

ITK

The Insight Segmentation & Registration Toolkit



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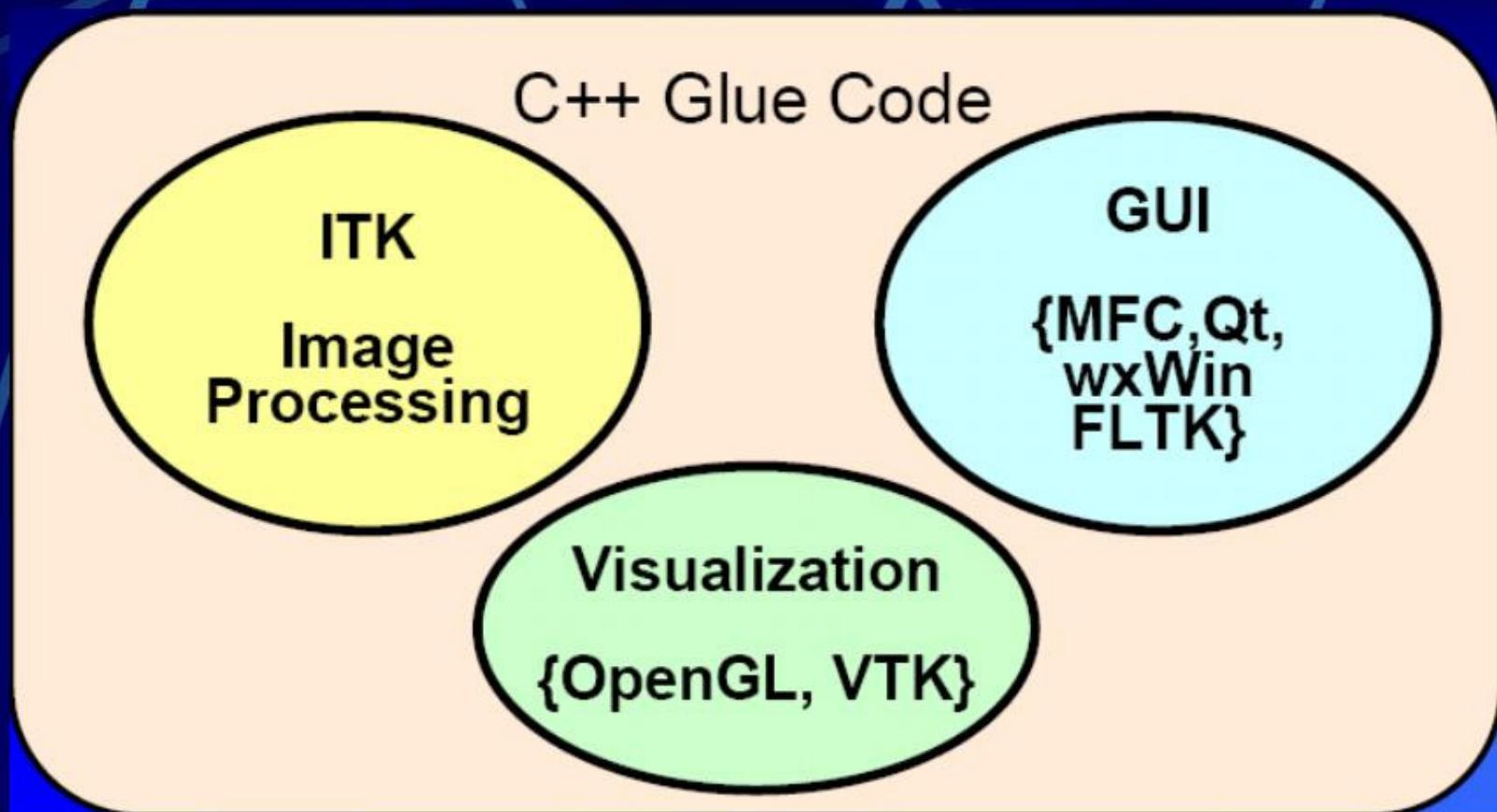
What is ITK?

- (Medical) Image Processing in C++
- Segmentation
- Registration
- No Graphical User Interface (GUI)
 - Bindings to Qt, Fltk
- No Visualization
 - Bindings to Kitware VTK, VolView

Short History

- NLM ITK @ www.itk.org
- 1999: NIH grant for 3 years to develop open source medical seg. & reg. toolkit
- Insight Software Consortium:
 - GE Corporate R&D
 - Kitware (vtk, VolView)
 - UNC, UT, UPenn

How To Integrate ITK?



What Does One Need?

C++ Compiler

gcc 2.95 – 3.2
Visual C++ 6.0
Visual C++ 7.0
VC++ 7 2003
Intel 5.0
IRIX CC
Borland 5.0
Mac - gcc

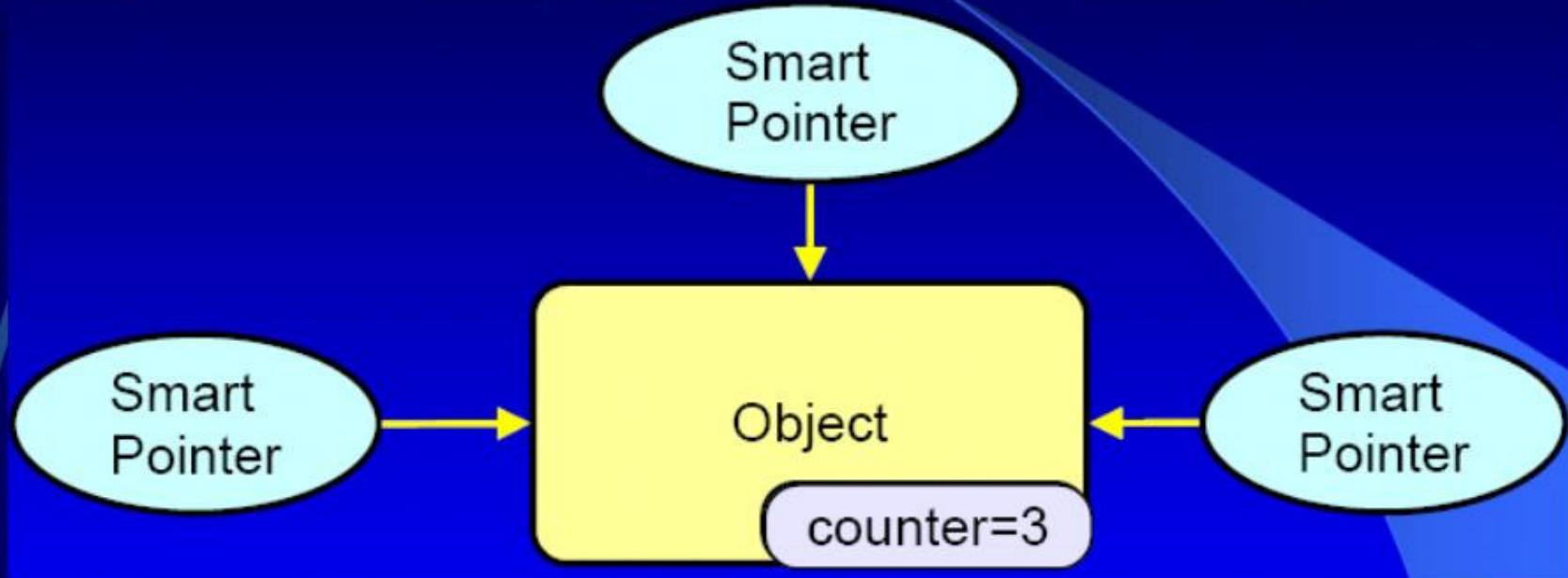
CMake

www.cmake.org

Concepts (I)

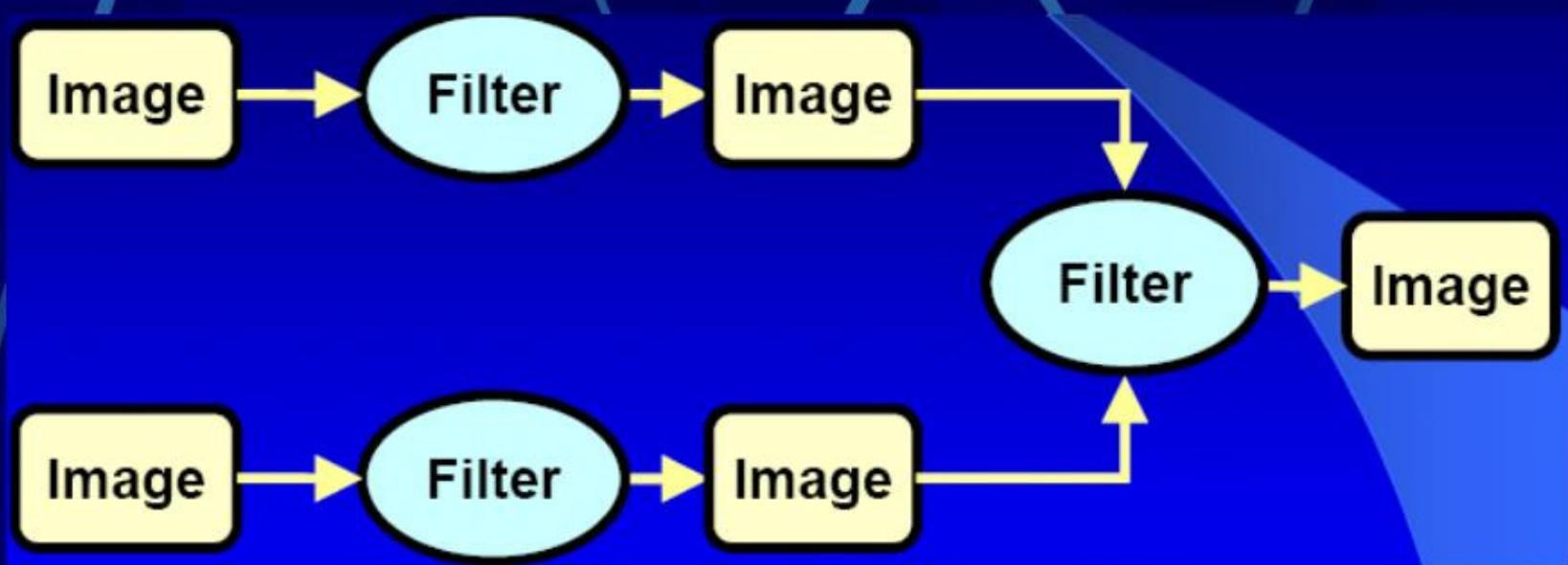
- C++ Generic Programming (Templates)
- Data Pipeline
- Support for Multi-Threading
- Events and Observers
- Smart Pointers
- Object Factories for Data Management
- TCL and Python wrappings
- Extreme Programming

Concepts (II)



Concepts (III)

Data Pipeline



Concepts (IV)

- vxl – vnl library (vxl.sourceforge.net)
 - C++ wrapper around netlib (fortran)
 - (specialized) matrix & vector classes
 - Matrix decompositions (svd, ...)
 - Real polynomials and root finder
 - Optimization (levenberg-marquardt, gradient descent, ...)

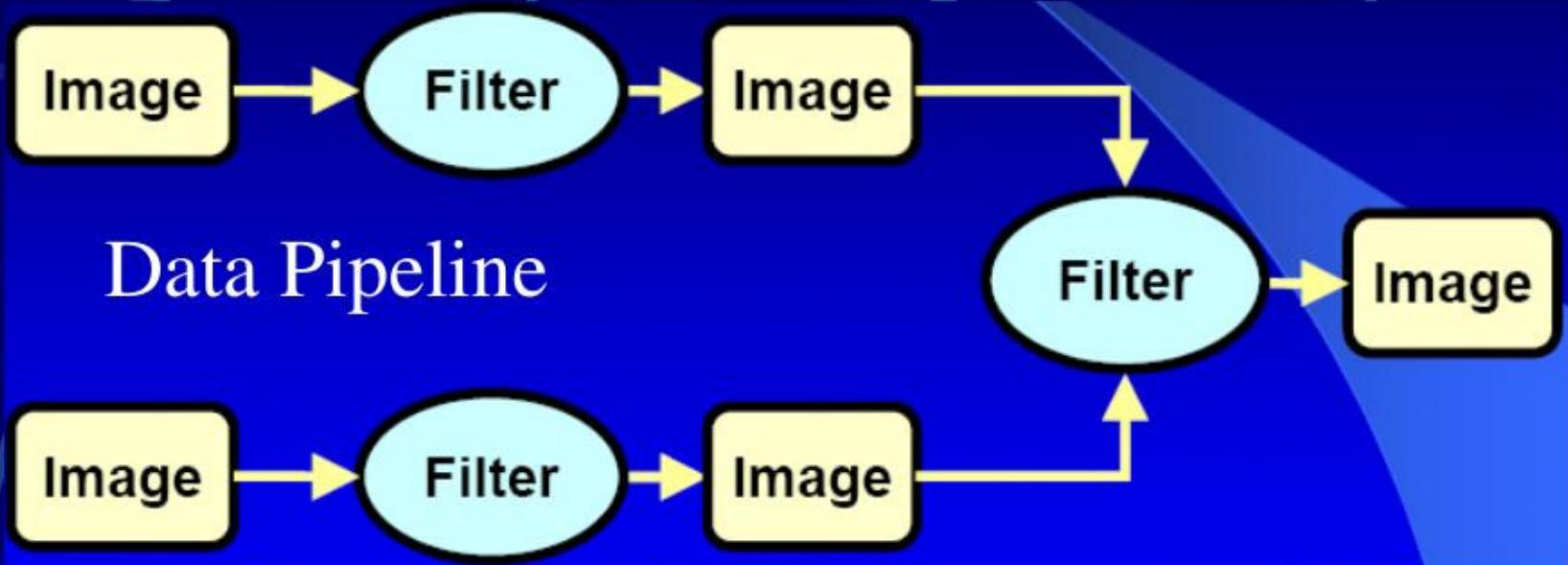
Itk::Image & itk::Mesh

- `Image< PixelType, Dimension >`
- Regions
 - `LargestPossible`
 - `Buffered`
 - `Requested`
- `Mesh< PointType, Dimension, MeshTrait >`
 - Indexed face set

Spatial Objects

- Scene Graph - Object hierarchy
- Stores transformations
- Check if points are inside SO, ...
- E.g. Image, Surface, Landmark, Tube, Ellipse, ...

Basic Filters

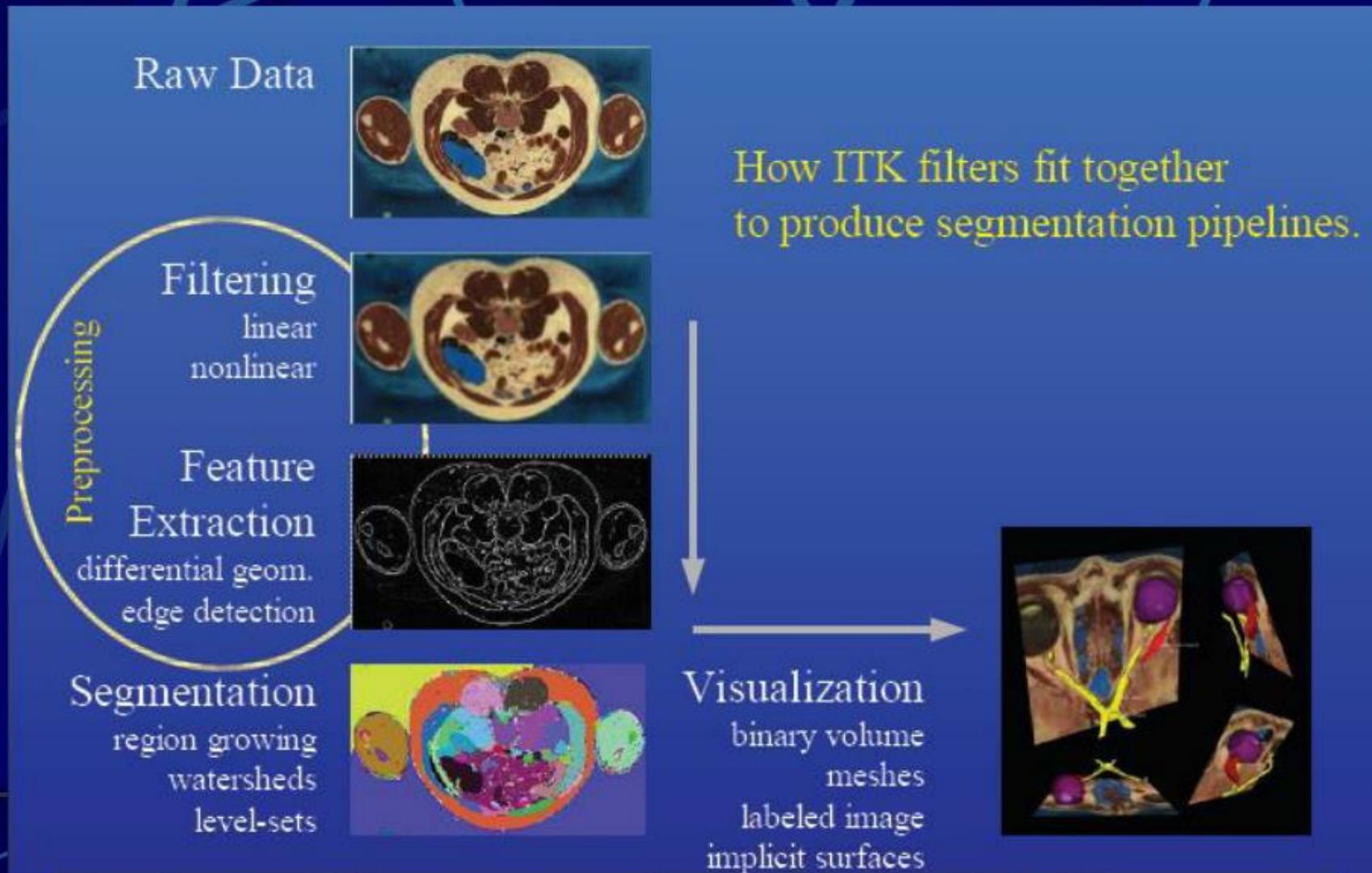


e.g. Threshold, Casting, Intensity Mapping, Gradient, Mean, Median, Binary & Grayscale Morphology, (Recursive) Gaussian-Blur, Canny Edge Detect, Laplacian, Anisotropic Diffusion, Bilateral Filtering, DistanceMap, Image Resampling, ...

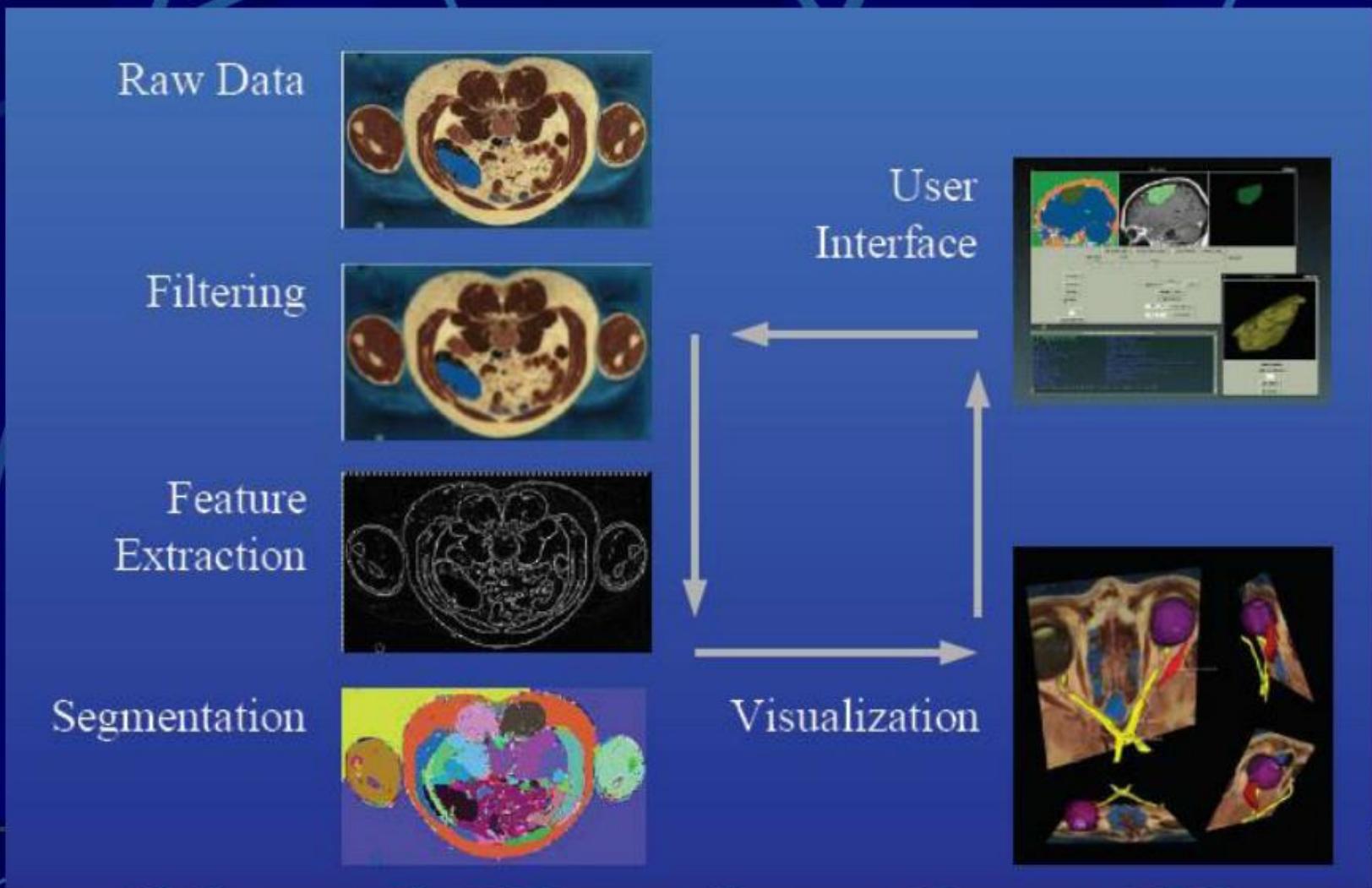
Segmentation

- *Partitioning images into meaningful pieces, e.g. delineating regions of anatomical interest.*
 - Edge based – find boundaries between regions
 - Pixel Classification – metrics classify regions
 - Region based – similarity of pixels within a segment

Segmentation Pipeline



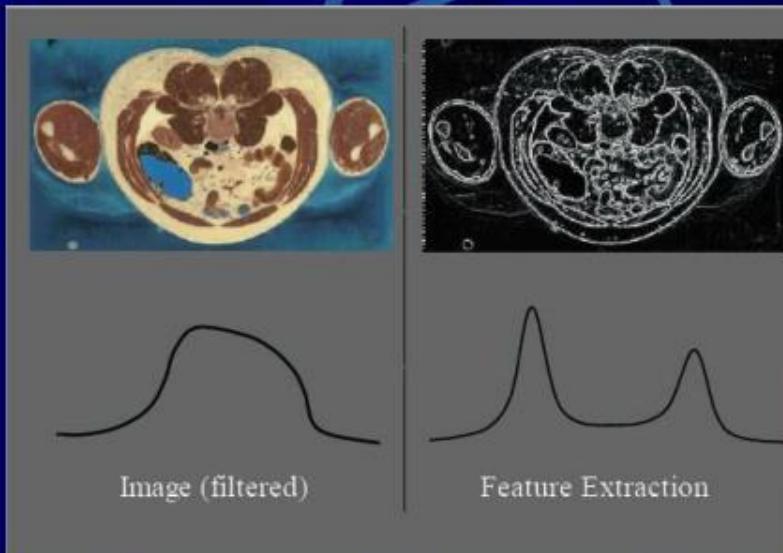
Segmentation Pipeline



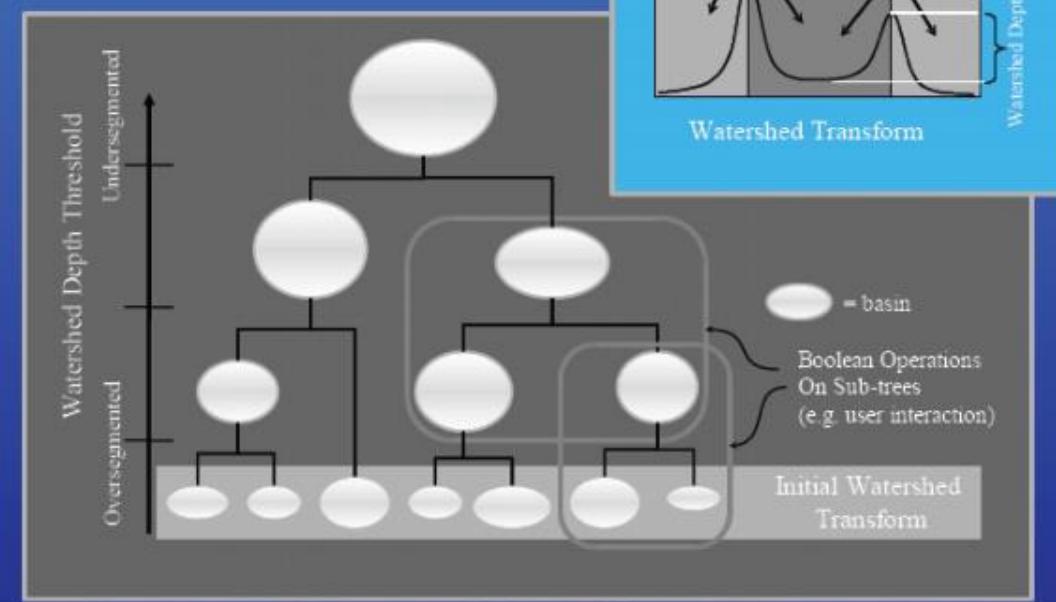
Segmentation

- Region Growing, different criterions
 - Connected threshold
 - Neighbourhood connected
 - Confidence connected
 - Statistical model of region (mean, std-dev)
 - Fuzzy connected
 - Unsharp definition of an affinity relation.

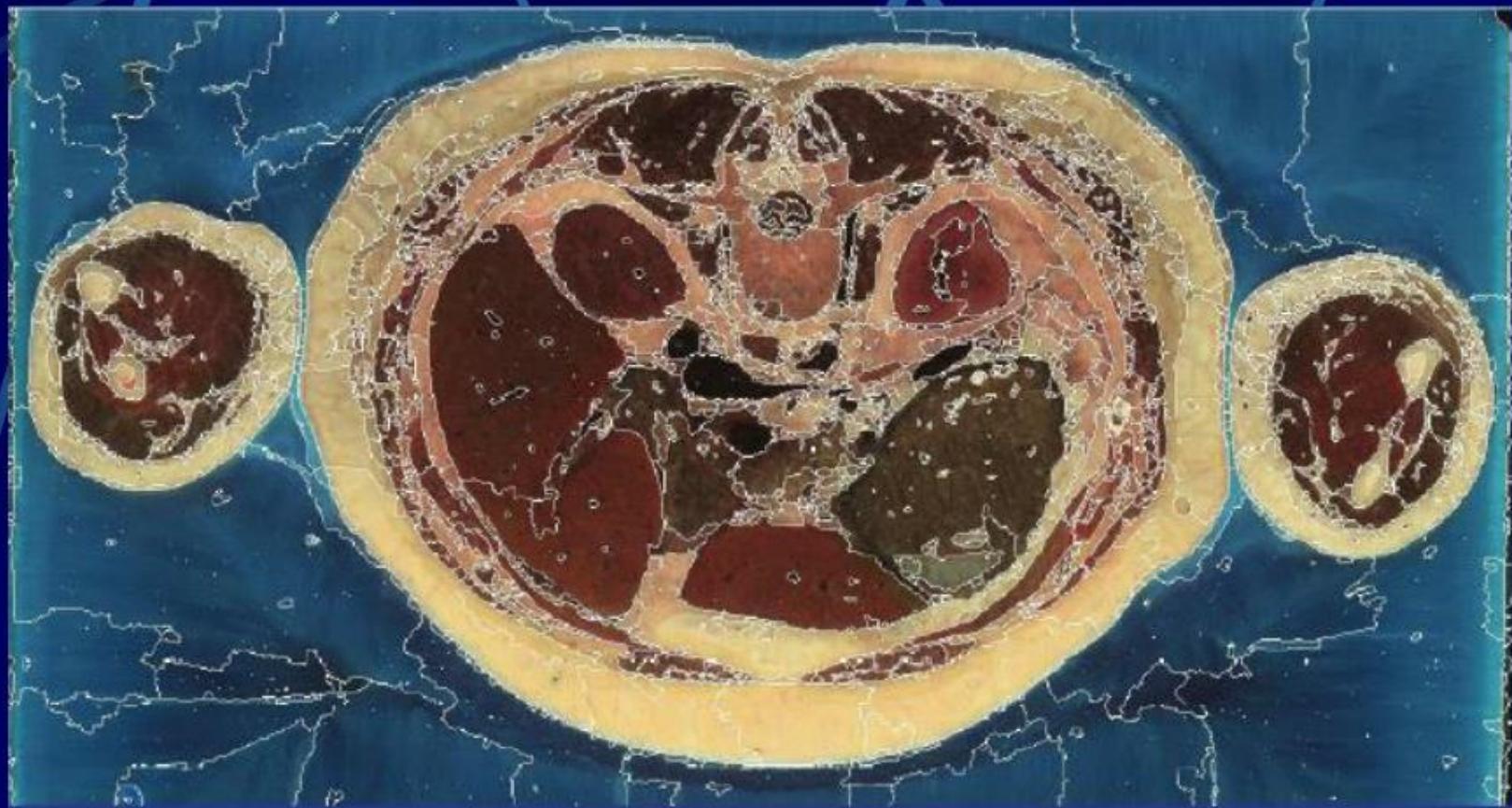
Watershed Segmentation



Enforce a minimum watershed depth

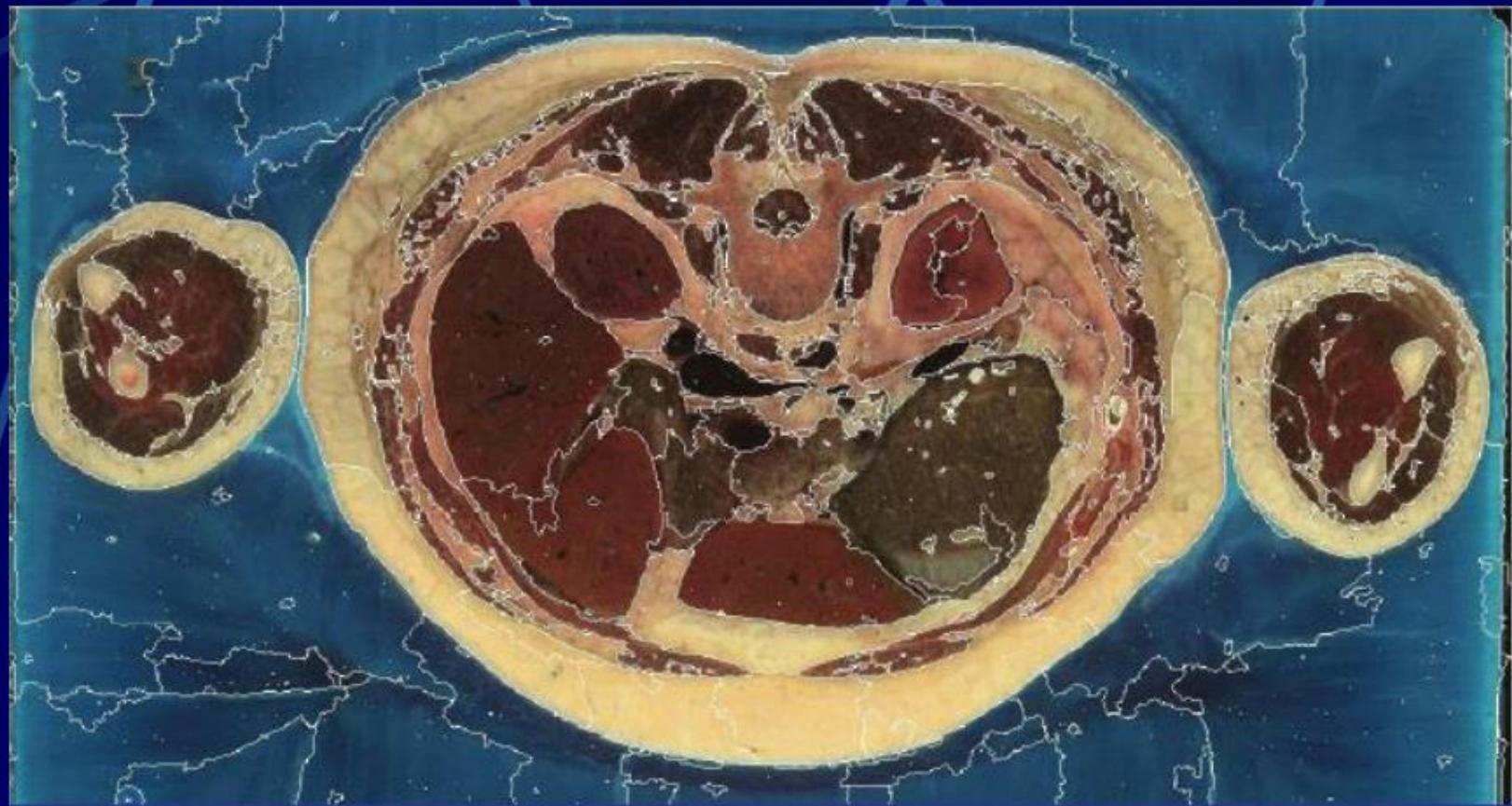


Watershed Segmentation



Level 1

Watershed Segmentation



Level 2

Level Set Segmentation

- Model n-dim. Surface movement as an evolving wavefront
 - Surface is zero level set of n+1-dim. function f
-
- Solve PDE

Level Set Segmentation

- Define speed term $v(x)$ to go to zero at edges – data fitting term
- Surface motion based on image features or intensities

Combine different Speed terms in *plug and play* manner

Speed:
Data Fitting
Term

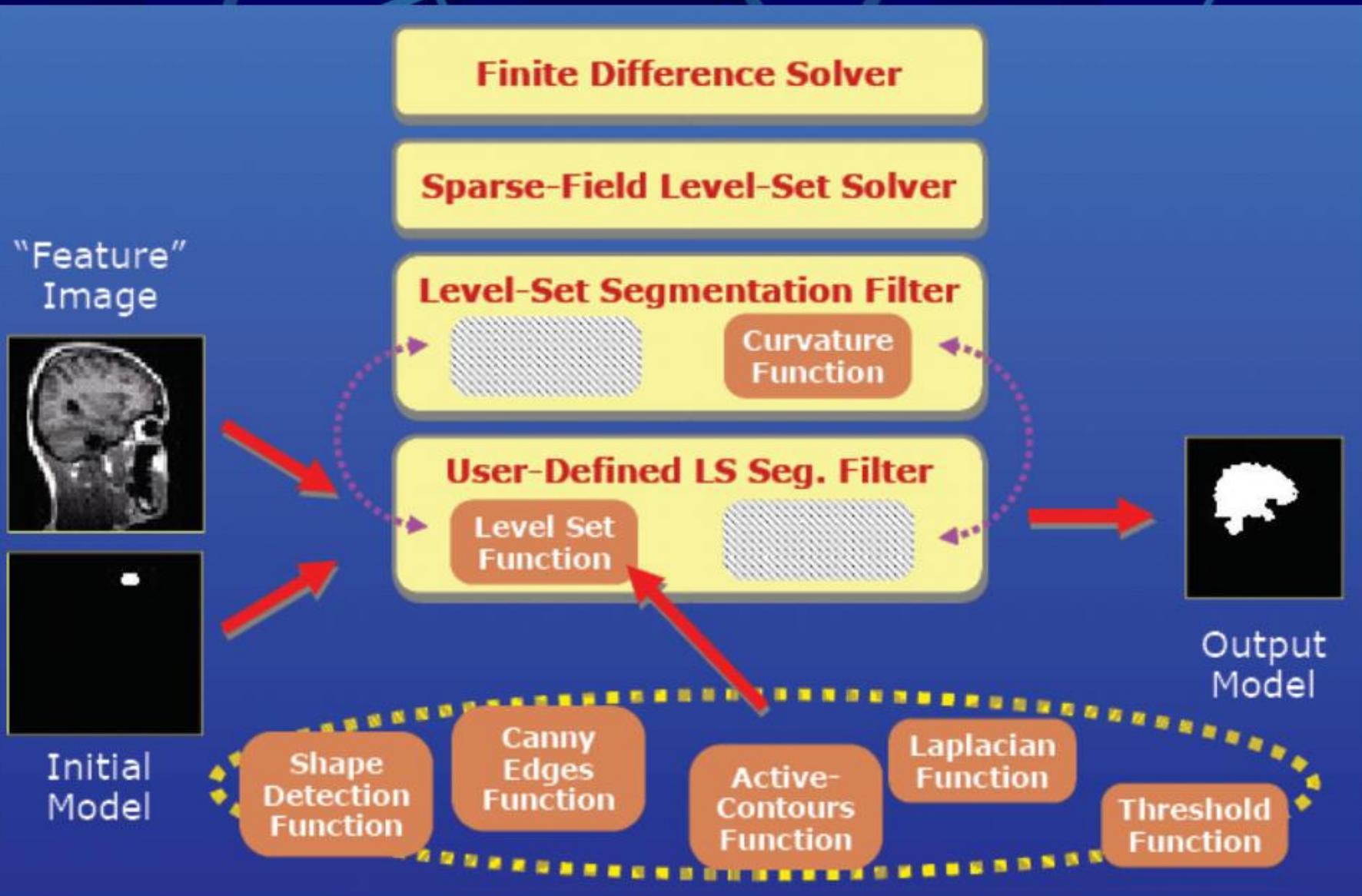
+
Regularization/
Smoothing

=
Surface
Motion/
Segmentation



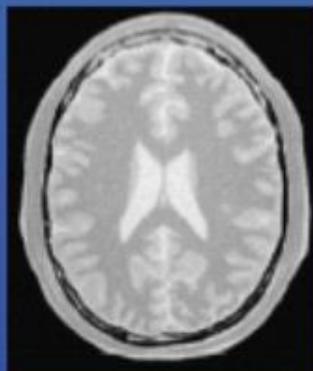
- Insight PDE solver framework

Level Set Segmentation



Level Set Segmentation

Example: ThresholdLevelSetImageFilter



Original



White matter



Ventricle



Gray matter

(60,116)

150

180

(81,112)

210

250

(107,69)

180

210

: Seed Point

: Lower thresh.

: Upper thresh.

Level Set Segmentation

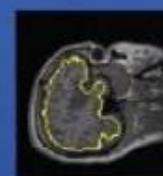
Example: Multiscale 3D Segmentation

Scale Seed surface Data

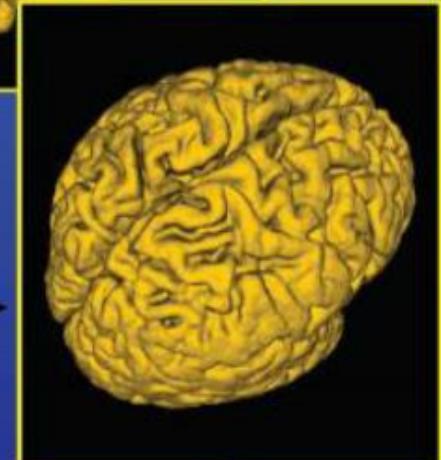
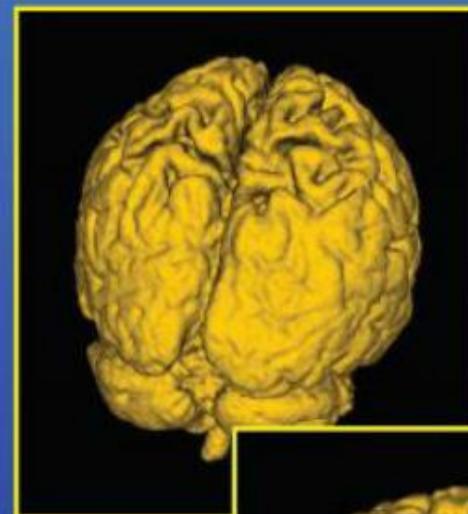
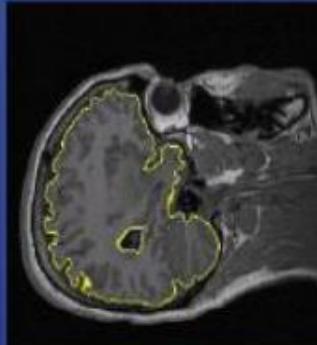
1/4



1/2

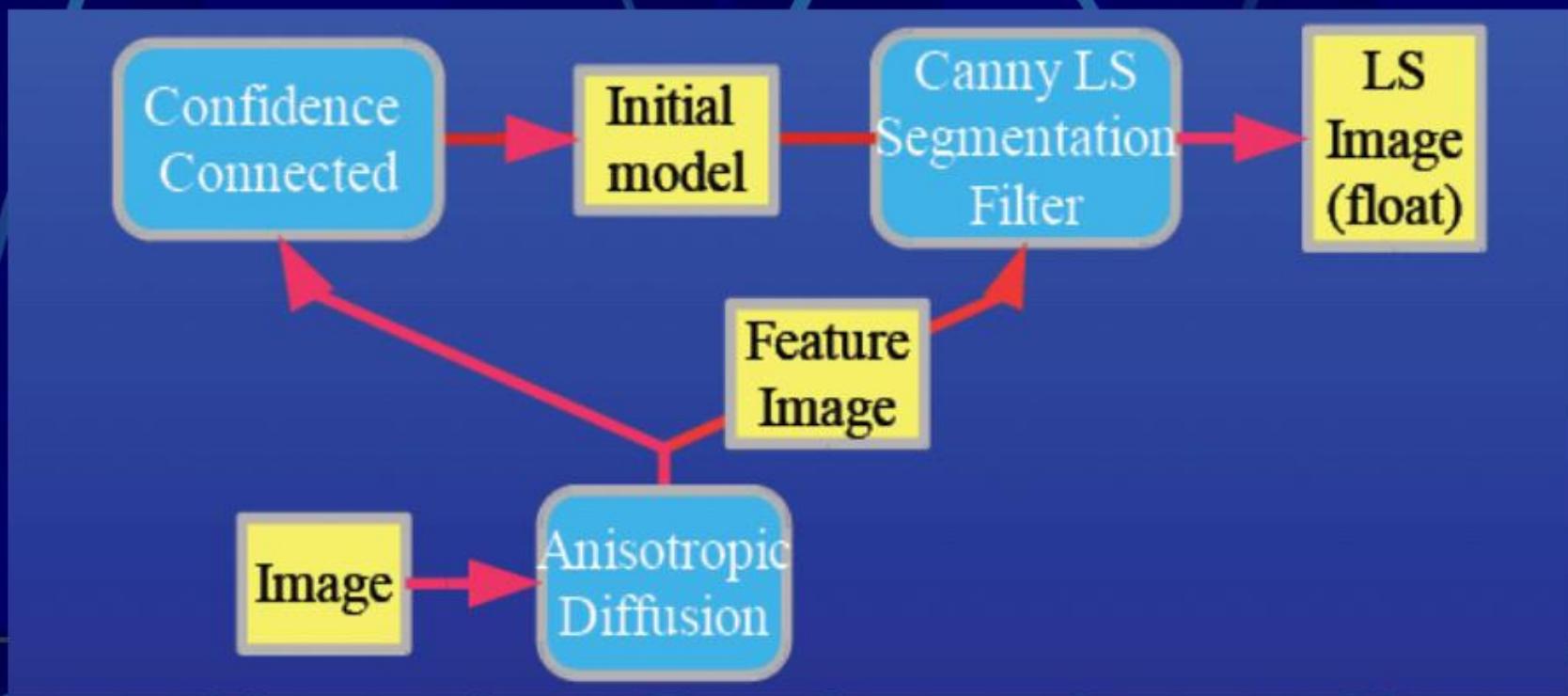


1/1



Combined Segmentation

- Initial model – confidence conn. region grow
- Fit to data using canny based level set filter

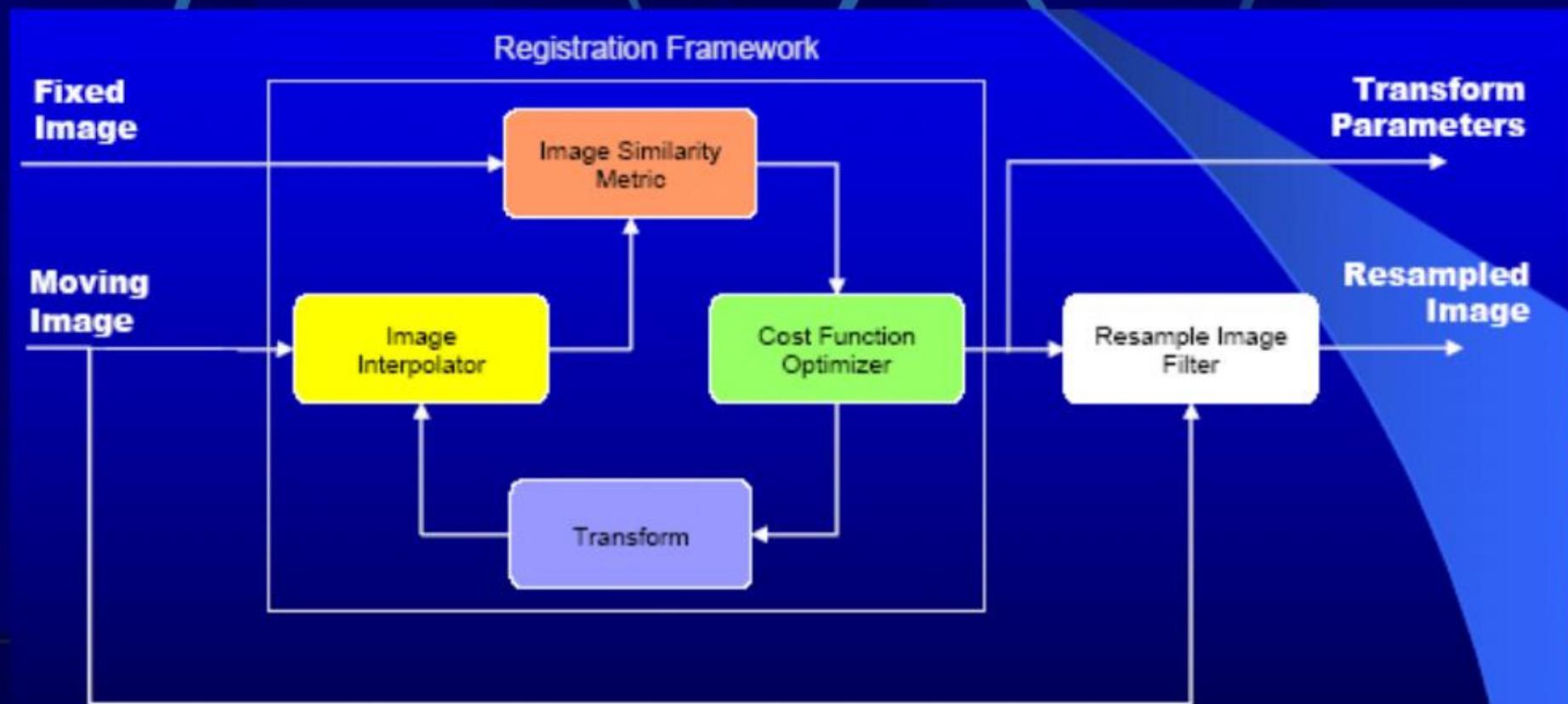


Registration Framework

- Find transformation mapping homologous points into each other
- Many medical applications:
 - Time series registration
 - Multi-modality image fusion (MR/CT – SPECT, ...)
 - Atlas construction (for segmentation)

Registration Framework

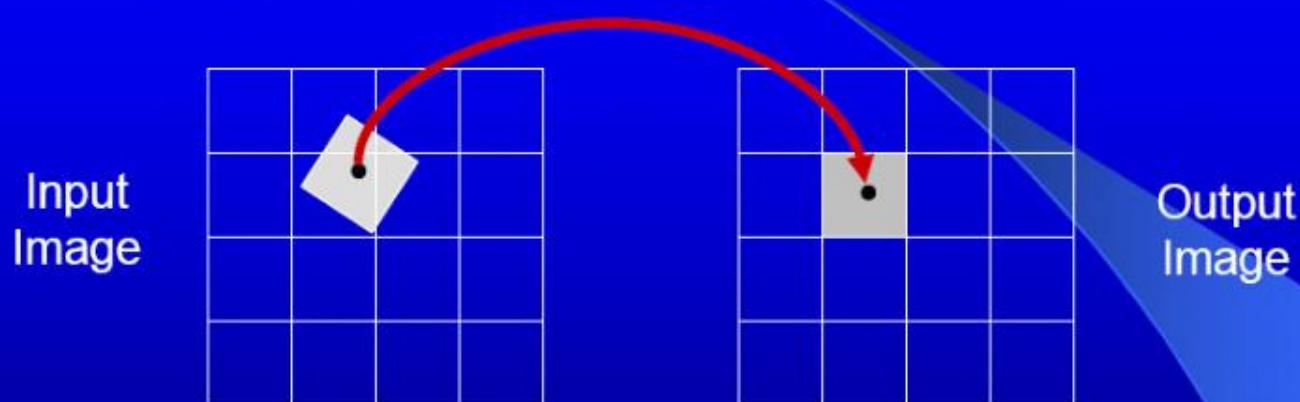
- Components:



Inverse Mapping

- Relationship between points of two images
- Output pixels are mapped back onto the input image

- Avoids holes in output
- Interpolate output pixel from input neighbourhood



Note on Spacing & Origin

- In medical img. registration, a transform is rigid only with respect to physical coordinate and not pixel coordinate
- $\text{Phys.-Coord} = \text{Pixel-Coord} * \text{Img-Spacing} + \text{Img-Origin}$
- Registration is always with respect to physical coordinates!
-> make sure that image spacing and origin are set accordingly!

Registration

- **itkTransform:**

- Identity, Translation, Rotation, Similarity, Affine, ...
- Alternative 3D rigid transform:
 - Quaternion/VersorRigidTransform
 - Exact representation of 3D rotation
 - Versor leads to smoother parameter space for optimization
 - Avoids Gimbal Lock!

Registration

- `itkInterpolateImageFunction`:
 - Choice: Efficiency vs. Quality
 - `NearestNeighbor` (piecewise constant image)
 - `Linear` (piecewise linear image)
 - `BSpline`

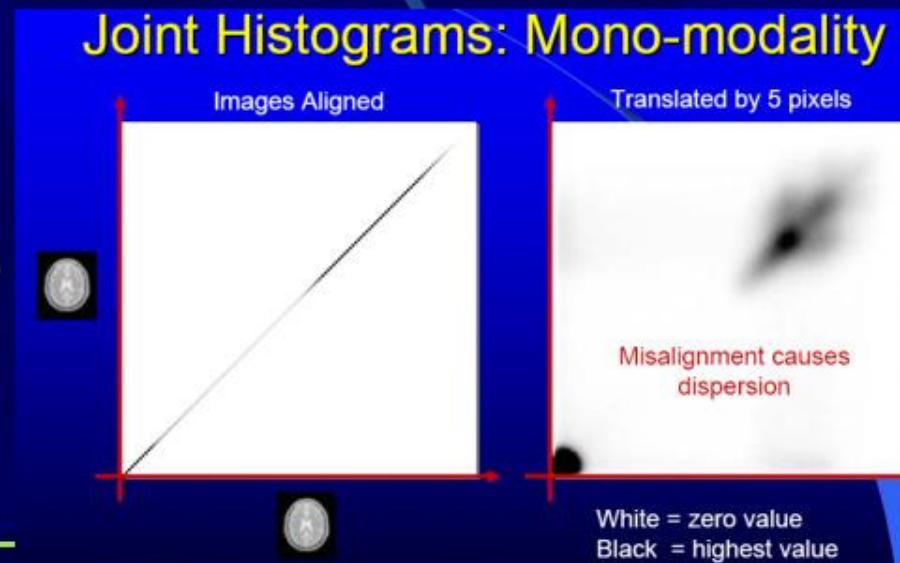
Registration

- `ImageToImageMetric`:
 - Measure how well „moving“ image matches fixed one
 - Mean Squares
 - Normalized Correlation
 - Mutual Information (different implementations available)

Registration

- Mutual Information:

- Entropies of images A,B: $H(A)$, $H(B)$
- Joint entropy of A,B: $H(A,B)$
- If A and B independent $H(A,B) = H(A)+H(B)$
- Else difference is MI
- \rightarrow Minimize difference
- Problem: estimate pdfs for $H(A)$, $H(B)$, $H(A,B)$



Registration

- Optimizer:
 - Conjugate Gradient
 - GradientDescent
 - RegularStep GradientDescent
 - Evolutionary
 - Levenberg-Marquardt
 - Some specialized algorithms

Registration

- Itk(MultiResolution)ImageRegistration class combines all components
- Robustness:
 - Multiscale Approach based on image pyramids
 - Translation to Rigid to Deformable
 - Coarse to fine grid strategy



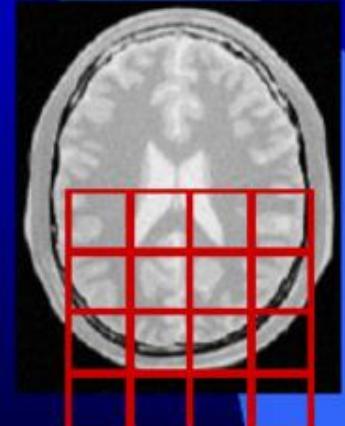
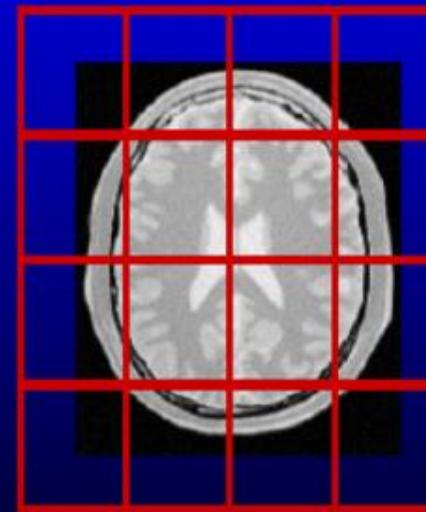
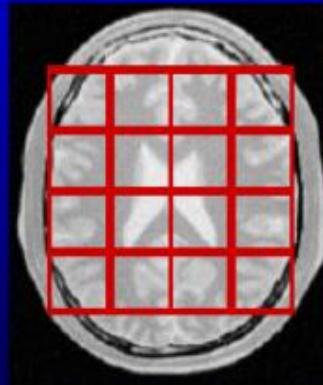
Deformable Registration

- FEM-based
 - Model image as physical body on which external forces act
 - Body deforms to minimize external force
 - Resistance of body to deformation serves as regularization
 - Formulation as regularized variational energy optimization

Deformable Registration

- BSplineDeformableTransform
 - Deformable warp
 - Deformation field by optimizing BSpline coefficients

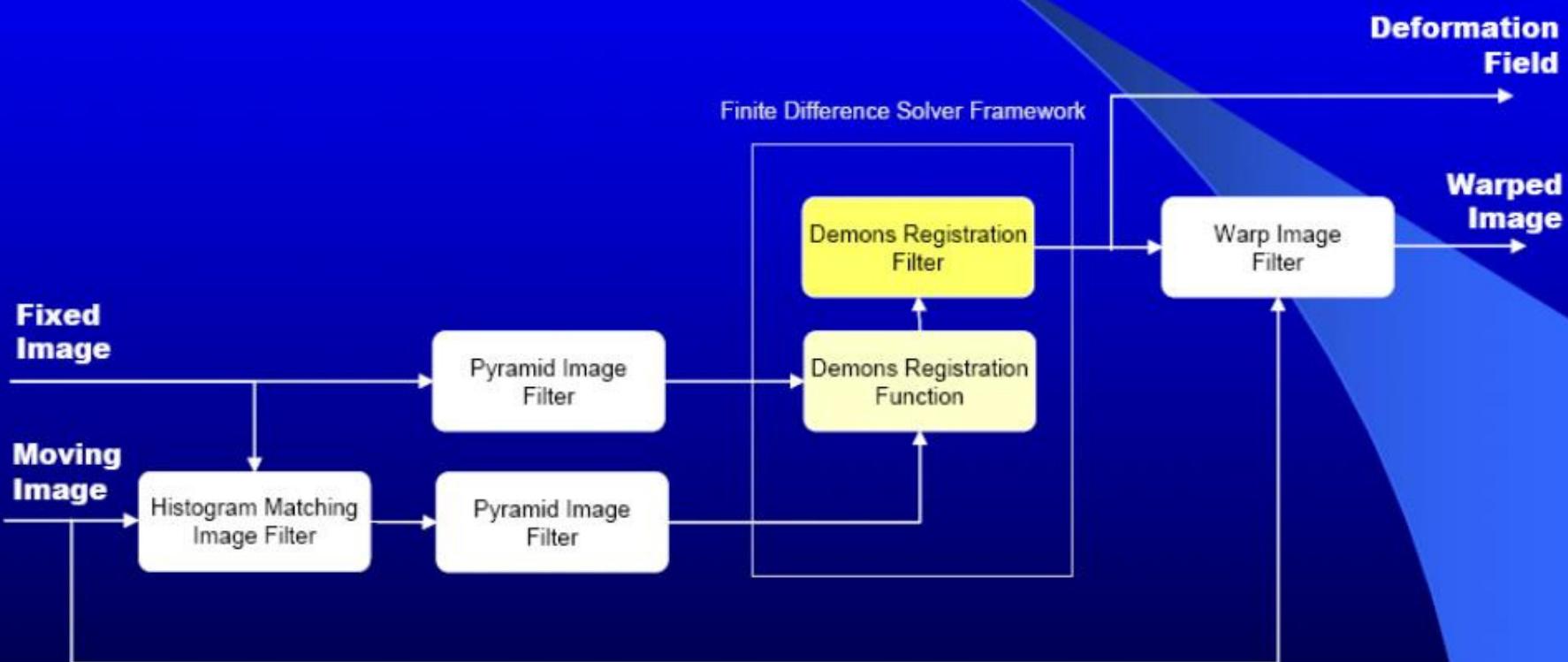
Grid positioning



Deformable Registration

- Demons algorithm (J.P. Thirion)
 - Intra-Modality
 - Image is set of iso-contours
 - Regular grid of forces deforms image by pushing contours in normal direction
 - Displacement from optical flow equation with regularization term
- Useful for segmentation by registering to atlas.

Demons Algorithm Scheme



Conclusion

- Very useful for rapid prototyping
- Strongly growing community and code base
- Problems:
 - Very complex
 - Overhead -> higher run-times
 - Still under development