Introduction to Artificial Intelligence

Subject 9: AI for Perception and Interaction

Part B. Introduction to Image Processing

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Learning Objectives

By the end of this lecture, students will be able to:

Define what is a digital image

Define what is digital image processing?

History of digital image processing

State of the art examples of digital image processing

Recognize the Key stages in digital image processing

What is a Digital Image?

A digital image is a picture stored on a computer, phone, or camera. It is made up of tiny dots called **pixels** arranged in a grid. Each **pixel** is a **single point of color**, and together, all the pixels form the complete image.

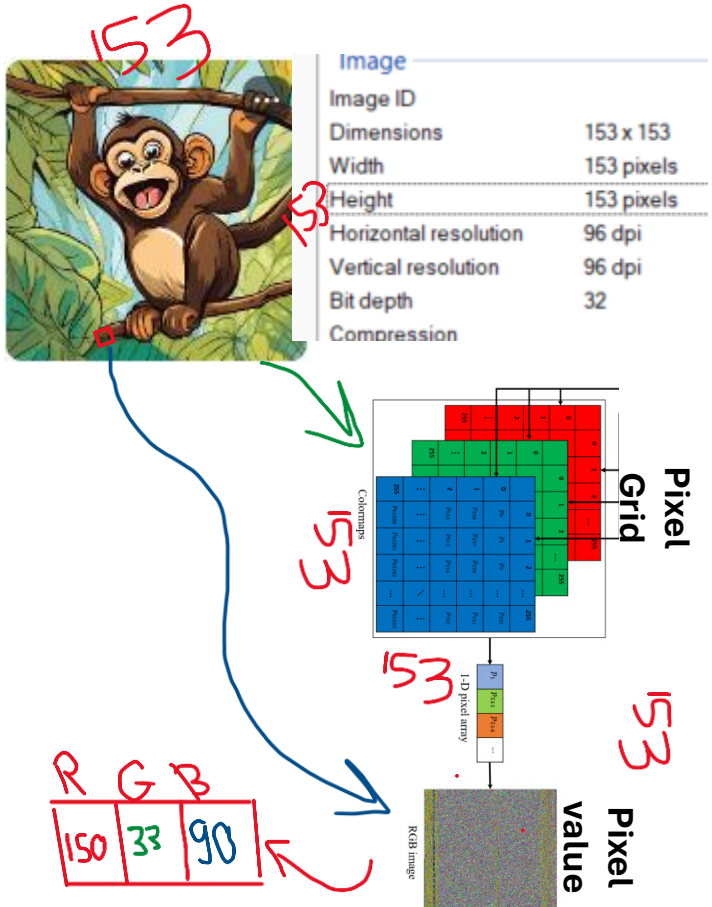
What is a Digital Image?

Key Details:

•**Pixel Grid:** The image is divided into rows and columns of pixels — for example, a 153×153 image is a grid of 153 pixels wide and 153 pixels tall.

•**Pixel Values:** Each pixel stores a number (or set of numbers) that represents its color and brightness. For example:

- In a black-and-white image, each pixel is a single number representing its shade of gray.
- In a color image, each pixel usually has three numbers representing the amount of **Red, Green, and Blue (RGB)** light.



What is a Digital Image?

This diagram outlines the **Digital Image Acquisition** process, showing how real-world objects are converted into digital data.

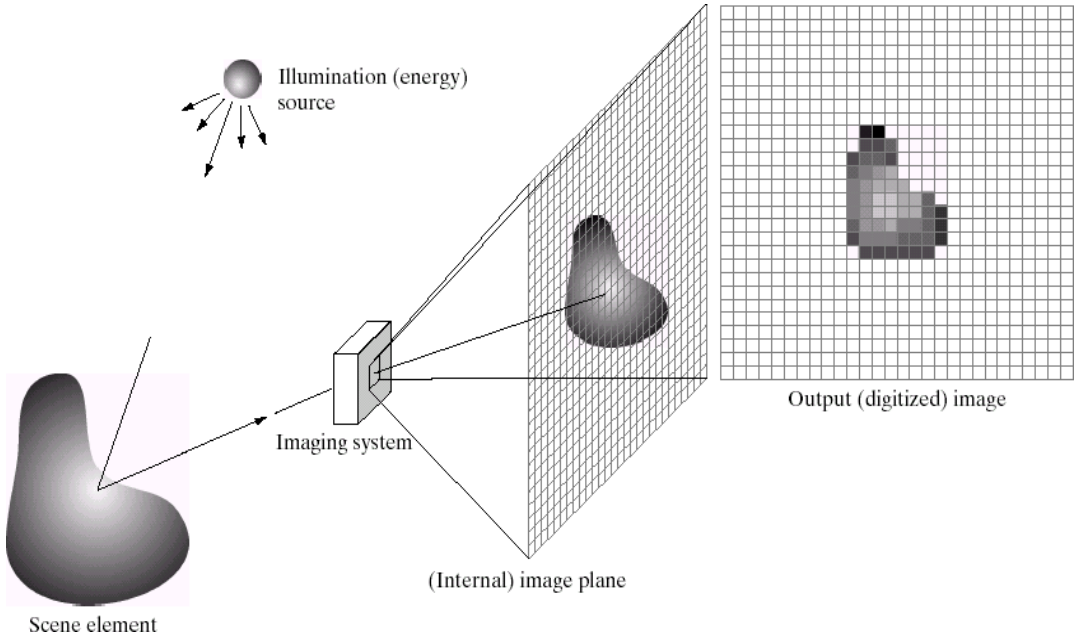
•**Illumination Source:** This represents the light source (such as the sun or a light bulb) that provides the energy needed to "see" the object.

•**Scene Element:** The physical 3D object being captured.

•**Imaging System:** The optical hardware (lens and aperture) that collects and focuses the incoming energy onto the sensor or film.

•**Internal Image Plane:** The surface inside the camera (sensor) where the continuous light pattern is projected before being divided into a grid.

•**Output (Digitized) Image:** The final result—a discrete 2D grid of **pixels**, where each point has a specific numerical value representing its brightness.



What is a Digital Image?

Common image formats include:

- 1 sample per point (B&W or Grayscale)
- 3 samples per point (Red, Green, and Blue)
- 4 samples per point (Red, Green, Blue, and “Alpha”)

What is Digital Image Processing (DIP)?

Digital image processing focuses on two major tasks

1. Improvement of visual Information for Human Interpretation

The goal is to take an input image and process it so that it is more useful or pleasing to a human viewer.

Key Tasks & Applications:

•**Enhancement**: Adjusting brightness, contrast, color balance, and sharpness making details more visible (e.g., making a dark photo brighter).

•**Restoration:** Removing noise, distortion, or defects to recover the original scene (e.g., removing scratches from an old photograph).

•**Color Processing:** Correcting colors, creating false-color images to highlight features invisible to the human eye (e.g., In CT: Assign colors to different tissue densities (white for bone, black for fluid,etc).

2. Processing of Image Data for Autonomous Machine Perception

The goal is to extract meaningful information from the image to enable a machine to understand the scene and make decisions.

Key Tasks & Applications:

•**Segmentation**: Partitioning an image into meaningful regions (e.g., separating roads, cars, and pedestrians in a self-driving car's video feed).

•**Feature Extraction:** Identifying key points, edges, textures, or shapes within an image (e.g., extracting facial features).

•**Object Detection & Recognition:** locating and classifying objects within an image (e.g., identifying products on a supermarket shelf).

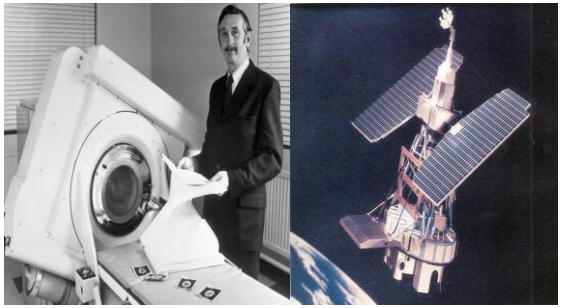
History of Digital Image Processing (DIP)

•**1920s:** The Bartlane System:- Pictures were first sent via submarine cable between London and New York. Specialized printing equipment coded and reconstructed the images, reducing transmission time from weeks to hours.

•**1957:** The First Digital Image Russell Kirsch and his team at the National Bureau of Standards (NIST) created the first digital image by scanning a photo of Kirsch's son. It was a 176 × 176 pixel black-and-white scan using the SEAC computer.

•**1960s:** The Space Race & NASA:- The modern field of DIP began at NASA's Jet Propulsion Laboratory (JPL). They used computers to correct distortions and enhance the quality of lunar photos sent back by the Ranger 7 spacecraft in 1964.

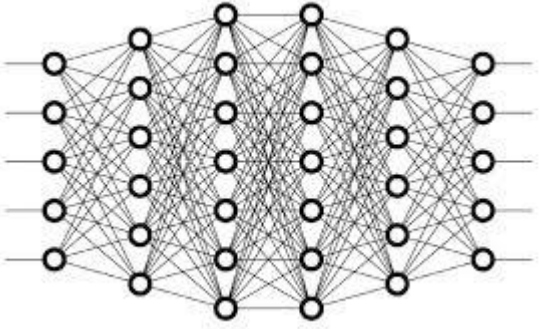
History of Digital Image Processing (DIP)



•**1970s (Medical and space achievements):** The invention of the computed tomography (CT) scanner in 1972 revolutionized medicine by using image processing to create "slices" of the human body. At the same time, the **Landsat 1** satellite began transmitting the first digital images of Earth for environmental monitoring.

•**1975:** The First Digital Camera:- Steven Sasson at Kodak built the first portable digital camera prototype. It weighed 8 pounds, recorded images onto a cassette tape at 0.01 megapixels, and took 23 seconds to capture a single shot.

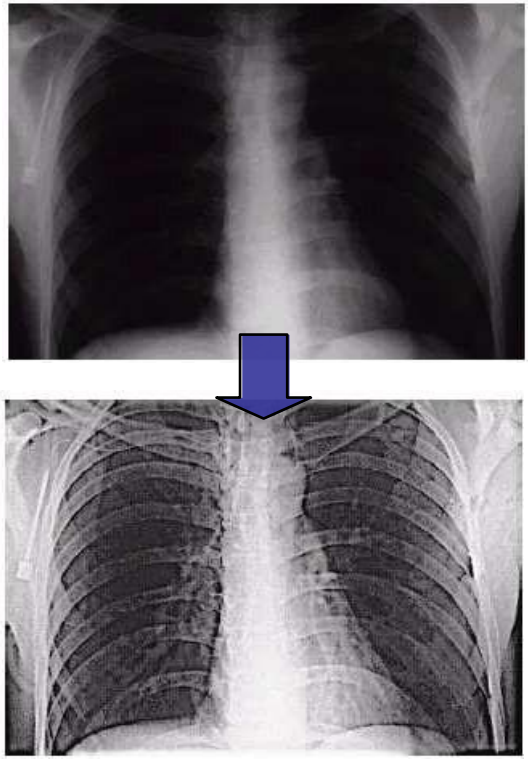
•**1990s:** The release of the JPEG standard allowed digital images to be compressed into small files without losing significant quality.

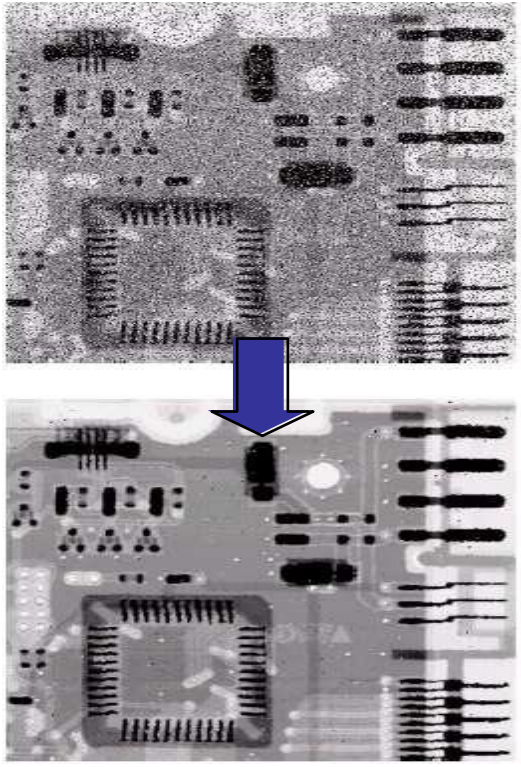


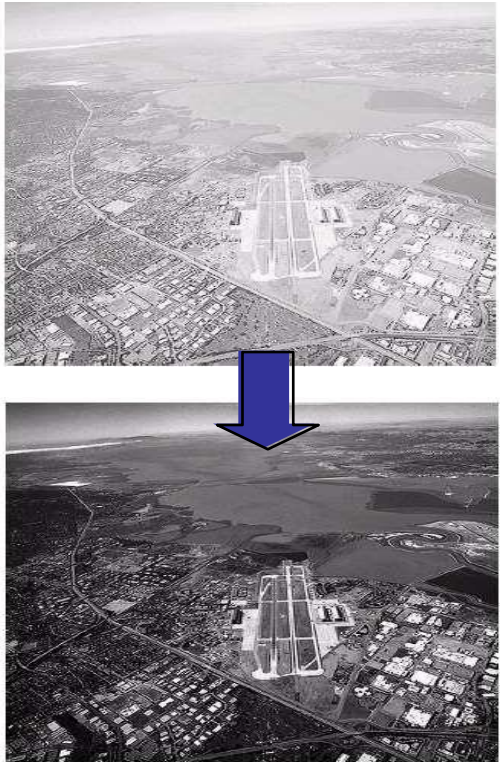
•**2010s – Present: The AI Revolution** Processing shifted from manual algorithms to **Deep Learning**. Tools like CNNs and models like YOLO now allow computers to recognize objects, enhance low-light photos, and even generate realistic new images.

Examples: Image Enhancement

Some of the most common uses of DIP technology are: quality improvement, noise reduction, etc.

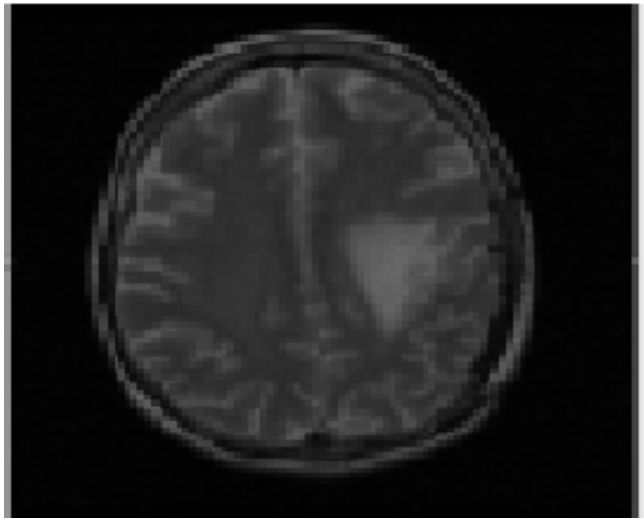






Examples: Medicine

Take a slice of the brain MRI image and identify the boundaries shape.



Original MRI Image of brain

Edge Detection Image

https://www.researchgate.net/publication/228959338_Graph_cut_based_segmentation_of_brain_tumors_from_MR_images/figures?lo=1

Examples: Industrial Inspection

Humans are expensive, slow, and unreliable for repetitive visual tasks. That's why industrial vision systems have become essential in modern manufacturing, quality control, and automation.

Expert Guide to Industrial Machine Vision

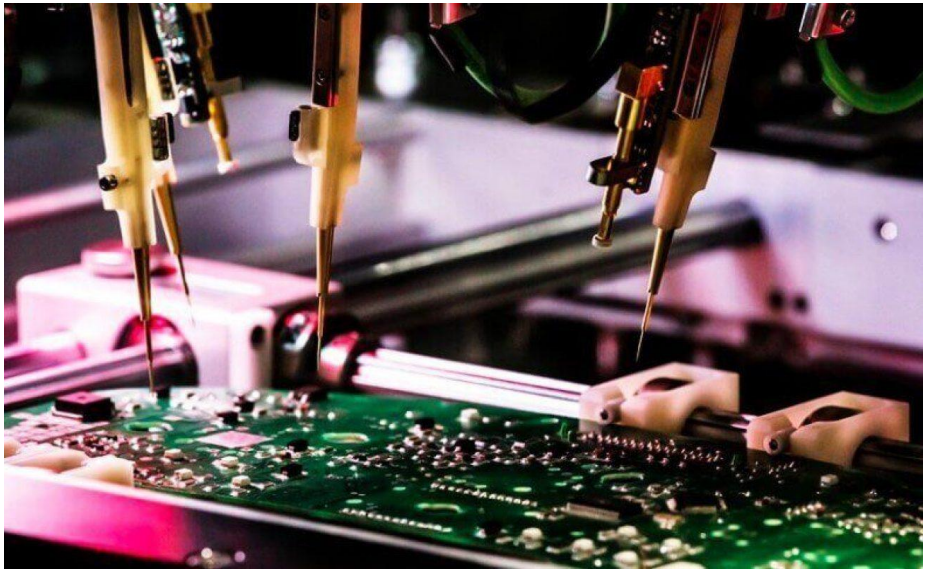
https://www.elementaryml.com/blog/vision-systems-expert-guide-to-industrial-machine-vision-technology

Vision Systems for Pharmaceutical Machines

https://sp-automation.co.uk/vision-systems-for-pharmaceutical-machines-types-and-applications/

Examples: Printed circuit board (PCB) inspection

Machine inspection is used to verify that all components are present and that all solder connections are acceptable.



PCB Testing - PCB Inspection and Testing

https://www.viasion.com/pcb-tests-inspections/

Examples: Law Enforcement

Law enforcement agencies widely use image processing technologies:

- License plate recognition for speed cameras/automated toll collection systems
- Fingerprint recognition
- Enhancing surveillance camera images

License Plate Recognition

https://yeahlowflicker.com/project/license-plate-recognition

Biometric fingerprint recognition

https://www.vecteezy.com/vector-art/2503308-biometric-fingerprint-recognition

Surveillance with CCTV Cameras

https://cctvvillage.co.uk/blogs/blog-post/zooming-in-enhancing-surveillance-with-cctv-cameras?srsltid=AfmBOooPmK9aQnDb5iUuBZuJuujJmEw0lkNyckSWeZd14kin3NFcTfdZ

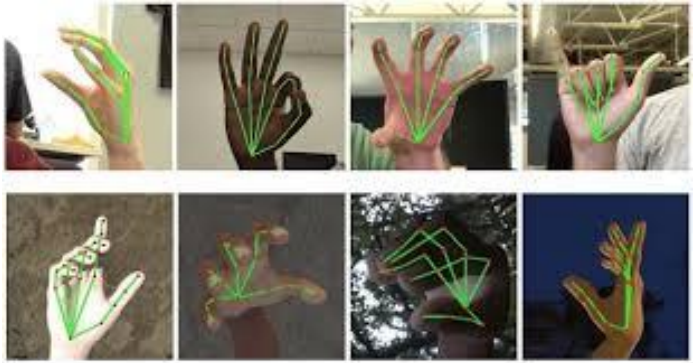
Examples: Human-computer interfaces (HCI)

Try to make human-computer interfaces more natural:

- Facial recognition
- Gesture recognition (commonly originate from the face or hand)

FACE RECOGNITION

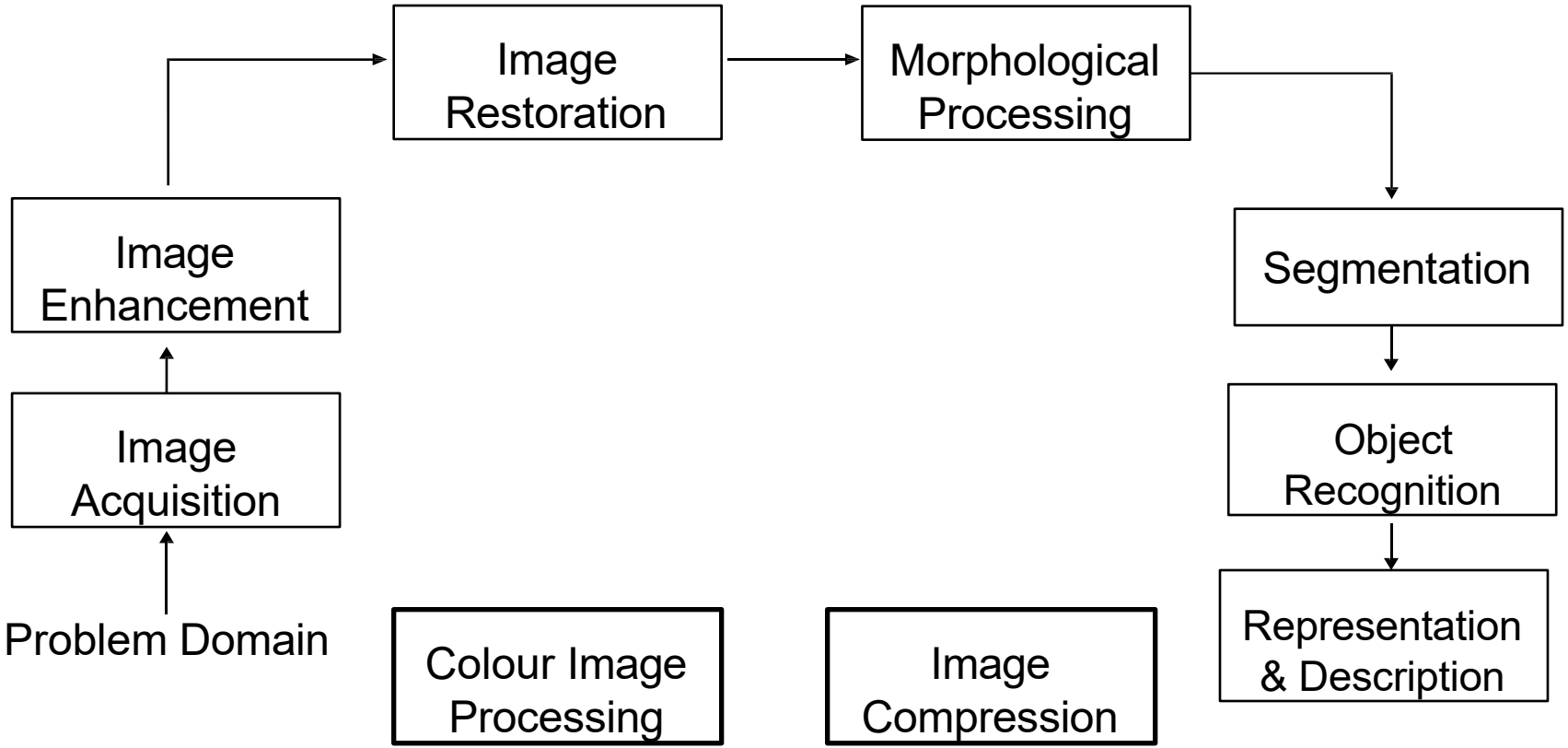
https://medium.com/@khwabkalra1/face-recognition-e45aff329fba



Gesture recognition

https://how2electronics.com/gesture-recognition-application-machine-learning/

Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Aquisition

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

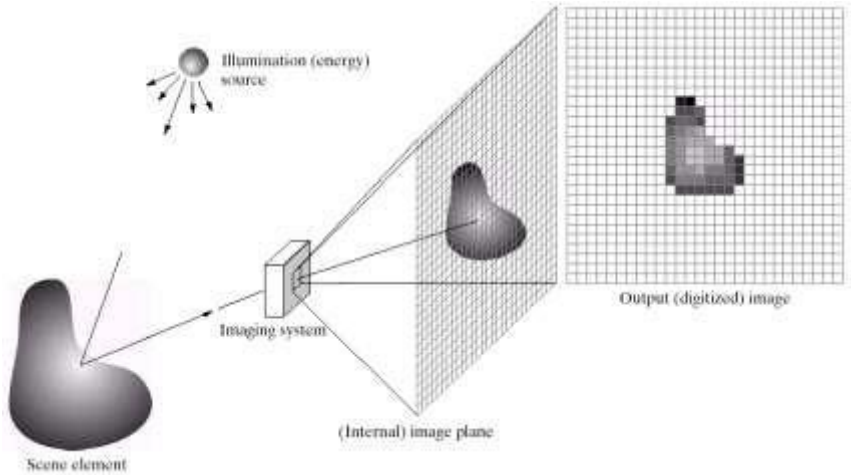
Segmentation

Object Recognition

Representation & Description

Image Compression

Colour Image Processing



e.g. Using a smartphone camera to snap a selfie or a satellite capturing a high-resolution view of Earth.

Key Stages in Digital Image Processing: Image Enhancement

e.g. Increase contrast and reveal hidden details in structure.

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

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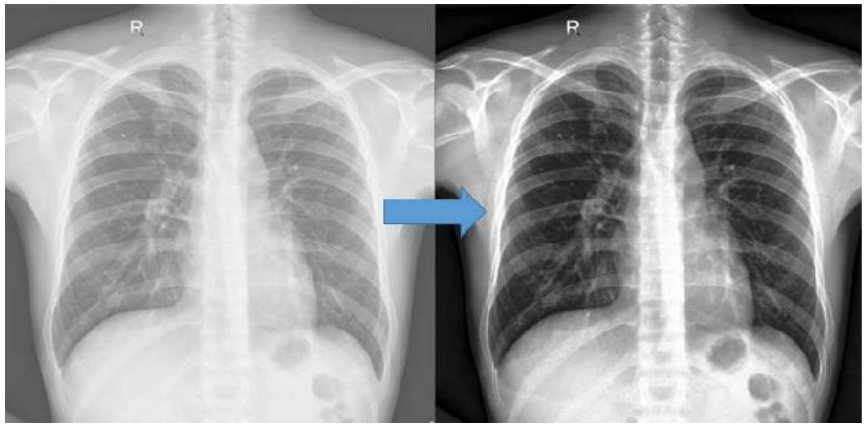
Object Recognition

Representation & Description



Colour Image Processing

Image Compression

https://www.researchgate.net/figure/Ray-Histogram-Equalization_fig2_339501140

Key Stages in Digital Image Processing: Image Restoration

e.g. Use filters to repair images that have become distorted over time.

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

Segmentation

Object Recognition

Representation & Description

Colour Image Processing

Image Compression

https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRCOUX9JkWqGLMVfa_Dj9HMnOPtEcgQOn2S7w&s

Key Stages in Digital Image Processing: Morphological Processing

Problem Domain

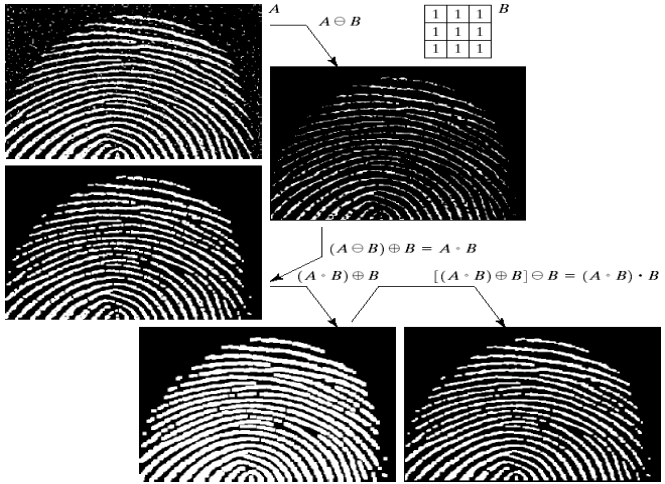
Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

e.g. To clean up a scanned fingerprint image to make feature extraction reliable.



Segmentation

Object Recognition

Representation & Description

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Segmentation

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

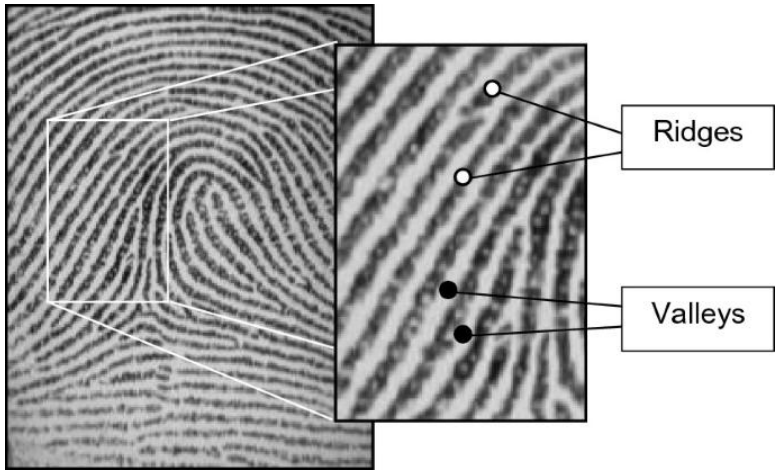
Morphological Processing

e.g. To partition the fingerprint image to the actual fingerprint ridges and ignore low-quality, or empty areas.

Segmentation

Object Recognition

Representation & Description



Colour Image Processing

Image Compression

https://link.springer.com/chapter/10.1007/978-3-030-83624-5_3

Key Stages in Digital Image Processing: Object Recognition

e.g. Identify the cat images among a set of images

Image Restoration

Morphological Processing

Segmentation

Object Recognition

Representation & Description

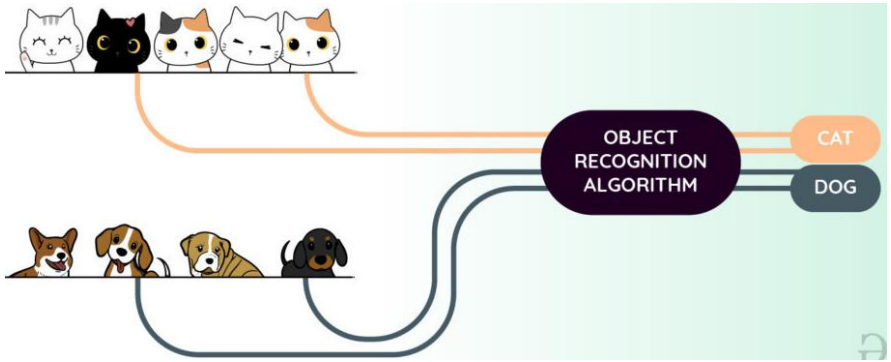
Image Compression

Colour Image Processing

Image Enhancement

Image Acquisition

Problem Domain



https://www.geeksforgeeks.org/machine-learning/object-detection-vs-object-recognition-vs-image-segmentation/

Key Stages in Digital Image Processing: Representation & Description

Problem Domain

Image Acquisition

Image Enhancement

Image Restoration

Morphological Processing

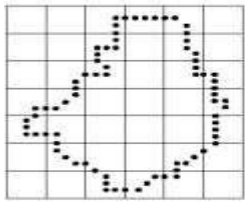
Segmentation

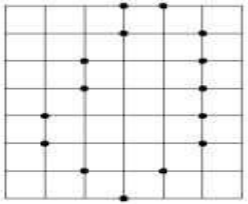
Object Recognition

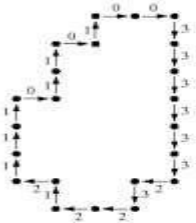
Representation & Description

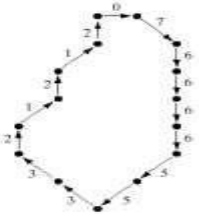
Colour Image Processing

Image Compression



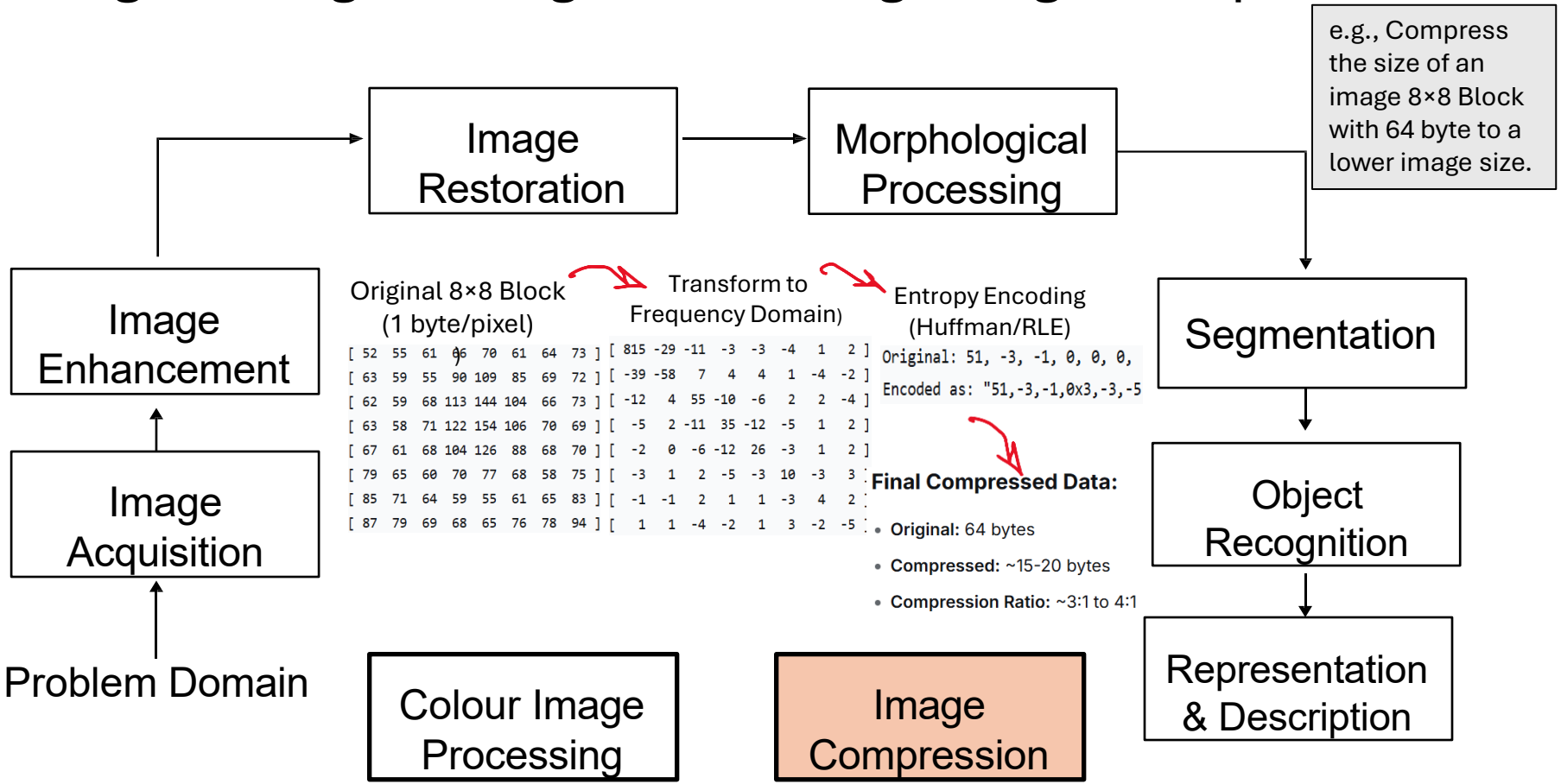




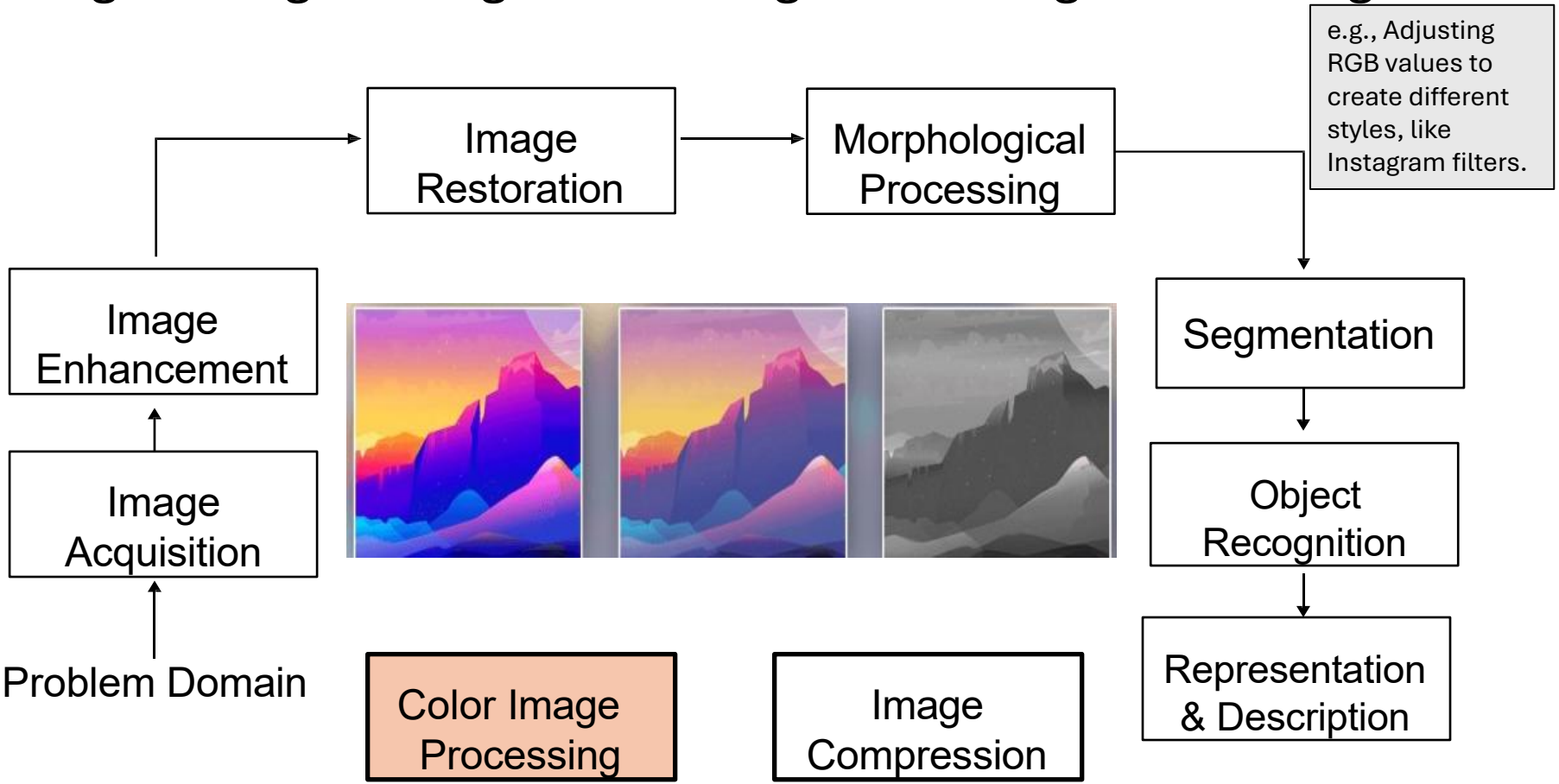
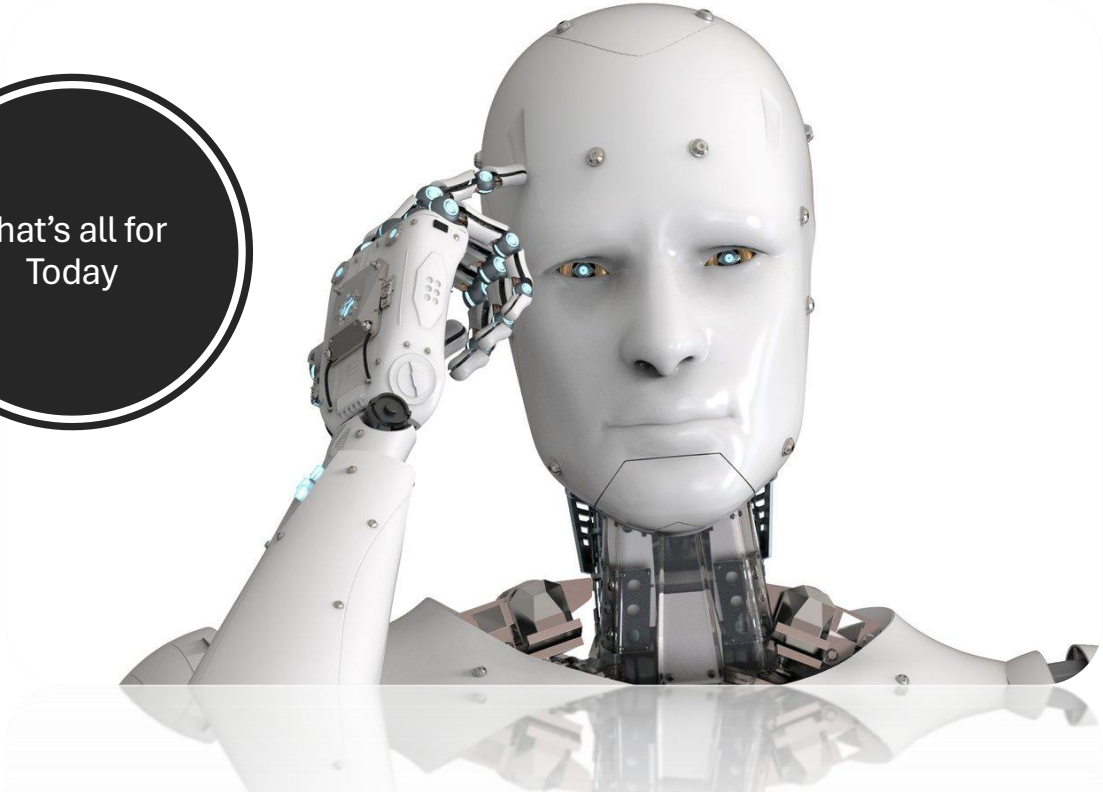


e.g., Define the boundaries of a region (i.e., the set of pixels that separate one image region from another) or all points in the same region.

Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Color Image Processing



That’s all for Today