MEDICAL IMAGING PROCESSING

FOURTH STAGE

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Segmentation in Medical Imaging

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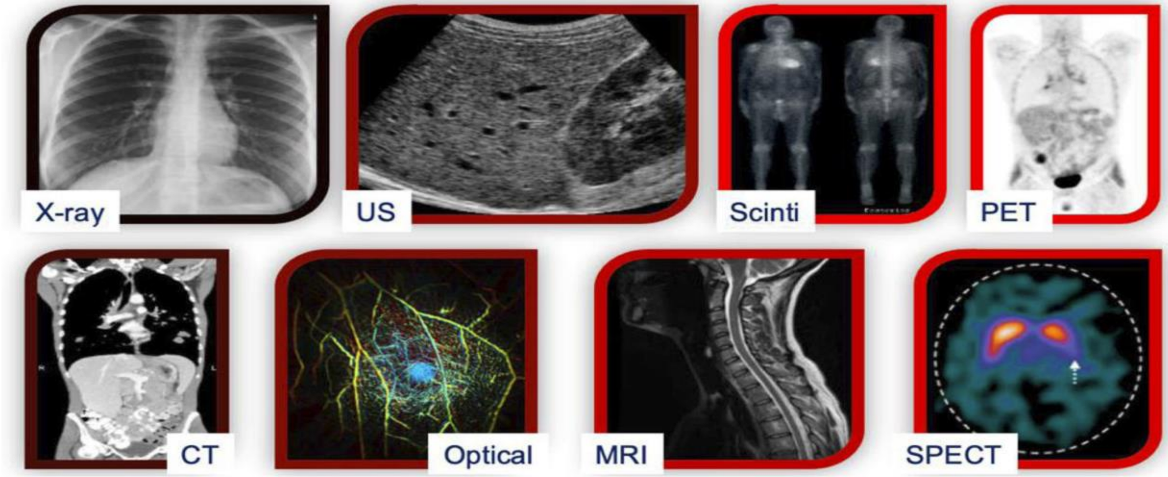
Introduction

Image analysis is an essential part of modern medical imaging. It focuses on extracting meaningful information from various medical image modalities such as X-ray, CT, MRI, and ultrasound.

In medical physics, image analysis helps radiologists and researchers to visualize, measure, and interpret clinical data. It is vital for diagnosis, treatment planning, and follow-up assessment.

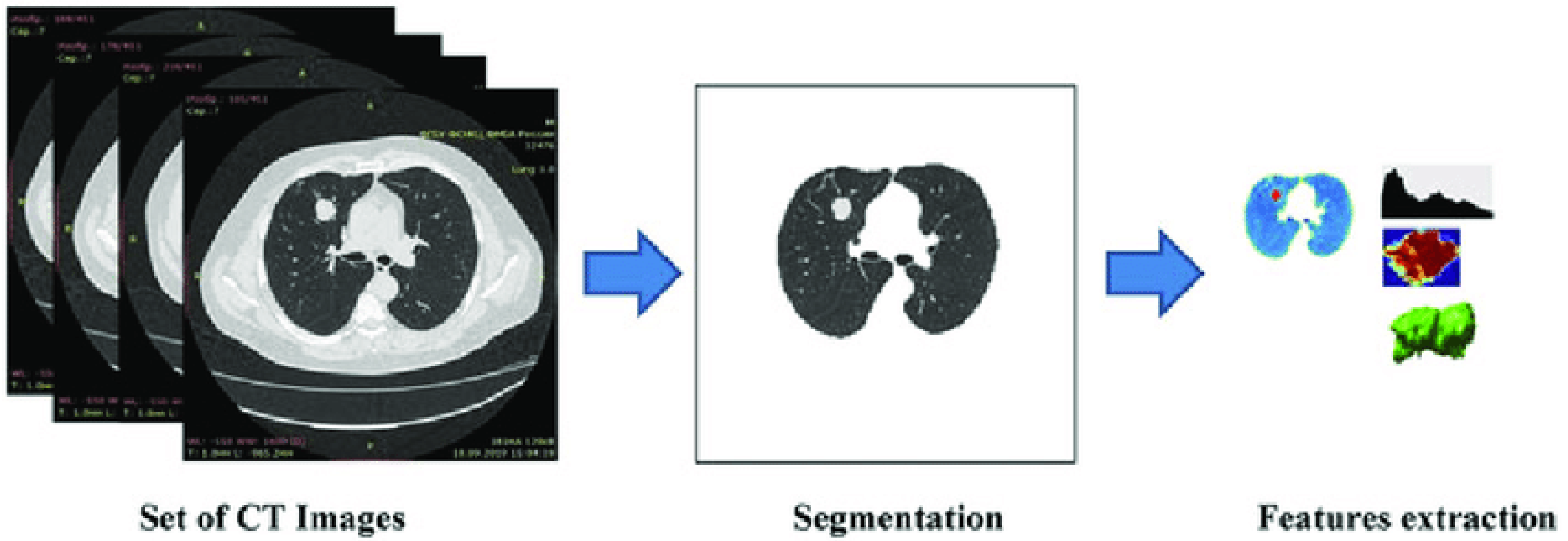
digital image is a 2D function f(x,y), where x and y are spatial coordinates, and f(x,y) represents pixel intensity. Image analysis depends on **relationships between pixels** and their intensity values.



2. Stages of Medical Image Analysis

Medical image analysis generally follows several key stages:

1. Image Acquisition – obtaining the image from a medical imaging device.
2. Image Enhancement – improving visibility and quality.
3. Segmentation – identifying the region of interest (ROI).
4. Quantitative Analysis – extracting numerical measurements.
5. Interpretation – linking image features with medical knowledge.



3. Image Enhancement

Image enhancement aims to improve image clarity by removing noise and increasing contrast. Common methods include:

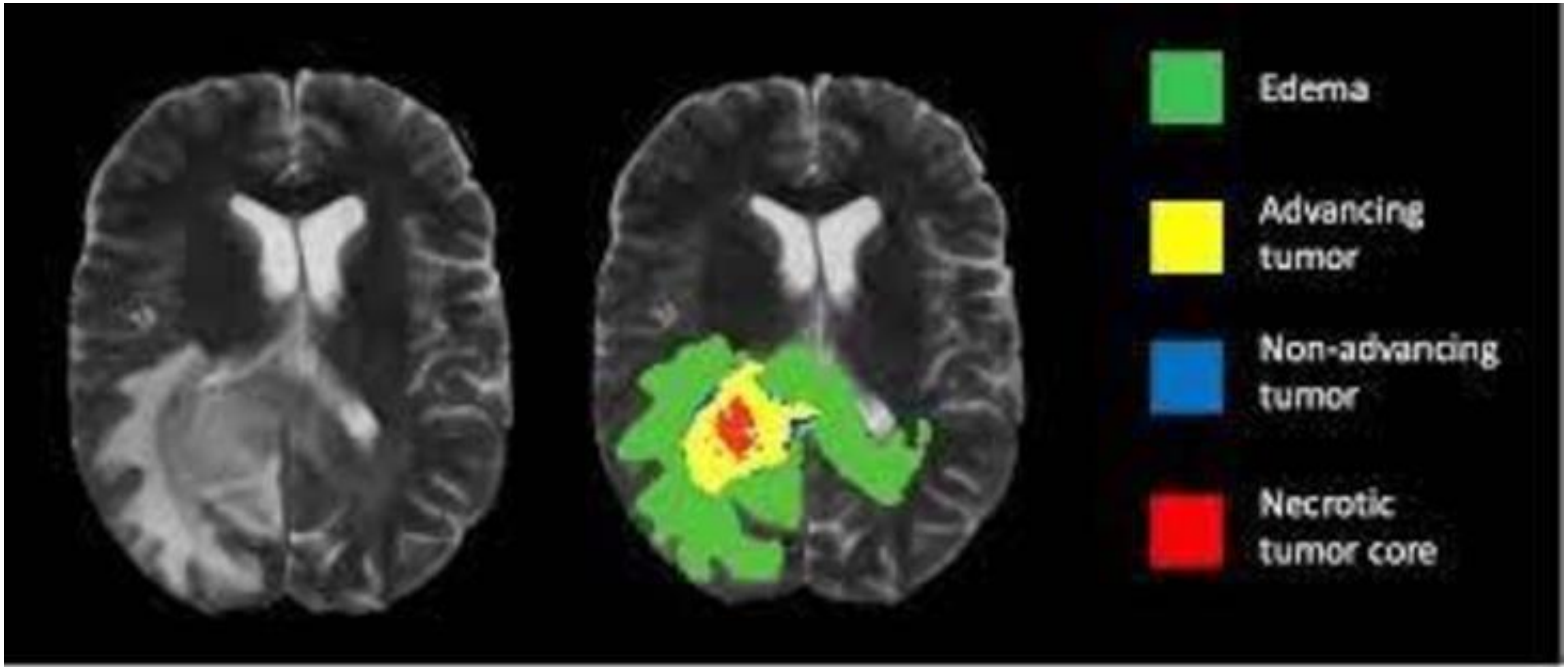
- Histogram Equalization
- Gaussian or Median Filtering
- Contrast Stretching

These methods help highlight structures such as bones or soft tissues before segmentation.

4. Image Segmentation

Image segmentation divides an image into distinct regions representing specific anatomical structures or abnormalities.

It helps in isolating tumors, bones, or fractures for further analysis. Segmentation is a key step toward computer-aided diagnosis (CAD).

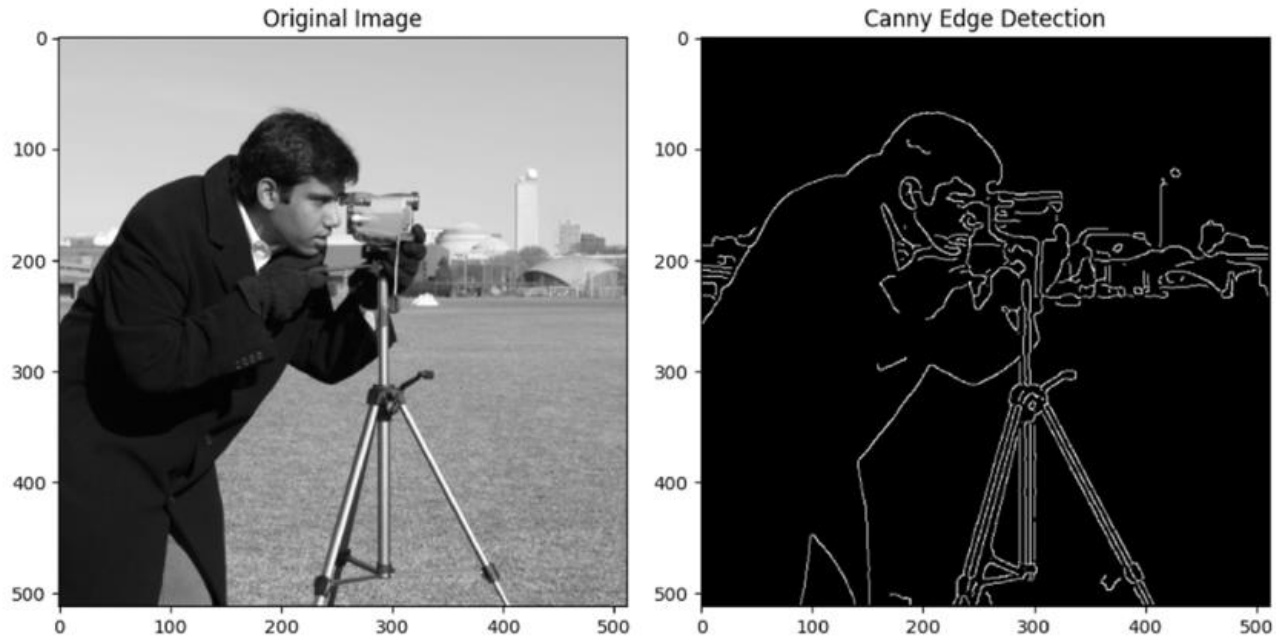


5. Traditional Segmentation Methods

Traditional methods are based on mathematical and image intensity models, including:

- **Thresholding:** is a foundational image processing technique used to create binary images from grayscale or color images.

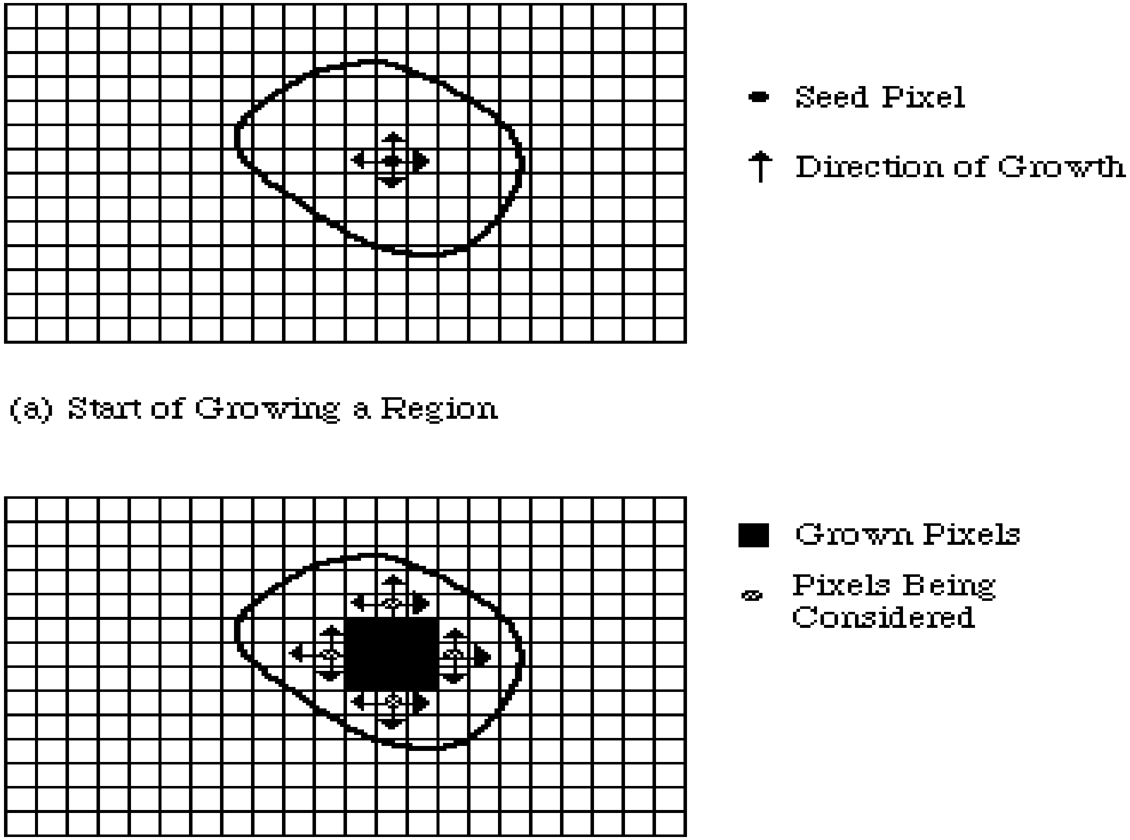
- **Edge Detection (Sobel, Canny):** two widely used edge detection algorithms that identify significant changes in image intensity, which typically correspond to object boundaries.



5. Traditional Segmentation Methods

- **Region Growing**: is a pixel-based image segmentation technique that groups neighboring pixels with similar properties into a larger region.

While simple, these techniques often struggle with low-contrast or noisy medical images



(a) Start of Growing a Region

(b) Growing Process After a Few Iterations

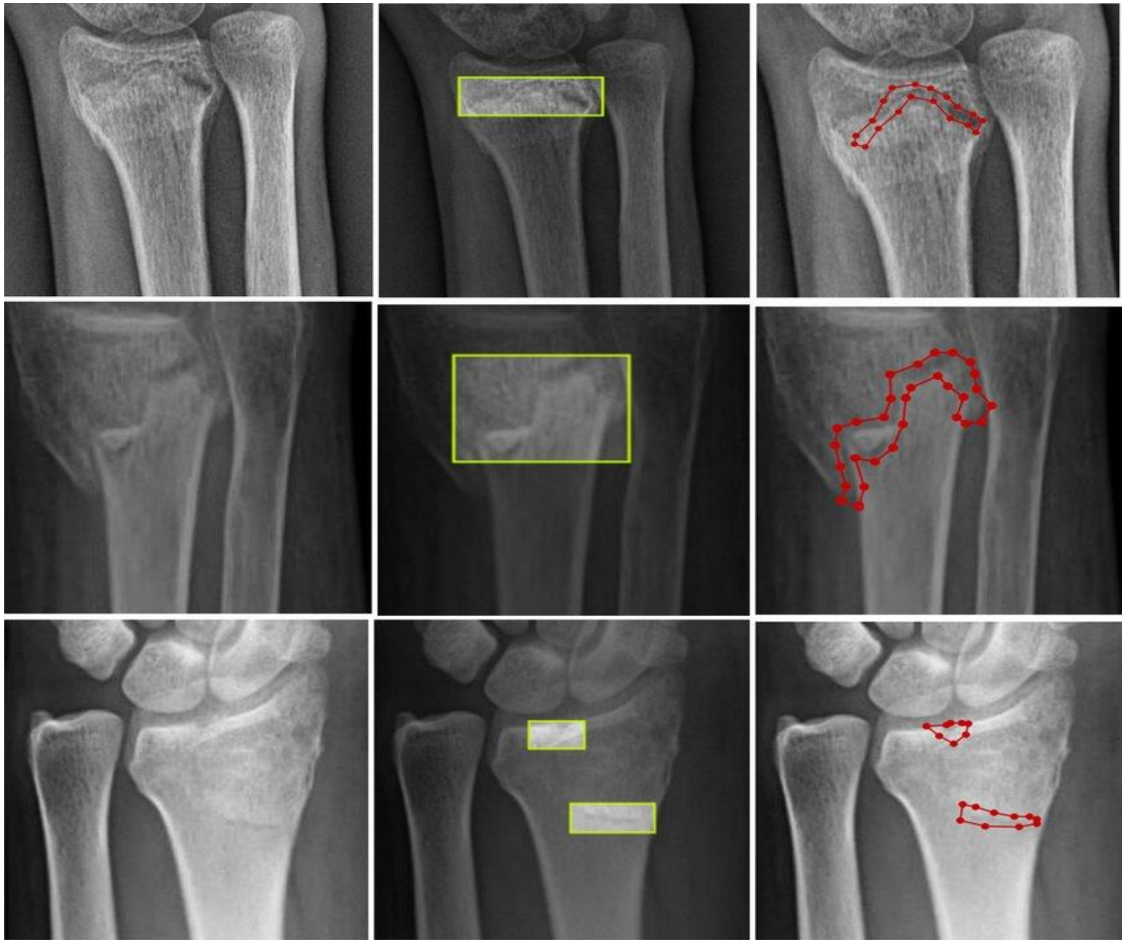
* * While simple, these techniques often struggle with low-contrast or noisy medical images.

6. AI-Based Segmentation

Deep learning has transformed medical image segmentation. Models such as U-Net, SegNet, and Mask R-CNN automatically learn image features, achieving high accuracy. They can detect and delineate complex structures such as fractures, tumors, or organs with minimal human input.

7. Example: X-ray Fracture Segmentation

In X-ray imaging, segmentation can automatically identify and outline bone fractures. By using deep learning models, even subtle fractures can be detected, providing faster and more consistent diagnosis assistance to radiologists.



8. Evaluation Metrics

To measure segmentation performance, several metrics are commonly used:

- **Precision and Recall (Sensitivity)**
- **Accuracy/Rand index**
- **Dice coefficient(F1-Score)**
- **Jaccard index (IoU)**

All presented metrics are based on the computation of a **confusion matrix** for a binary segmentation mask, which contains the number of true positive (TP), false positive (FP), true negative (TN), and false negative (FN) predictions. The value ranges of all presented metrics span from zero (worst) to one (best).

8. Evaluation Metrics

- **TP (True Positive)**: represents the number of FTU pixels that have been properly classified as FTU
- **FP (False Positive)**: represents the number background pixels being misclassified as FTUs (due to misalignment)
- **FN (False Negative)**: represents the number of FTU pixels being misclassified as background
- **TN(True Negative)**: represents the number of background pixels that have been properly classified as background

	Actually Positive (1)	Actually Negative (0)
Predicted Positive (1)	True Positives (TPs)	False Positives (FPs)
Predicted Negative (0)	False Negatives (FNs)	True Negatives (TNs)

Precision & Recall:

For pixel classification:

Precision score is the number of true positive results divided by the number of all positive results

$$Precision = \frac{TP}{TP + FP}$$

Recall score, also known as *Sensitivity* or *true positive rate*, is the number of true positive results divided by the number of all samples that should have been identified as positive

$$Recall = \frac{TP}{TP + FN}$$

Accuracy: Accuracy score, also known as Rand index is the number of correct predictions, consisting of correct positive and negative predictions divided by the total number of predictions.

$$Accuracy = \frac{TP + TN}{TP + TN + FN + FP}$$

Dice Coefficient (F1-Score):

F-measure, also called F-score: one of the most widespread scores for performance measuring in computer vision and in MIS (Medical Image Segmentation).

$$Dice = \frac{2TP}{2TP + FP + FN}$$

Jaccard Index (IoU):

Jaccard index, also known as Intersection over Union (IoU), is the area of the intersection over union of the predicted segmentation and the ground truth

$$IoU = \frac{TP}{TP + FP + FN}$$

9. Clinical Applications and Conclusion

Segmentation and image analysis are crucial in clinical practice:

- X-ray: fracture detection.

- MRI: tumor segmentation.

- CT: organ and tissue identification.

In conclusion, image analysis and segmentation are central to the future of medical imaging, especially when combined with artificial intelligence.

GOOD LUCK EVERYONE