MEDICAL IMAGING PROCESSING

FOURTH STAGE

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Image Registration in Medical Imaging

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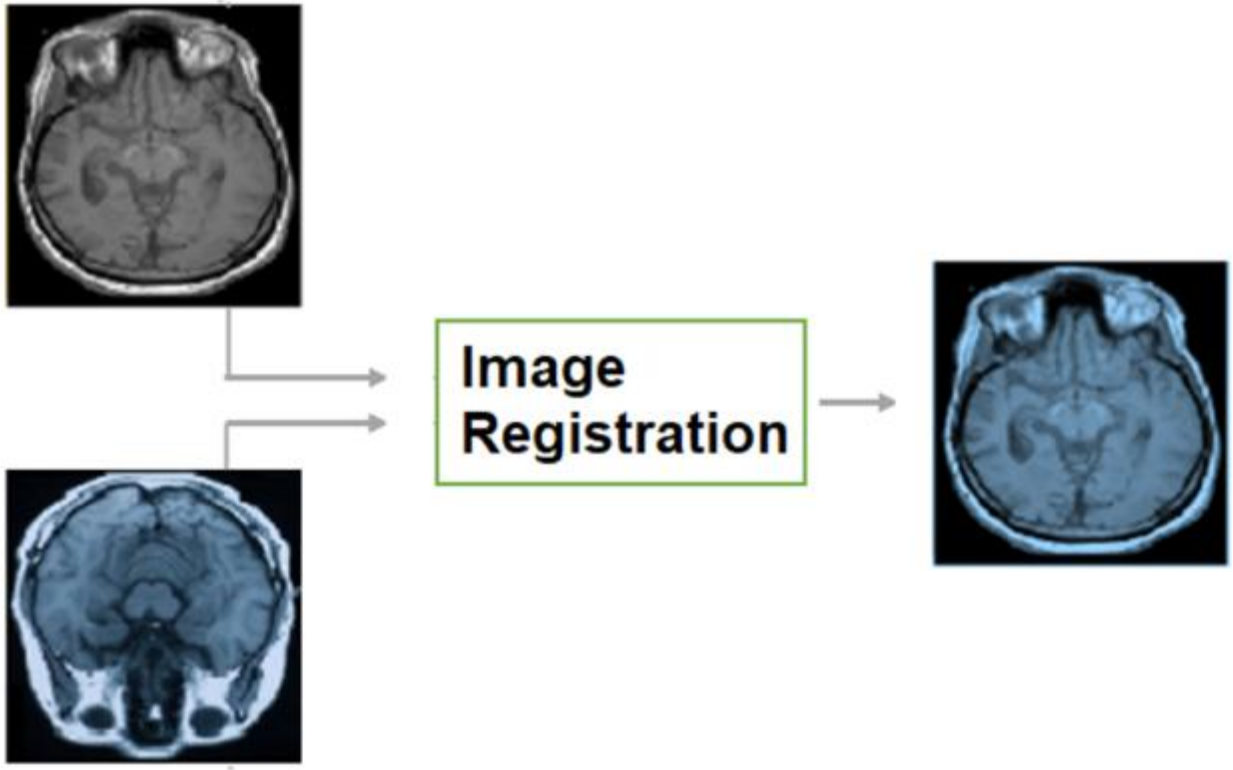
Image Registration in Medical Imaging



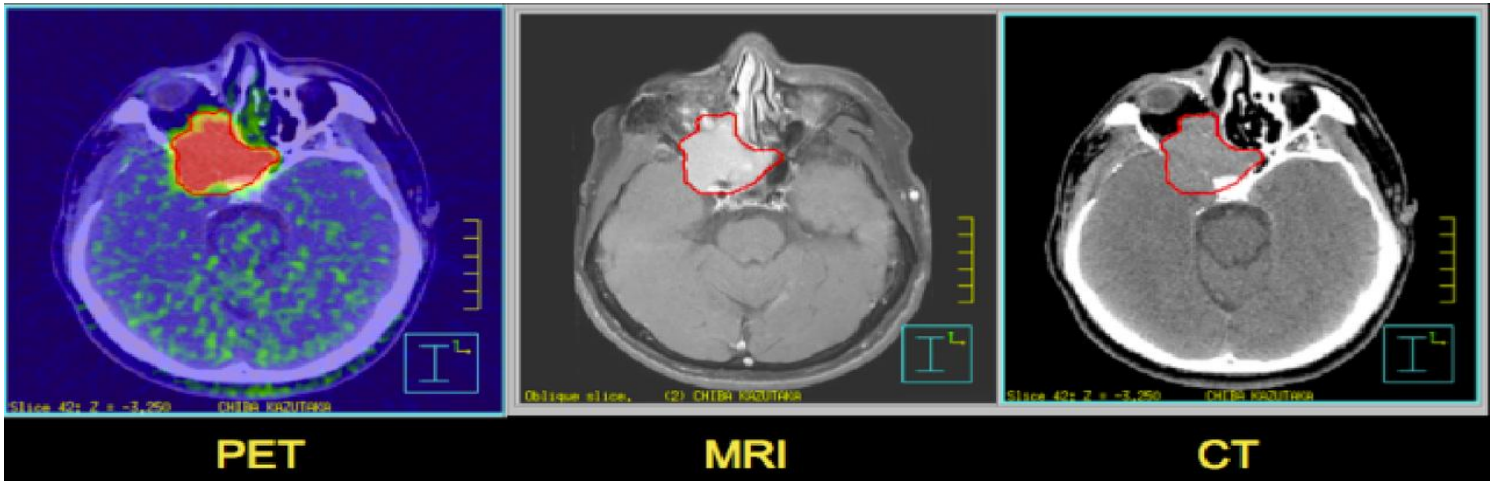
Introduction

Image recording is the process of aligning two or more images of the same organ or body region so that they are in the same coordinate system.

It is used when the images are from:

- Different devices (MRI + CT)
- Different times, before and after treatment
- Different patient positions
- Different camera angles

The primary goal is to make the images comparable and allow for joint analysis.



2. Why Do We Need Image Recording

Medical images often appear with significant variations due to:

- ❑ **Patient position changes**
- ❑ **Varying instrument resolution**
- ❑ **Differences in lighting or contrast levels**
- ❑ **Movement during the examination**

Recording makes the images:

- ✓ **Spatially consistent**
- ✓ **Comparable**
- ✓ **Uniform in shape and orientation**

Example: Combining MRI (for tissue details) with CT (for bone visualization).

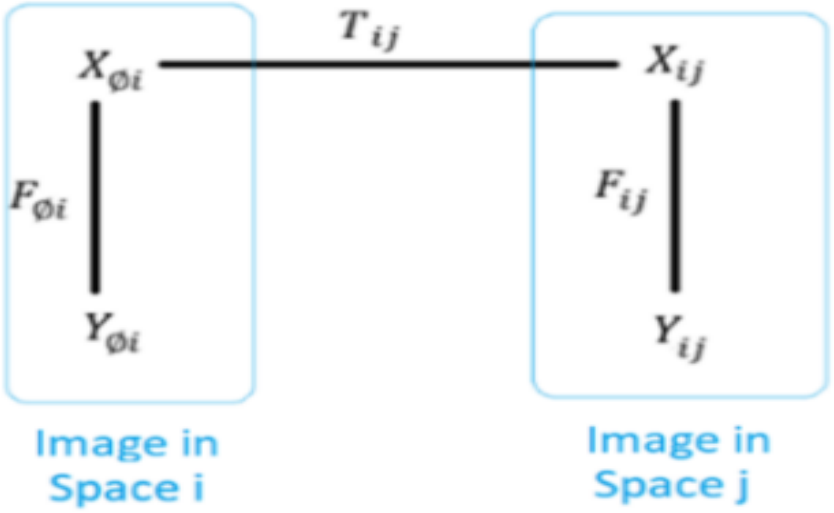
3. Basic Recording Components

A recording system consists of three elements:

1) **Reference Image:** The image we want to use as the base.

2) **Moving Image:** The image that needs to be moved and aligned with the reference image.

3) **Transformation:** The process that changes the position of the second image to match the first.



4. Types of Transformations in Image Recording

There are three main types:

1) Rigid Transformation: Includes(**Rotation , Translation**)

Used with bones because they are stable and not easily deformed.

2) Affine Transformation: Includes(**Rotation , Translation , Scaling , Shearing**)

Used when there are differences in image size or angle of the imaging.

3) Non-Rigid/Deformable Transformation

Allows for subtle deformations such as:

- Tissue Indentation
- Organ Movement
- Extension or Contraction of a Region

Commonly used in brain, cardiac, and chest MRI.

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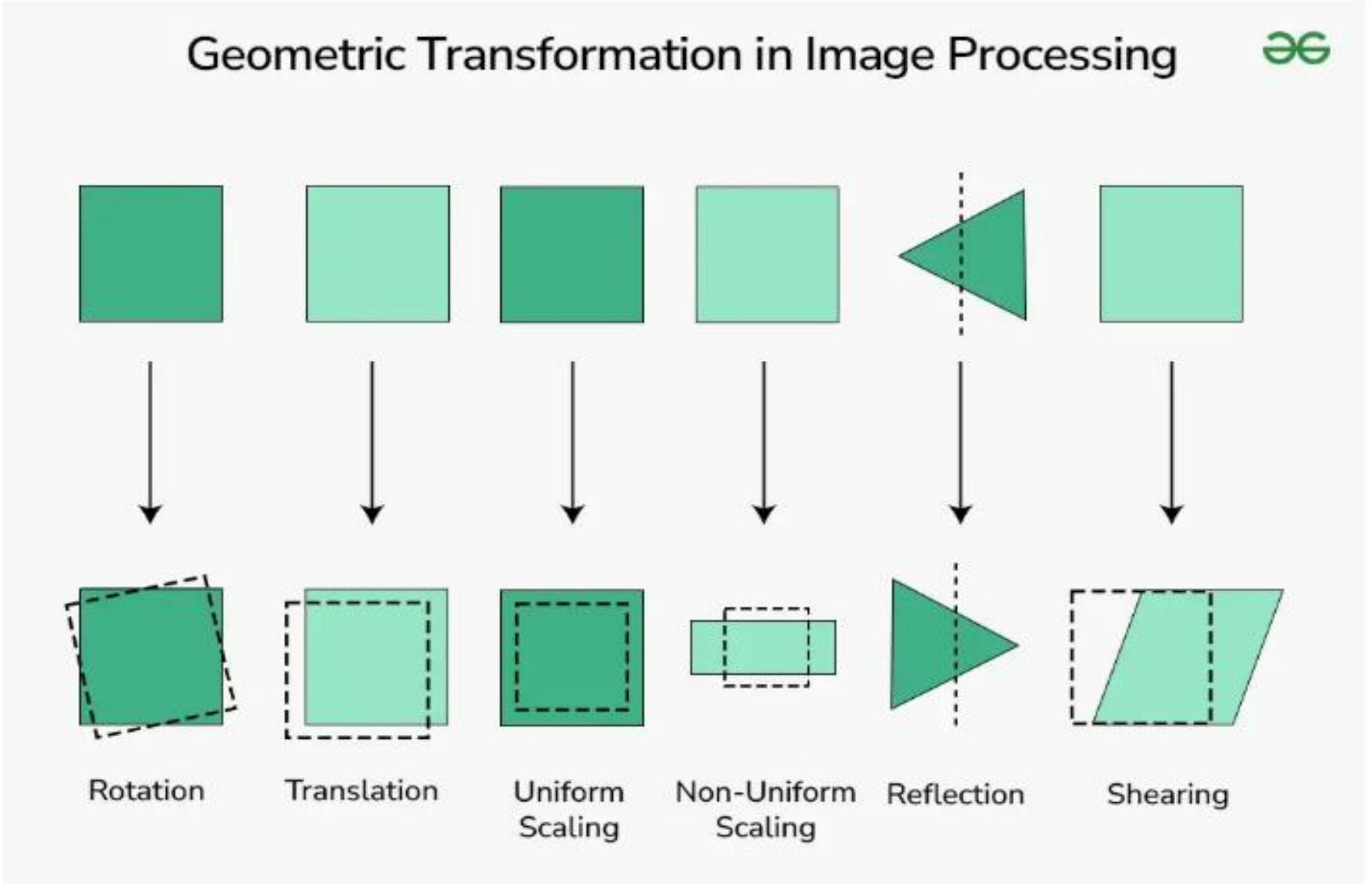


5. Similarity Measures

To determine the degree of similarity between two images, we use a similarity measure, such as:

- **Mean Squared Error (MSE)**

Measures the difference between pixels; suitable for similar images.

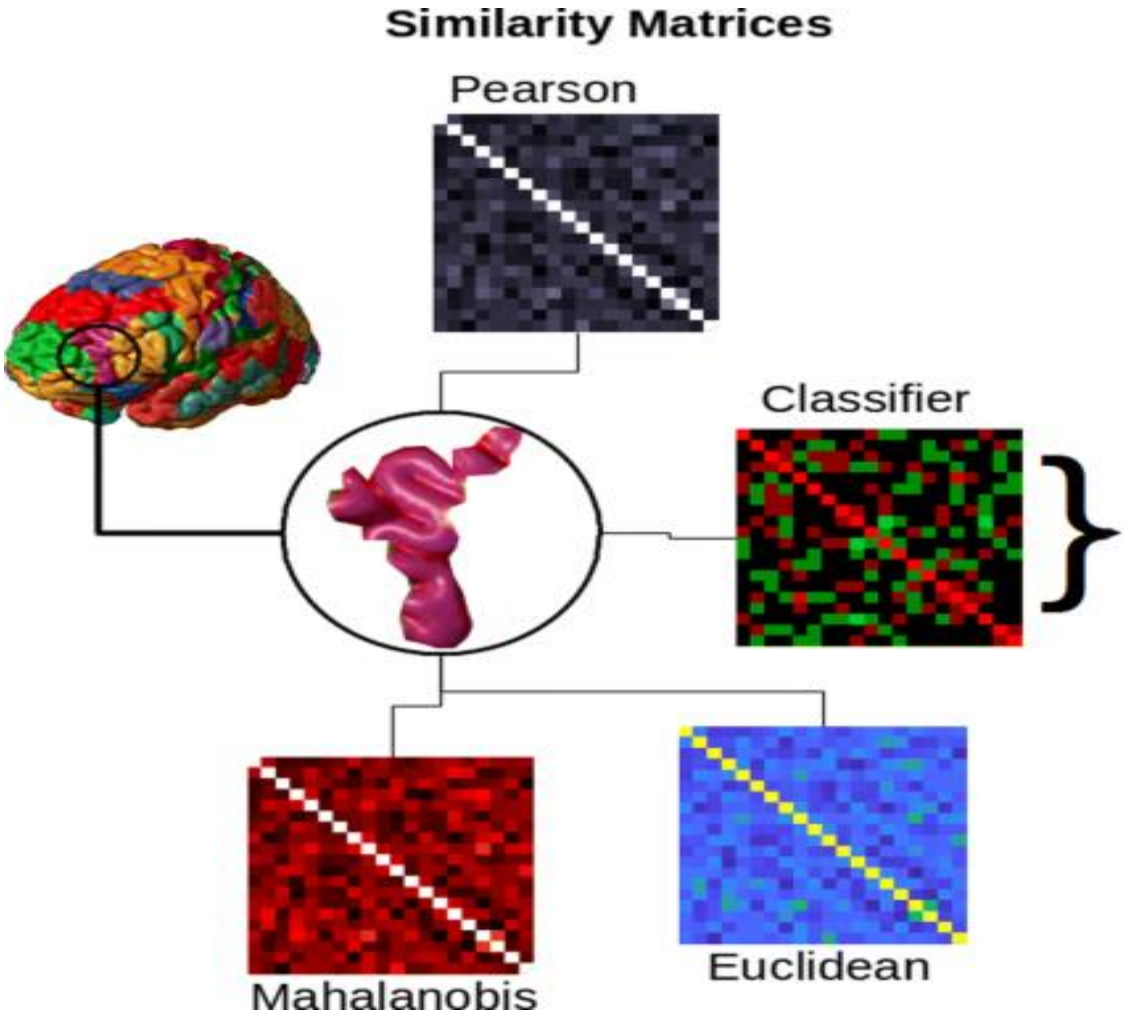
- **Cross Correlation (CC)**

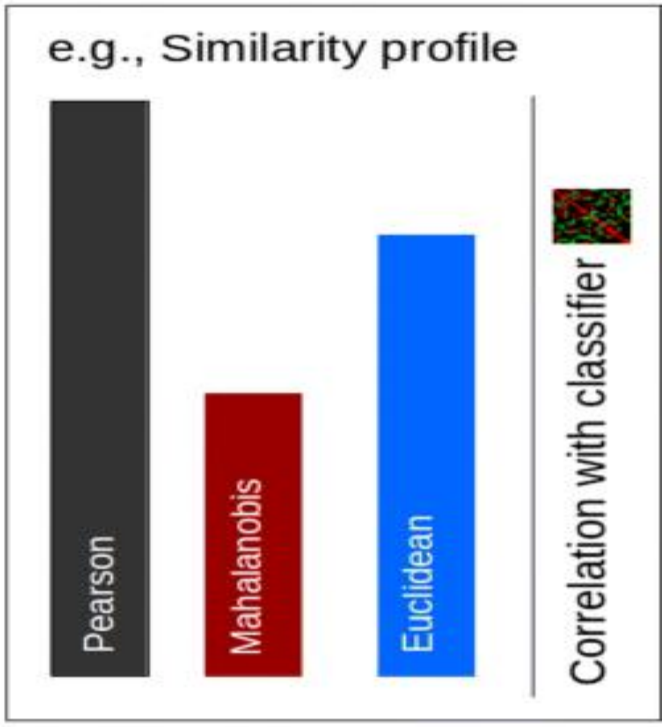
Measures structural similarity.

- **Mutual Information (MI)**

Most commonly used in medicine. Excellent for images from different devices (MRI + CT).

5. Similarity Measures





6. Image Registration Steps

Any registration process can be summarized in 4 steps:

- **Selecting the reference image:** This is determined based on the best quality or angle.
- **Selecting the similarity scale:** such as MI or MSE.
- **Selecting the optimization algorithm:** such as Gradient Descent or Evolutionary Algorithms.
- **Applying the transformation:** This involves moving the image until it matches the reference image.

7. Popular Recording Algorithms

- **Demon's Algorithm**

Excellent for anomaly-prone images (MRI).

- **Optical Flow**

Based on pixel movement.

- **B-Spline Registration**

Extensively used for complex anomalies.

- **Deep Learning-based Registration**

Latest techniques: CNNs or Transformers learn the transformation directly.

8. Practical Examples

- **Brain**

✓ Comparing MRI images before and after treatment

✓ Monitoring tumor size

- **Cancer**

Combining PET + CT to obtain:

✓ Cell function (PET)

✓ Anatomical shape (CT)

- **Heart**

Recording images over time to monitor:

✓ Ventilation movement

✓ Blood flow

- **Bones**

Using rigid recording to identify fractures

9. Challenges of Image Recording

Despite its benefits, several problems exist:

- High noise in medical images
- Variability of imaging devices
- Significant variations in patient position
- Unexpected tissue abnormalities
- Long processing times required for some algorithms

10. Conclusion

Image recording is a fundamental element in medical image analysis because it allows for:

✓ **Integrating information from different devices**

✓ **Monitoring temporal changes**

✓ **Improving diagnostic accuracy**

✓ **Performing high-precision measurements**

✓ **Supporting image-guided surgical systems**

It represents an important skill for students of medical physics and biomedical engineering.

GOOD LUCK EVERYONE