Registration Methods In Multi-modality Imaging

Ankur Kapoor
Clinical Center, National Institutes of Health

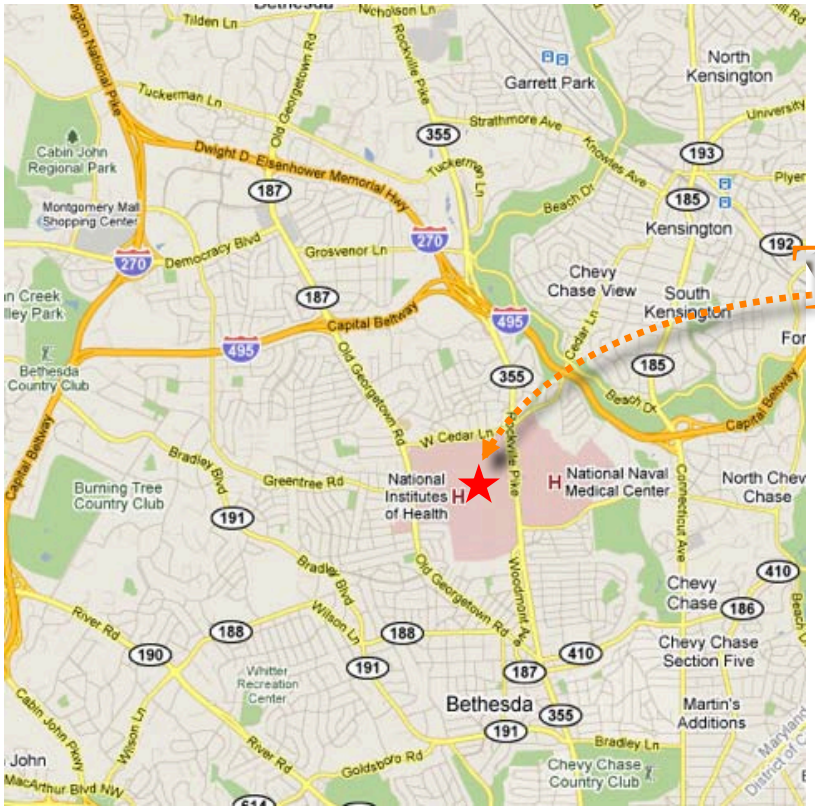
Objectives

- Define the terms registration and image fusion
- Present different registration algorithms
- Discuss features and limitations of these
- Match potential algorithms with applicable clinical applications

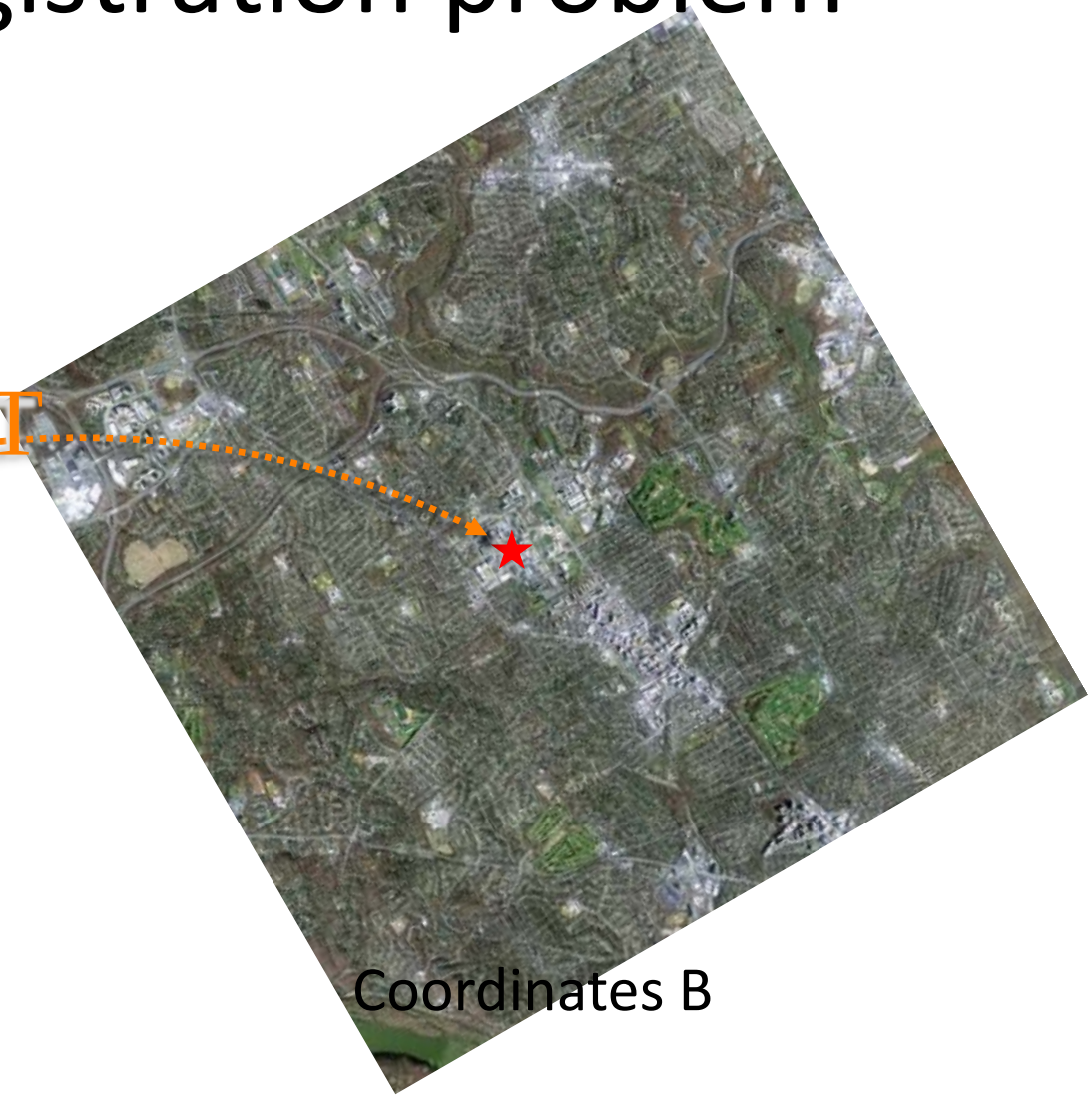
What is Registration?

- Finding the spatial transform that maps points from one data set to corresponding points in another data set.
- Data sets
  - 2D or 3D Image
  - Intra-operative tool positions
  - Robot coordinates
  - Patient position

A typical registration problem

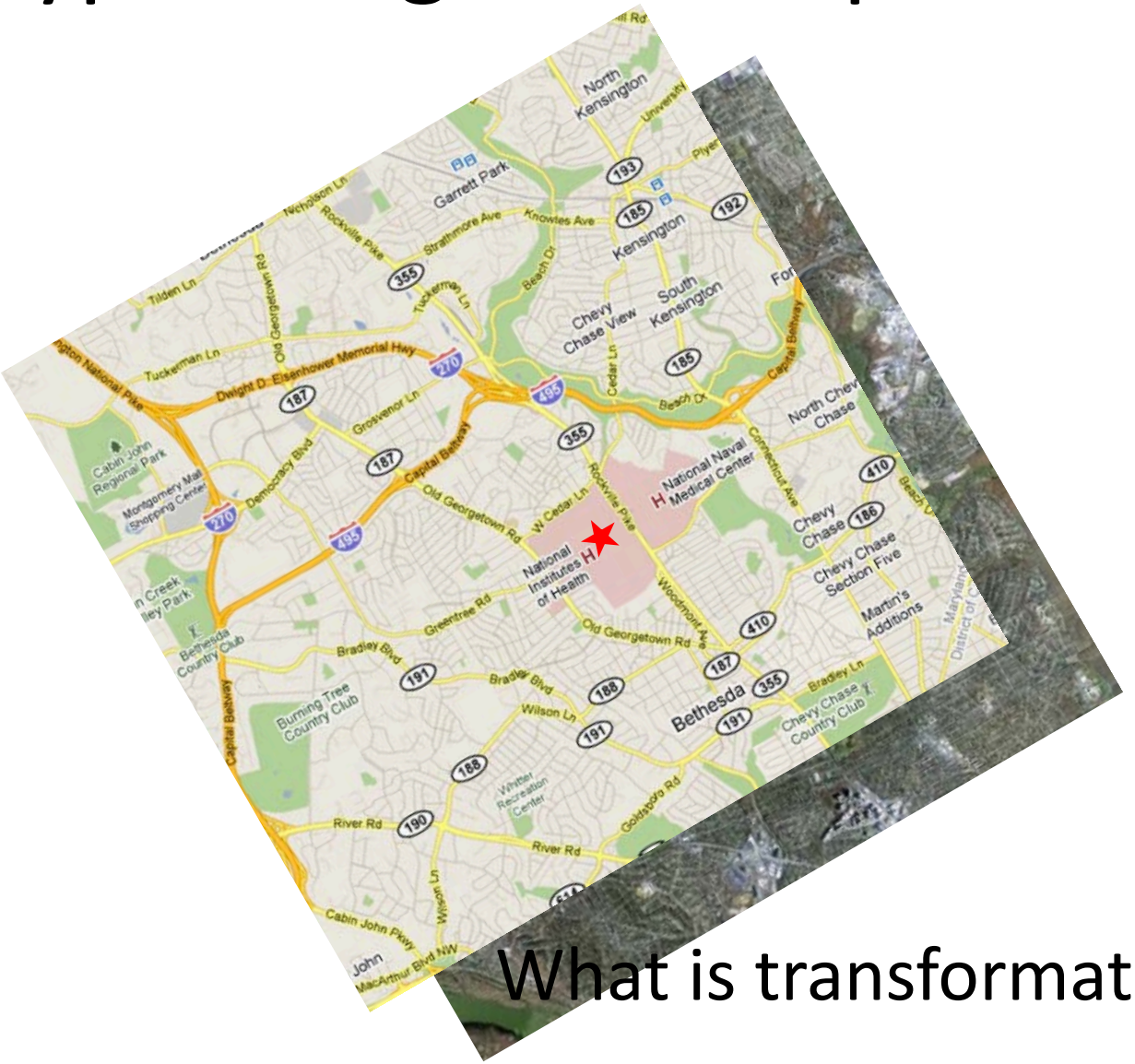


Coordinates A



Coordinates B

A typical registration problem



What is transformation, T?

Why Registration?

Navigation for RFA planning & treatment

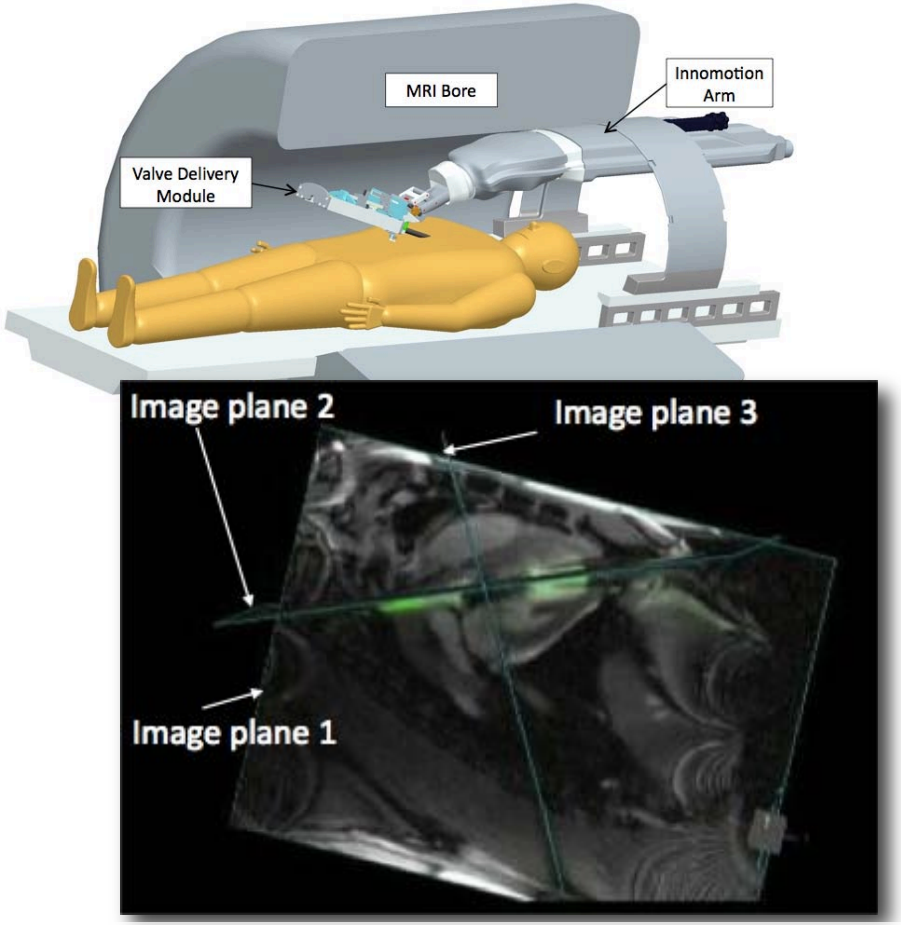
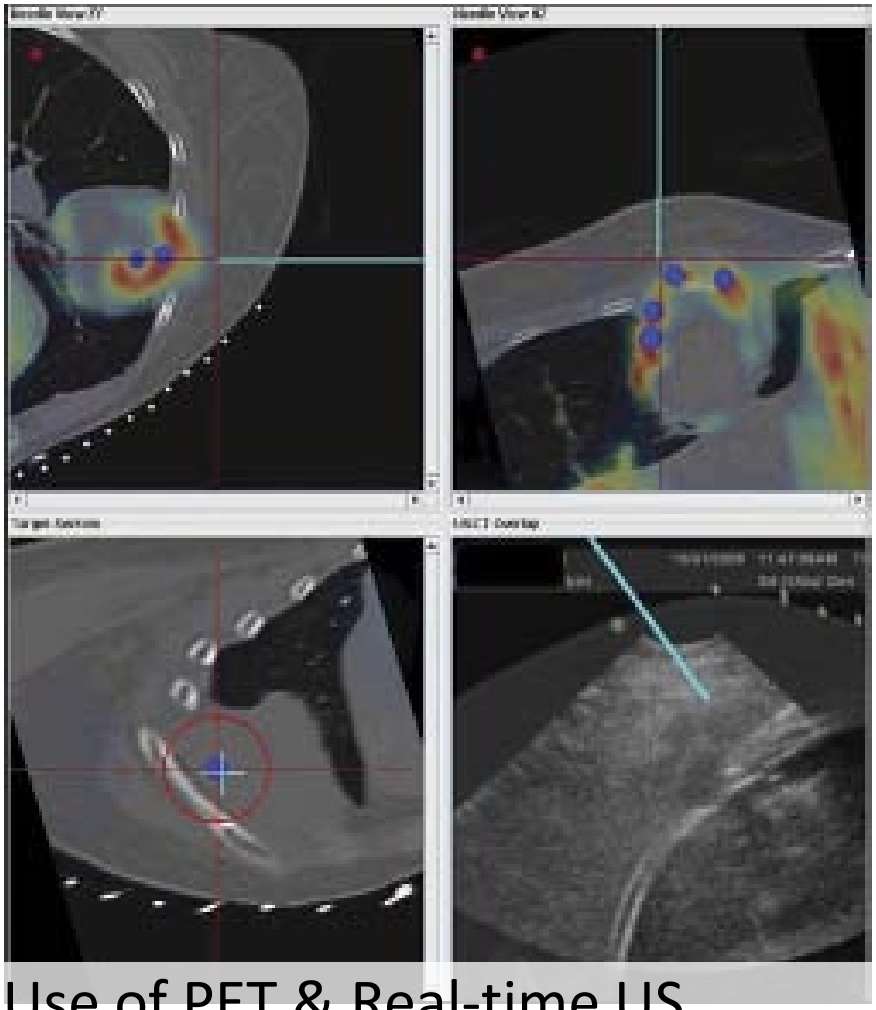


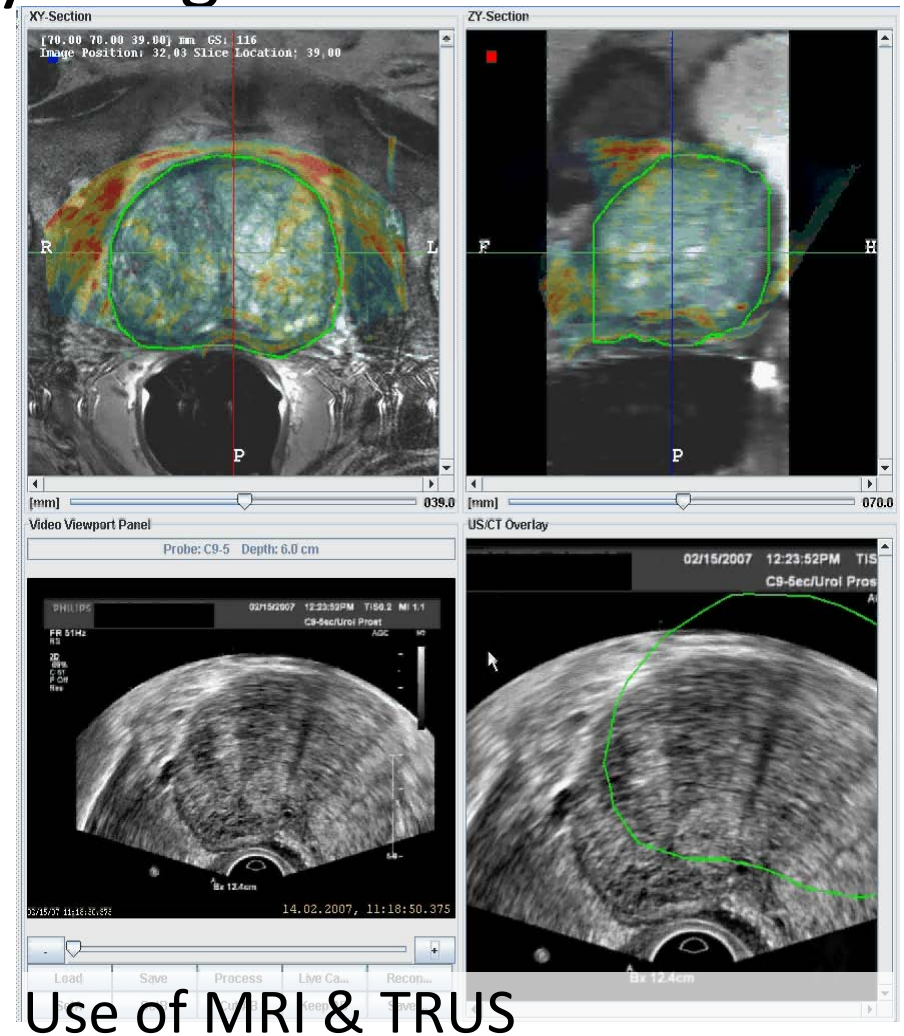
Image Guided Robotics for Valve Repair

Why Registration?

Multi modality image fusion

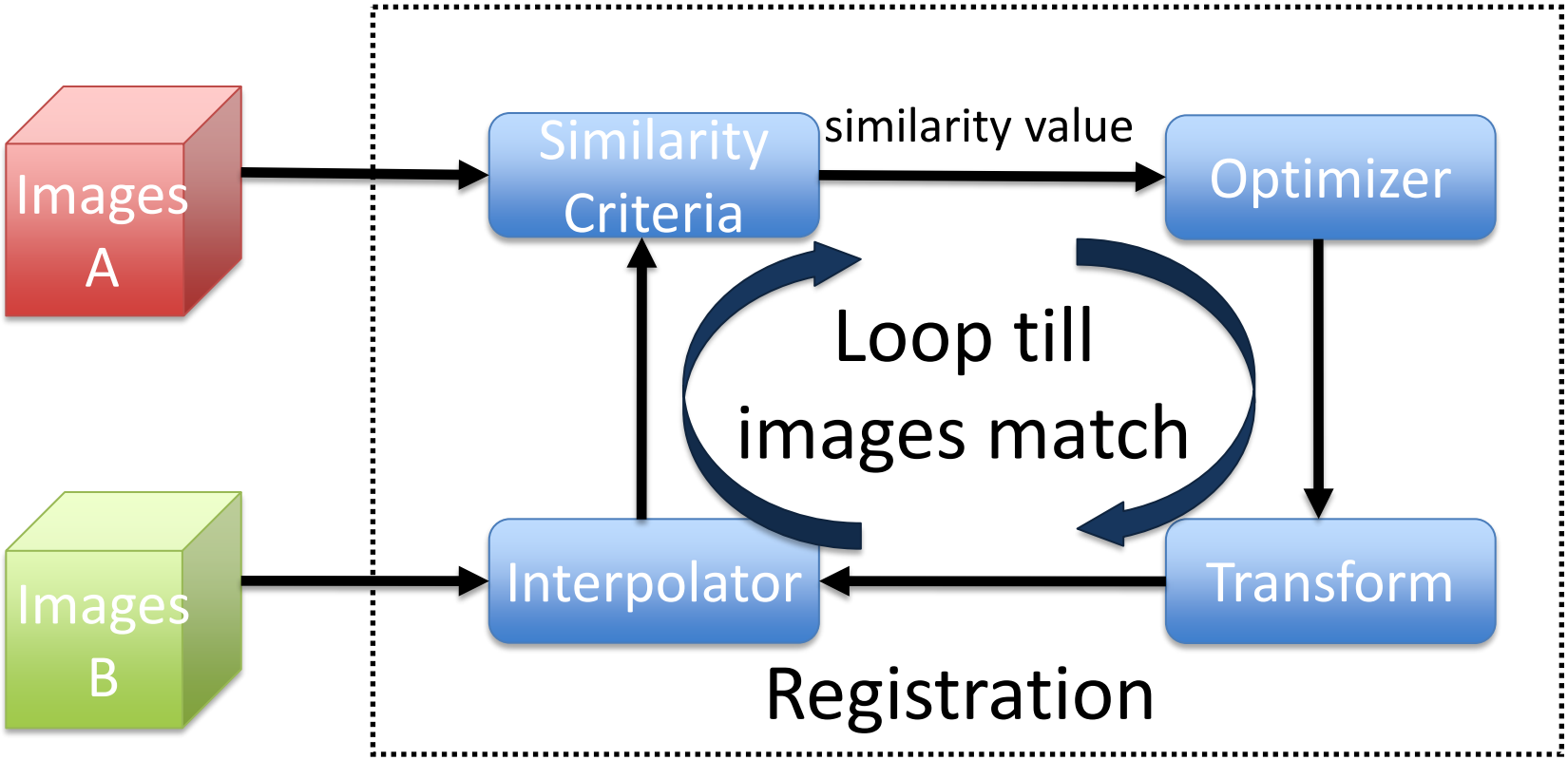


Use of PET & Real-time US

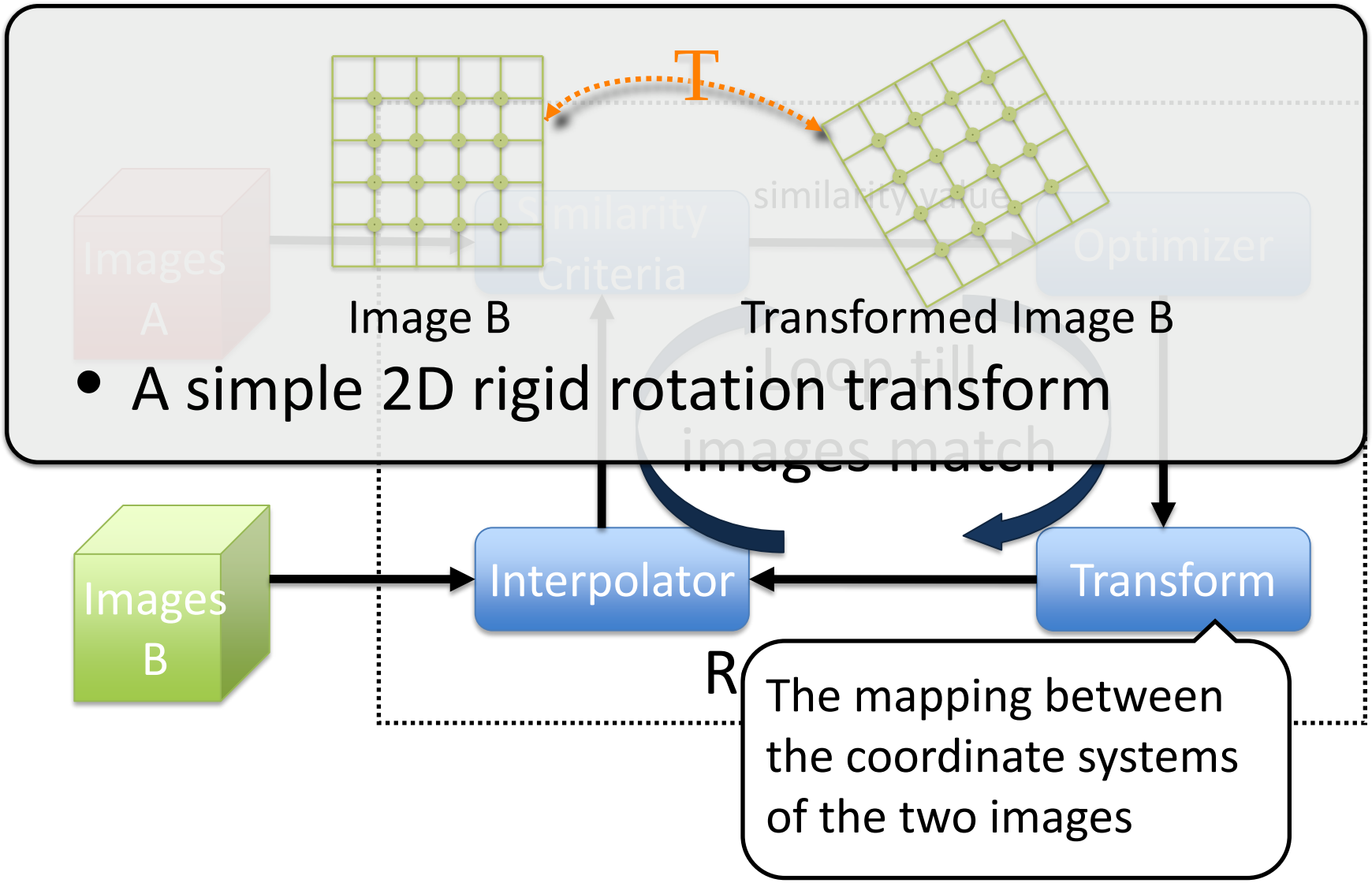


Use of MRI & TRUS

Basic Flowchart

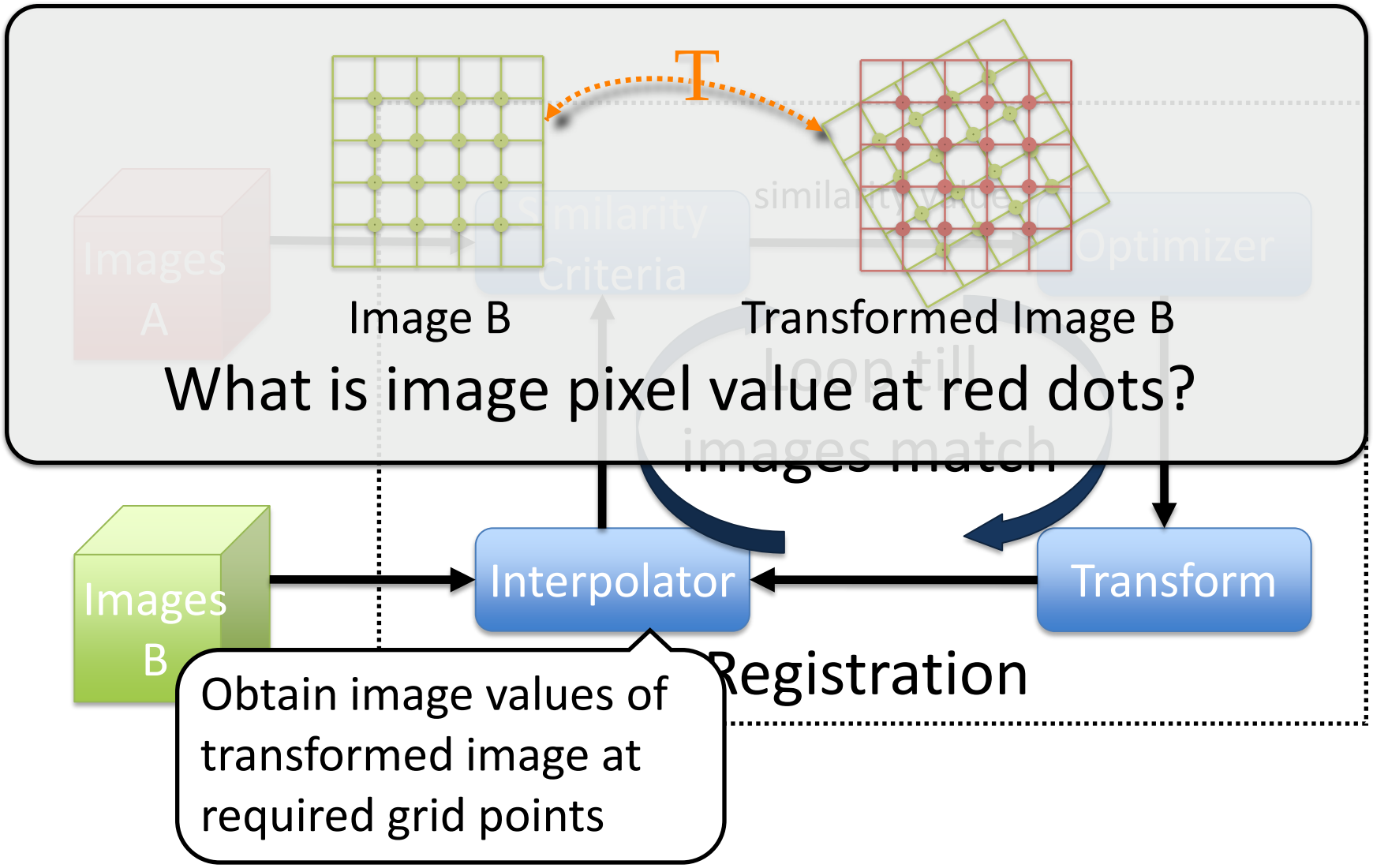


Basic Flowchart

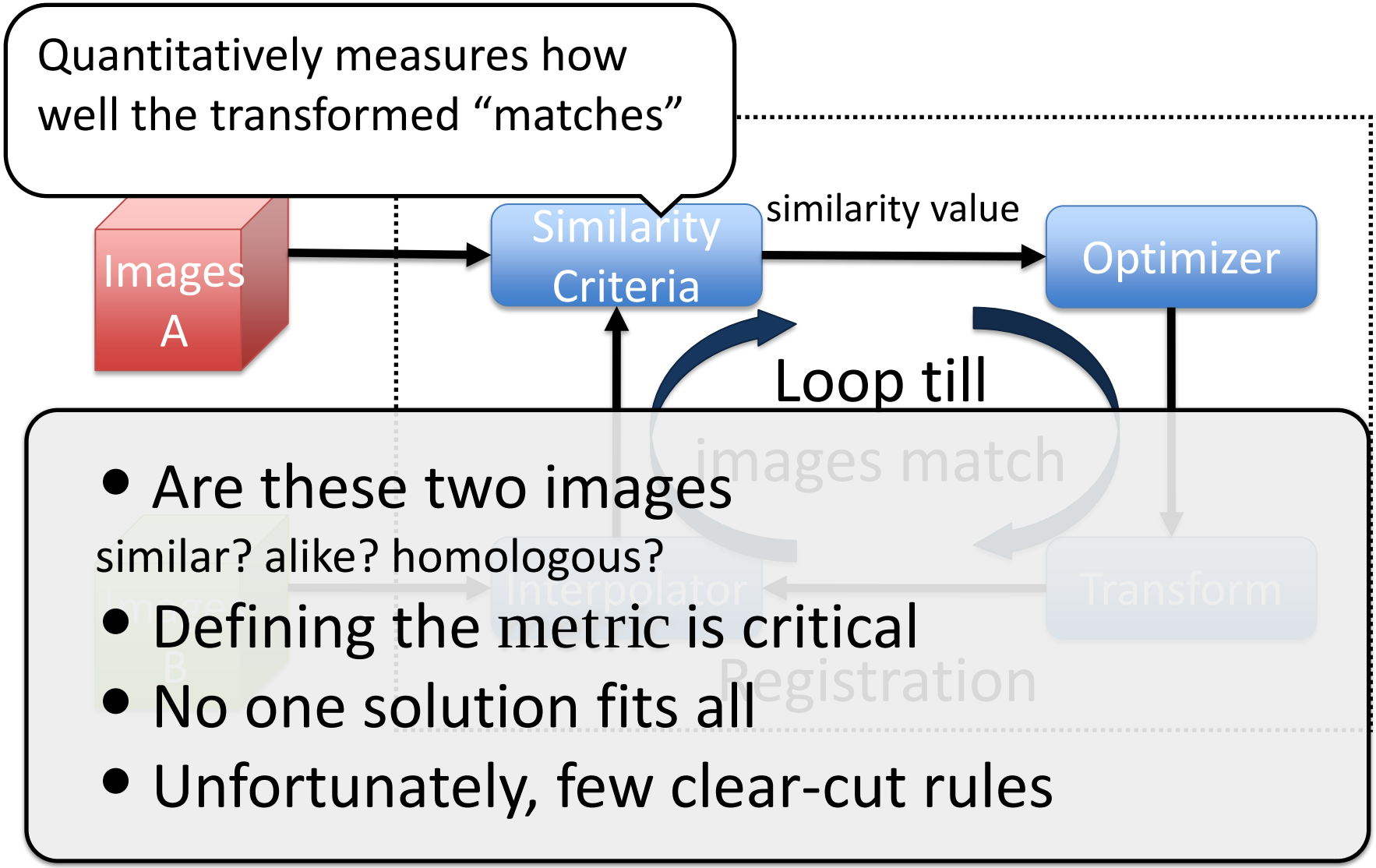


- A simple 2D rigid rotation transform

Basic Flowchart

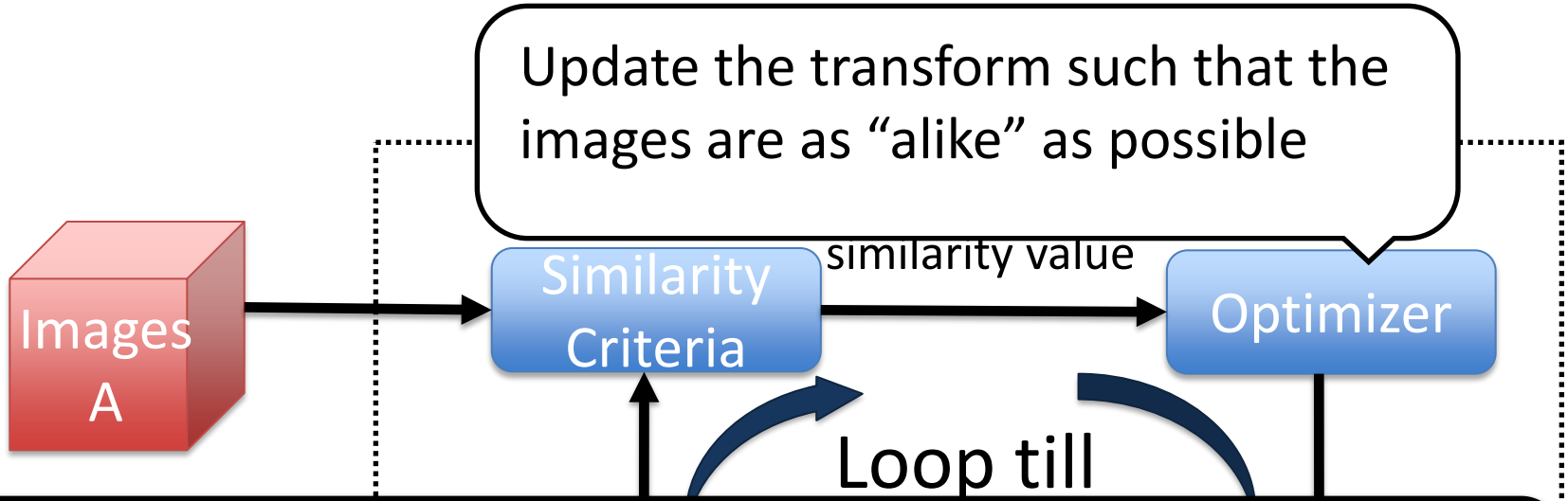


Basic Flowchart



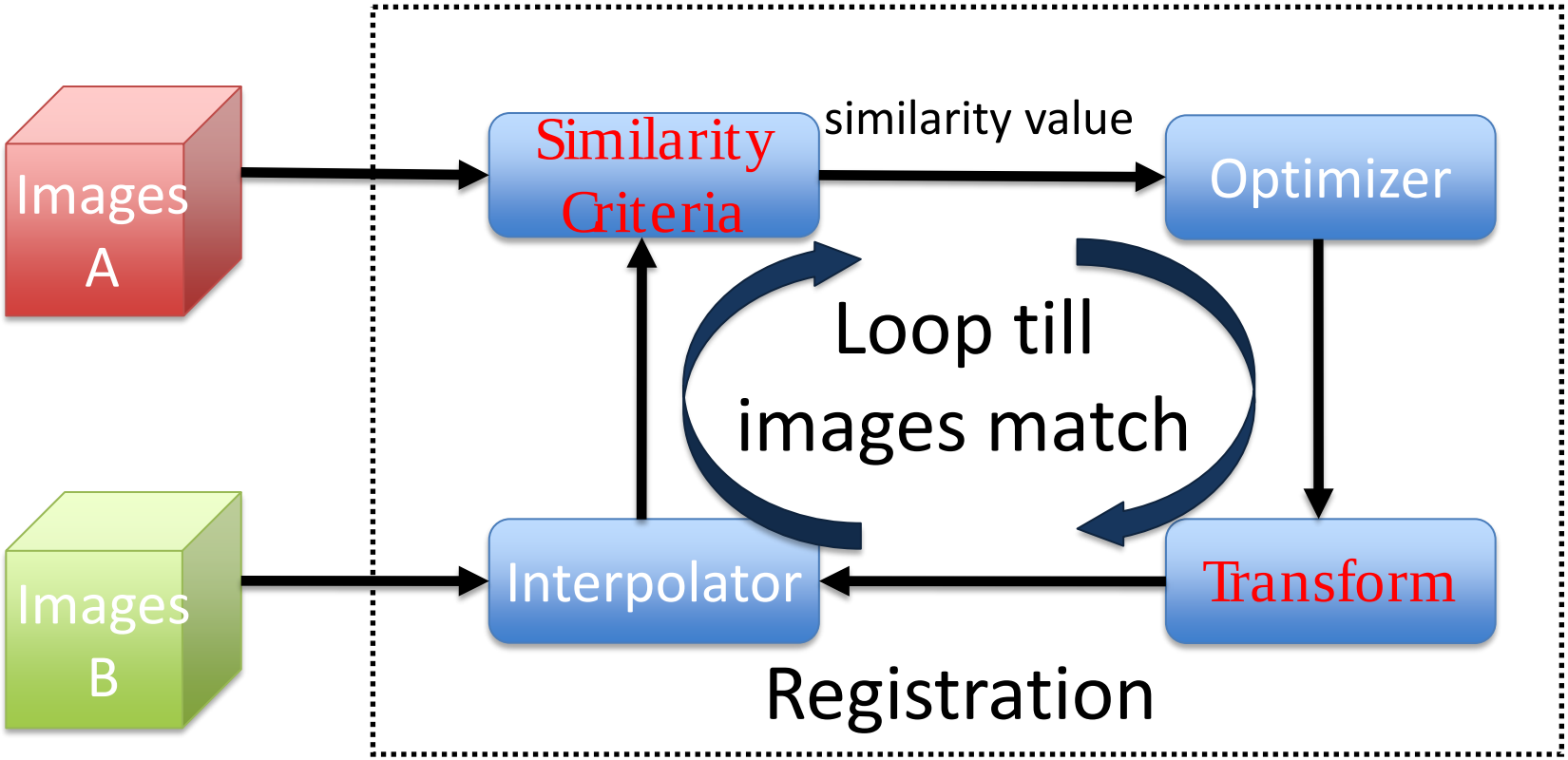
- Are these two images similar? alike? homologous?
- Defining the metric is critical
- No one solution fits all
- Unfortunately, few clear-cut rules

Basic Flowchart

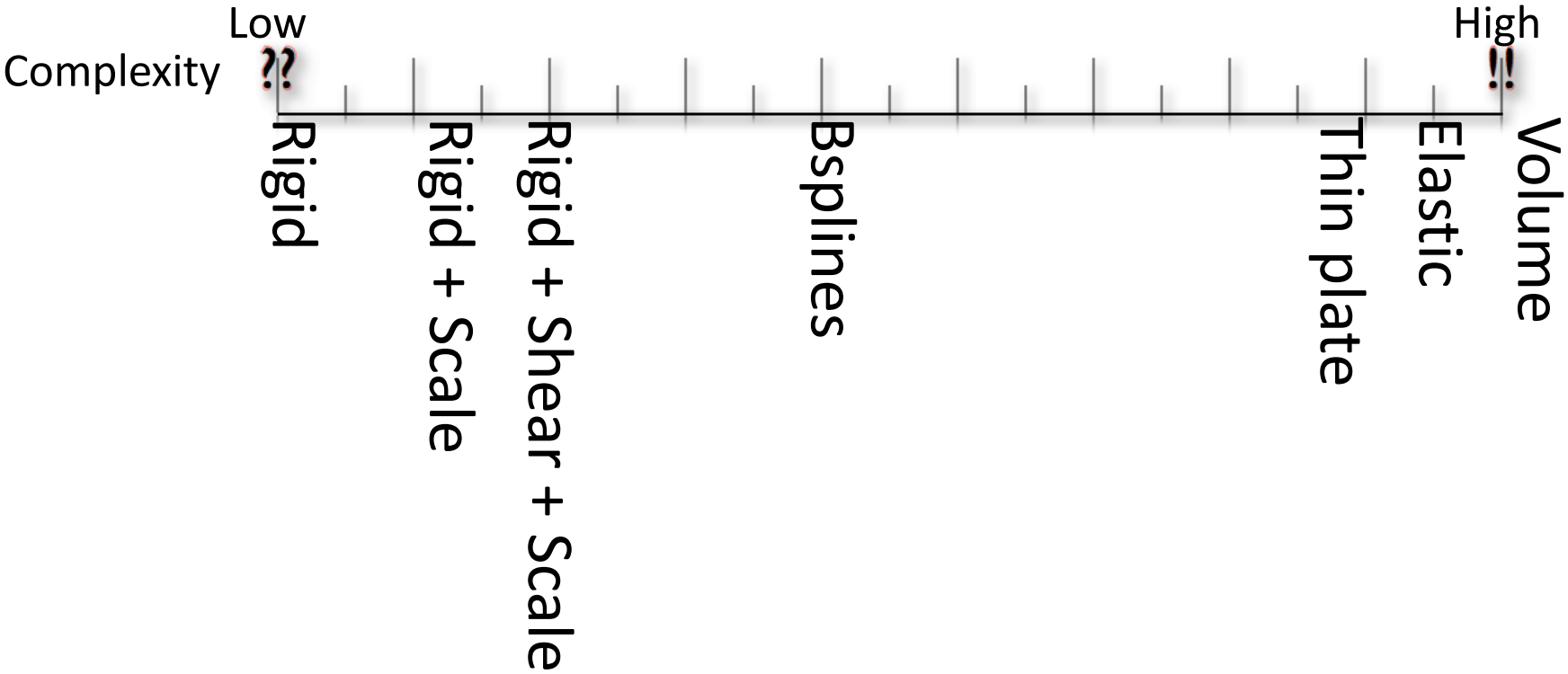


- Based on the metric, modify the transform parameters
- Most registration algorithms require iterative and non-linear optimizers

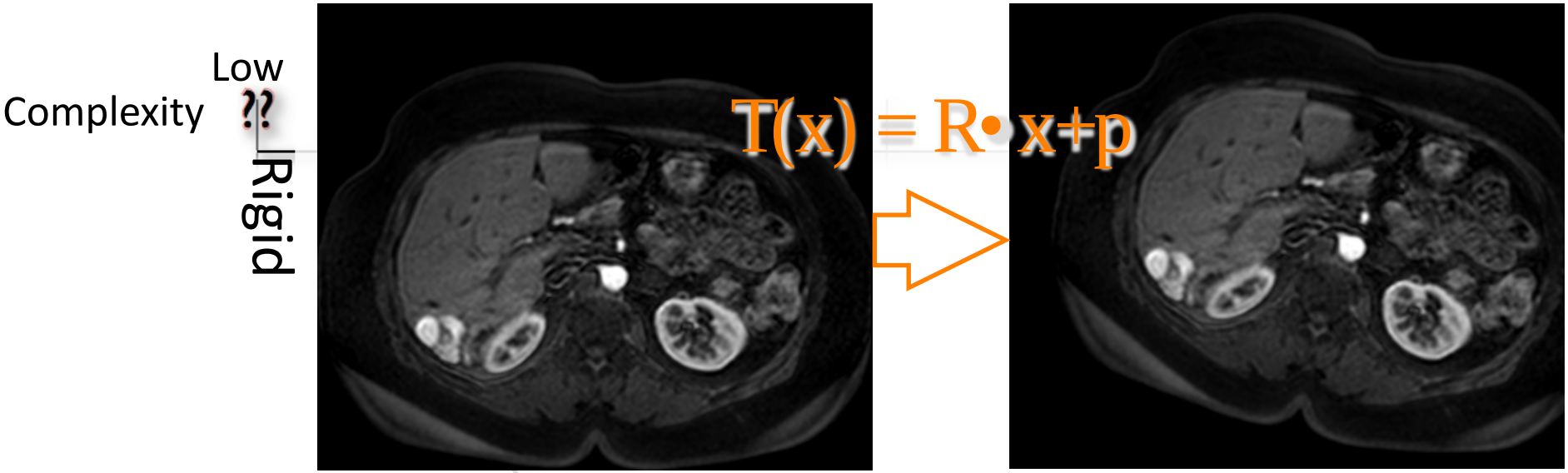
Basic Flowchart



Transform

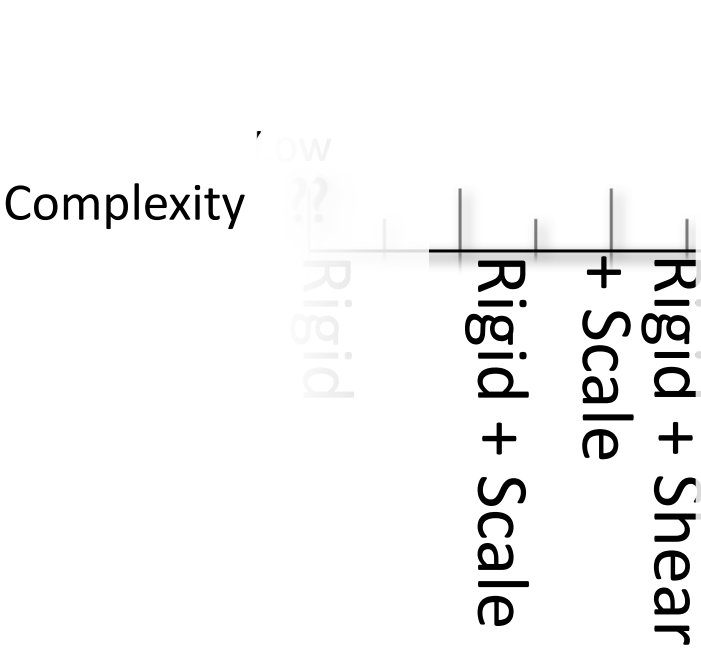

Volume
High
!!
Elastic
Thin plate
Bsplines
Rigid + Shear + Scale
Rigid + Scale
Rigid
??
Low
Complexity

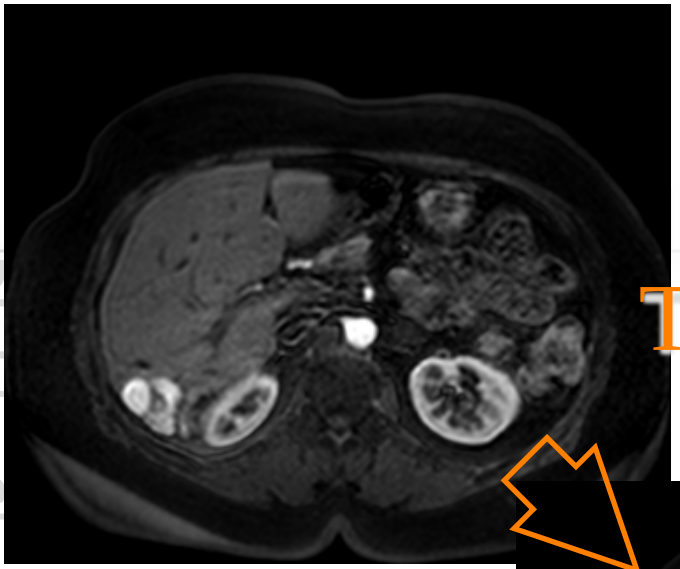
Rigid Transform



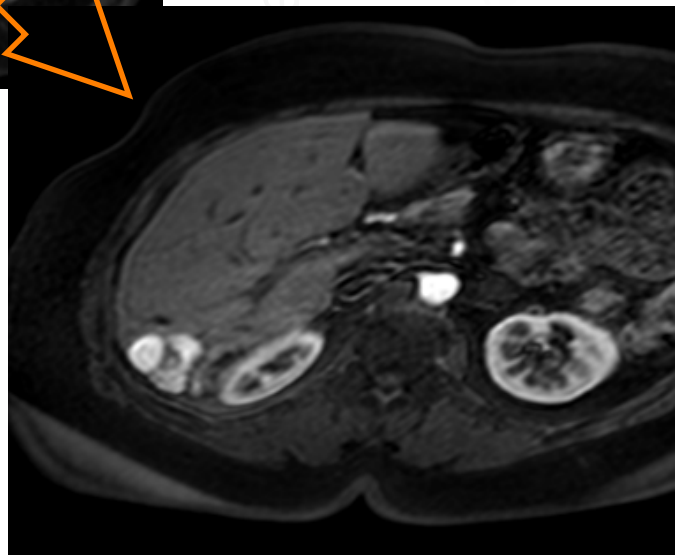
- Rigid rotation & translation transform
- 2D or 3D
- Max 6 independent parameters
  - three translations in X, Y, Z directions
  - three rotations about X, Y, Z axis

Affine Transform





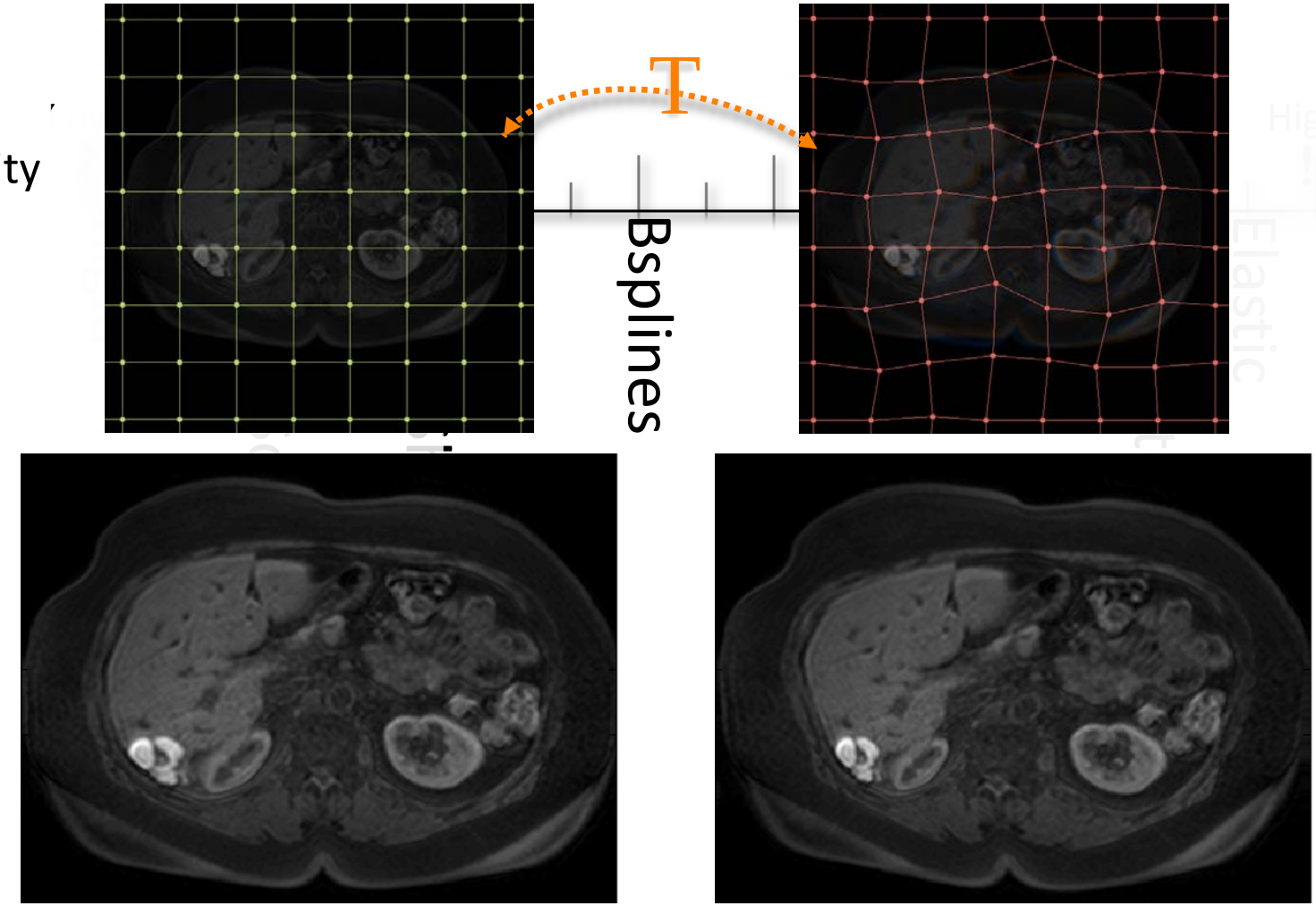
$$T(x) = A \bullet x + p$$



- Deceptively simple & Tricky
- Scaling has non-linear effects
- Max 12 parameters

Non-rigid Transform

Complexity



- A special case of non-rigid transform

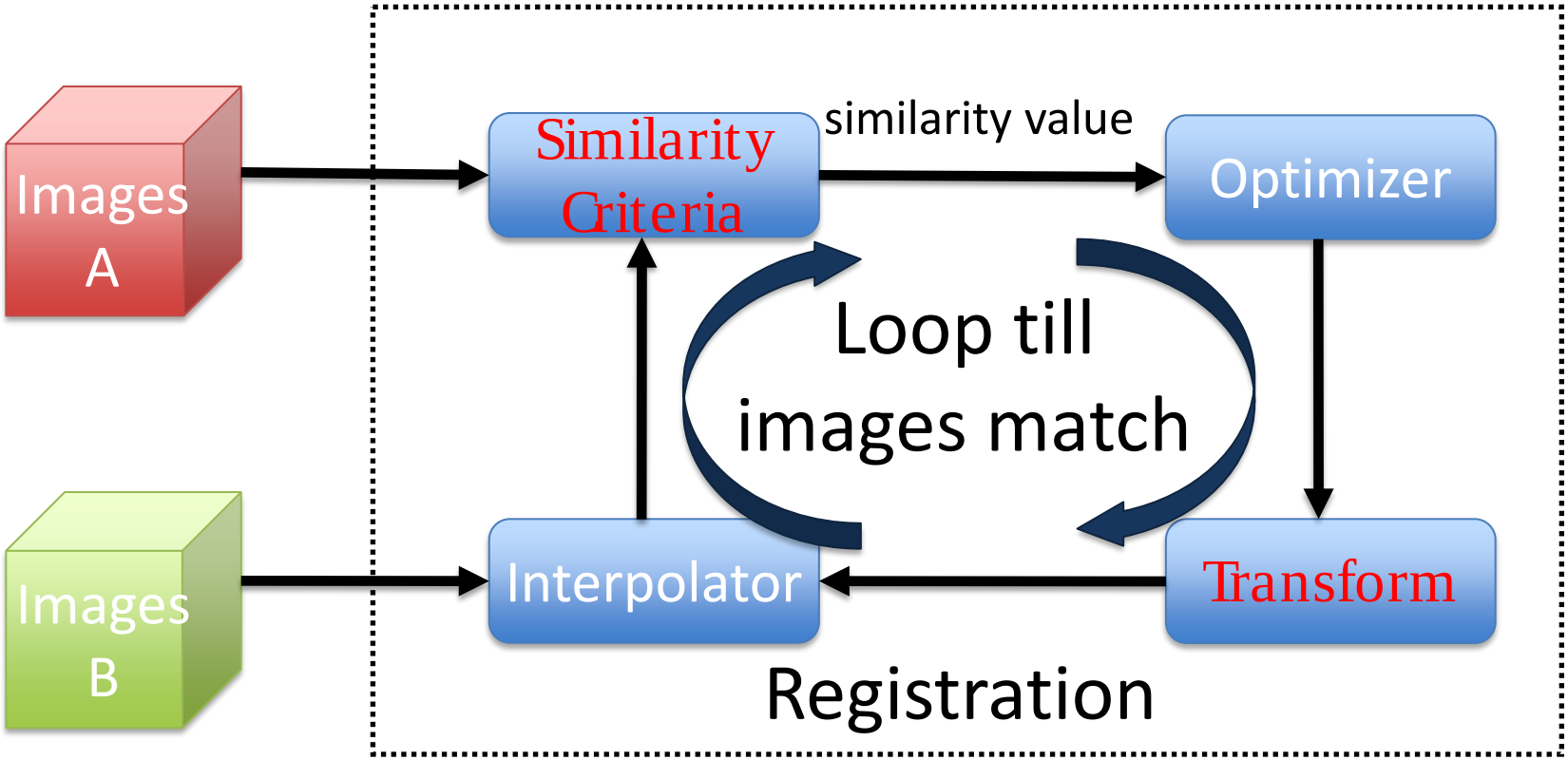
Non-rigid Transform

- Type of transform largely application driven
- Example
  - Modeling image as a continuum - plastic, elastic
  - Volumetric deformation fields
- Under-constrained, almost infinite dimensional

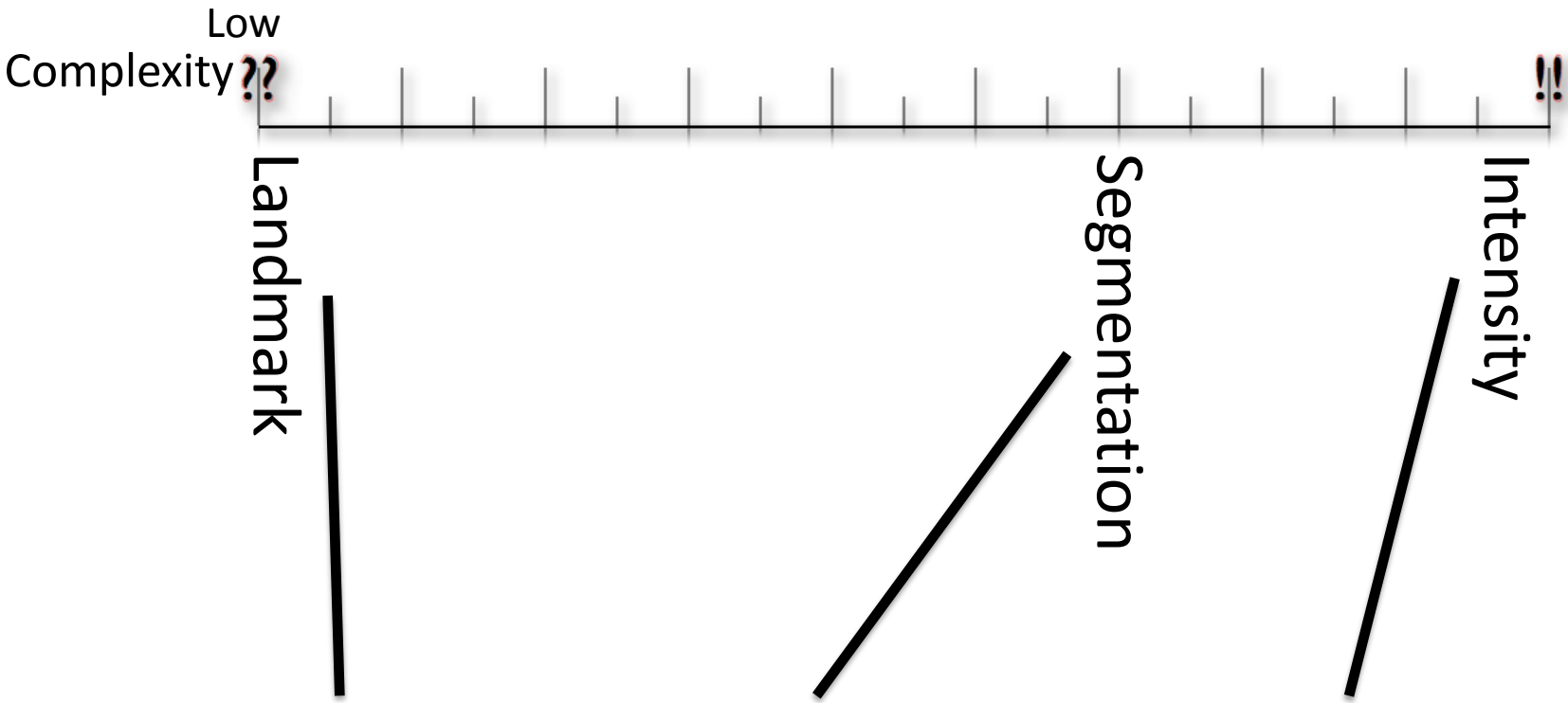
Typical Usage

Rigid	Non-Rigid
• Approximately “fuse” multiple images • Transfer coordinates between tracker and images • Image guided robot assistance • Initialize non-rigid transformations	• Register different patients • Study over a large time period • Compensate for deformation during US image acquisition • Atlas-based Segmentation

Basic Flowchart



Similarity Criteria



- Internal Fiducial
- External Fiducial

- Surfaces
- Vessels, etc

- Mutual Information
- Voxel property

Point to Point Landmark

Extrinsic

- Stereotactic frame
- Screw markers
- Skin markers

Intrinsic

- Anatomical point landmarks identified by user

Criteria:

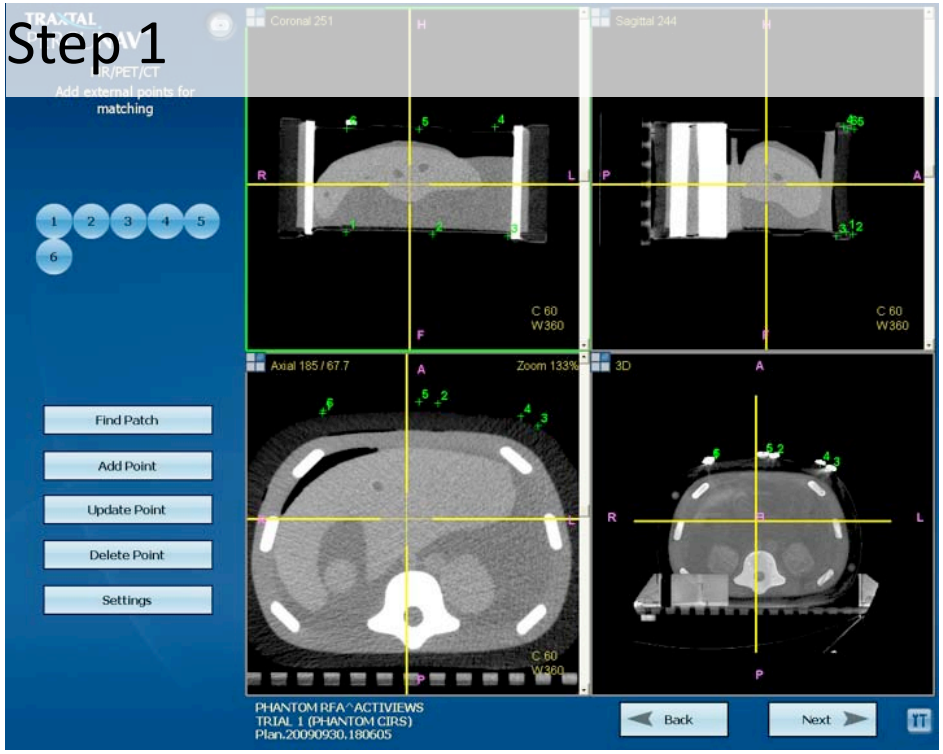
Sum of square distances between landmarks

Point to Point Landmark Registration

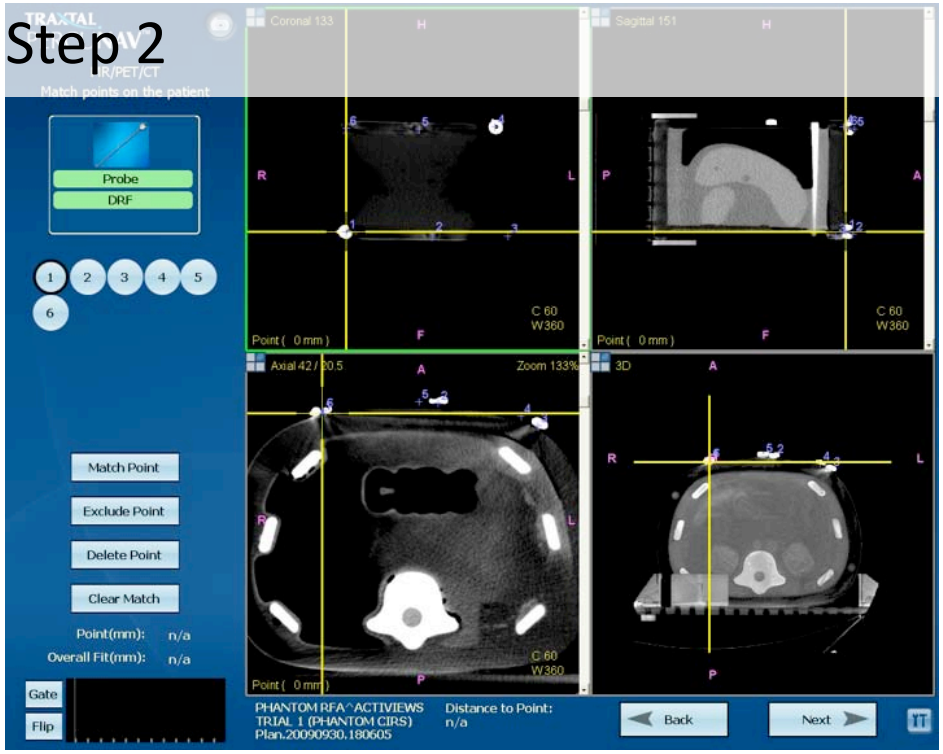
- Requires two sets of N points, N > 3
- Robust, versatile, very fast
- Finding correspondence
- Transfer coordinates between tracker & images
- In practice, limited to rigid/affine transformations

Point to Point Landmark Registration

Example



Identify points in first image set



Match corresponding points using tracker

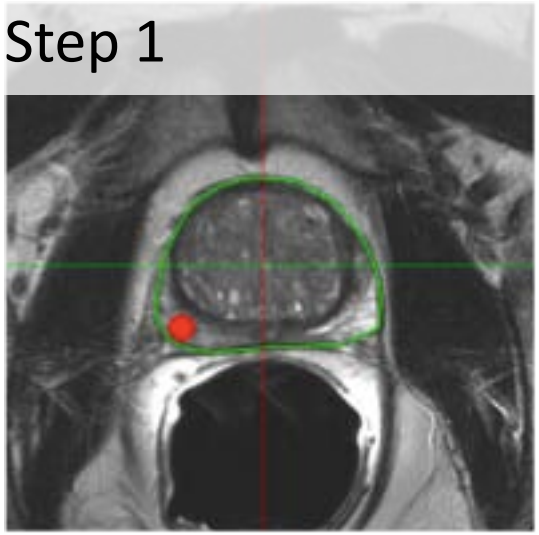
Traxtal, Inc

Segmentation based

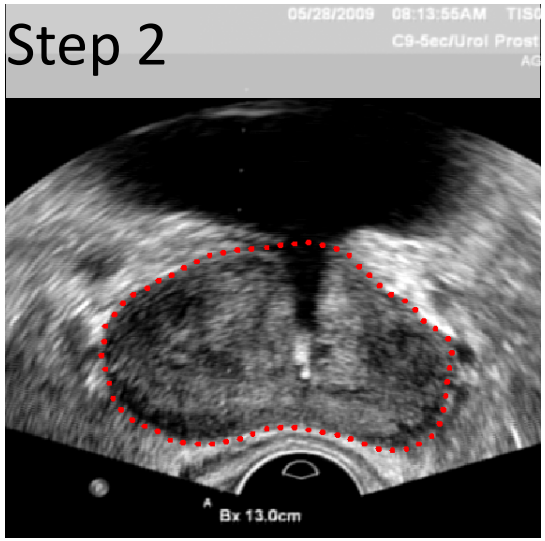
- Extract structure (surface, and curve)
- Criteria:
  - Depends on structure
- Segmentation can be range from automatic-manual
  - Largely defined by application
  - Segmentation effects accuracy
- Applicable to non-rigid, lower computational complexity

Surface to Surface Registration

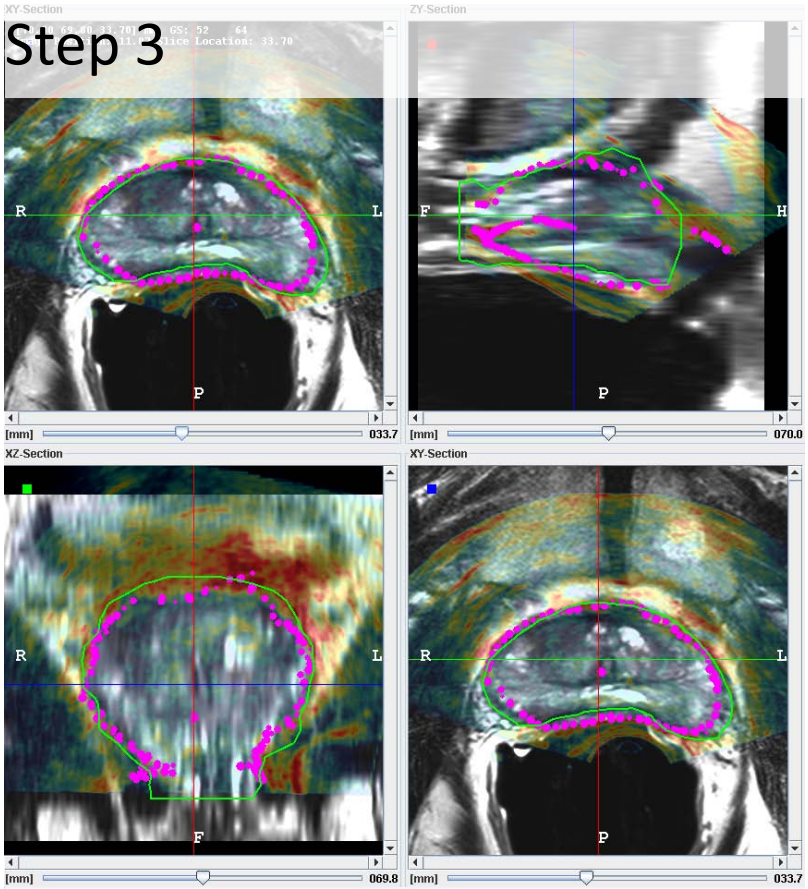
Example



Identify surface in MRI



Automatic segmentation in axial TRUS



Semi-Automatic 3DUS/MRI

Xu S, Philips Research

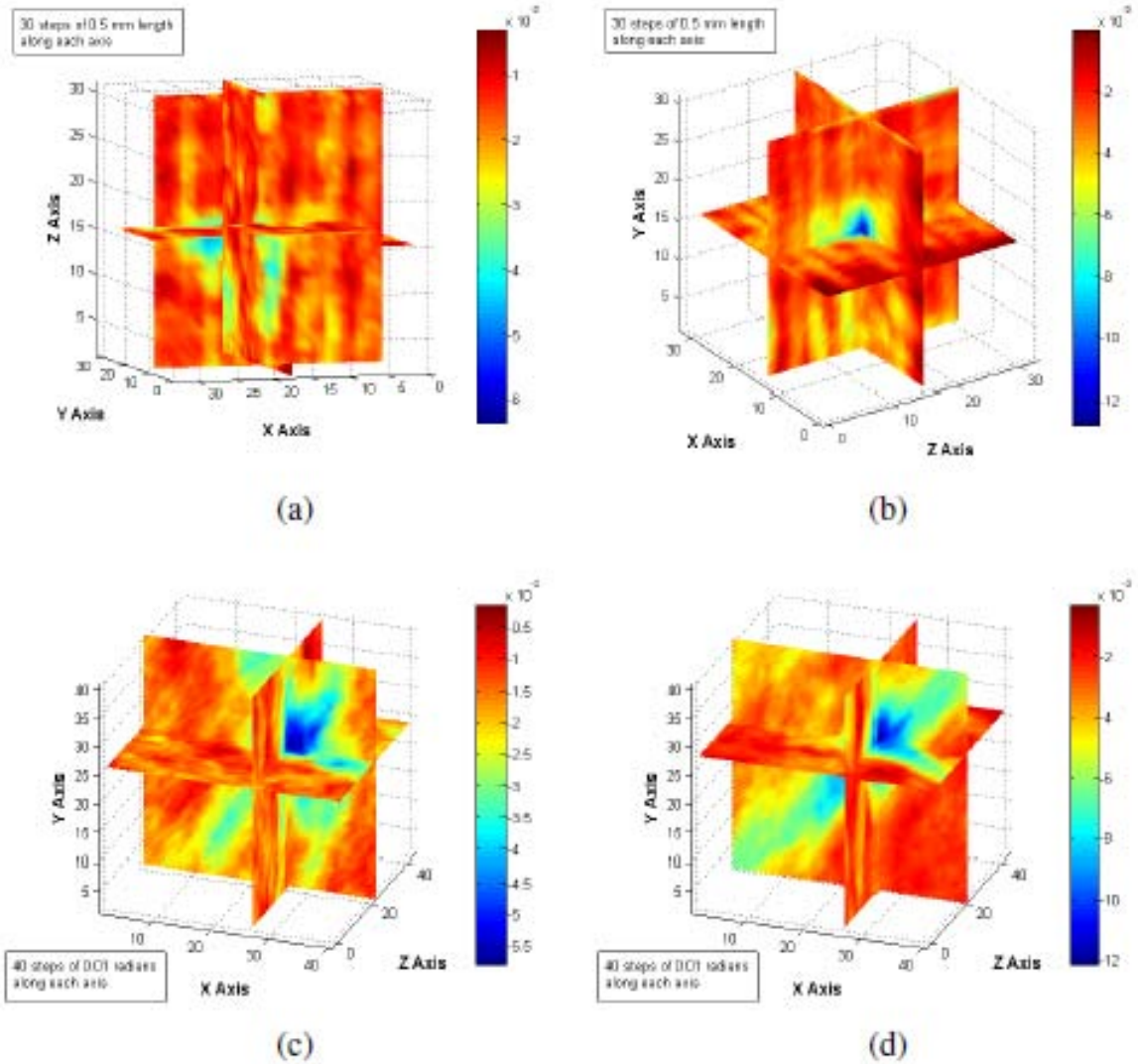
Surface to Surface RegistrationExample

- 2D US/3D MRI registration is sensitive
- Multiple images increase robustness
- Accuracy up to 3mm
- Motion compensation
  - Using 3D US / TRUS registration
  - Improved MRI / US overlap

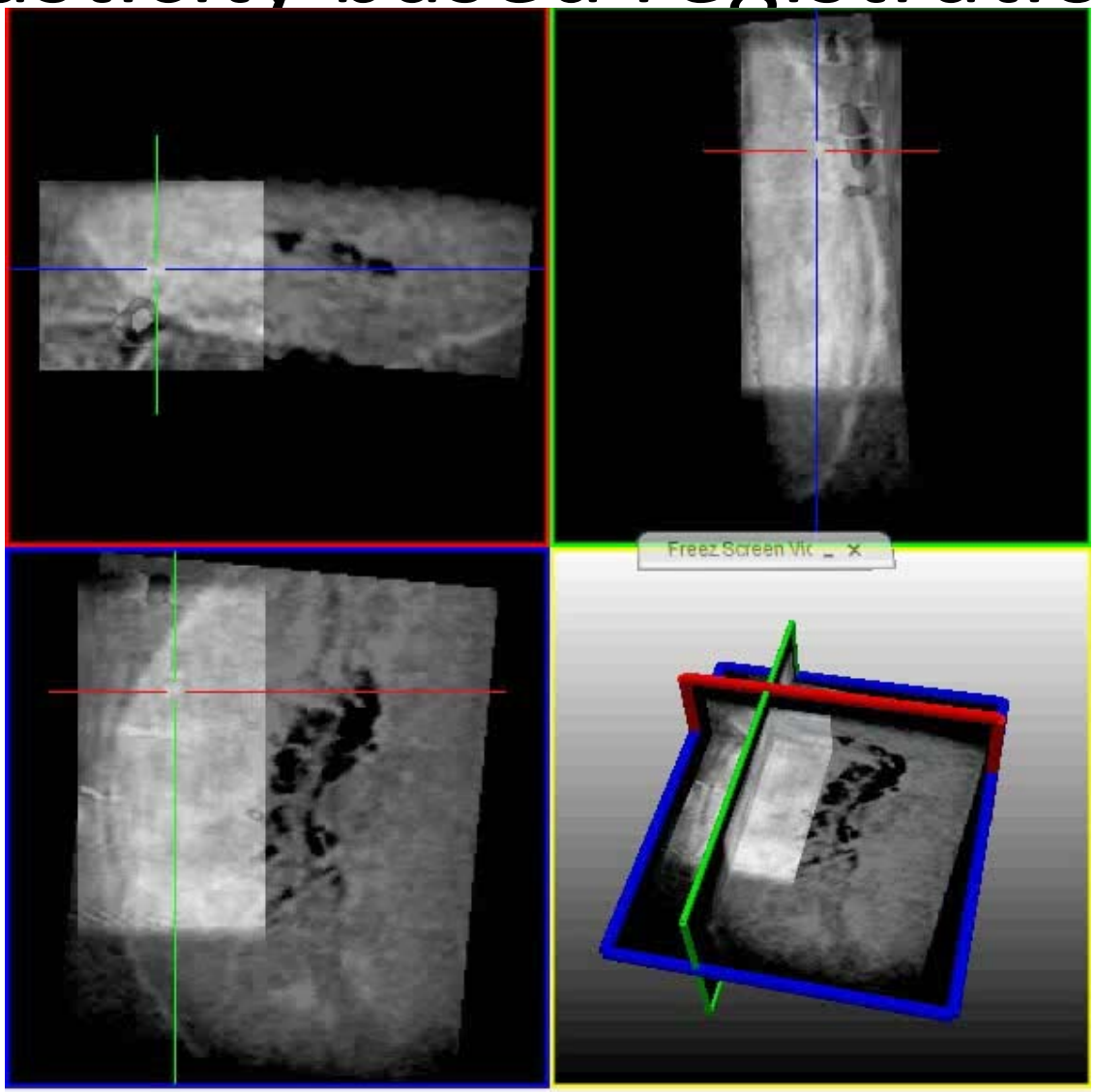
Voxel property

- Derived full image content
- Most flexible
- Considerable computation costs
- Common Criteria:
  - Absolute difference of intensities
  - Mean squares difference of intensities
  - Cross-correlation
  - Mutual information

Elasticity based registration



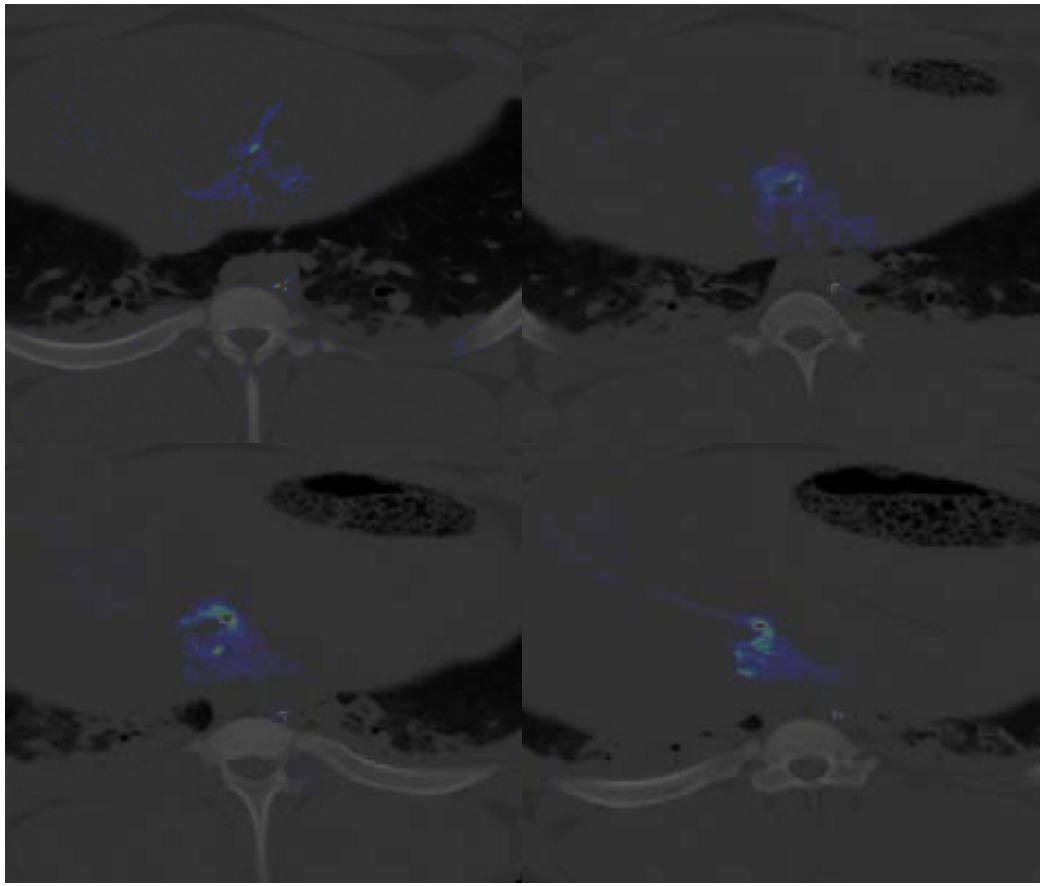
Elasticity based registration



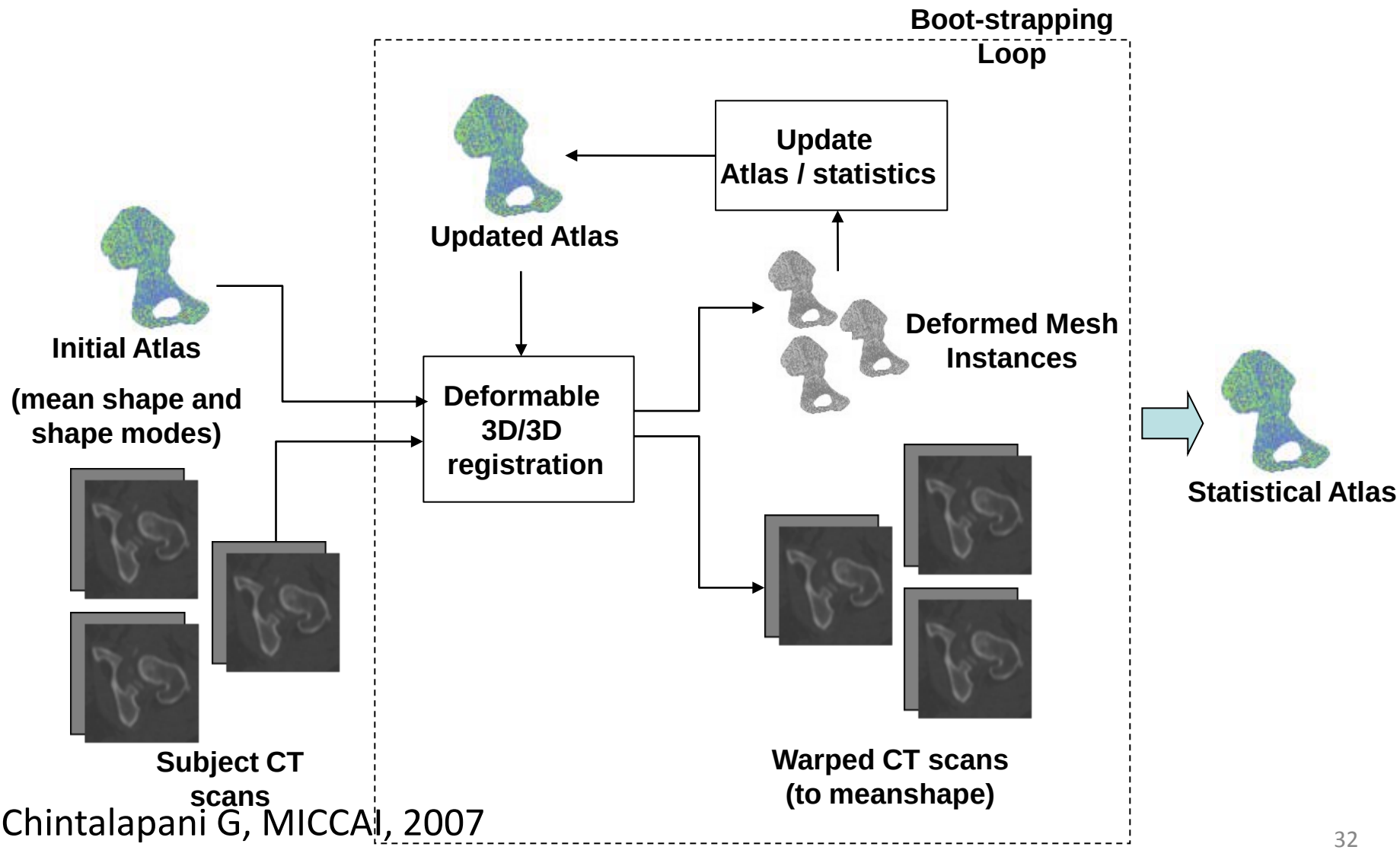
3D-3D Rigid Registration

Mean Squares Example

- Series of images at different interval
- Same Imaging modality
- Simple, less computationally expensive



3D-3D Deformable Example



Chintalapani G, MICCAI, 2007

3D-3D Deformable Example

Step 1

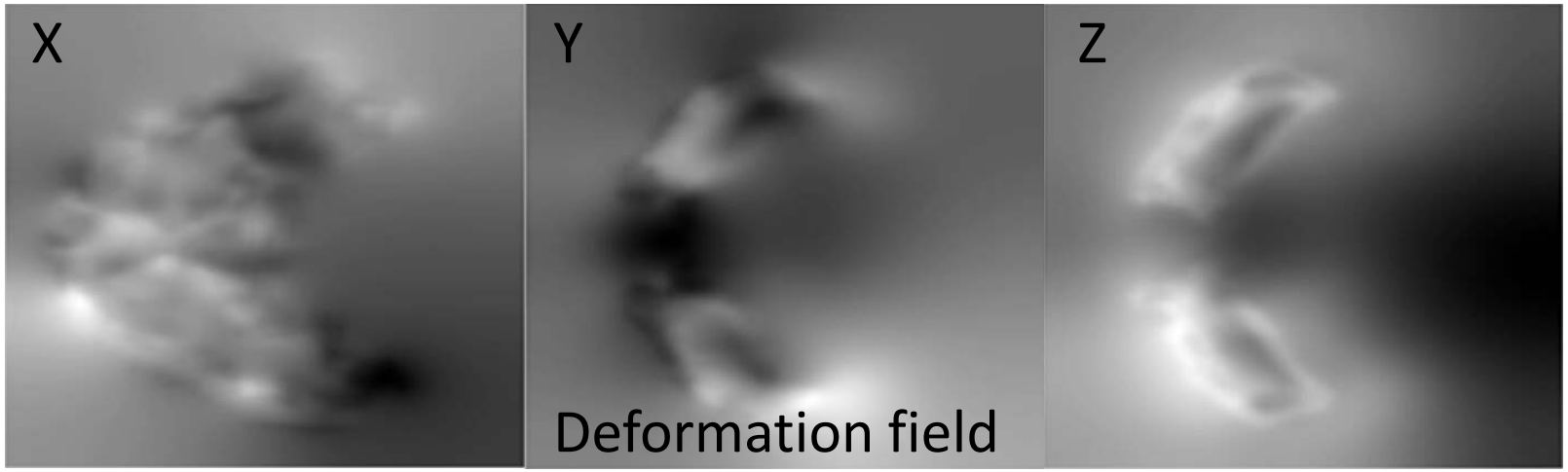
- Start with a initial approximate atlas, subject CT scans, subject mesh
- Do a Rigid registration
- Obtain a mean CT-like volume, mean shape and modes

Chintalapani G, MICCAI, 2007

3D-3D Deformable Example

Step 2

- Do a deformable registration of the CT scans to mean CT-like volume
  - Uses prior knowledge
  - Increases registration accuracy



Chintalapani G, MICCAI, 2007

3D-3D Deformable Example

Step 3

- Generate mesh from deformably registered CTs
- Create a new atlas from the deformed mesh

Chintalapani G, MICCAI, 2007

3D-3D Deformable Example

Step 4

- Repeat steps 2 & 3 until satisfied

Chintalapani G, MICCAI, 2007

Summary

- Define the terms registration and image fusion
- Different methods based on need
- Scope and limitations
- Clinical applications

References

- Toolkits
  - ITK (itk.org)
  - MITK (mitk.org)
  - MeVisLab (mevislab.de)
  - Slicer (slicer.org)
- A Survey of Medical Image Registration
  - Maintz and Viergever, Med. Img. Anal., 1998, 2(1), 1-36

References

- Xu S. et al., Real-time MRI-TRUS fusion for guidance of targeted prostate biopsies. Comp Aided Surg. 2008, 13(5), 255-64
- Krücker J. et al, Electromagnetic tracking for thermal ablation and biopsy guidance: clinical evaluation of spatial accuracy. J Vasc Interv Radiol. 2007, 18(9), 1141-50

References

- Sadowsky O. et al., Deformable 2D-3D registration of the pelvis with a limited field of view, using shape statistics. MICCAI. 2007, LNCS 4792, 519-26
- Chintalapani G. et al., Statistical Atlases of Bone Anatomy: Construction, Iterative Improvement and Validation. MICCAI. 2007 LNCS 4791, 499-506
- Ellingsen L.M. and Prince JL., Mjolnir: extending HAMMER using a diffusion