Computer Vision

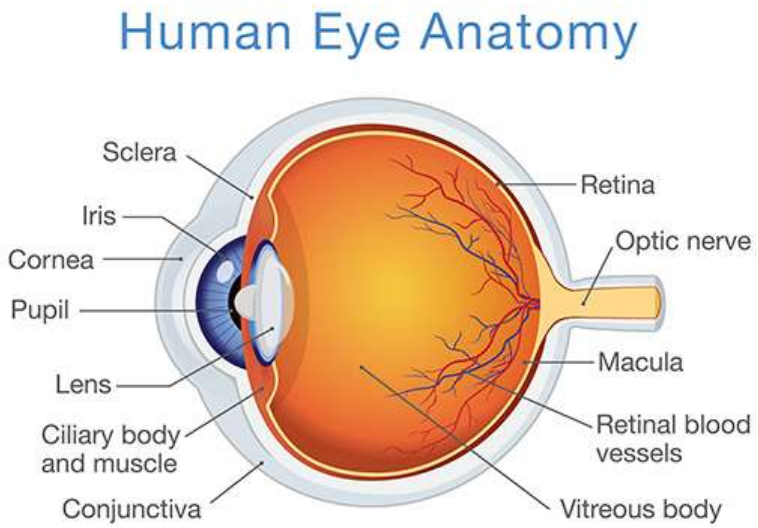
Computer Vision is the subfield of AI that enables computers to "see" and interpret visual data. While AI handles the thinking, CV handles the observing.

How It Works: The Learning Process

1. **Massive Data Requirements:** CV models require vast datasets to learn patterns (e.g., seeing thousands of tires to identify a "perfect" one vs. a defective one).
2. **Self-Teaching:** Using **Machine Learning**, computers teach themselves context through data rather than being manually programmed for every specific object.
3. **The Engine (CNNs):** Convolutional Neural Networks are the primary tool. They:
    - Break images into pixels.
    - Assign tags/labels to these pixels.
    - Perform convolutions (mathematical operations) to predict what the image is.
    - Iterate until the accuracy of their predictions is high.

Image Formation

1. **Human Eye –**



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Part	Description & Key Function
Sclera	The "white of the eye." A tough, protective outer layer.
Cornea	The transparent front part of the sclera; the "window" where light first enters.
Iris	The colored ring of muscle. It acts like a camera shutter, adjusting the **Pupil** size to control light exposure.
Pupil	The black opening in the center of the Iris that allows light to pass into the eyeball.
Lens	A flexible muscular structure behind the iris. It changes its focal length to converge light precisely on the retina.
Vitreous Chamber	The inner cavity of the eyeball. Filled with fluid to maintain eye pressure and shape.
Retina	The light-sensitive "screen" at the back of the eye. It converts light into electrical impulses.
Optic Nerve	The communication cable that carries electrical data from the retina to the brain.

The Photoreceptors (Optic Nerve Cells)

The retina uses two specialized cells to translate light into information:

- **Rods:** Specialized for low light (night vision).

  Responsible for peripheral vision.
- **Cones:** Specialized for color visualization.

  Function best in bright light.

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How the Eye Works (The "Camera" Process)

The human eye functions much like a high-tech digital camera:

1. **Entry:** Light enters through the **Cornea**.
2. **Regulation:** The **Iris** expands or contracts the **Pupil** to manage the intensity of light.
3. **Focusing:** The **Lens** adjusts its shape to focus the light rays.
4. **Projection:** The light hits the **Retina**, where an image is formed.
5. **Conversion: Rods and Cones** capture the visual details (color/light) and turn them into electrical signals.
6. **Transmission:** The **Optic Nerve** sends these signals to the brain, which interprets them as the final image.

The Brain's Role in Vision

The eye captures the data, but the brain does the "editing":

- **Image Inversion:** The eye actually sees images **upside down**; the brain flip-processes them so we perceive them correctly.
- **Processing Speed:** The brain can identify an image in as little as **13 milliseconds**.
- **Filling in the Blanks:** * **The Blind Spot:** Where the optic nerve leaves the eye, there are no receptors.
    - **The Fix:** The brain uses data from the other eye or the surrounding visual field to "fill in" this empty space so we don't see a hole in our vision.

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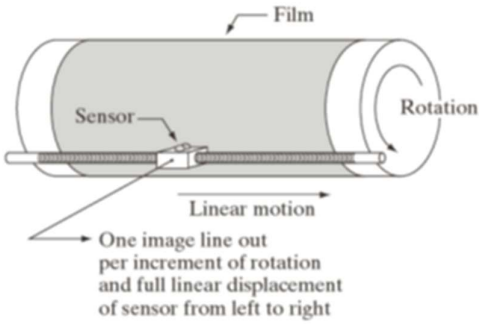
Image Formation on Analog and Digital Camera

In picture is created by a chemical reaction that occurs on the strip in analogue cameras. Analogue cameras use a 35mm film strip. Silver halide is applied to these strips. One type of chemical is silver halide. An analogue camera uses a 35mm strip. The figure uses a 35mm film cartridge to represent it. This strip has a chemical coating called silver halide on it. The photon particles, which are tiny particles, are all that make up light. Thus, these photon particles react with the silver halide particles on the strip when they pass through the camera, producing silver, which is the image's negative. Examine this equation to gain a better understanding of it. Silver halide and photons—light particles combined? ? silver picture negative. Photon particles are the smallest particles that make up light rays. This photon particle interacts with silver halide particles on the strip after passing through the camera. Additionally, it creates a negative image.

Silver Halide+Photons→Silver (Negative Image)



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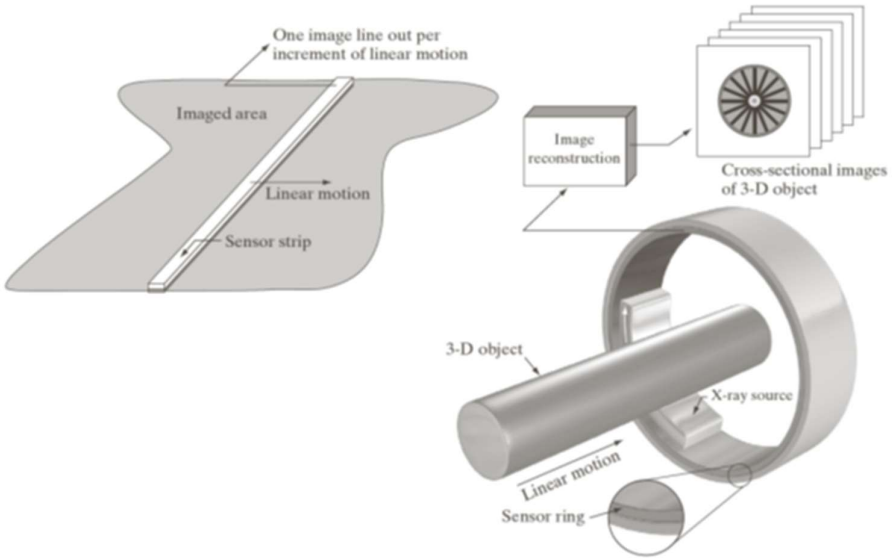

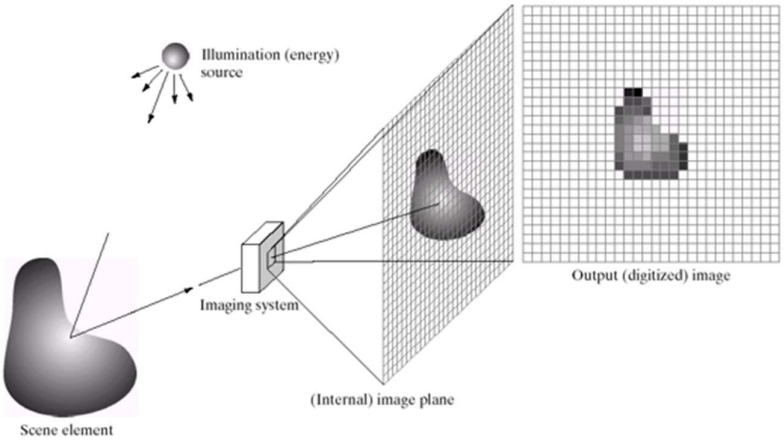

The formation of images in digital cameras is not the result of a chemical reaction; rather, it is more complicated than that. A CCD array of sensors is used to create images in digital cameras. Charge-coupled device is spelled CCD. It is an image sensor that, like other sensors, detects values and produces an electric signal from them. In the case of a CCD, the image is detected and converted into an electric signal, etc. Actually, this CCD is an array or a rectangular grid. It is comparable to a matrix, except that each cell contains a censor that measures a photon's intensity. Digital cameras, like analog ones, allow light to enter the camera when it hits an object and reflects back after striking it, just like analog cameras do. Analog sensors make up each sensor in the CCD array itself. Each photo sensor stores a small electrical charge in response to light photons striking the chip. Each sensor's response is directly proportional to the amount of light or (photon) energy struck on its surface.

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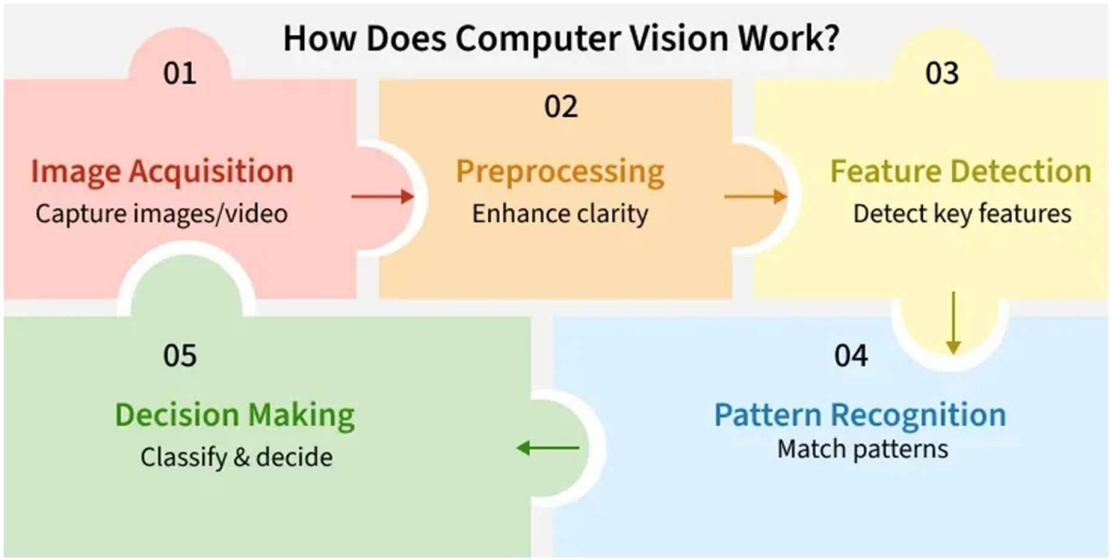
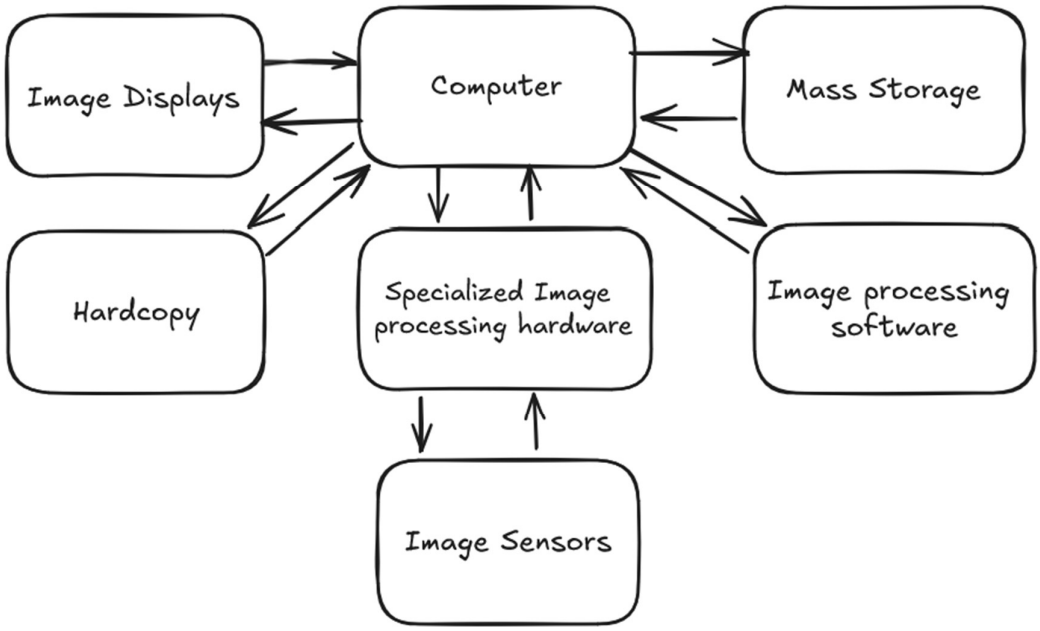


Components of Image Processing



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1. Image Sensors

- **Capture:** This is the starting point, where devices like digital cameras use **CCD (Charge-Coupled Device)** arrays.
- **Conversion:** These sensors measure photon intensity and convert light into electrical signals.
- **Input:** The signals are sent upward to specialized hardware for initial processing.

2. Specialized Image Processing Hardware

- **Efficiency:** This hardware is designed to handle high-speed mathematical operations, such as **convolutions**.
- **Preprocessing:** It helps break images down into pixels and tags them, preparing the data for the computer and software to analyze.

3. Image Processing Software

- **Intelligence:** This is where **Machine Learning** and **Neural Networks (CNNs)** reside.
- **Analysis:** The software runs algorithms to perform **Object Detection**, **Recognition**, and **Classification**.
- **Action:** It enables the computer to make recommendations or take actions based on what it "sees".

4. Mass Storage

- **Data Banks:** Computer Vision requires vast quantities of data for training.
- **Retention:** Mass storage holds the datasets (like thousands of images of tires) used to teach the system to recognize patterns and defects.

5. Output: Image Displays & Hardcopy

- **Visual Feedback: Image Displays** (monitors) show the processed results, such as facial recognition bounding boxes or medical anomaly highlights.
- **Physical Records: Hardcopy** refers to printed versions of the processed visual data.