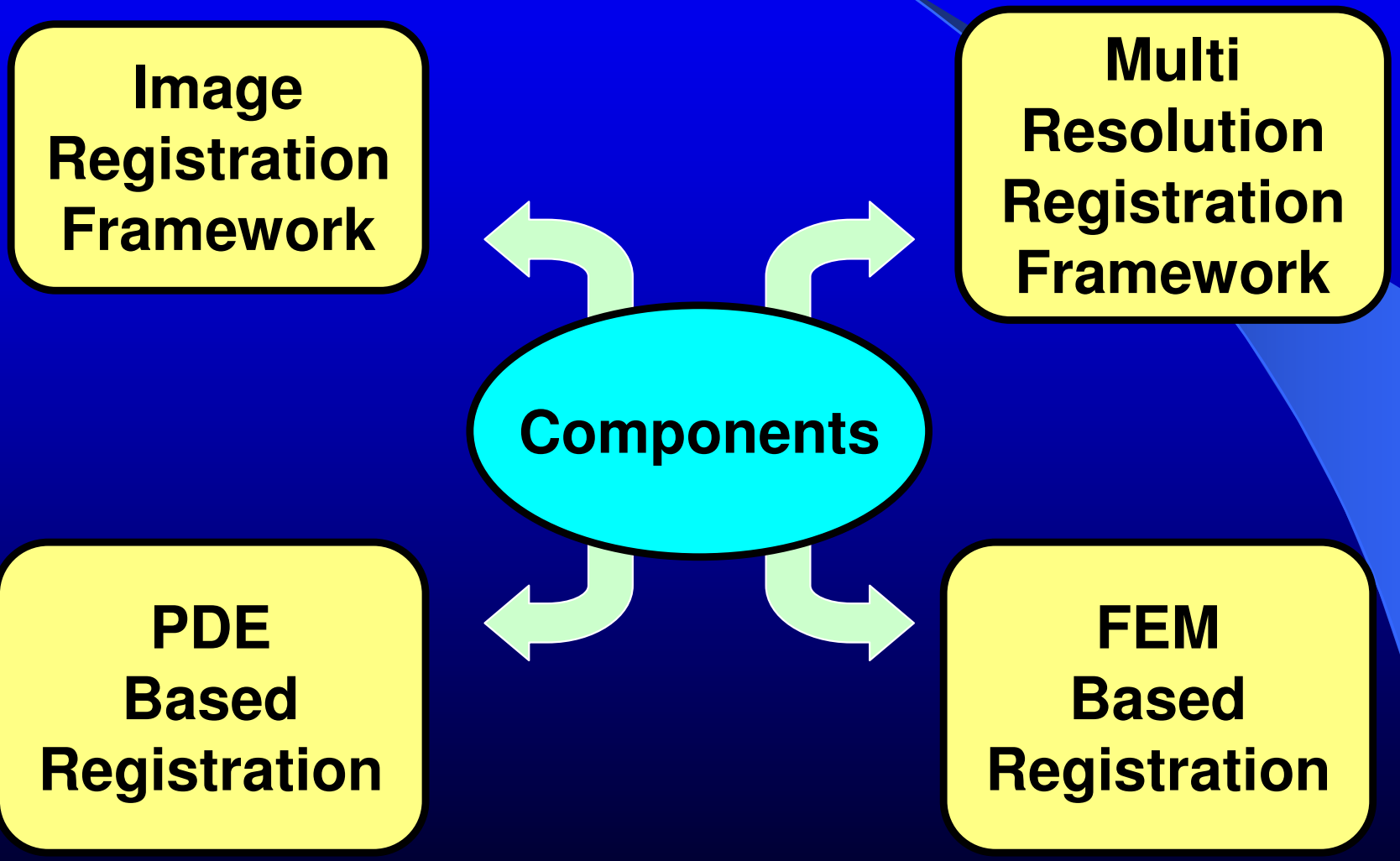
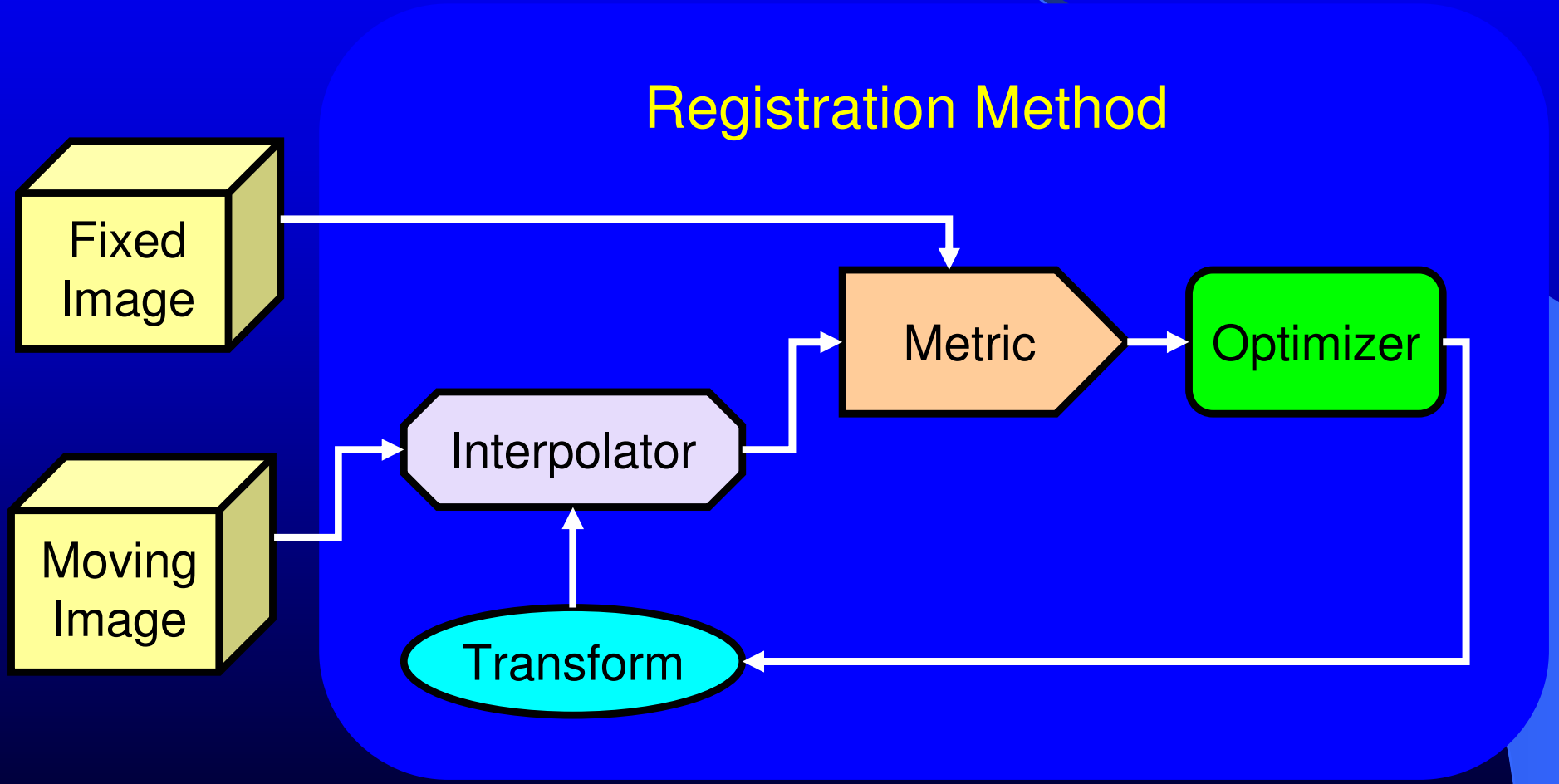
The Insight Toolkit

Image Registration
Algorithms & Frameworks

Registration in ITK



Components


Registration Method
Fixed Image
Moving Image
Interpolator
Metric
Optimizer
Transform

Metrics

- Mutual Information
- Mean Squares
- Normalized Correlation
- Pattern Intensity

Transforms

- Translation
- Scale
- Rotation
- Rigid3D
- Rigid2D
- Affine
- Splines: TPS, EBS, VS

Optimizers

- Gradient Descent
- Regular Step Gradient Descent
- Conjugate Gradient
- Levenberg-Marquardt

Interpolators

- Nearest neighbor
- Linear
- BSpline

Multi-Resolution Registration Framework

- Improve speed, accuracy & robustness
- Images down-sampled using image pyramid filters
- Results from one resolution level use as initial estimate for the next resolution level
- Flexible framework
  - Allow change of parameters and/or components between resolution levels

Example Applications

Distributed with the Code

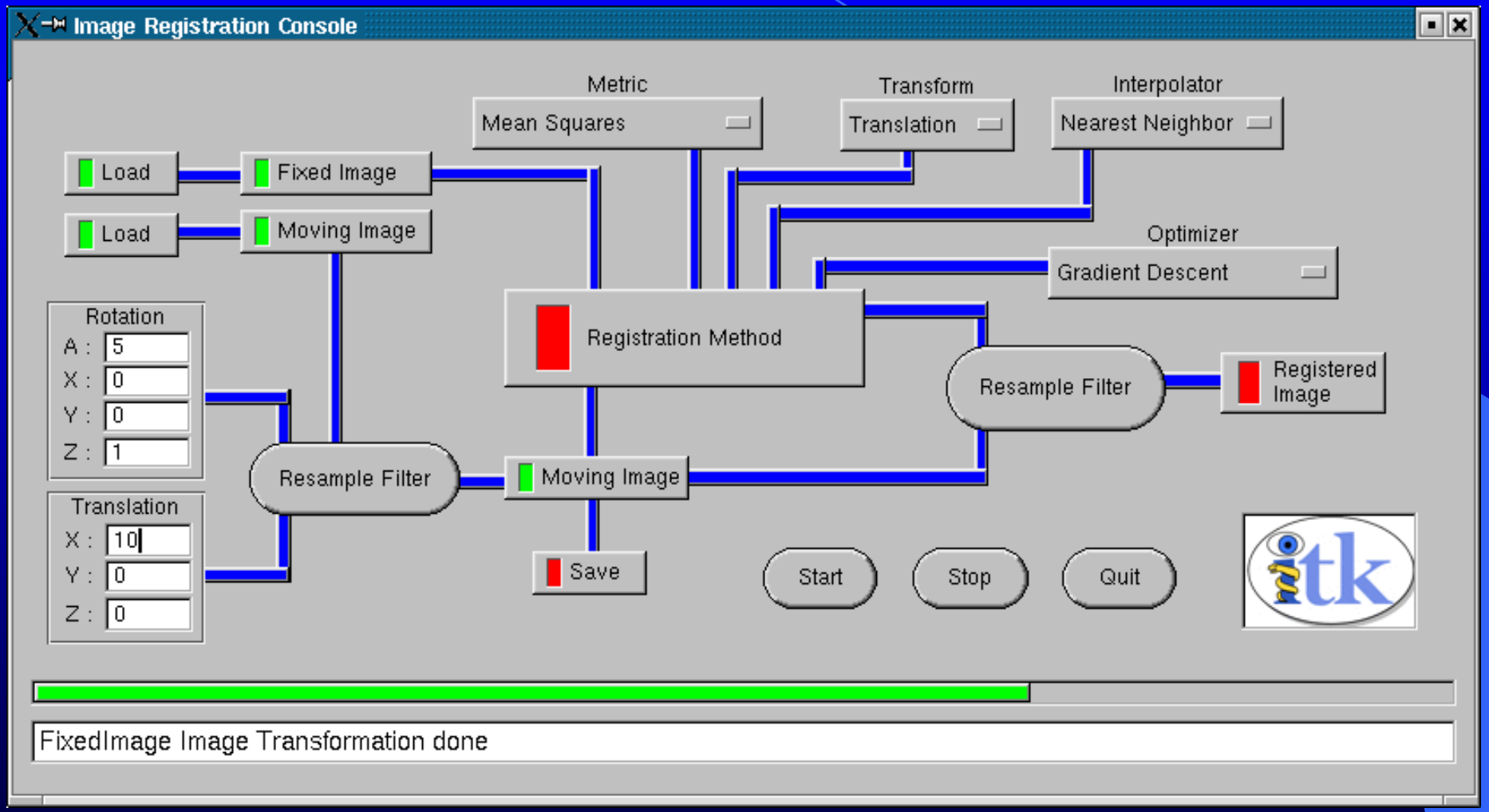
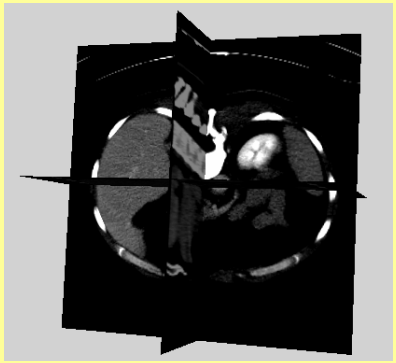
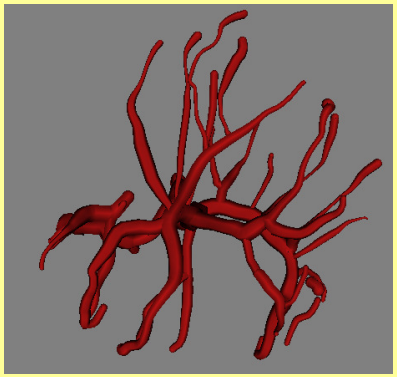


Image Registration Example (from the Examples directory)

Vascular Registration



Fixed 3D Image
(US)



Moving Vasculature
(extracted from CT)

Vascular Registration Method

ImageToTube Metric

Gradient Descent Optimizer

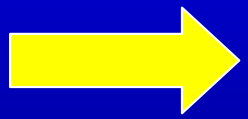
Tri-linear Interpolator

Euler 3D Rigid Transformation

Vascular Registration

Goal: Register 3D Ultra-Sound data with pre-operative CT/MRI using vasculature as a support for registration.

Time is critical if we want to use the registration during a clinical operation



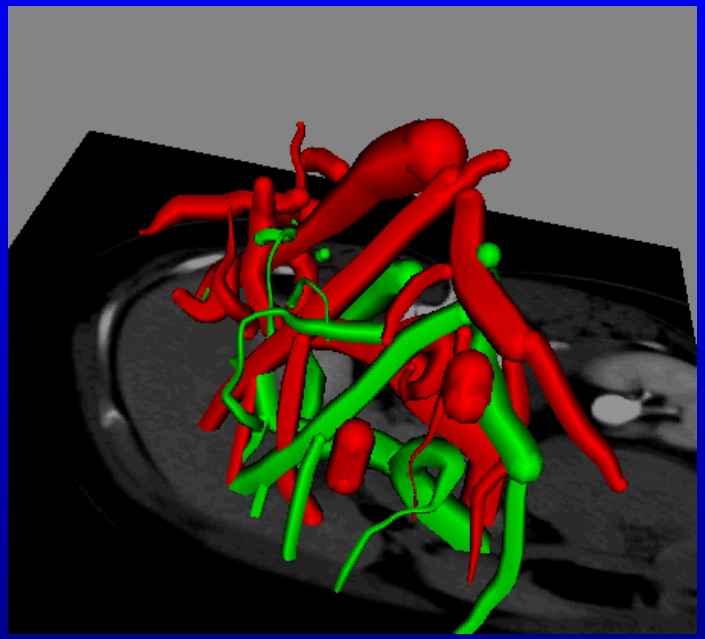
MultiThreading

The Insight Toolkit is the perfect tool for this:

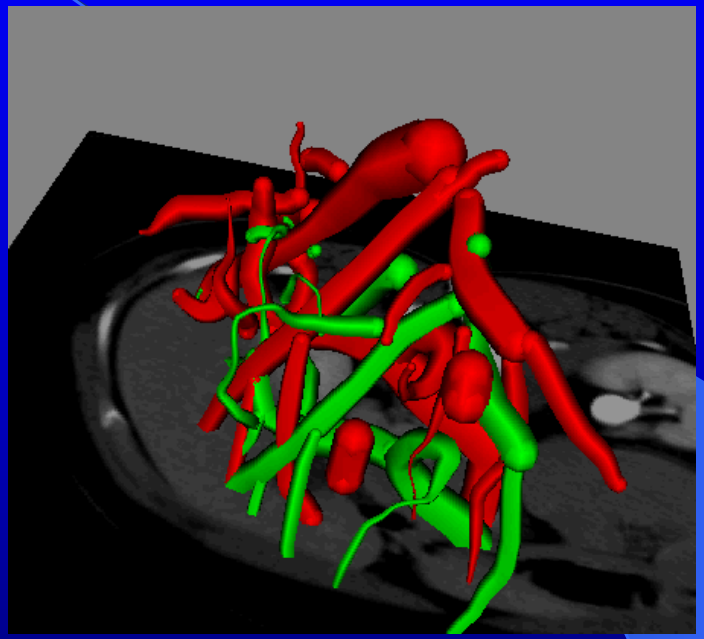
- Base Classes for registration are already implemented. (just need to write the metric !).
- Sophisticated optimizers are provided.
- Multi-Platforms multithreading classes are ready to use.

Vascular Registration

Using 1 Processor



Using 2 Processors



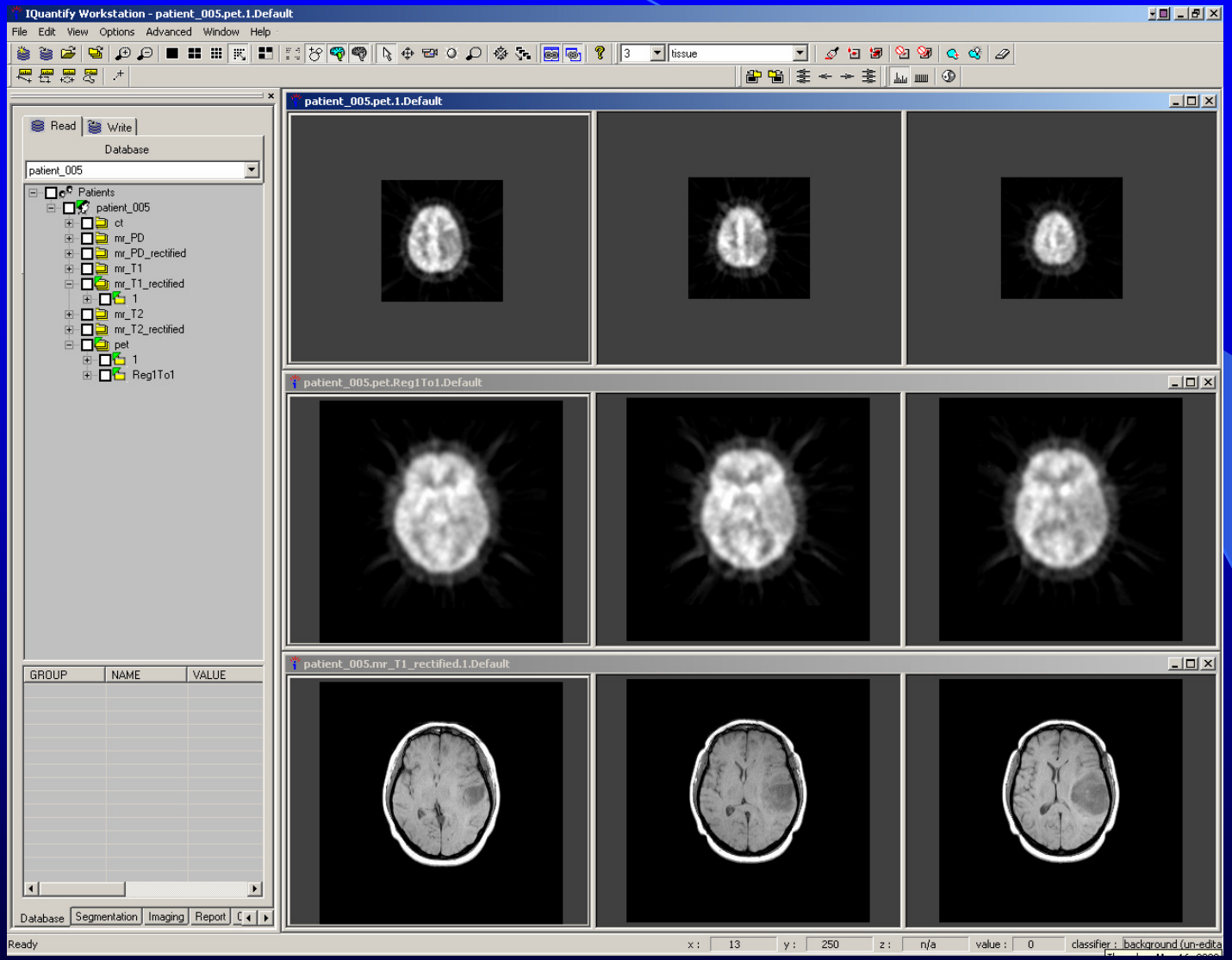
Performances: running on a dual Intel Pentium III 733Mhz (512MB)

Number of Processors used	Time / Iteration (sec)	Total time
1	0.153	6.31
2	0.297	12.25

This is 1.94 time faster !

UNC vascular registration

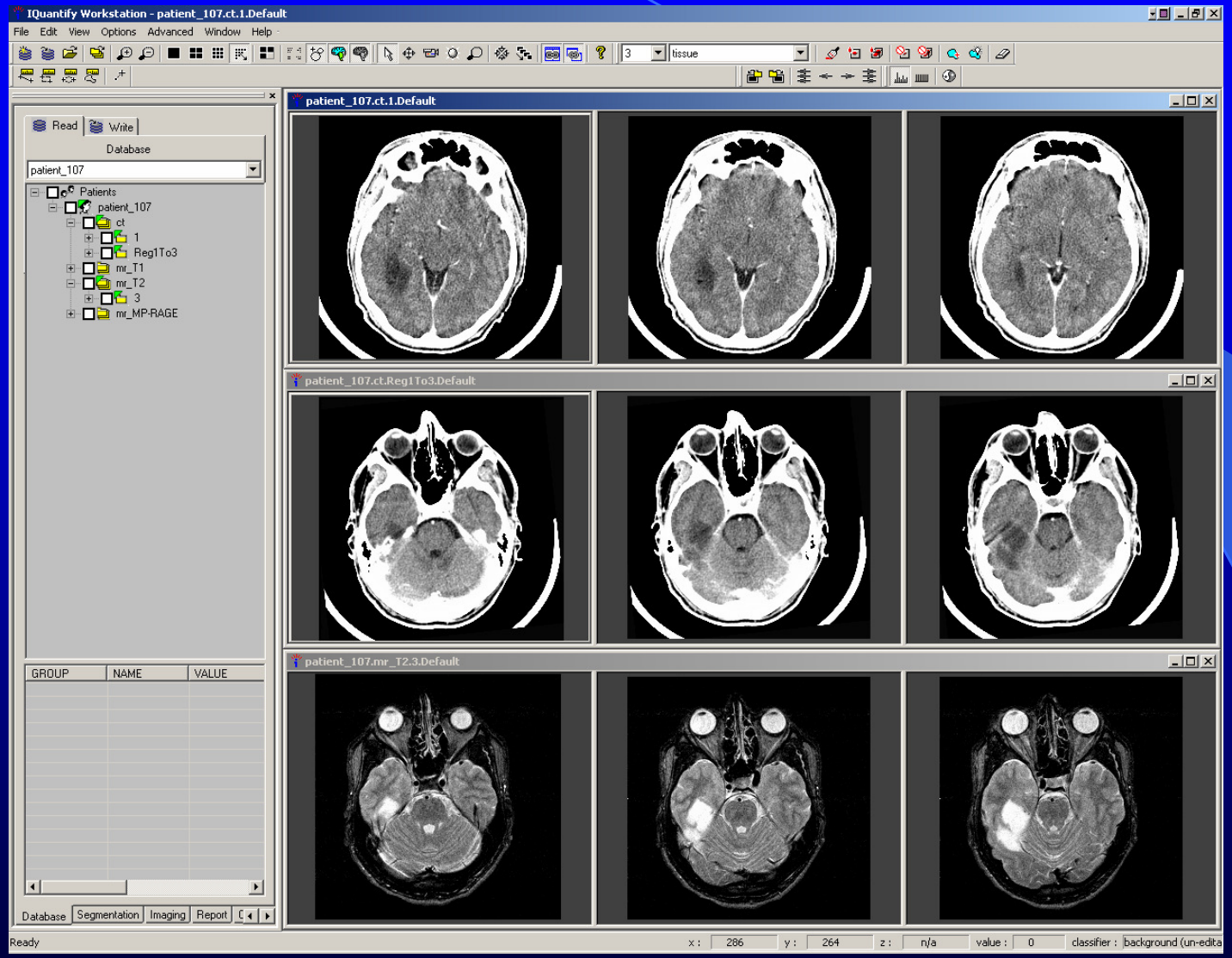
Product Integration: IQuantify*



PET to **MR-T1** Rigid Registration using Mutual Information. Top row shows selected **PET** slices before registration. The middle and bottom rows respectively shows the **PET** slices after registration with the corresponding **MR-T1** slices.

***Insightful internal product codename (www.insightful.com/iquantify)**

Product Integration: IQuantify*



CT to **MR-T2** Rigid Registration using Mutual Information. Top row shows selected **CT** slices before registration. The middle and bottom rows respectively shows the **CT** slices after registration with the corresponding **MR-T2** slices.*

***Insightful internal product codename (www.insightful.com/iquantify)**

Validation Study: Rigid Multi-Modality Registration of 3D CT, MR and PET Images of the Brain

Data:

- "Retrospective Registration Evaluation Project" conducted by Dr Fitzpatrick at Vanderbilt University
- Gold standard:
  fiducial markers which were then airbrushed out

Validation Study: Rigid Multi-Modality Registration of 3D CT, MR and PET Images of the Brain

Scoring:

- Blinded study:
  participants submit registration to Vanderbilt
- Error = difference in registered position of 10 volumes of interest between the submitted registration and the gold standard

- Results:

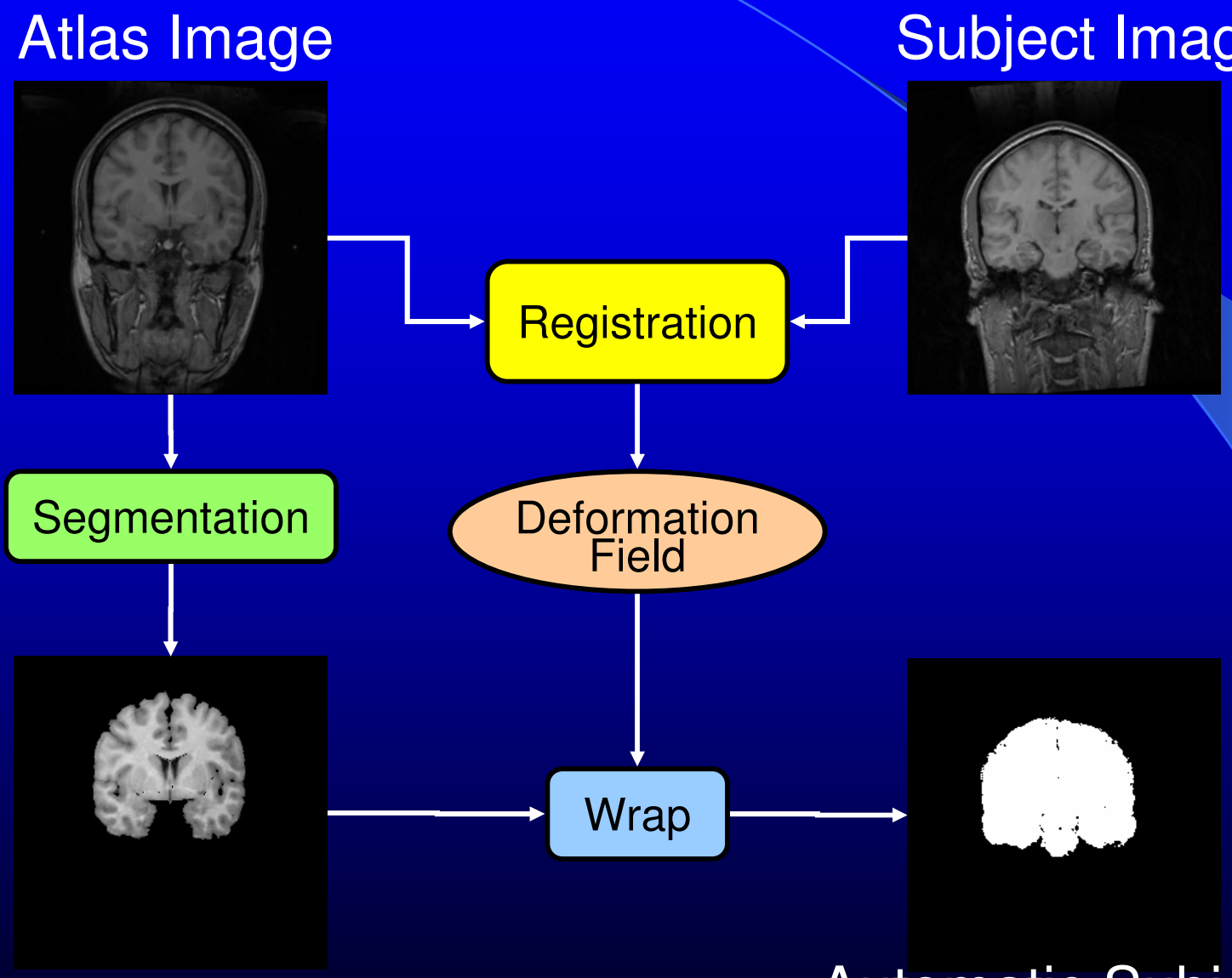
"From" Modality	"To" Modality	Mean Error (mm)	Median Error (mm)
CT	MR_PD	2.51	2.11
CT	MR_T1	1.71	1.65
CT	MR_T2	2.42	2.44
CT	MP-RAGE	5.14	2.04
PET	MR_PD	4.41	4.03
PET	MR_T1	6.52	4.33
PET	MR_T2	3.16	3.34
MP-RAGE	MR_T2	2.79	2.73
CT	MR_PD_rectified	0.90	0.86
CT	MR_T1_rectified	1.06	0.91
CT	MR_T2_rectified	1.23	1.00
PET	MR_PD_rectified	4.46	2.71
PET	MR_T1_rectified	4.11	2.09
PET	MR_T2_rectified	2.68	2.77

Typical slice thickness: CT (3-4mm), MR(3-4mm),
MP-RAGE (1.6mm) and PET(8mm)

PDE-based Registration

- Deformable registration using Thirion's "demons" algorithm
- Deform image by pushing iso-brightness contours in the normal direction using an "optical flow" speed term
- Enforce elastic constraint on deformation by periodically smoothing with Gaussian filter
- Implemented with the Finite Difference Solver framework
- Application: atlas-based segmentation

Atlas-based Segmentation



Validation Study: Atlas-based Brain Volume Segmentation From MRI Images

- Data:
  - 20 Normal T1 weighted dataset from IBSR
  - Gold standard: manual delineation
- Metric:
  - Kappa statistic based similarity index
  - Range from 0 (no overlap) to 1 (perfect alignment)
- Results:
  - Mean similarity index = 0.955
  - Estimated and manual delineated volume correlation = 0.992

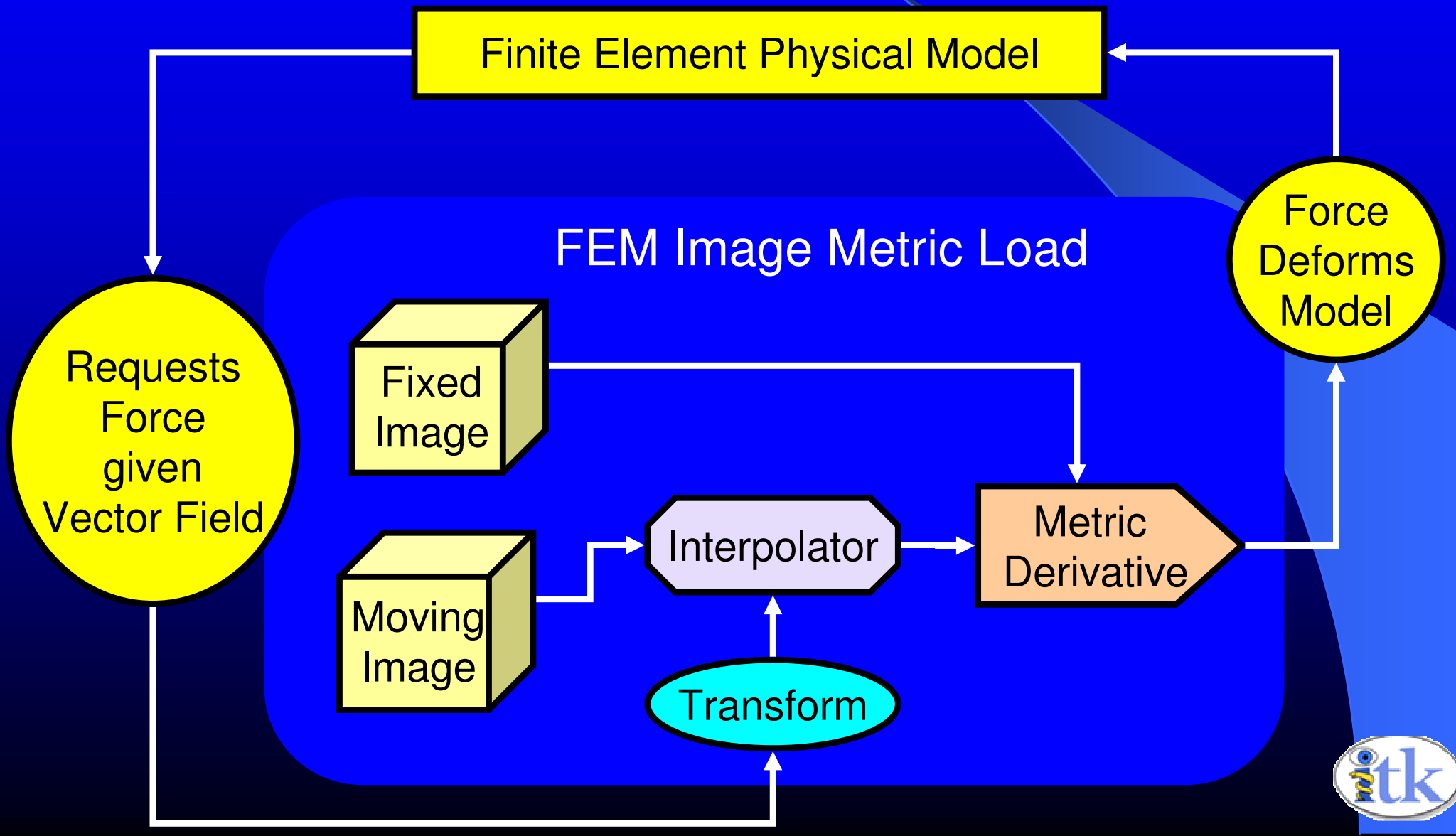
FEM-Based Deformable Registration

- Deformable registration using FE-Model
  - Requires assumptions about physics (material properties) and geometry (element and mesh).
- Deform image by computing a vector field that follows the gradient of an image potential
  - Potential Implemented with ITK Image Metrics.
  - Use Translation Transform (others possible).
  - Vector field is smooth due to material properties.

FEM-Based Deformable Registration

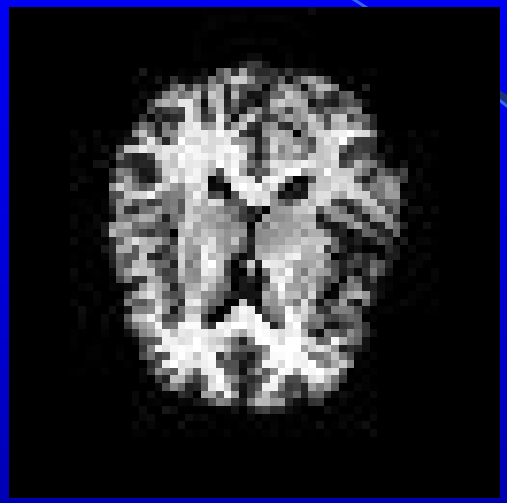
- User allowed to set
  - Mesh resolution
  - Metric region size
  - Metric
  - Physics
- Line search to guarantee
  energy minimized

FEM Image Registration

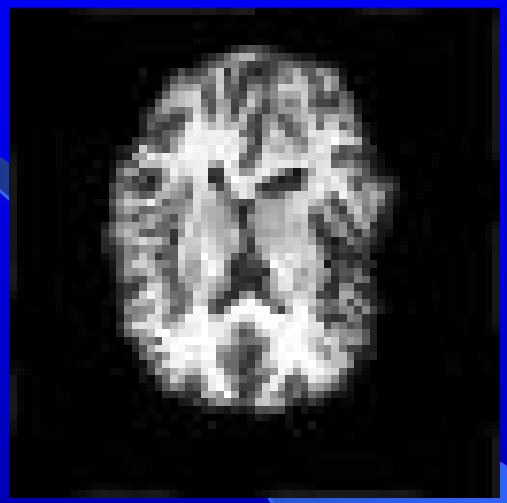


FEM Registration Example

Fixed Image



Moving Image



Deformed Image