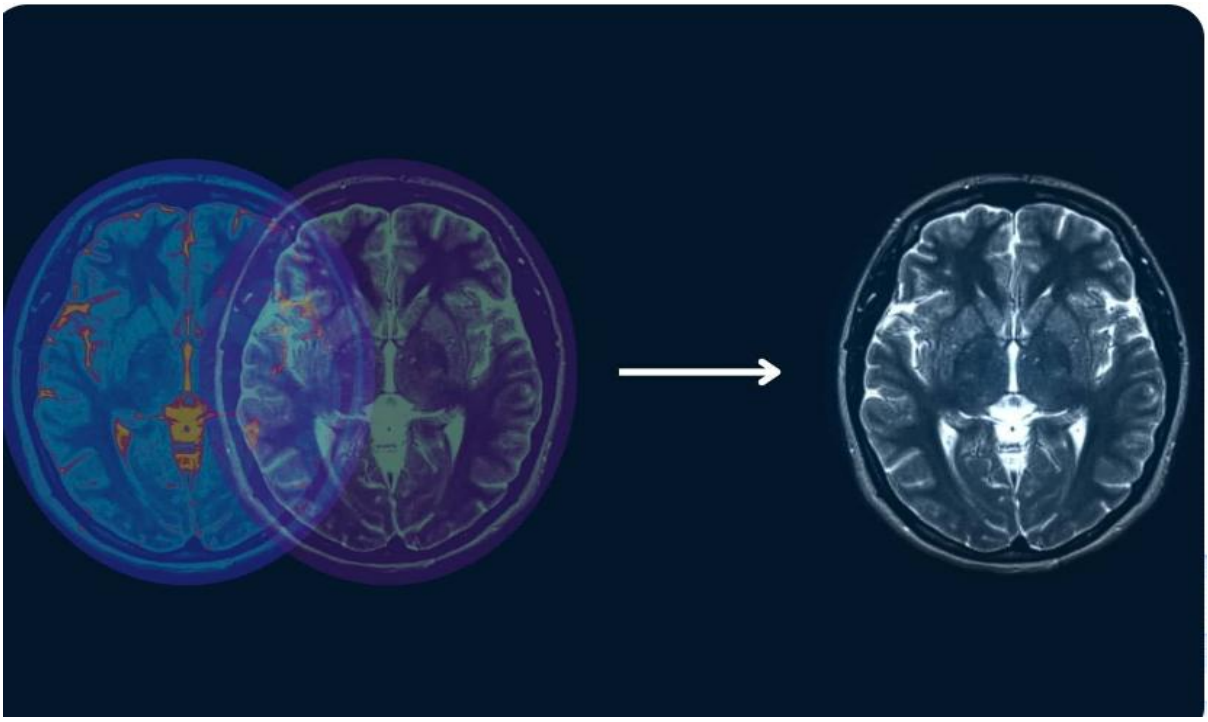
Image Registration Algorithms

3. Image Registration Algorithms

3.1 What is the image registration

Image registration is the process of transforming different data set into one coordinate system.

- Data may be multiple photographs data from different sensors,time ,depths or viewpoint.
- Image registration is establishment of correspondence between image of the same scan



3.2 . Image Registration Algorithms

The image registraction are categories of algorithms.

Content:

1. Feature-Based Algorithm
2. Intensity-Based Algorithm
3. Transformation Models
4. Deep Learning Approaches

Feature Based Algorithm

Feature based algorithm focuse on identifying distinct feature in image and matching then to achieve alignment.

Types of the feature based algorithm

- SIFT
- SURF
- ORB
- RANSAC

SIFT (Scale-Invariant Feature Transform)

SIFT is the detect and describe local feature in image invariant to the scale and rotation.

Scale-Space Construction

- Images may contain features at different scales (fine vs. coarse).
- SIFT builds a **scale-space pyramid** by progressively blurring the image using a Gaussian filter:

  L(x,y,σ)=G(x,y,σ)∗I(x,y)L(x, y, \sigma) = G(x, y, \sigma) * I(x,y)L(x,y,σ)=G(x,y,σ)∗I(x,y)

  where I(x,y)I(x, y)I(x,y) is the original image, G(x,y,σ)G(x, y, \sigma)G(x,y,σ) is a Gaussian kernel, and σ\sigmaσ is the scale parameter.

- Multiple blurred versions are created, and their **Difference-of-Gaussian (DoG)** is computed:

  D(x,y,σ)=L(x,y,kσ)−L(x,y,σ)D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma)D(x,y,σ)=L(x,y,kσ)−L(x,y,σ)

- The algorithm searches for local maxima/minima in the DoG space by comparing each pixel to its 26 neighbors (8 in the same scale, 9 above, and 9 below).
- Low-contrast points and edge responses are removed using:
  - Taylor series expansion for precise localization.
  - A Hessian matrix to filter out unstable edge points.
- Each keypoint is assigned one or more dominant orientations based on the local image gradient:

  m(x,y)=(Lx+1,y−Lx−1,y)2+(Lx,y+1−Lx,y−1)2m(x, y) = \sqrt{(L_{x+1, y} - L_{x-1, y})^2 + (L_{x, y+1} - L_{x, y-1})^2}m(x,y)=(Lx+1,y−Lx−1,y)2+(Lx,y+1−Lx,y−1)2 θ(x,y)=tan−1(Lx,y+1−Lx,y−1Lx+1,y−Lx−1,y)\theta(x, y) = \tan^{-1}\left(\frac{L_{x, y+1} - L_{x, y-1}}{L_{x+1, y} - L_{x-1, y}}\right)θ(x,y)=tan−1(Lx+1,y−Lx−1,yLx,y+1−Lx,y−1)

- This ensures **rotation invariance**.
- For each keypoint, a region (usually 16×16 pixels) is divided into 4×4 sub-blocks.
- Each sub-block computes an orientation histogram (typically 8 bins).
- The descriptor becomes a **128-dimensional vector (4×4×8)** representing gradient distributions.
- Descriptors from two images are compared using Euclidean distance.
- The nearest neighbor with a distance ratio test is selected to avoid false matches.

Advantages of SIFT

- **Scale and Rotation Invariant** → Works across different resolutions and orientations.
- **Robust to Noise** → Gaussian smoothing improves stability.
- **Distinctive Features** → High-dimensional descriptors allow unique identification.
- **Wide Applications** → Medical imaging, remote sensing, object detection, panorama stitching.

Limitations

- **Computationally Expensive** → Not ideal for real-time applications.
- **Patent Issues (historically)** → Restricted use in some cases.
- **Not Fully Illumination-Invariant** → Extreme lighting changes reduce performance.