

How Are Image Processing and Computer Vision Related?

- Image processing provides the foundation for computer vision
- Computer vision systems almost always start with image processing
- Good image processing simplifies vision algorithms
- Poor image processing increases complexity and errors

Note

Image processing answers: *"How should the image be transformed?"*

Computer vision answers: *"What does this image represent?"*

Human Vision vs Computer Vision

Human Vision	Computer Vision
Biological and perceptual system	Engineered computational system
Non-linear response to light intensity	Linear response to light intensity (sensor output)
Perception is approximately logarithmic	Pixel values are linearly proportional to light
Naturally adapts to lighting changes	Requires explicit algorithms for adaptation
Perceives brightness consistently	Appears dark or flat without correction
No explicit correction required	Requires gamma correction for display

Note

Gamma correction compensates for the difference between the **linear camera response** and the **non-linear response of human vision**.

Definition

A digital image is the result of a physical-to-digital conversion process that transforms photons into numerical data.

- Illumination
- Interaction
- Optics
- Sensing
- Digitization
- Storage

Stage 1: Illumination

Definition

Illumination is the availability and distribution of light in a scene.

- Natural or artificial light sources
- Determines signal strength and contrast
- Affects noise and visibility

Stage 2: Interaction

Definition

Interaction describes how light behaves when it strikes an object.

- Reflection
- Absorption
- Transmission

Note

Vision systems measure reflected light, not objects directly.

Stage 3: Optics

Definition

Optics project a 3D scene onto a 2D sensor plane using a lens system.

- Focal length
- Aperture (f-number)
- Focus distance
- Optical distortion

Stage 4: Sensing

Definition

Sensing converts incident light into electrical charges using an image sensor.

- Photoelectric conversion
- Charge proportional to light intensity
- Analog signal representation

Important

Any loss of quality in illumination, interaction, optics, or sensing is irreversible.

Warning

Image processing algorithms cannot recover missing photons or correct severe optical blur.

Definition

Image sensors convert optical energy into electrical signals.

- CCD (Charge-Coupled Device)
- CMOS (Complementary Metal-Oxide Semiconductor)

CCD Image Sensors

Definition

CCD sensors transfer charge across the chip to a single readout node.

- Very uniform pixel response
- Low noise
- High image quality
- High power consumption
- Slow readout

Example

Applications:

- Scientific imaging
- Astronomy
- High-end microscopy

CMOS Image Sensors

Definition

CMOS sensors integrate amplification and readout circuitry within each pixel.

- Fast readout
- Low power consumption
- On-chip integration
- Slightly higher noise (modern CMOS minimized)

Example

Applications:

- Mobile phones
- Industrial cameras
- Robotics and embedded vision

CCD vs CMOS Comparison

CCD	CMOS
Charge transferred across chip	Per-pixel amplification
Single readout node	Multiple readout nodes
Sequential readout	Parallel readout
Lower noise	Slightly higher noise
Higher power consumption	Lower power consumption
Slower readout speed	Faster readout speed
Higher manufacturing cost	Lower manufacturing cost
Limited on-chip integration	Extensive on-chip integration
Better uniformity	Good uniformity (modern)

Note

Modern CMOS sensors have closed the performance gap with CCDs while maintaining advantages in speed, power, and integration.

Definition

Cameras can be classified based on how spatial data is captured.

- Area scan cameras
- Line scan cameras

Area Scan Cameras

Definition

Area scan cameras capture the entire 2D image in a single exposure.

Example

- Mobile devices
- Surveillance
- Robotics

Line Scan Cameras

Definition

Line scan cameras capture one row of pixels at a time to form a 2D image through motion.

Example

- Conveyor belt inspection
- Web inspection
- High-speed quality control

Key Distinction

Important

Area scan captures space.

Line scan captures space through time.

Definition

Image sensors measure light intensity, not colour.

Note

Colour information must be reconstructed using optical filters.

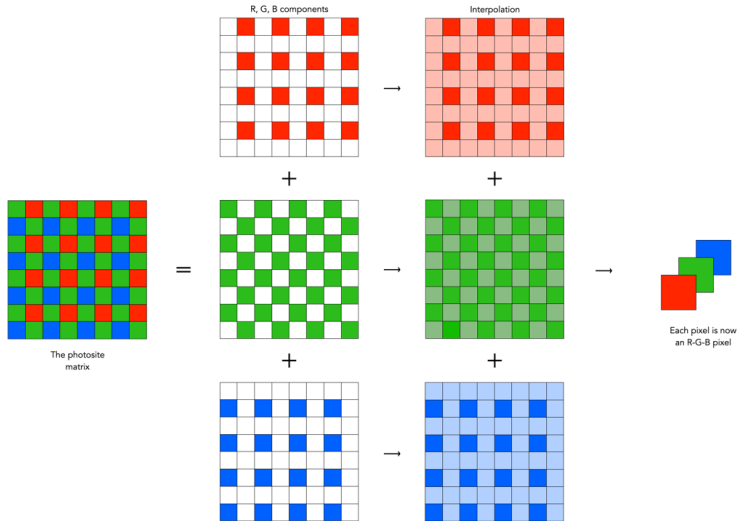
Bayer Colour Filter Array

Definition

The Bayer pattern is a colour filter array used to capture colour information.

- 50% Green
- 25% Red
- 25% Blue

Bayer Pattern Visualization



Definition

A raw image is the direct output of the image sensor.

- One colour component per pixel
- No white balance
- No gamma correction
- No demosaicing

Definition

An RGB image is produced after demosaicing and colour reconstruction.

- Each pixel has R, G, and B values
- Ready for display
- Some information loss due to interpolation

Important

Image processing algorithms often perform better on raw or minimally processed data.