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2017

Bachelor of Science in Electrical and Electronics Engineering (BSEEE) in 2017 from IUBAT.

- **HUMAP scholarship** at the University of Hyogo, Japan, from 2016 to 2017.

2018–2022

Researcher at the University of Hyogo, Japan, from 2018 to 2022.

- **Specially Appointed Researcher** at Glory LTD. Japan, from 2018 to 2022.

2021–2024

Doctor of Engineering (D. Eng.) from University of Hyogo, Japan, from 2021 to 2024.

- **UoH Fellowship** from 2022 to 2024.
- Teaching assistant from 2021 to 2024.

2024

Research Associate at the University of Hyogo, Japan, in 2024.

Autumn 2024

Adjunct. Assistant Professor

- CSE104, CSE210

2025

Assistant Professor

- Spring - CSE210, CSE310, CSE425
- Summer – CSE310, CSE425, CSE420

- Preferred language? – Bangla/English
- Evaluation

Assessment Type	Assessment Tools	Marks Distribution	Sub Total
Assignment	Written Assignment	10%	20%
	Coding Assignment	10%	
Mid	Mid Term Examination	30%	30%
Final	Group Project	20%	50%
	Final Assessment	30%	

Assignment submission process –

- Written assignment must be submitted as a hand-written copy with a printed cover page.
- Coding assignment must be submitted as Google Colab file. An excel sheet will be shared in the classroom. Paste only the link of your Colab file there.
- ***You must submit all assignments before/on due date.***

Group project and final assessment –

Assessment Type	Assessment Tools	Marks Distribution	Sub Total
Group project	Continuous assessment of progress	15%	30%
	Continuous Assessment of Code	15%	
Final Assessment	Final report	25%	70%
	Final Code	20%	
	Presentation	25%	

Introduction to Image Processing

Image

Processing

Processed image

Outline

Part 1	What is image?
Part 2	What is image processing?
Part 3	An Example of Real-life problem-solving using image processing

Part 1
What is an image?!

What is an image?!

- **From general perspective**: Visual impression of something.
- **From engineering perspective**: Multi-dimensional representation of a scene, object, or pattern. It consists of a grid of picture elements called ***pixels***, where ***each pixel holds a value*** that represents specific information about the scene.
  - Mathematically, an image can be represented as a function: $f(x, y)$

  Where:

  - x and y are spatial coordinates in the 2D plane.
  - $f(x, y)$ is the intensity or color value at the point (x, y).

What is an image?!

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \cdots & f(1,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \cdots & f(M-1,N-1) \end{bmatrix}$$

Pixels in an image

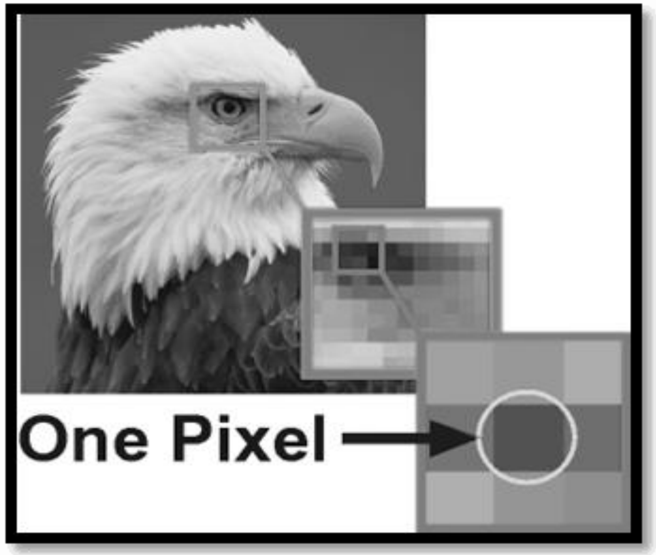


Image is basically a matrix.

(0,0) x

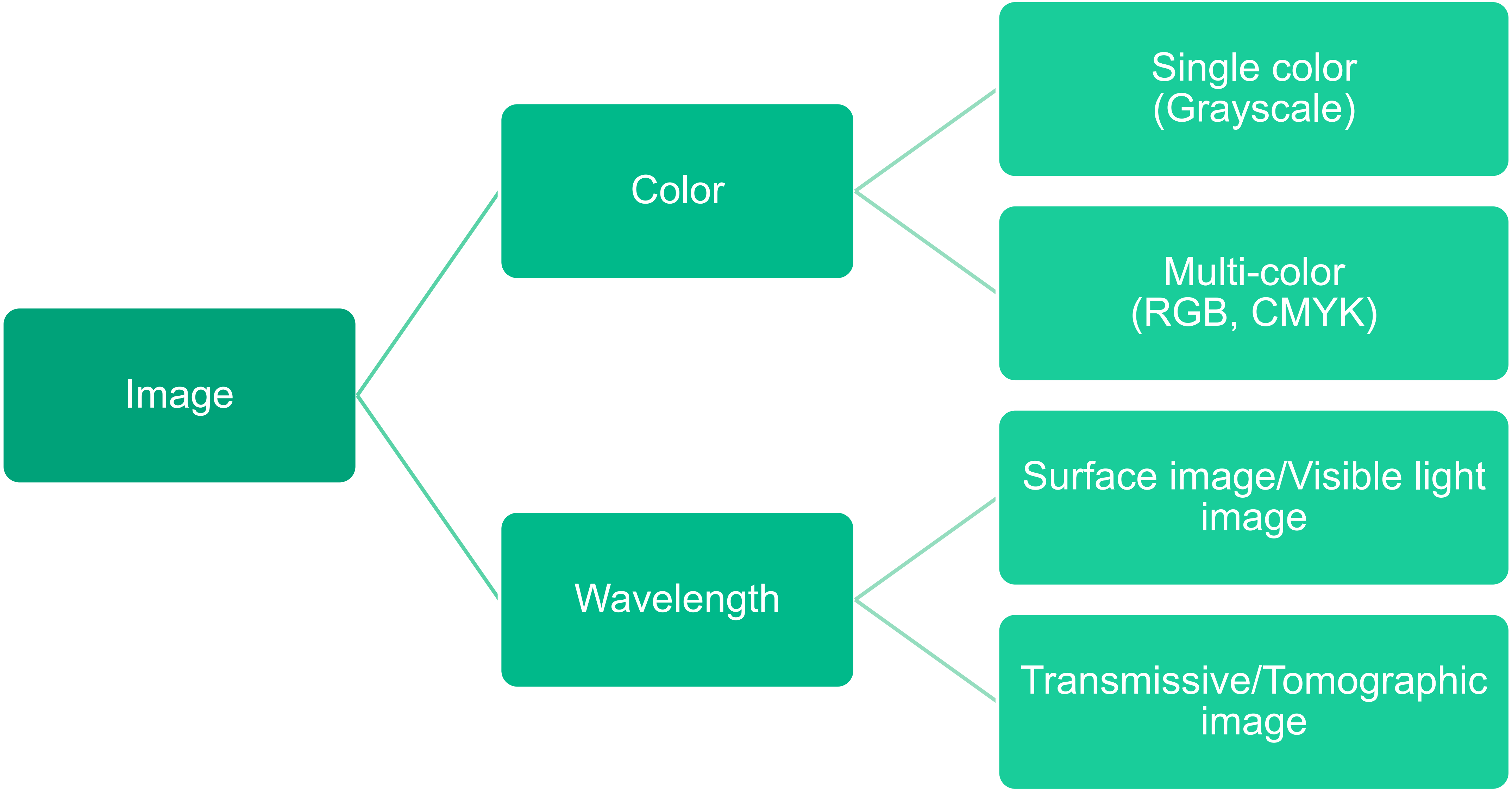
y

221	134	240	244	190	238	221
228	219	129	215	224	124	226
224	205	115	214	200	106	240
221	221	210	116	106	206	239
235	110	121	214	116	225	206
122	180	229	212	211	112	225
224	235	229	235	130	210	207

Pixels in a gray-scale image

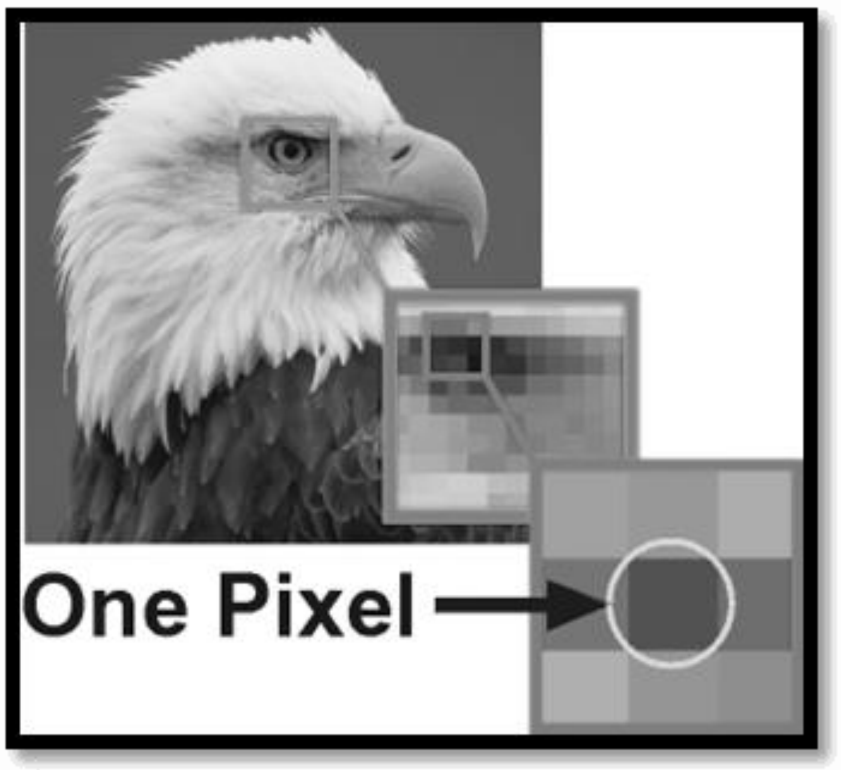
$$\boxed{f(4,3) = 106}$$

Types of images



Types of images – Single Color

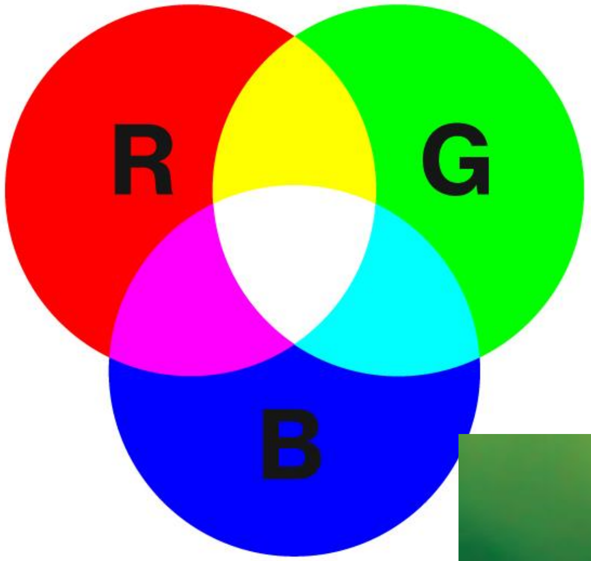
Each pixel contains information of a single color – usually shade of black and white.

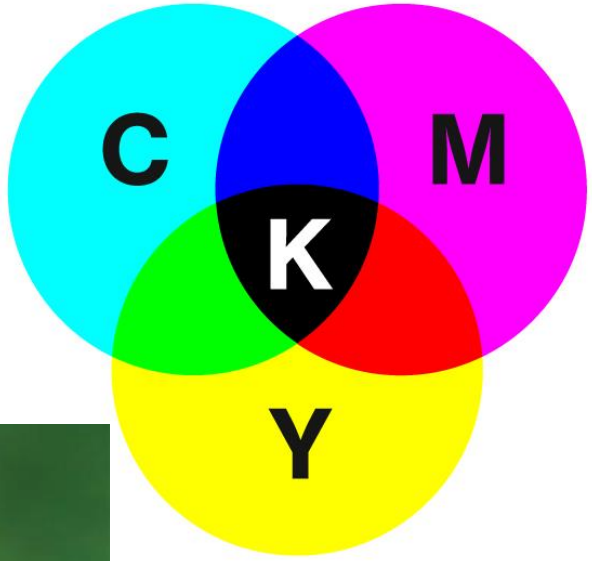


221	134	240	244	190	238	221
228	219	129	215	224	124	226
224	205	115	214	200	106	240
221	221	210	116	106	206	239
235	110	121	214	116	225	206
122	180	229	212	211	112	225
224	235	229	235	130	210	207

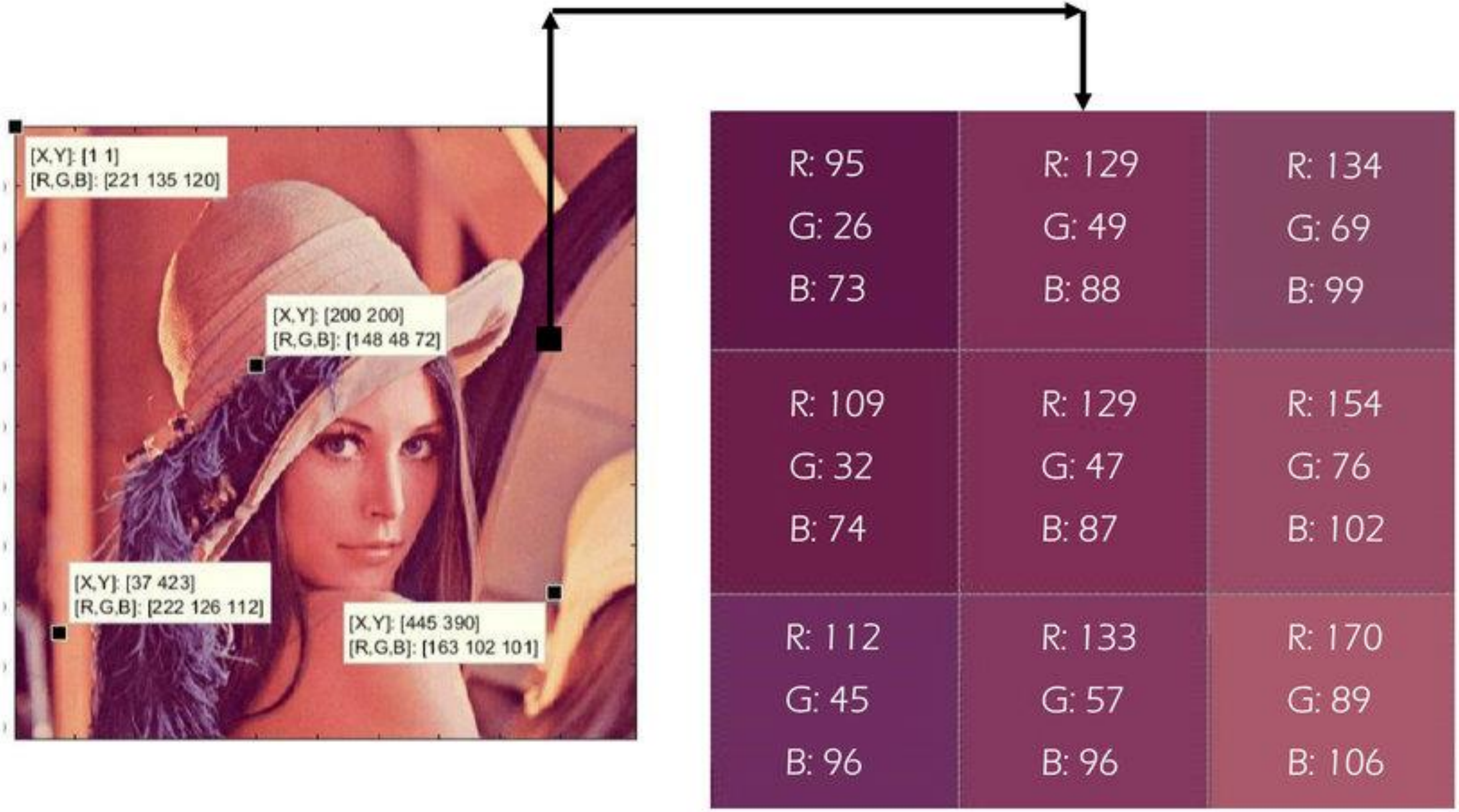
Pixels in a grayscale image

Types of images – Multi-color





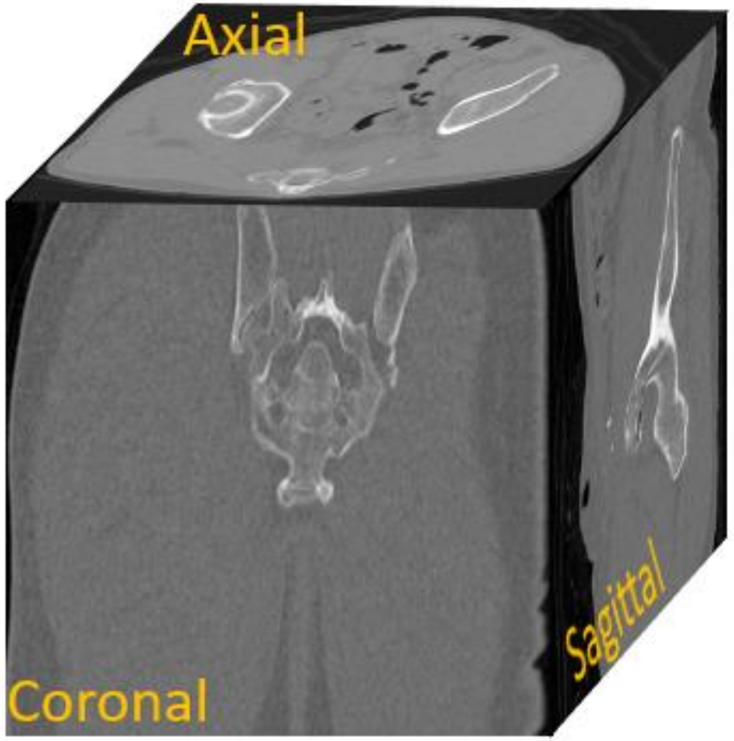
Types of images - Surface image/Visible light image



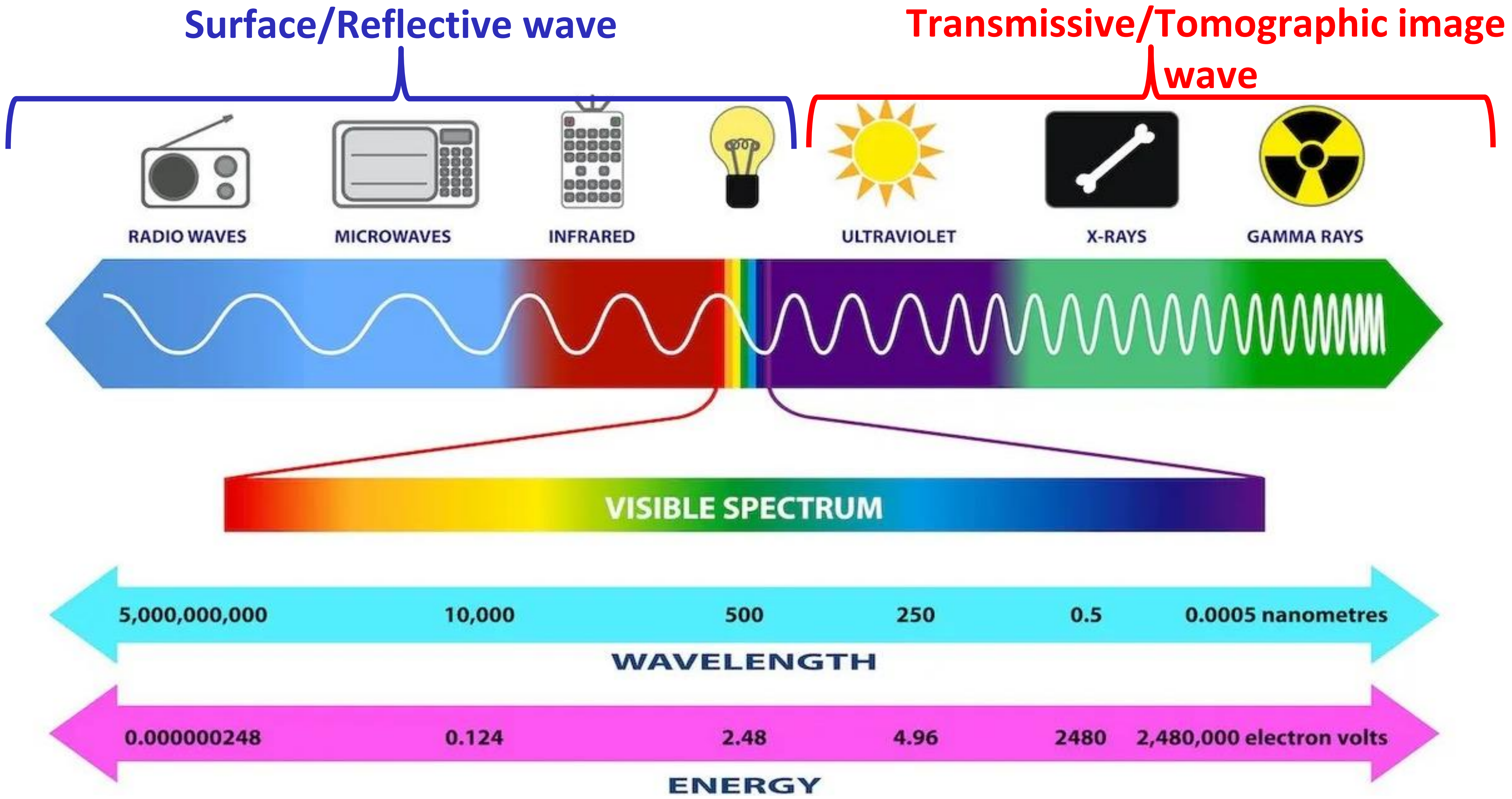
Types of images - Transmissive/Tomographic image

X-ray

Computed Tomography (CT)



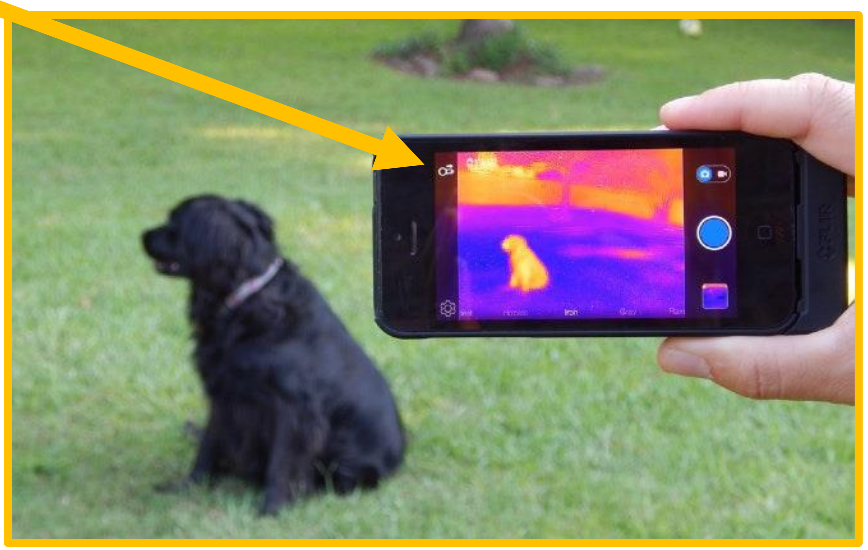
How to acquire image?!

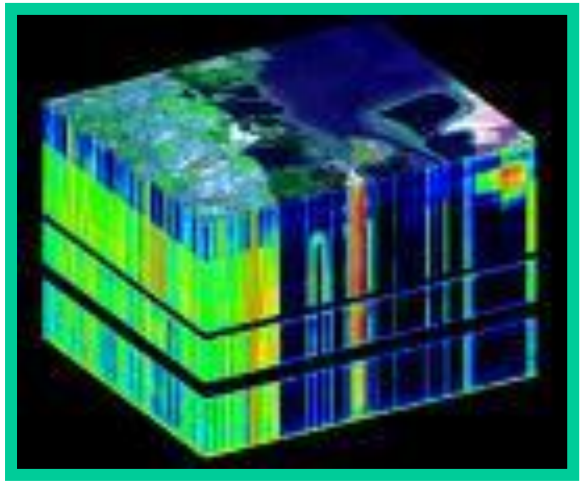


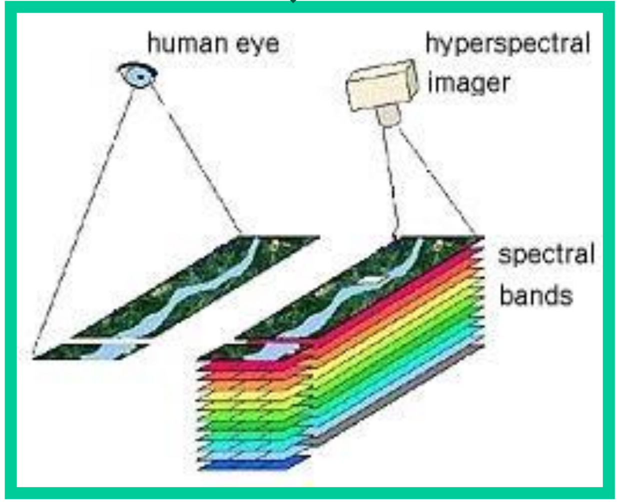
How to acquire surface image?!

Reflective images are acquired by "Camera"

- ❑ Video camera
- ❑ Infrared camera
- ❑ Range camera
- ❑ Line-scan camera
- ❑ Hyperspectral camera
- ❑ Omni-directional camera
- ❑ and more …

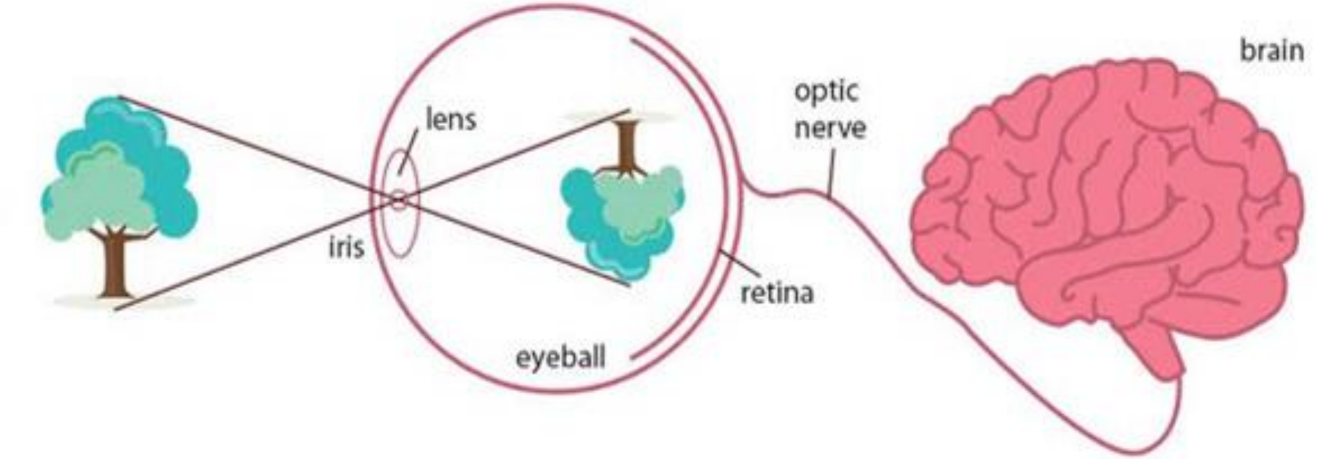


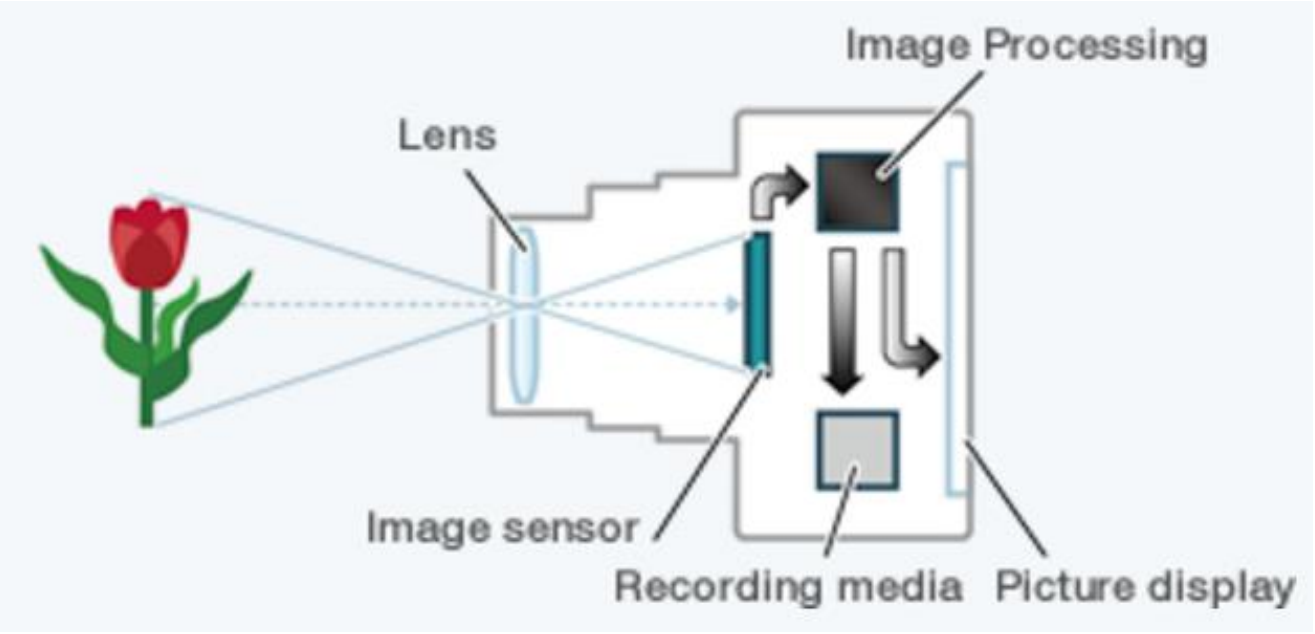




How to acquire surface image?!

- **Camera mechanism ≈ How we see**
- Reflected light passes through lens of our eye and make a projection on the **retina**.
- The projection is transmitted to our brain via **optic nerve**.
- Reflected light passes through **lens of camera** and make a projection on the **image sensor**.



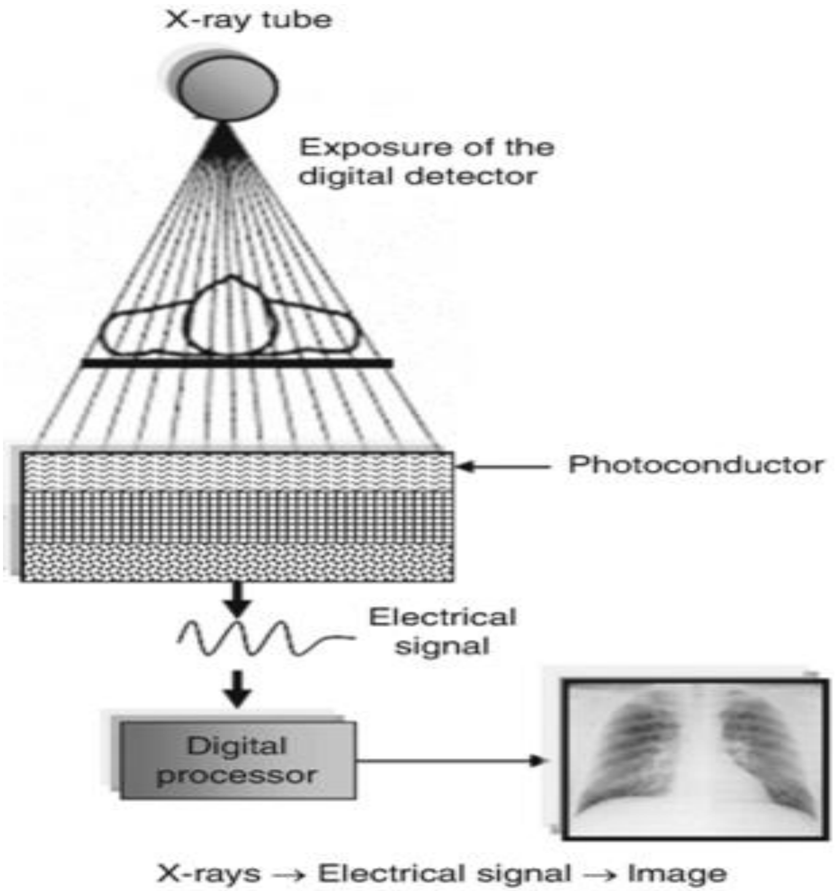


How to acquire tomographic image?!

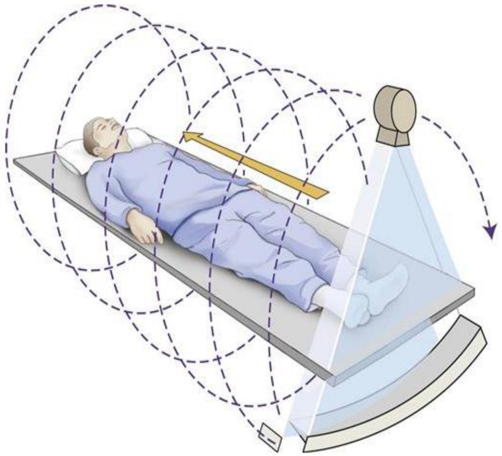
❑ Total setup has 2 major components –

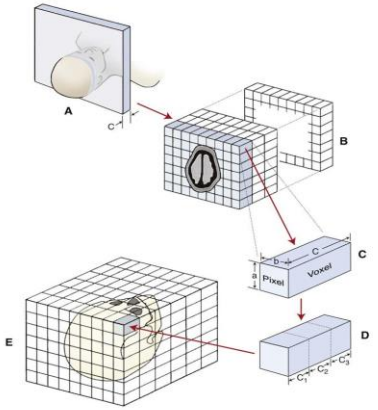
- ➢ Emitter
- ➢ Detector

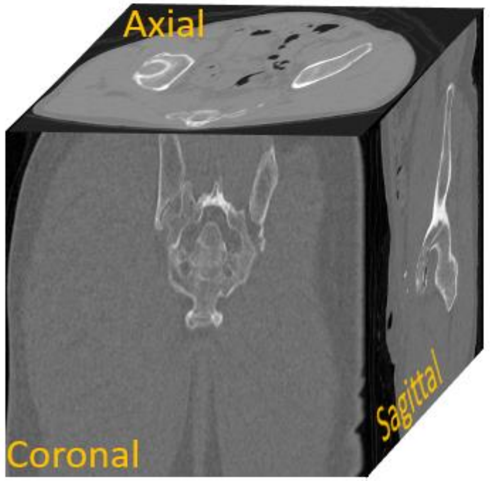
X-ray



Computed Tomography (CT)







Part 2
What is image processing?!

What is image processing?!

- Process: To perform operations on images
- Objective
  - ✓ To process/enhance images
  - ✓ To extract meaningful information

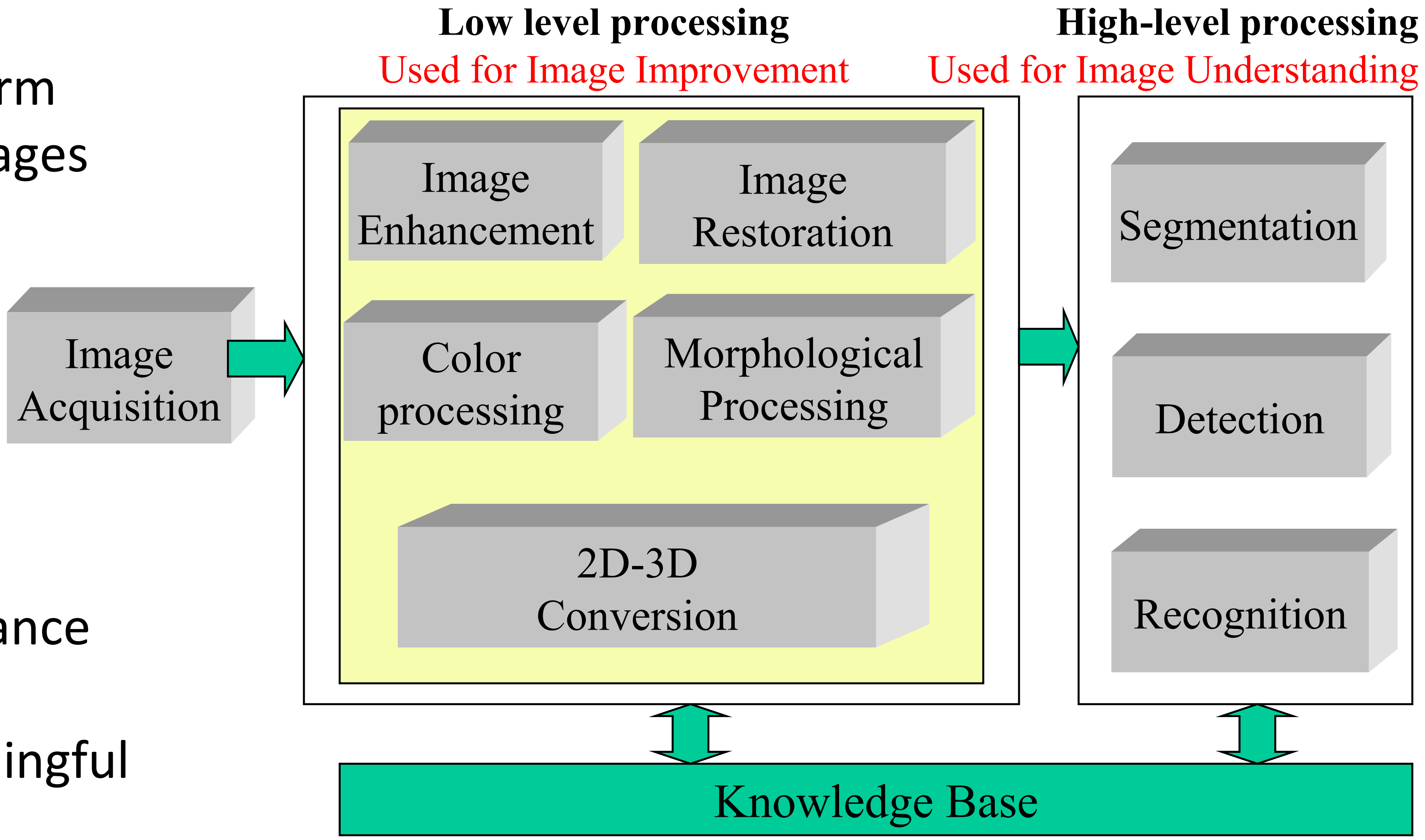


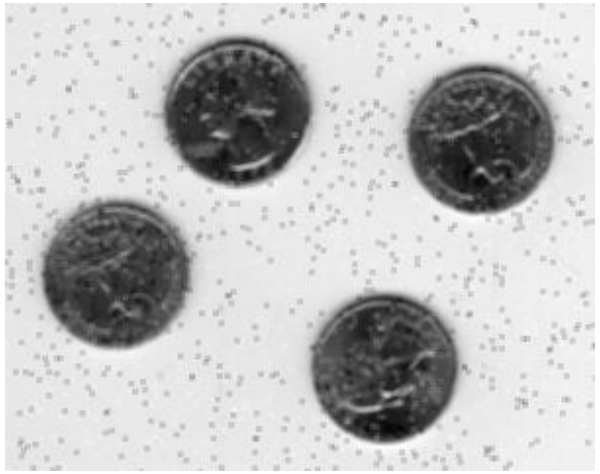
Image Restoration

- ❑ Process of recovering or reconstructing an image
  - ➢ To improve image quality
  - ➢ To recover lost information

- ❑ Methods –
  - ➢ Noise removal
  - ➢ Deblurring
  - ➢ Interpolation
  - ➢ Fourier Transform-Based Methods

Image Restoration

- Noise Removal Techniques -
  - **Mean Filtering**: Reduces noise by averaging the pixel values in a neighborhood.
  - **Median Filtering**: Removes noise while preserving edges by replacing each pixel with the median of its neighborhood.
  - **Wiener Filtering**: A frequency-domain technique that minimizes mean square error between the restored and original image.



Noisy image

Restored image

Image Restoration

- Deblurring Techniques
  - **Inverse Filtering**: Reverses the degradation caused by blurring but is sensitive to noise.
  - **Regularized Filtering**: Adds constraints to inverse filtering to make it robust against noise.
  - **Blind Deconvolution**: Restores the image without prior knowledge of the blur kernel (the degradation function).

Blur

Deblur

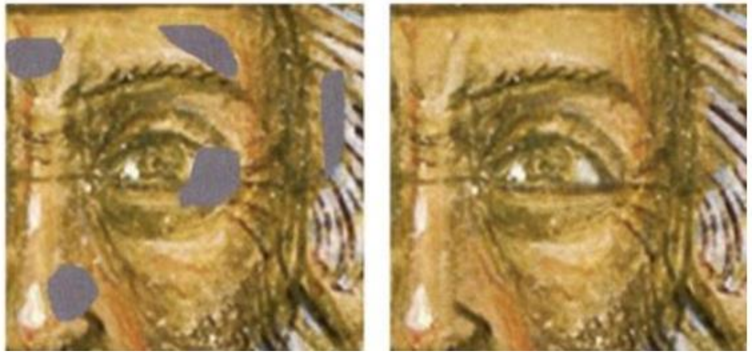
Image Restoration

- Fourier Transform-Based Methods
  - Operate in the frequency domain to address periodic degradation or blur.
  - Examples: High-pass filtering for edge sharpening, low-pass filtering for noise reduction.
- Interpolation-Based Techniques
  - Used for restoring images with missing pixels or incomplete regions (e.g., inpainting).

Image **Restored image**

Fourier space

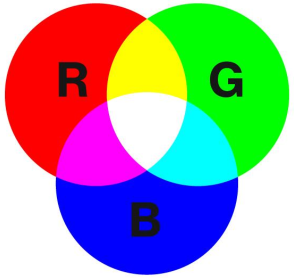
Image **Restored image**

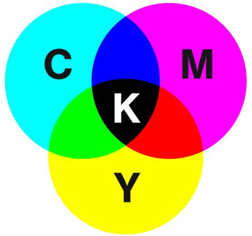


Color Processing

- ❑ Manipulating color information
  - ➢ Color enhancement
  - ➢ Color correction

- ❑ Methods –
  - ➢ RGB (Red, Green, Blue)
  - ➢ CMYK (Cyan, Magenta, Yellow, Black)
  - ➢ HSV (Hue, Saturation, Value)





Color Processing

- RGB (Red, Green, Blue)
  - A widely used additive model where colors are created by combining different intensities of red, green, and blue.
  - Used in displays, cameras, and computer graphics.
- CMYK (Cyan, Magenta, Yellow, Black)
  - A subtractive color model used in printing.
  - Colors are created by subtracting light from white using cyan, magenta, and yellow.
- HSV (Hue, Saturation, Value)
  - A cylindrical model that represents color based on human perception.
  - Hue: Represents the color type.
  - Saturation: Represents the intensity or purity of the color.
  - Value: Represents the brightness.

Color Processing

CMYK to RGB

$$R = 255 \times (1 - C) \times (1 - K)$$
$$G = 255 \times (1 - M) \times (1 - K)$$
$$B = 255 \times (1 - Y) \times (1 - K)$$

RGB to CMYK

$$R' = R/255$$

$$G' = G/255$$

$$B' = B/255$$

$$K = 1 - \max(R', G', B')$$

$$C = (1 - R' - K) / (1 - K)$$

$$M = (1 - G' - K) / (1 - K)$$

$$Y = (1 - B' - K) / (1 - K)$$

Color Processing

RGB to HSV

only one

$$R' = R/255 \qquad G' = G/255 \qquad B' = B/255$$

max

$$C_{max} = \max(R', G', B')$$
$$C_{min} = \min(R', G', B')$$
$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0^\circ & \Delta = 0 \\ 60^\circ \times \left(\frac{G'-B'}{\Delta} mod 6\right) & , C_{max} = R' \\ 60^\circ \times \left(\frac{B'-R'}{\Delta} + 2\right) & , C_{max} = G' \\ 60^\circ \times \left(\frac{R'-G'}{\Delta} + 4\right) & , C_{max} = B' \end{cases}$$

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases}$$

$$V = C_{max}$$

HSV to RGB

$$C = V \times S$$
$$X = C \times (1 - |(H / 60^\circ)\, mod\, 2 - 1|)$$
$$m = V - C$$

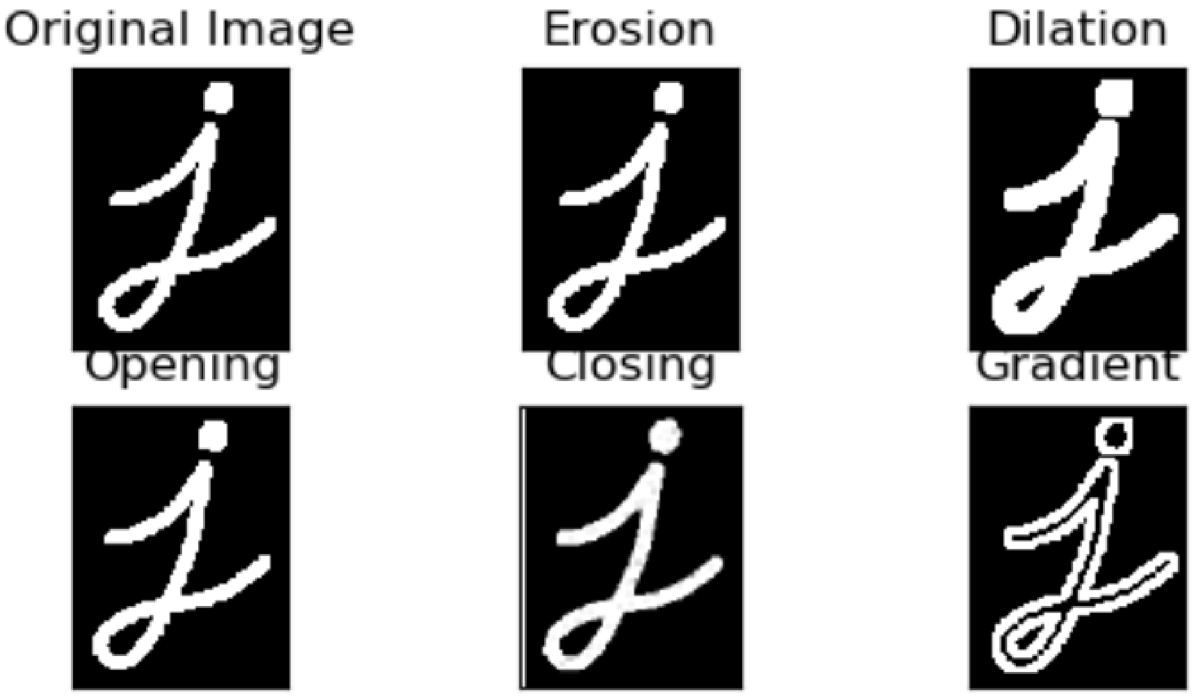
$$(R', G', B') = \begin{cases} (C, X, 0) & , 0^\circ \leq H < 60^\circ \\ (X, C, 0) & , 60^\circ \leq H < 120^\circ \\ (0, C, X) & , 120^\circ \leq H < 180^\circ \\ (0, X, C) & , 180^\circ \leq H < 240^\circ \\ (X, 0, C) & , 240^\circ \leq H < 300^\circ \\ (C, 0, X) & , 300^\circ \leq H < 360^\circ \end{cases}$$

$$(R, G, B) = ((R' + m) \times 255, (G' + m) \times 255, (B' + m) \times 255)$$

Morphological Processing

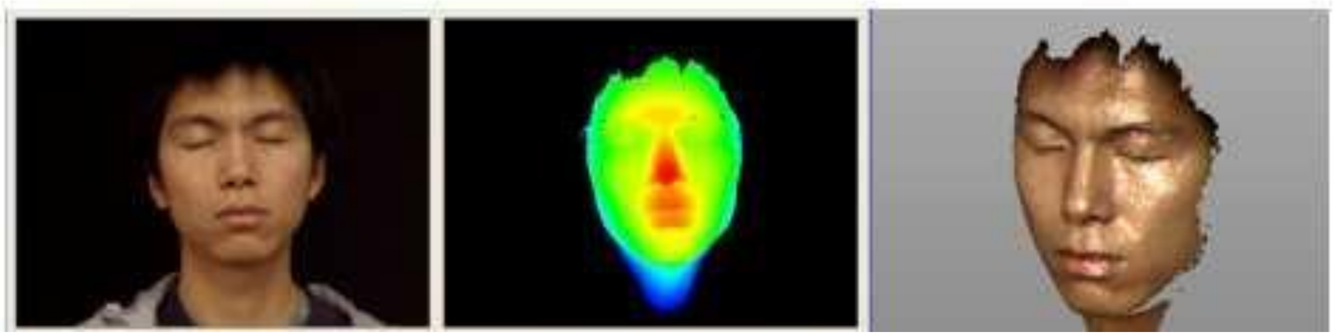
- Processing based on shape/structure
  - To enhance shape/structure
  - To extract features of shape/structure

- Methods –
  - Erosion
  - Dilation
  - Opening (Erosion + Dilation)
  - Closing (Dilation + Erosion)
  - Gradient (Difference of Dilation and Erosion)



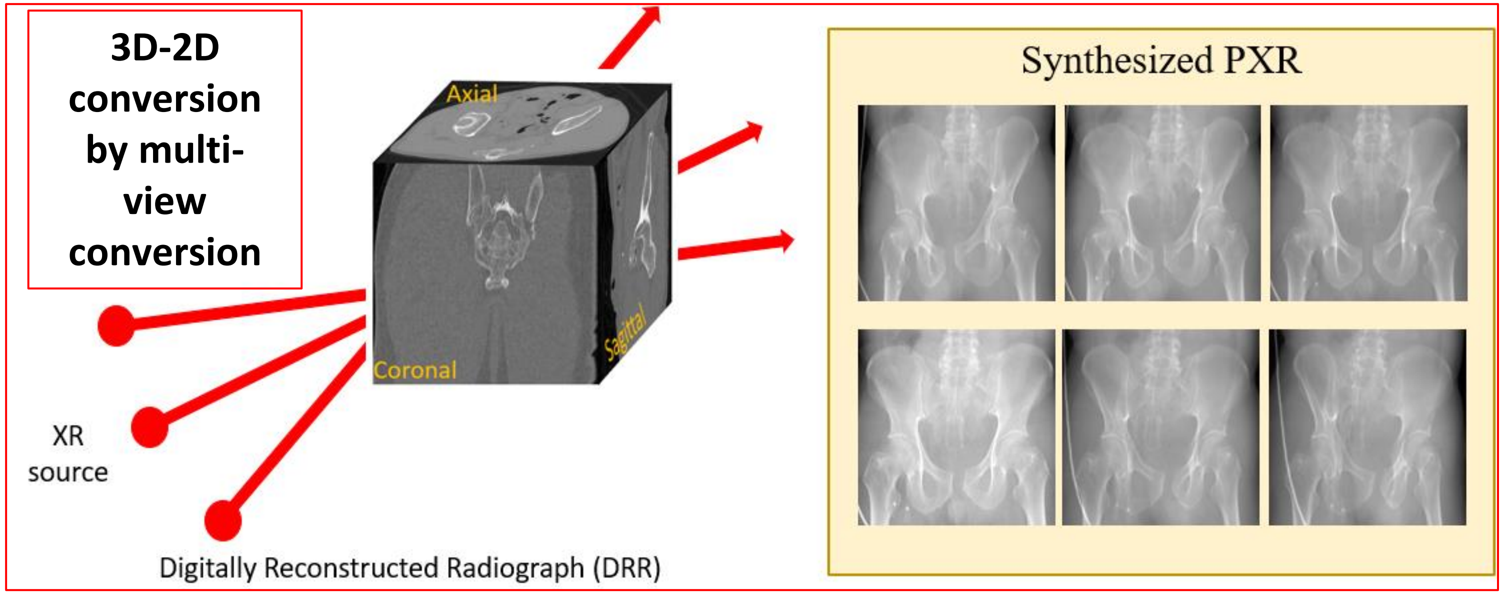
2D-3D Conversion

- Converting 2D from 3D and vice-versa
  - To visualize
  - To analyze



2D-3D conversion by depth mapping**

- Methods –
  - Depth mapping
  - Multi-view Conversion



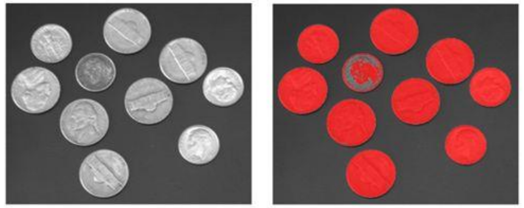
3D-2D conversion by multi-view conversion

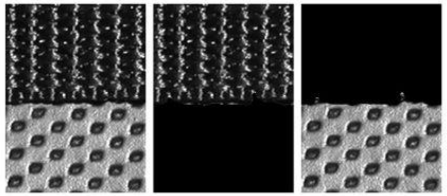
**Colbry, D., Stockman, G. and Jain, A., 2005, September. Detection of anchor points for 3d face veri. cation. In *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05)-Workshops* (pp. 118-118). IEEE.

Segmentation

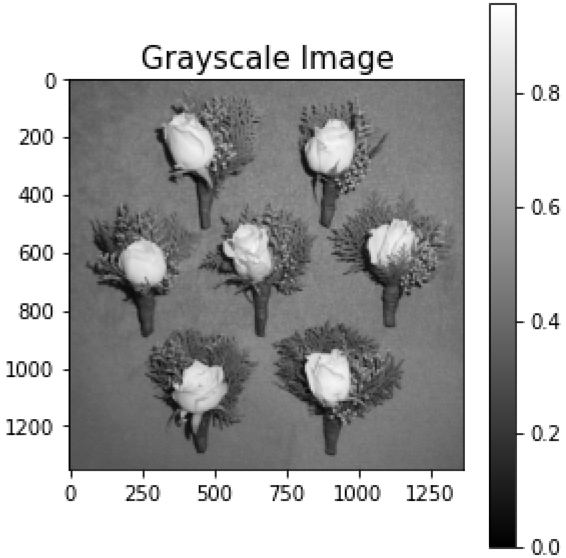
- ❑ Divide an image into meaningful regions -
  - ➢ To simplify analysis
  - ➢ To extract feature

Region-based segmentation based on color, shape, and texture

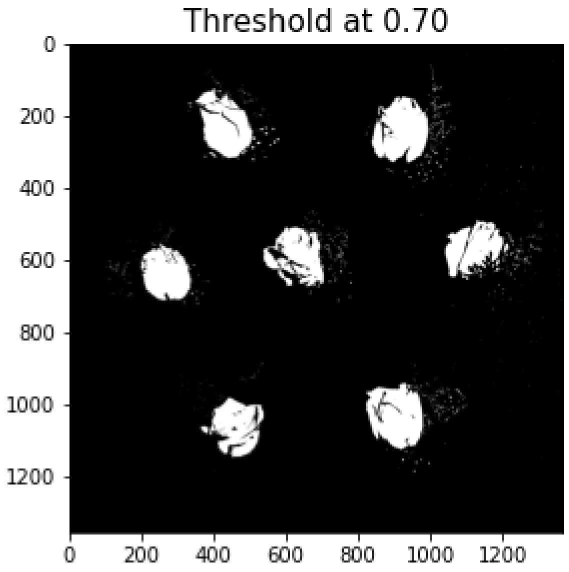


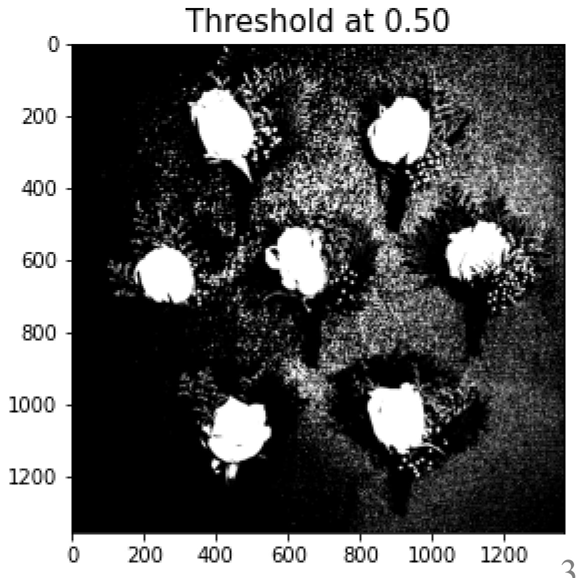


- ❑ Methods –
  - ➢ Threshold-based segmentation
  - ➢ Region-based segmentation
  - ➢ Clustering-based segmentation



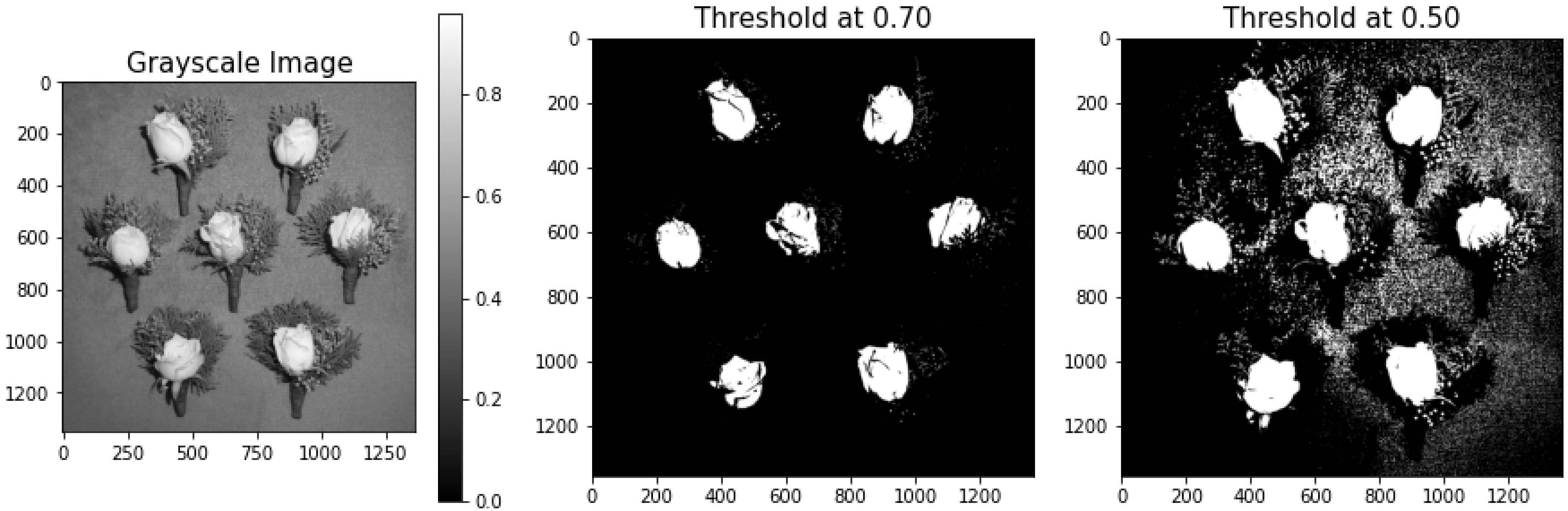
Threshold-based segmenation





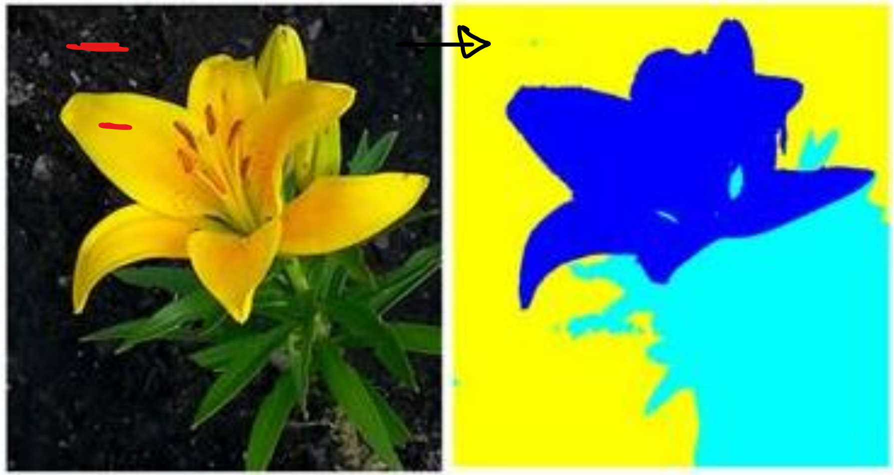
Segmentation – Threshold-based

- ❑ **Method**: Divide an image into regions based on pixel intensity values.
- ❑ **Types**:
  - ➢ Global Thresholding: Use a single threshold value for the entire image.
  - ➢ Adaptive Thresholding: Use different thresholds for different regions based on local properties.
- ❑ **Applications**: Separating objects from the background in grayscale images.
- ❑ **Advantages**: Simple and fast.
- ❑ **Disadvantages**: Ineffective for images with varying lighting conditions.



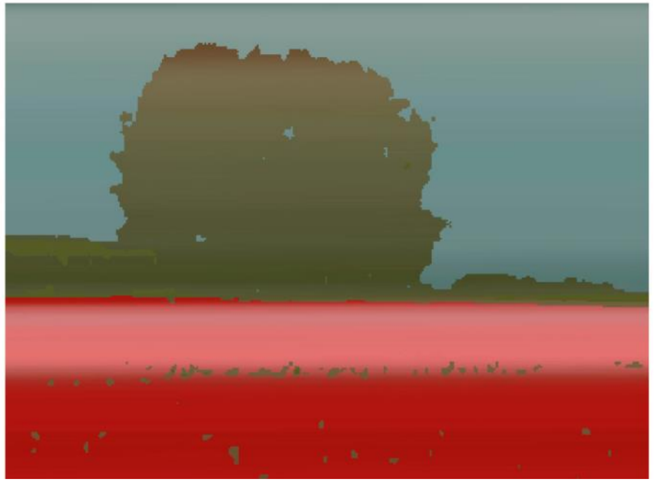
Segmentation – Region-based

- **Method**: Group pixels with similar properties (e.g., intensity, color, texture).
- **Techniques**:
  - Region Growing: Start from a seed pixel and grow the region by adding neighboring pixels with similar characteristics.
  - Region Splitting and Merging: Split an image into smaller regions, then merge adjacent regions based on similarity.
- **Applications**: Segmenting homogeneous areas.
- **Advantages**: Can handle noise better than threshold-based methods.
- **Disadvantages**: Computationally intensive.



Segmentation – Clustering-based

- **Method**: Treat segmentation as a clustering problem where similar pixels are grouped into clusters.
- **Techniques**:
  - K-Means Clustering: Group pixels into K clusters based on features like intensity or color.
  - Fuzzy C-Means: Allows pixels to belong to multiple clusters with varying degrees of membership.
- **Applications**: Separating objects with varying intensities or colors.
- **Advantages**: Effective for complex images.
- **Disadvantages**: Requires manual selection of the number of clusters.

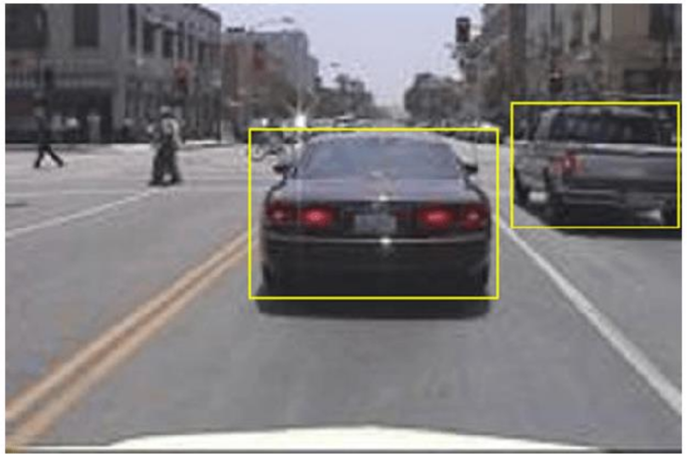


Detection

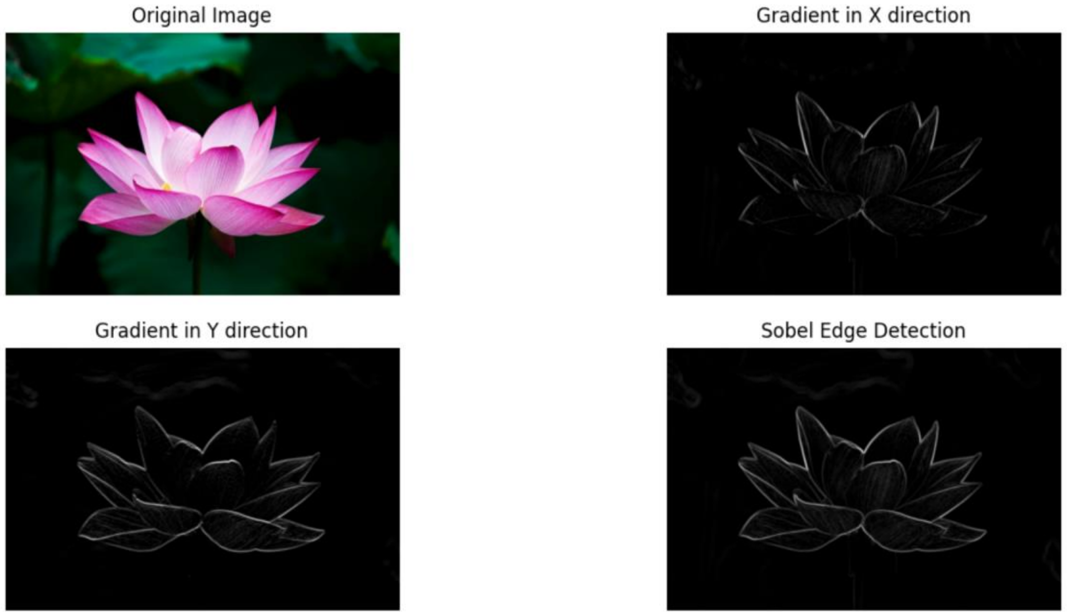
- Identify specific features, patterns, or objects -
  - To simplify analysis
  - To extract objects/features

- Methods –
  - Edge detection
  - Corner detection
  - Object detection

Object detection



Edge detection

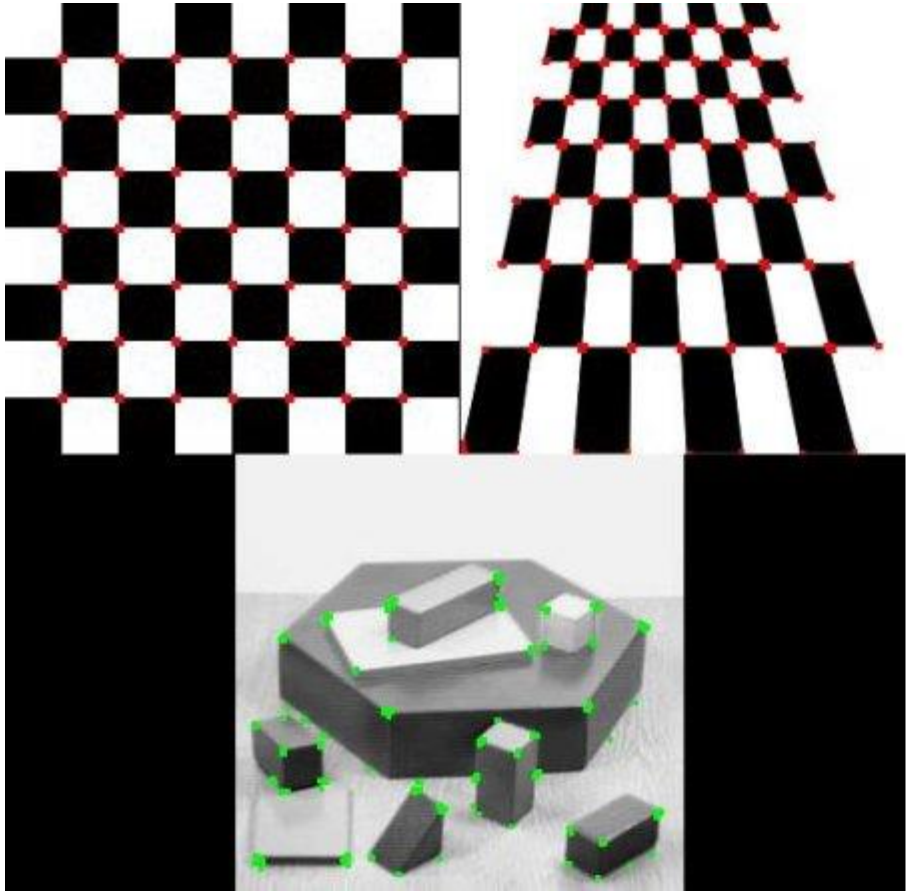


Detection - Edge

- **Purpose**: Identify discontinuities in pixel intensity to locate object boundaries.
- **Techniques**:
  - Sobel Operator: Detects edges by calculating the gradient of image intensity.
  - Canny Edge Detection: A multi-step process involving noise reduction, gradient calculation, and edge tracing.
- **Applications**: Object segmentation, image enhancement, and feature extraction.
- **Disadvantage**: Fails when edges are not clear.

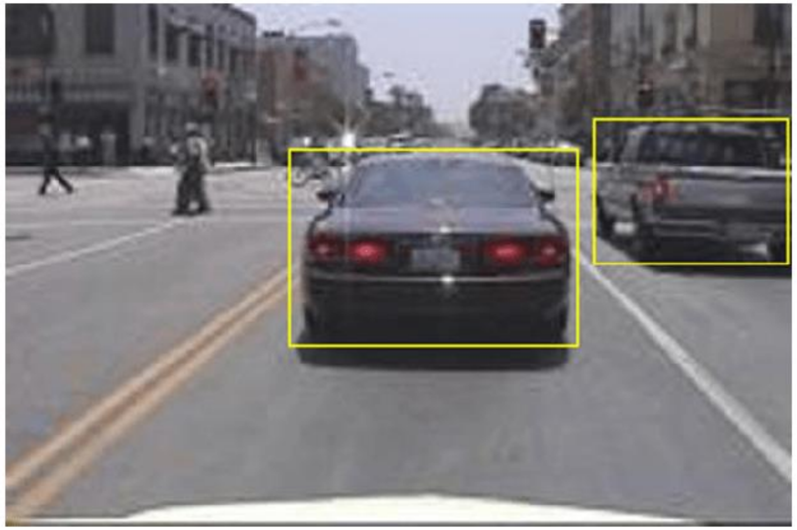
Detection - Corner

- **Purpose**: Identify points where two edges meet, useful for tracking and feature matching.
- **Techniques**:
  - Harris Corner Detector: Measures changes in intensity in all directions to find corners.
  - Shi-Tomasi Detector: Improves upon the Harris detector for better accuracy.
- **Applications**: Motion tracking, image stitching, and 3D reconstruction.
- **Disadvantage**: Fails for objects with smooth edge.



Detection - Object

- **Purpose**: Recognize and localize objects within an image.
- **Techniques**:
  - Statistical methods: Use pixel intensity distributions to detect objects.
  - Feature-based methods: Apply HOG, MIFT etc. to detect objects based or shapes.
- **Applications**: Facial recognition, autonomous driving, and video surveillance.
- **Disadvantage**: Fails when shapes of each objects are close to each other.



Recognition

- ❑ identifies and classifies objects, patterns, or features -
  - ➢ To identify object
  - ➢ To classify images

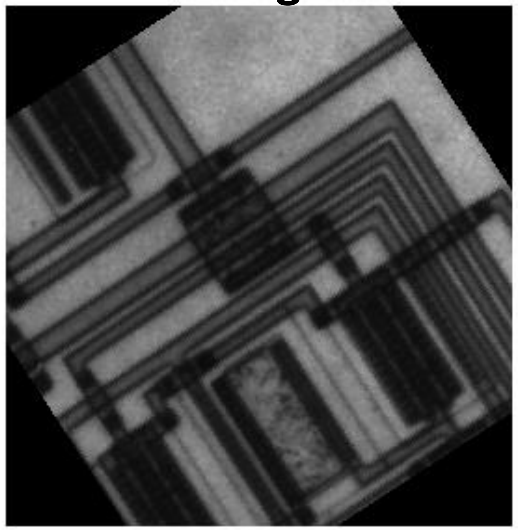
- ❑ Methods –
  - ➢ HOG (Histogram of Oriented Gradients)
  - ➢ Template matching

Recognition-Hogue transform

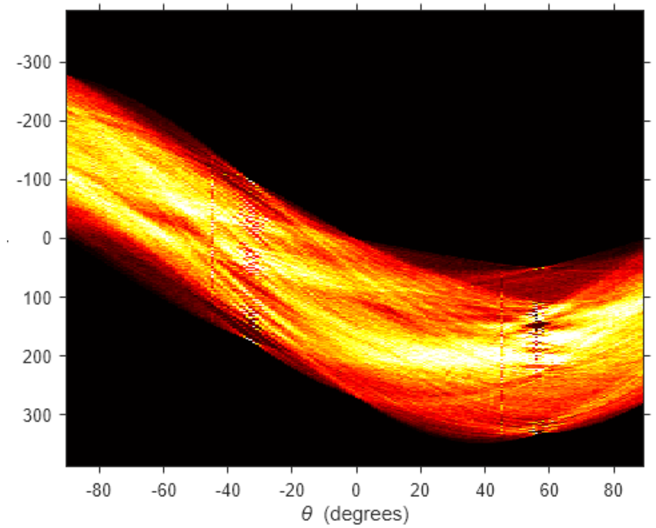
- **Purpose**: Detect lines in an image.
- **Techniques**: Calculate gradients of edge orientations.
- **Applications**: Line follower robot.
- **Disadvantage**: Can recognize lines only.

$$\rho = x\cos\theta + y\sin\theta$$

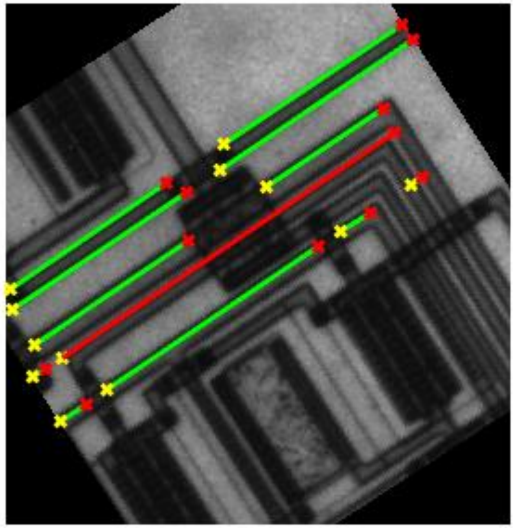
Image



Hogue transform matrix



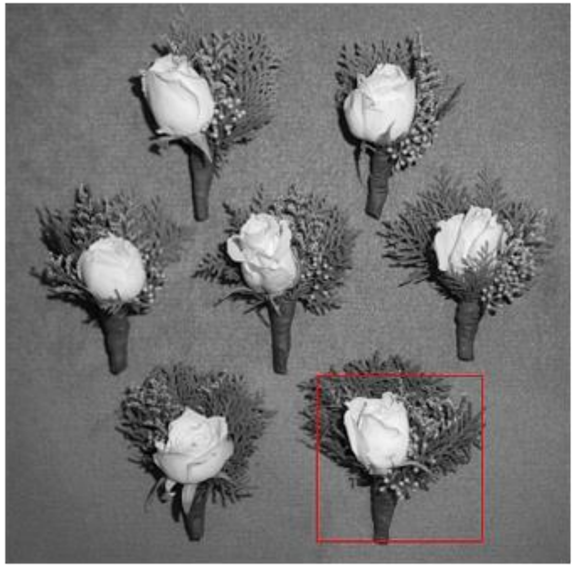
Detected lines on the image



Recognition-Template matching

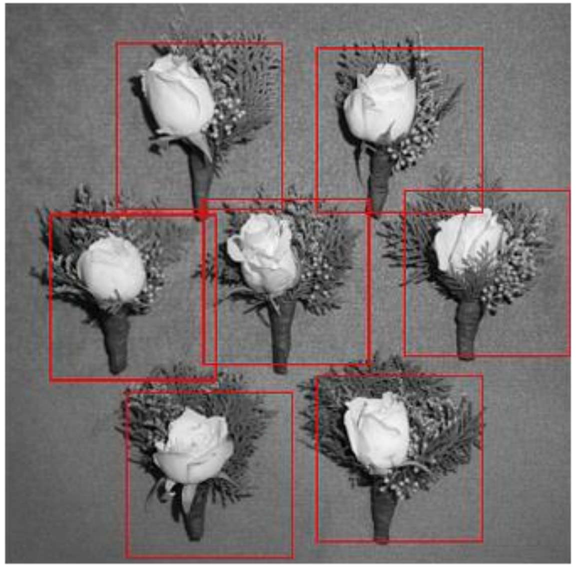
- **Purpose**: Detect objects in an image.
- **Techniques**: Calculate similarity index of different patches with the template.
- **Applications**: Object detection, object tracking.
- **Disadvantage**: Needs template to recognize objects.

Image



Template

Template matching

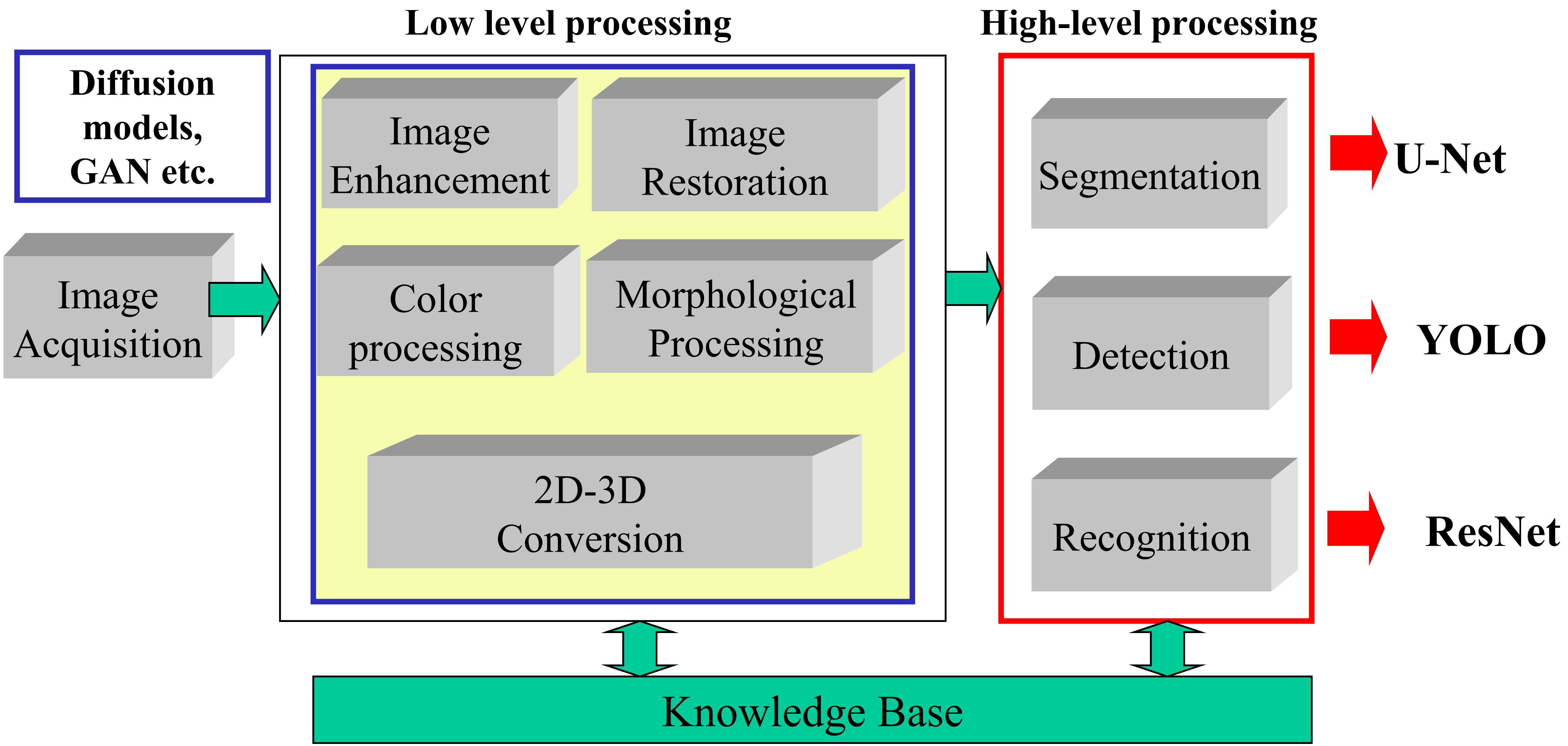


Application of image processing

- **Medical Imaging**: MRI, CT scans, and X-ray analysis.
- **Remote Sensing**: Satellite image analysis for weather forecasting or environmental monitoring.
- **Computer Vision**: Applications like facial recognition, autonomous vehicles, and robotics.
- **Entertainment**: Image editing and effects in photography and films.
- **Security**: Biometrics, surveillance, and intrusion detection.

Image processing

Image processing can be done by **Artificial Intelligence (AI)**.

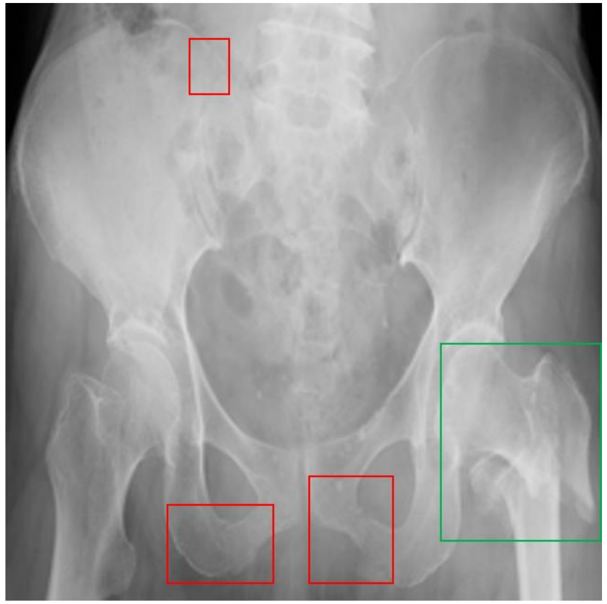


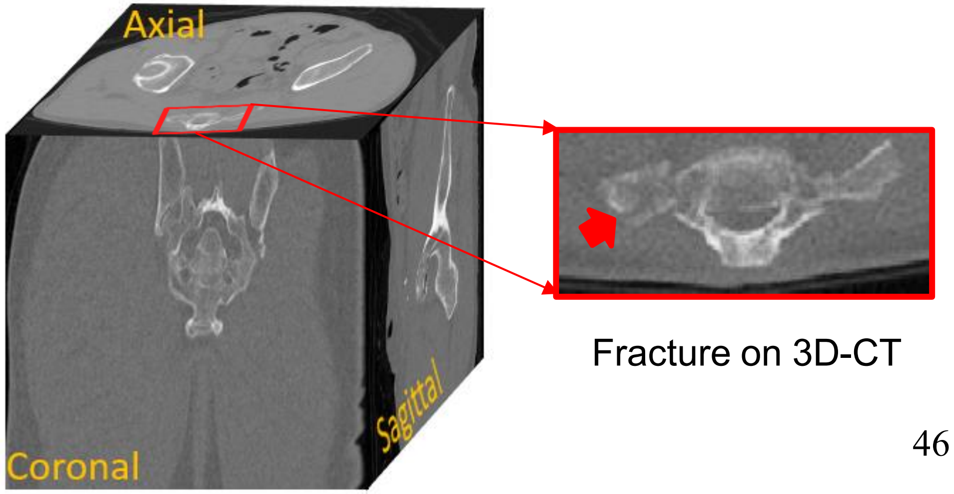
Part 3
Real-life problem-solving using image processing

Pelvic fracture

- Diagnostic method -
  - **Pelvic X-ray (PXR) – Initial diagnosis**
  - Computed tomography (CT) – Subsequent screening and difficult cases
- Characteristics of PXR -
  - 2D image of 3D human body
  - Constrained viewing angle, usually anterior-posterior (AP view)
- Challenge - **Some fractures are invisible (e.g. osteoporotic fractures)**

X-ray

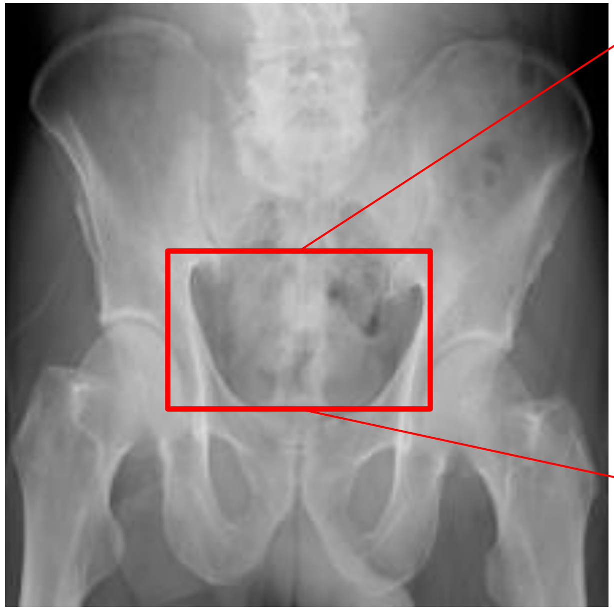




Fracture on 3D-CT

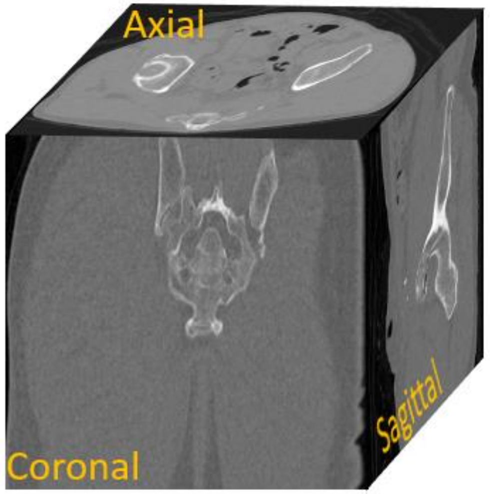
Invisible fracture on PXR can be detected on 3D-CT

PXR

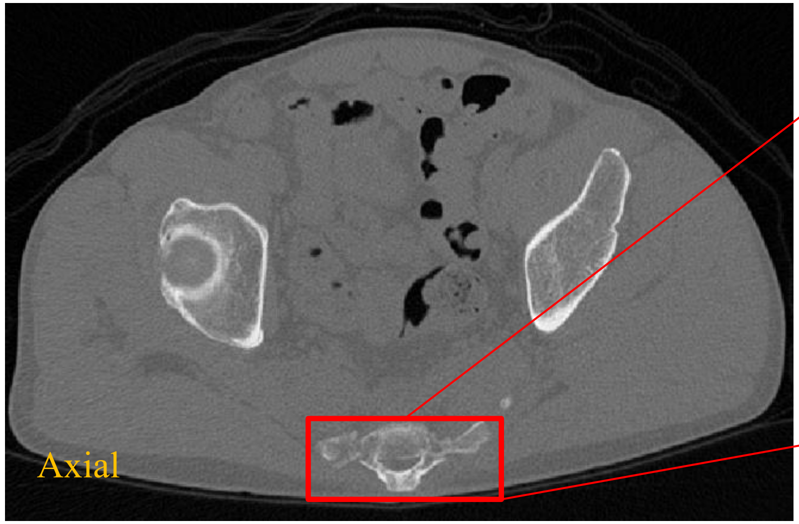


Fracture location on PXR

Fracture can’t be seen



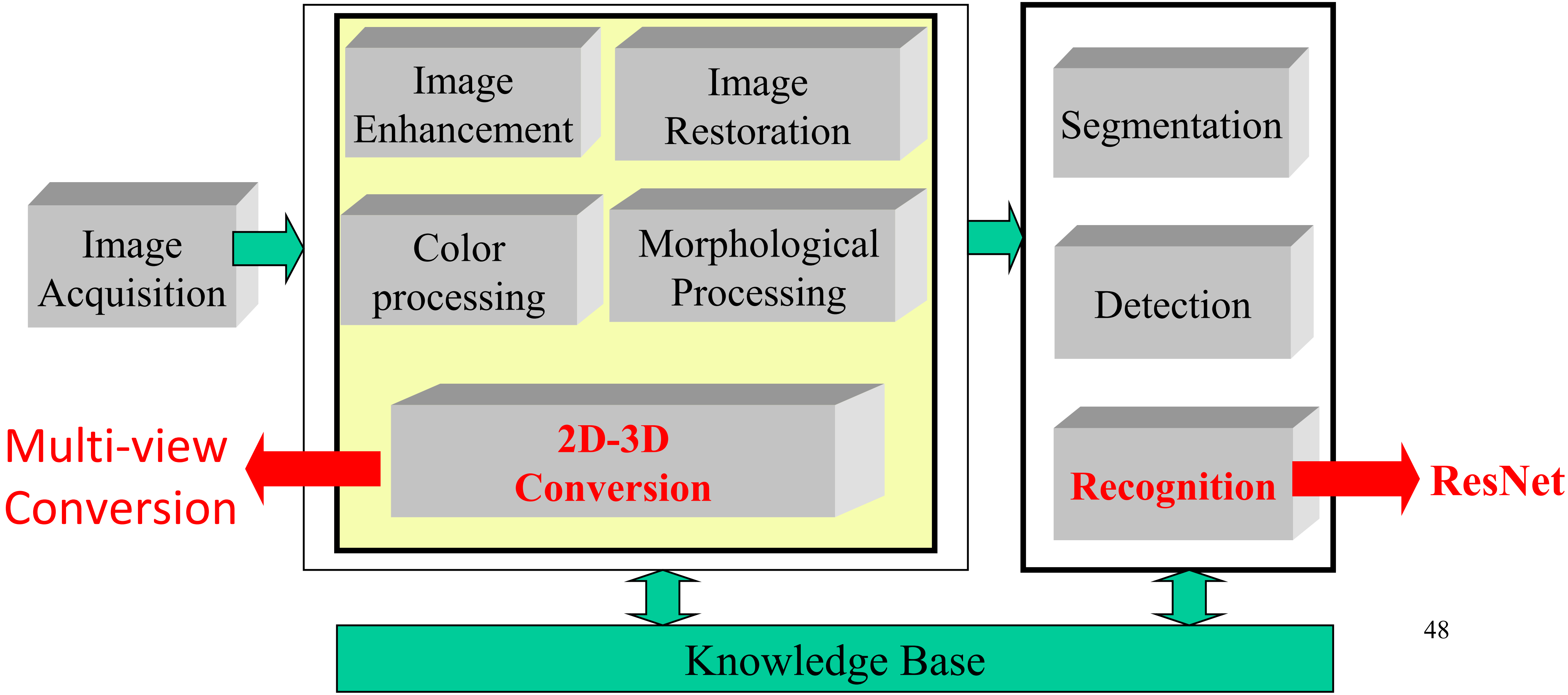
3D-CT



Fracture location on CT

Clearly visible

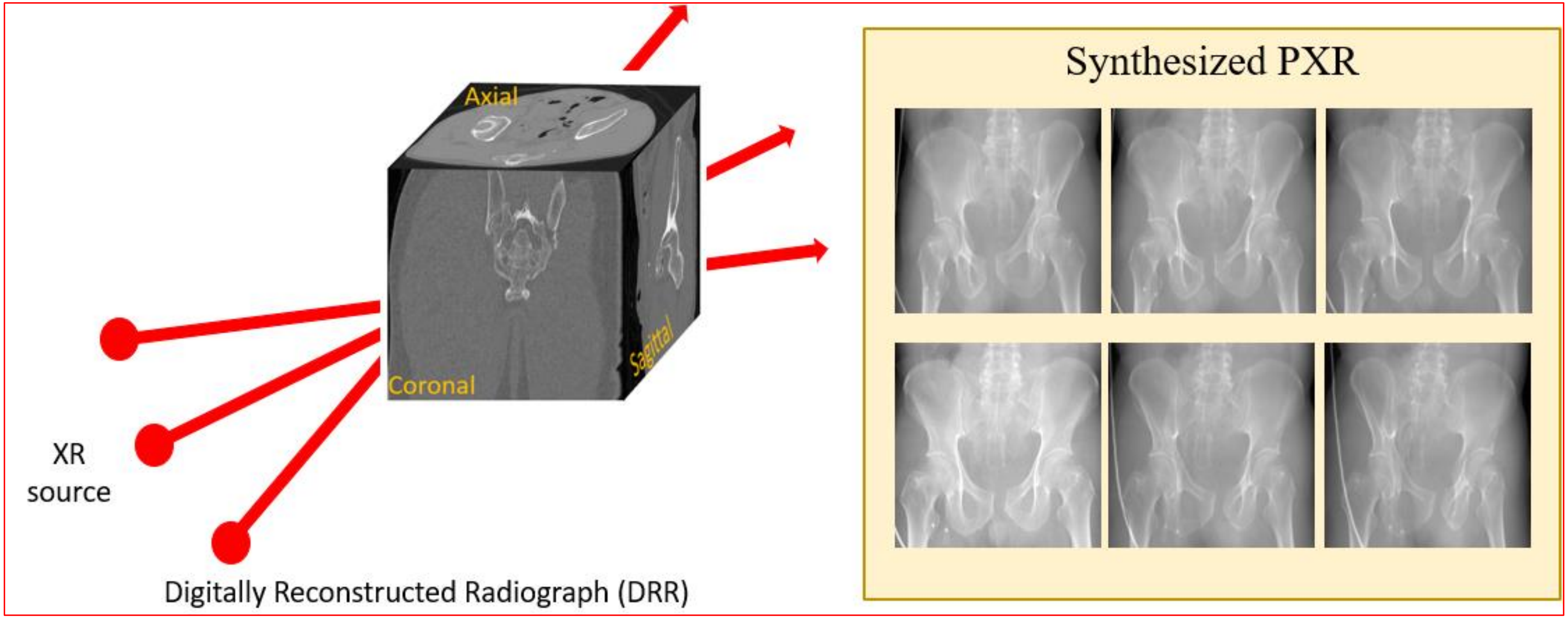
- Can we transfer the information of CT to PXR?
  - ✓ Yes, by applying 3D-2D processing.
- How to distinguish between images with fracture and normal images?
  - ✓ By applying recognition.



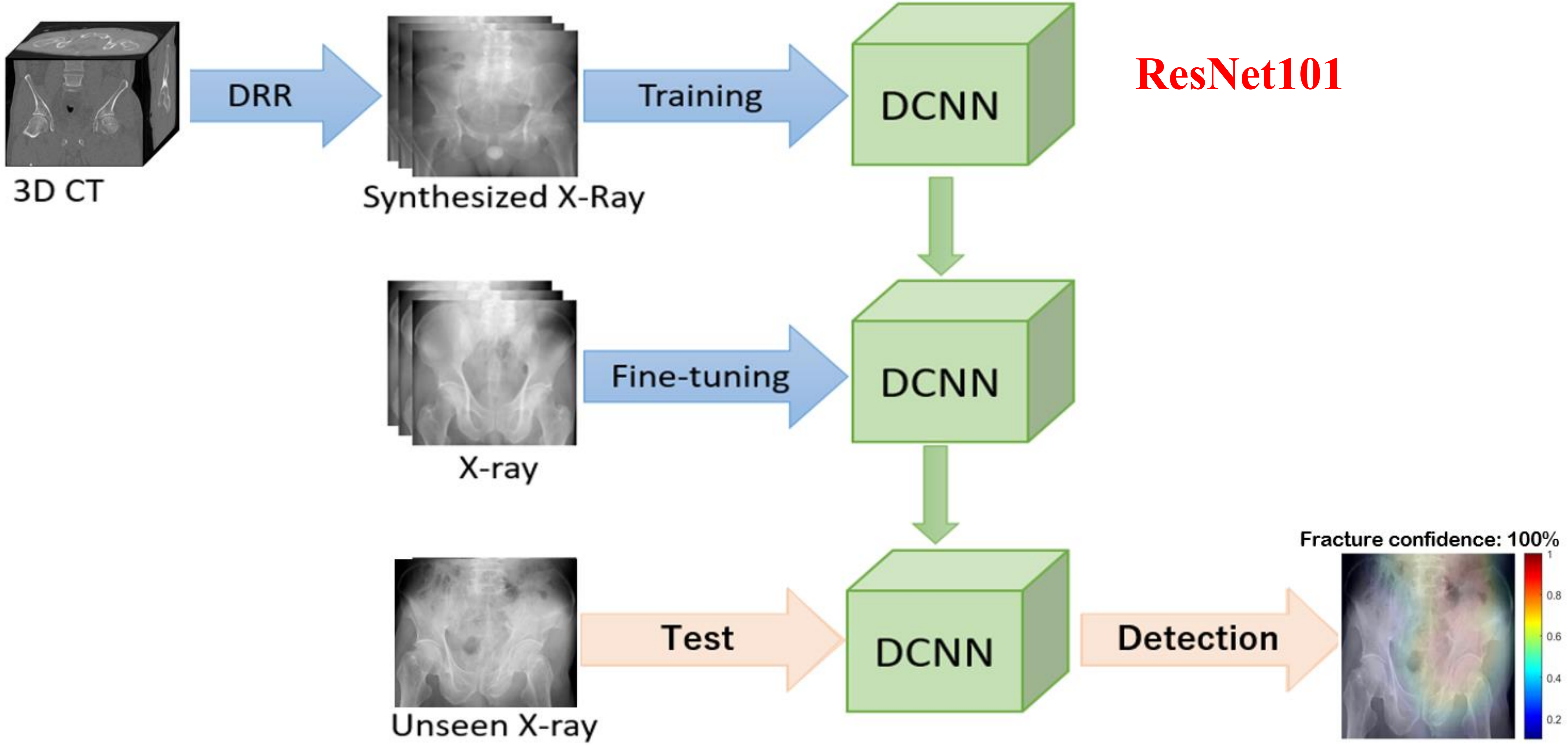
Multi-view conversion

$$x_{drr}(i,j) = \frac{1}{N}\sum_{k=1}^{N} e^{\left(\frac{\alpha}{100}\right)\times\left(\frac{x_{CT}(i,j,k)+1024}{1000}\right)}$$

$$\alpha = Absorption\ coeffeicient$$
$$x_{CT}(i,j,k) = CT\ value\ in\ location\ i,j,k\ of\ CT\ volume$$
$$x_{drr} = Synthesized\ PXR\ value$$

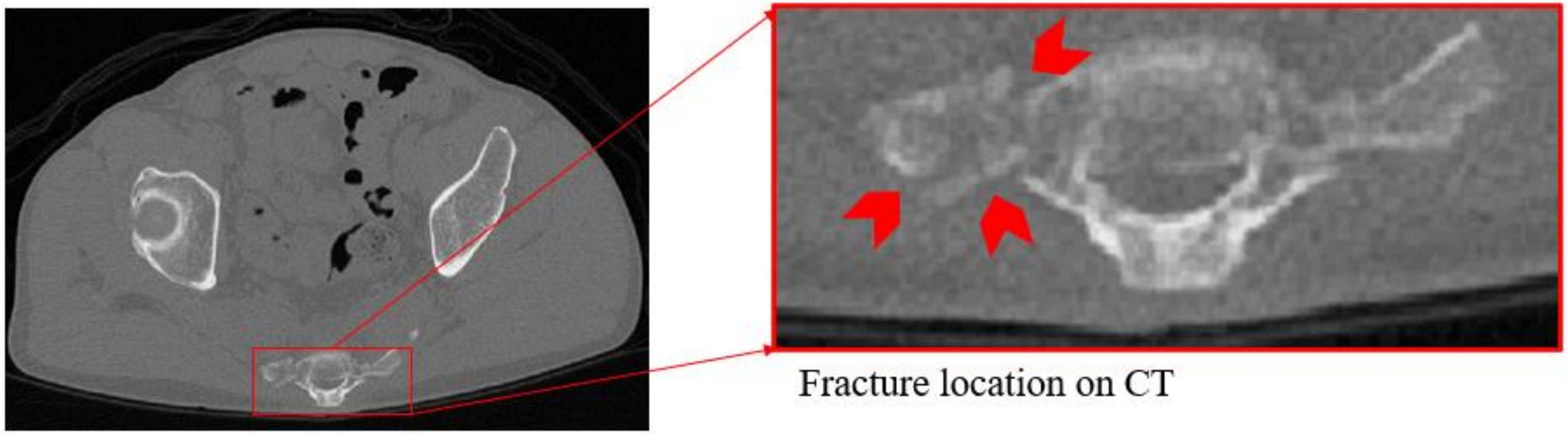


Recognition by AI



ResNet101

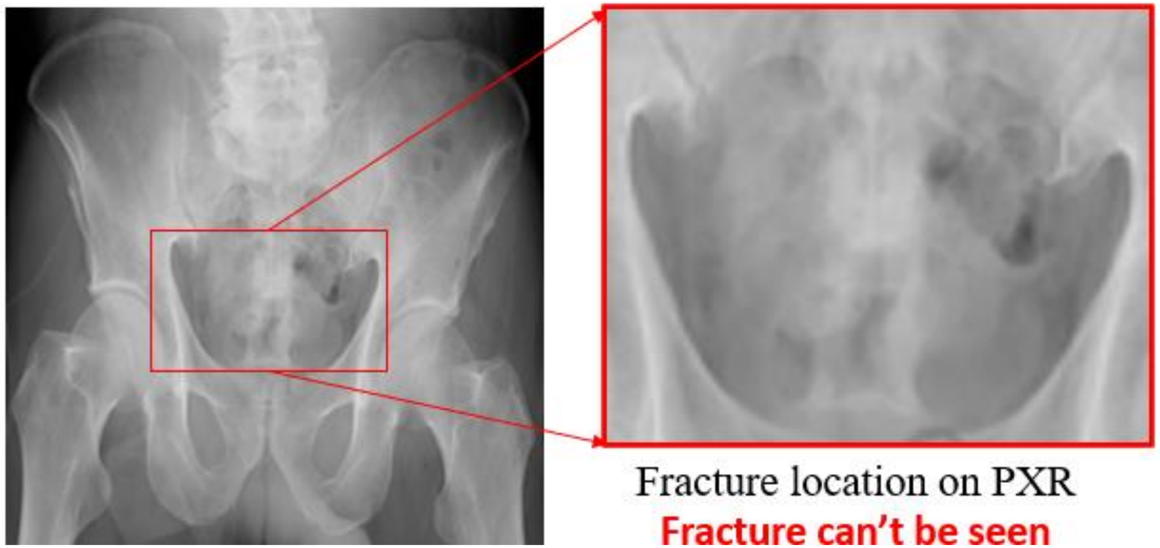
AI can recognize X-ray with invisible fracture.



Fracture location on CT

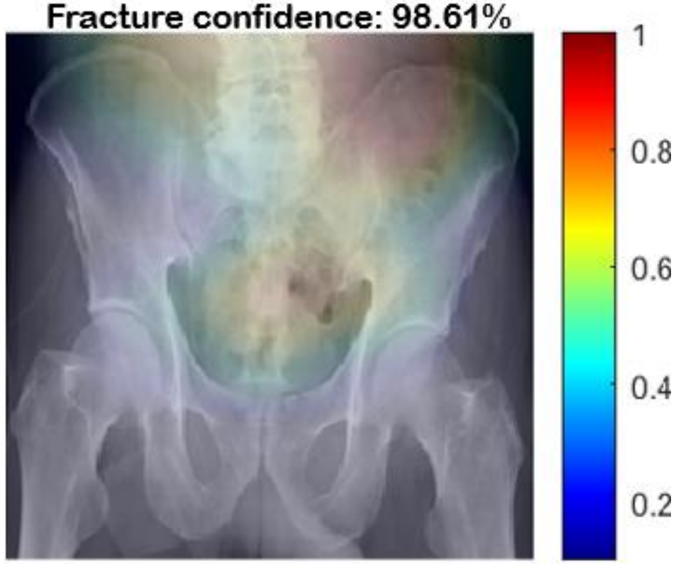
3D-CT Axial view

X-ray



Fracture location on PXR

Fracture can't be seen

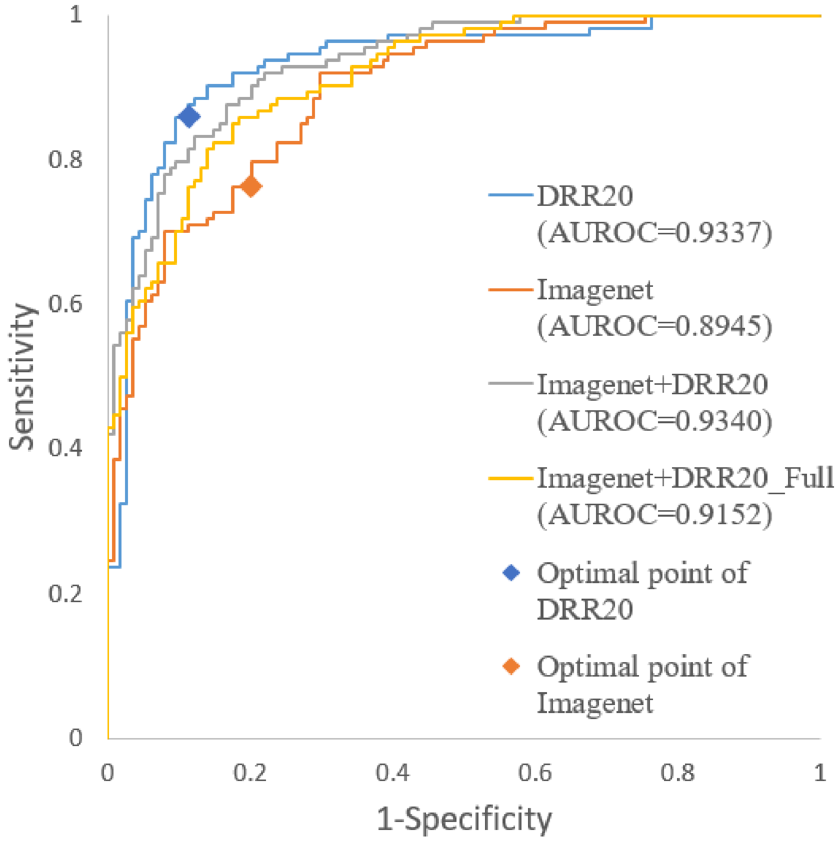


Performance comparison

Visible Fracture Detection

DRR (Proposed method) vs Conventional (ImageNet)

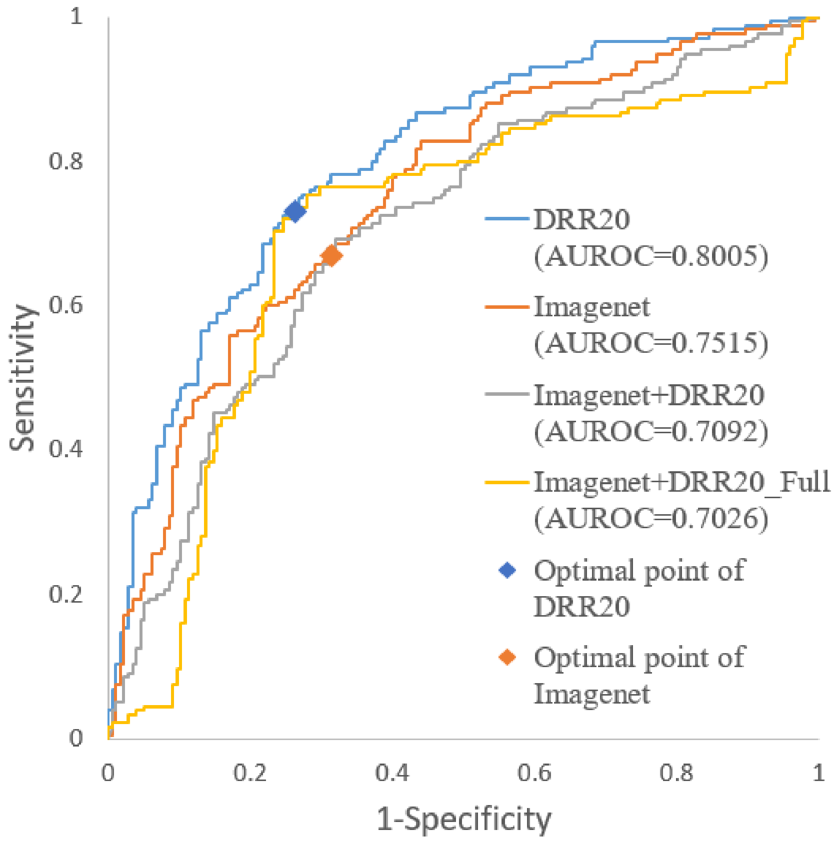
- Sensitivity: **0.9596** vs 0.7632
- Specificity: **0.9859** vs 0.7982



Invisible Fracture Detection

DRR (Proposed method) vs Conventional (ImageNet)

- Sensitivity: **0.8314** vs 0.6685
- Specificity: **0.8371** vs 0.6857



Reference

1. “Digital Image Processing” by Rafael C. Gonzalez and Richard E. Woods. (2018)
2. “Computer Vision: Algorithms and Applications” by Richard Szeliski. (2022)
3. “Digital Image Processing Using MATLAB” by Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins. (2020)
4. “Nonlinear Techniques for Color Image Processing”, S. Bogdan, P. Konstantinos, and V. Anastasios. (2003)
5. “Deep Learning for Medical Image Analysis”, S. K. Zhou, H. Greenspan, D. Shen. (2017)
6. “Practical Machine Learning and Image Processing: For Facial Recognition, Object Detection, and Pattern Recognition Using Python”, by H. Singh. (2019)
7. MATLAB Documentation, https://www.mathworks.com