

## 4.1 Image Registration – Rigid Body Transformation, Principal Axes Registration, and Feature-Based Registration

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Image registration is the process of aligning two or more images of the same scene taken at different times, from different viewpoints, or by different sensors. It is widely used in medical imaging, remote sensing, computer vision, robotics, and image-guided surgery.

### 1. Rigid Body Transformation

Rigid body transformation aligns images using only rotation and translation. It preserves distances and angles between points. No scaling or deformation occurs.

Mathematical representation:

$$\begin{aligned} [x'] &= [\cos\theta \ -\sin\theta][x] + [tx] \\ [y'] &= [\sin\theta \ \cos\theta][y] + [ty] \end{aligned}$$

Advantages:

- Preserves object shape
- Computationally efficient
- Commonly used in CT and MRI alignment

Applications:

- Medical image registration
- Robot navigation
- Object tracking

### 2. Principal Axes Registration

Principal Axes Registration uses the principal axes of an object to estimate alignment. The centroid and orientation of the object are computed first. The image is then rotated and translated to match the reference image.

Steps:

1. Compute centroid
2. Calculate covariance matrix
3. Determine eigenvalues and eigenvectors

4. Find principal axes
5. Align principal axes of both images

Advantages:

- Fast initialization
- Reduces search space
- Effective for roughly similar objects

Limitations:

- Sensitive to noise and segmentation errors

### **3. Feature-Based Registration**

Feature-based registration aligns images using extracted features such as corners, edges, contours, landmarks, or keypoints.

Common Features:

- Corners (Harris, Shi-Tomasi)
- Edges (Canny)
- SIFT keypoints
- SURF features
- ORB features

Procedure:

1. Feature detection
2. Feature description
3. Feature matching
4. Transformation estimation
5. Image resampling and alignment

Advantages:

- Works well with large image variations
- Robust to illumination changes
- Suitable for multimodal images

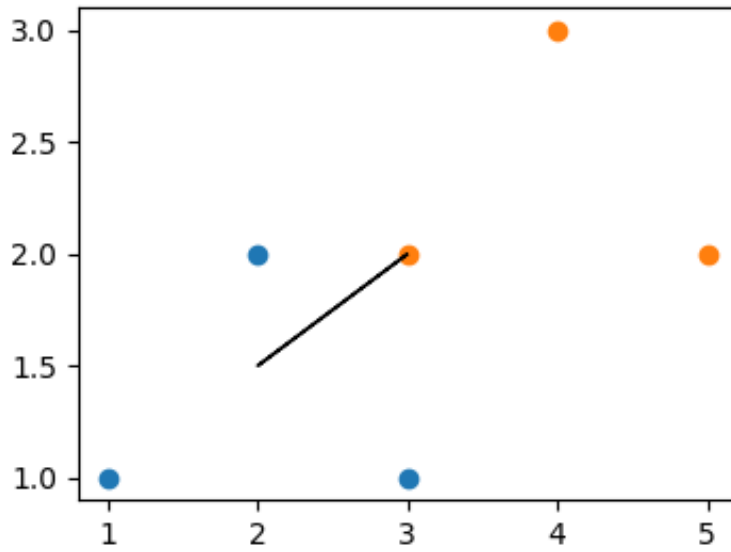
Applications:

- Panorama stitching
- Remote sensing
- Medical image fusion
- Augmented reality

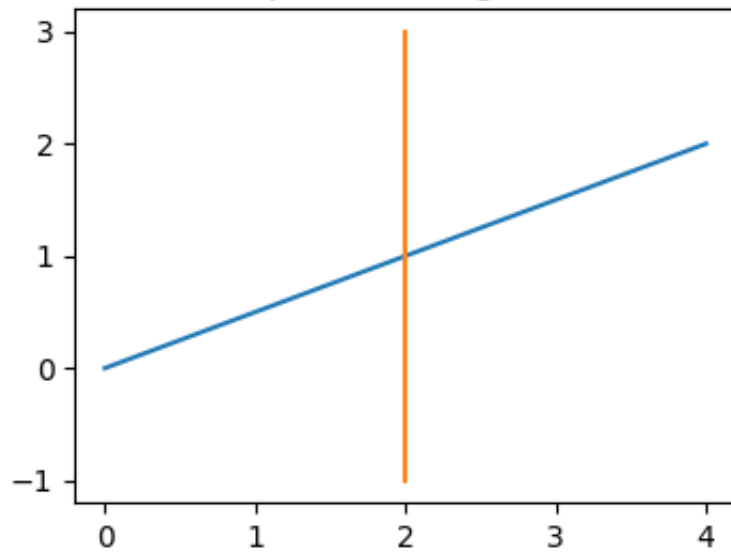


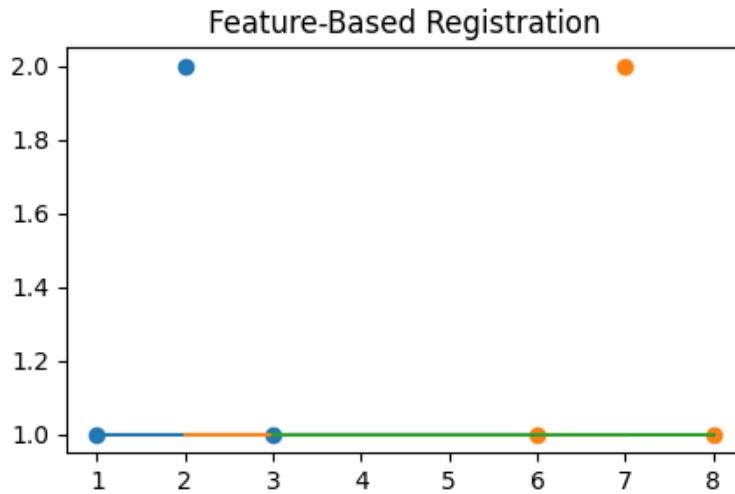
## Relevant Diagrams

### Rigid Body Transformation



### Principal Axes Registration





### Comparison of Registration Methods

Rigid Body Transformation:

- Uses rotation and translation only
- Preserves geometry
- Fast and simple

Principal Axes Registration:

- Uses centroid and orientation
- Good initial alignment
- Sensitive to noise

Feature-Based Registration:

- Uses image features
- Robust and accurate
- Higher computational cost