MIPAV

MEDICAL IMAGE PROCESSING AND VISUALIZATION

http://mipav.cit.nih.gov

Medical Image Processing and Registration in MIPAV

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http://mipav.cit.nih.gov

MIPAV Team

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MIPAV ALGORITHMS

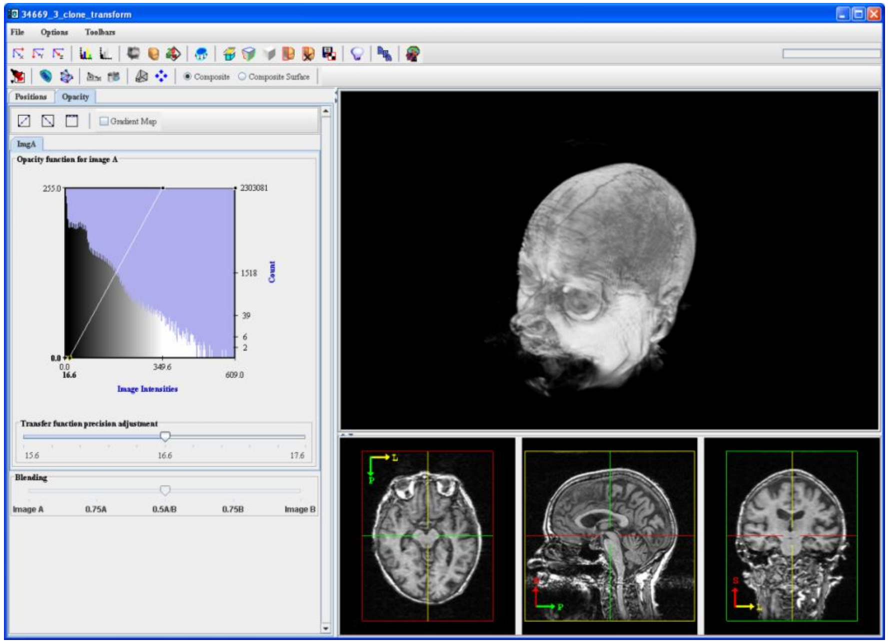
- Filters
  - Gaussian blurring, Laplacian, curvature, other higher order derivatives, median, gradient magnitude, edge detection, etc.
  - Anisotropic diffusion
  - Frequency domain (FFT, etc)
- Registration
  - Landmark – least squares, Thin-plate spline
  - AFNI registration technique
  - General Linear Registration (multiple cost function including, normalized and standard mutual information, correlation, least-squares, etc) and user selectable degree of freedom (DOF, 12 – affine, 6 – rigid,)
- Image transformations or resampling
  - nearest neighbor, tri-linear, sinc, bSpline and others interpolation methods.
- Skull stripping (BSE, BET)
- Midsagittal line alignment
- Histogram equalization and matching
- Shading correction
- Microscopy
  - FRET, FRAP, Co-localization

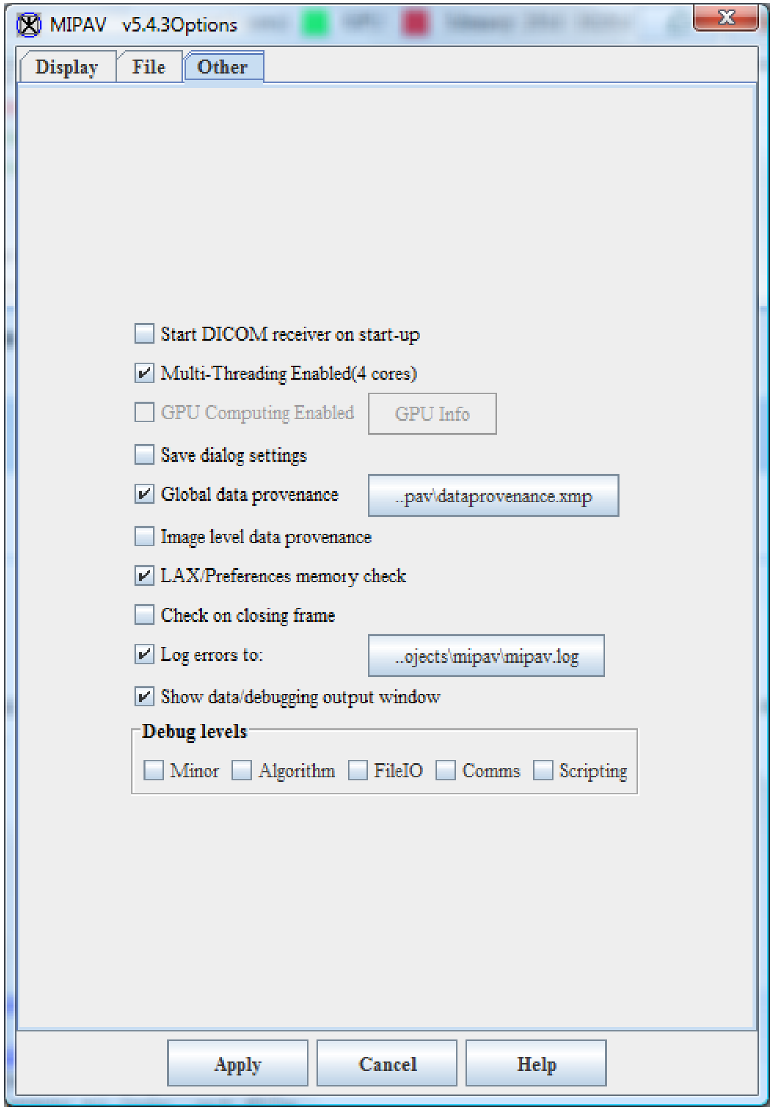
MIPAV ALGORITHMS (CONT.)

- Morphological operators (2D and 3D)
  - erode, dilate, open, close, distance, etc.
- Segmentation
  - Fuzzy C-means
  - Level set
  - Thresholding
  - Watershed
- Reslice 3D dataset to isotropic voxels
  - linear, cubic, cubic bspline.
- Surface extraction
- And more…

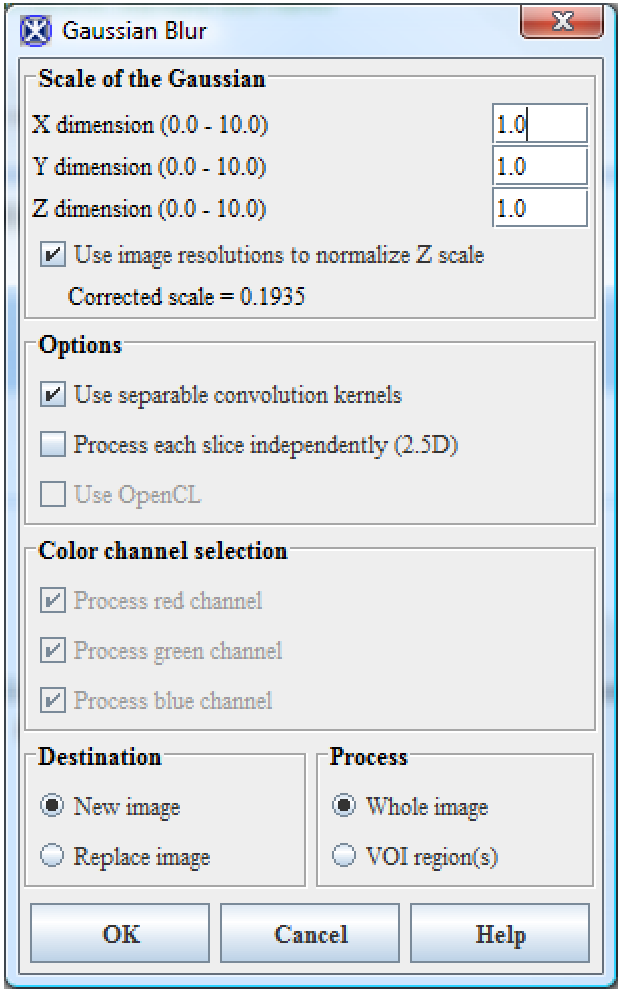
Image Processing Dimensionality

- 2D - image plane (slice)
- 2.5D - (3D treated as set of slices)
- 3D - (3D processed as volume)
- 3.5D
- 4D



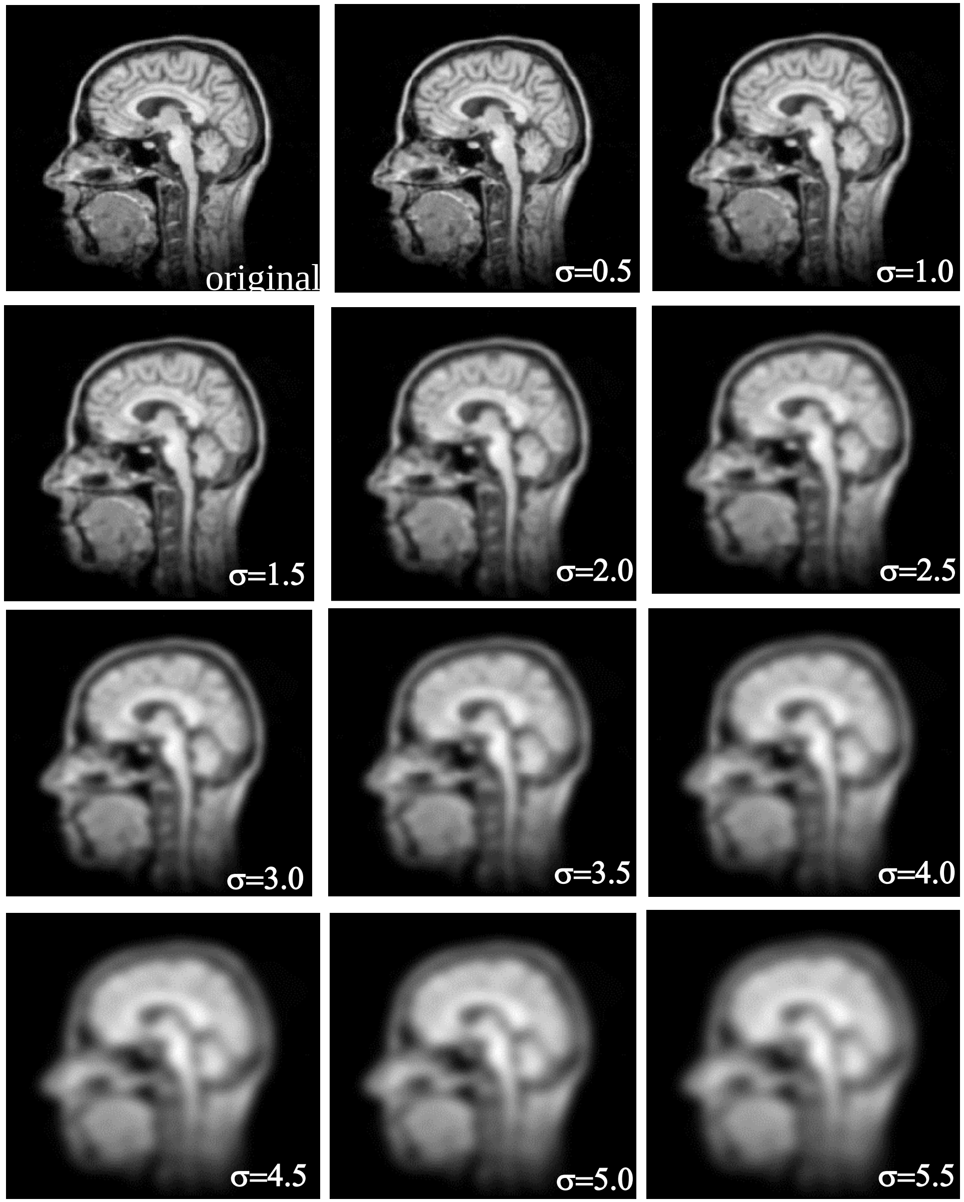

MIPAV v5.4.3Options
Display
File
Other
Start DICOM receiver on start-up
Multi-Threading Enabled(4 cores)
GPU Computing Enabled
GPU Info
Save dialog settings
Global data provenance
..pav\dataprovenance.xmp
Image level data provenance
LAX/Preferences memory check
Check on closing frame
Log errors to:
..ojects\mipav\mipav.log
Show data/debugging output window
Debug levels
Minor
Algorithm
FileIO
Comms
Scripting
Apply
Cancel
Help

Filters

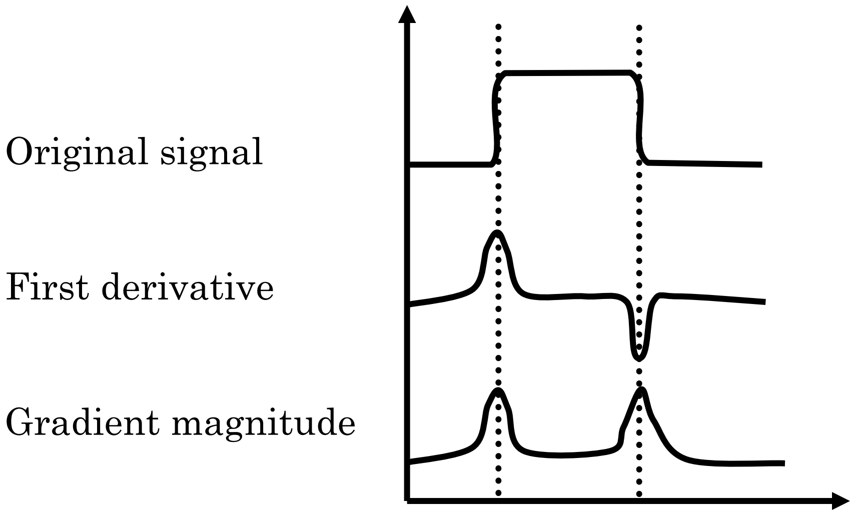

Gaussian Blur
Scale of the Gaussian
X dimension (0.0 - 10.0)
1.0
Y dimension (0.0 - 10.0)
1.0
Z dimension (0.0 - 10.0)
1.0
Use image resolutions to normalize Z scale
Corrected scale = 0.1935
Options
Use separable convolution kernels
Process each slice independently (2.5D)
Use OpenCL
Color channel selection
Process red channel
Process green channel
Process blue channel
Destination
New image
Replace image
Process
Whole image
VOI region(s)
OK
Cancel
Help

Scale-space

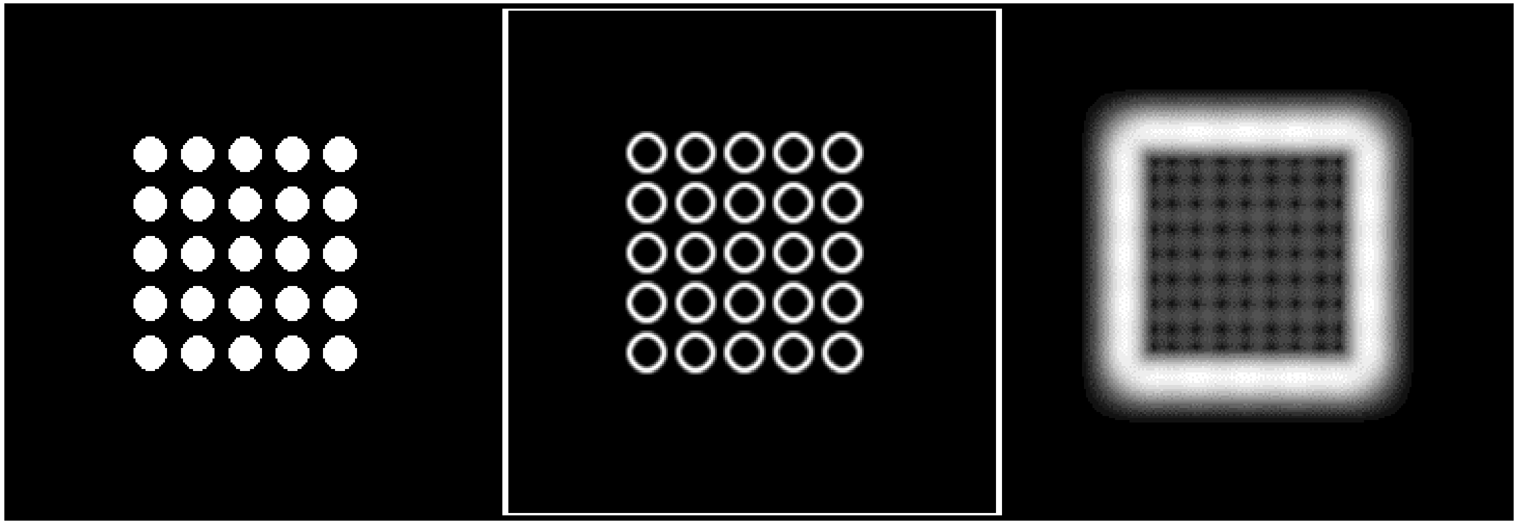
- Scale-space of the MR image of the head
- Produced by convolving the Gaussian of increasing standard deviation with the MR image



Gradient Magnitude 1D Example



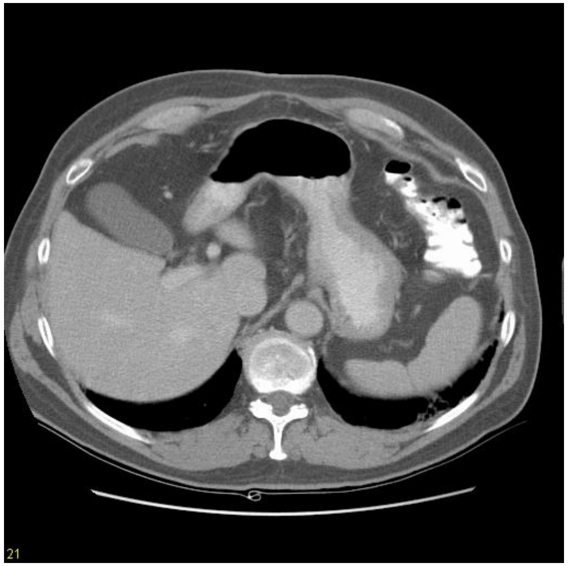
Importance of scale



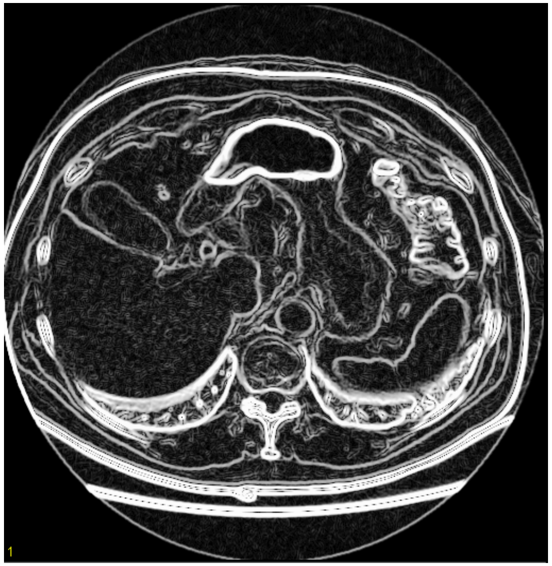
(a) (b) (c)

$I_{GM}(x,y) = (I_x^2 + I_y^2)^{0.5}$ - gradient magnitude

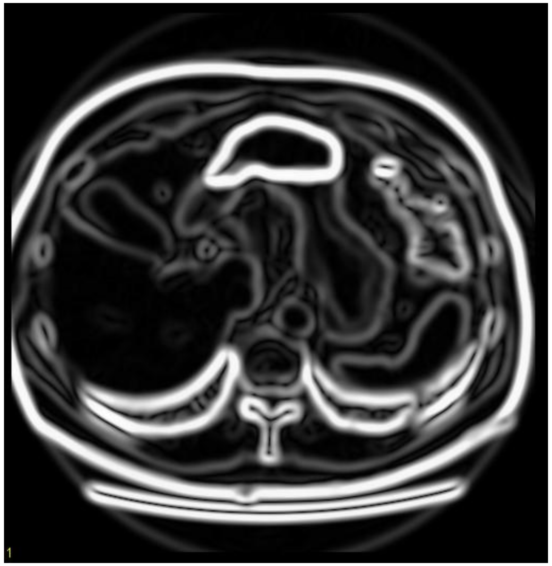
Importance of scale (Gradient Magnitude of CT image)



Axial CT image



Gradient magnitude (sigma = 1.0)



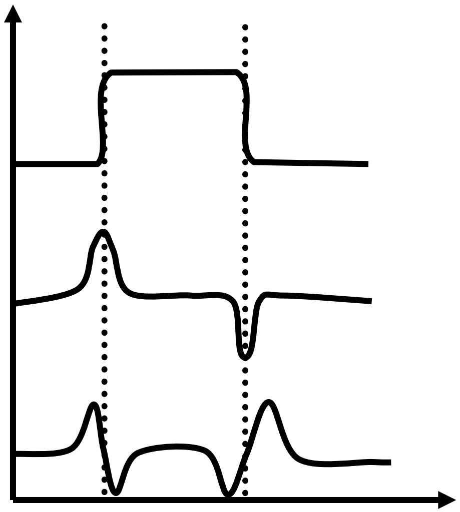
Gradient magnitude (sigma = 4.0)

LAPLACIAN

Original signal

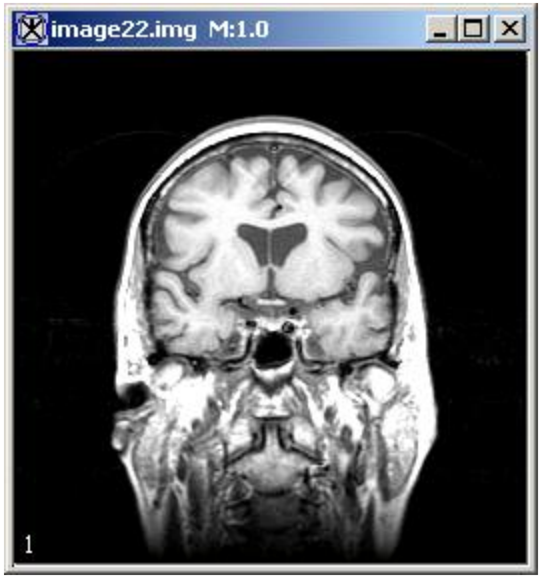
First derivative

Second derivative

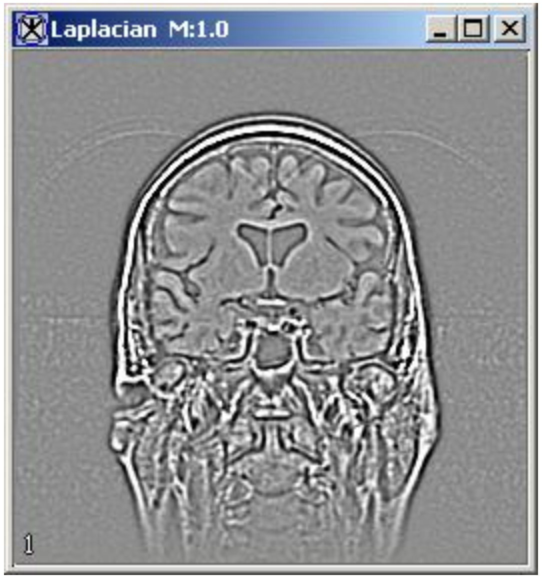


$$\nabla^2 I = I_{xx} + I_{yy}$$

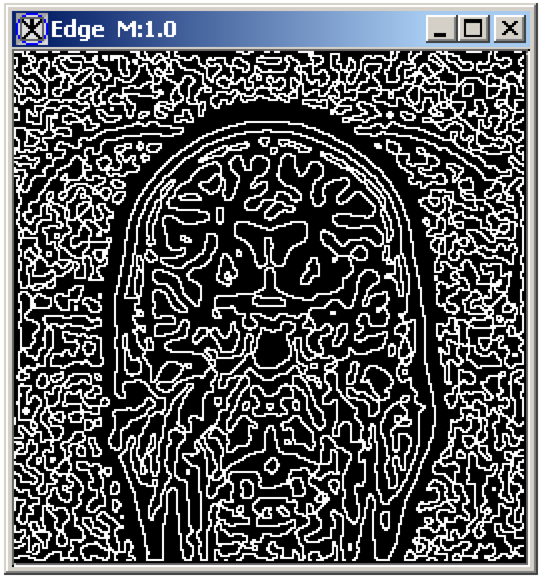
LAPLACIAN



Original MR Image



Laplacian of MR Image



Zero crossings

Median Filtering

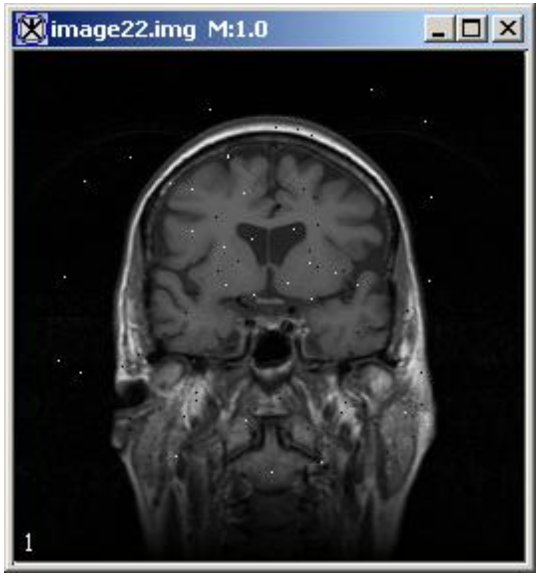


Image with noise

Median filter image

Gaussian smoothed image

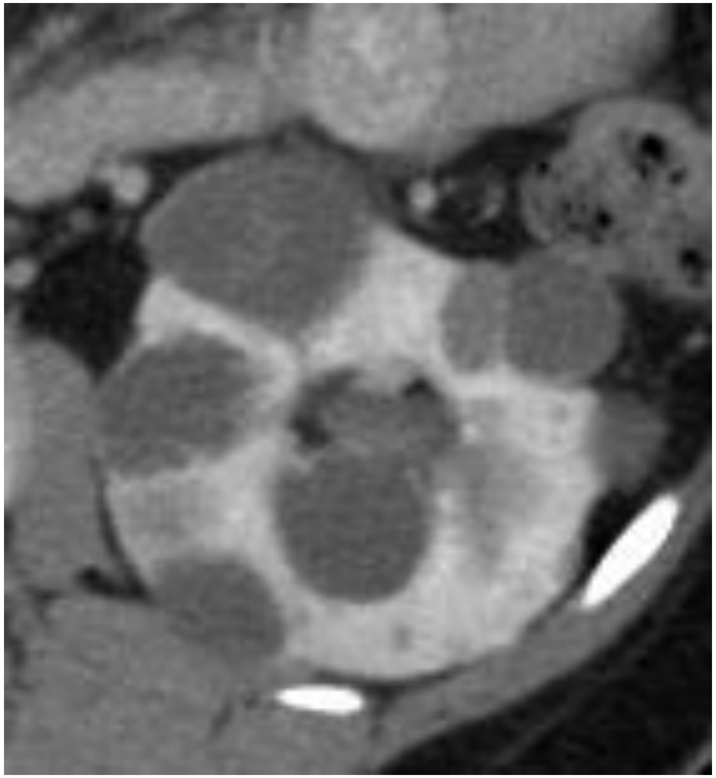
Median Filtering

Original MR Image

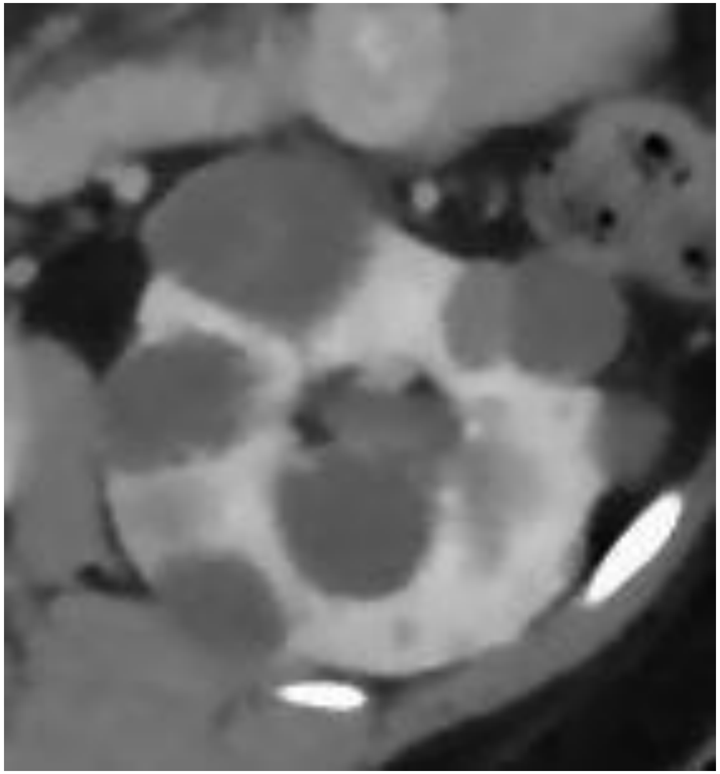
1 Iteration

5 Iterations

MIPAV: Example of Ansiotropic Diffusion on CT Images of the Kidney.

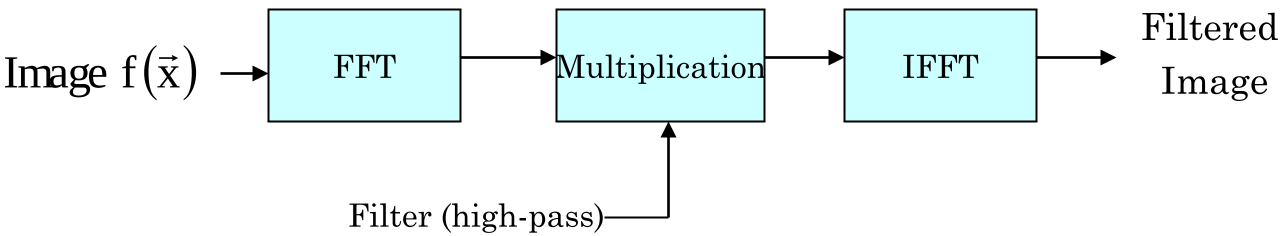


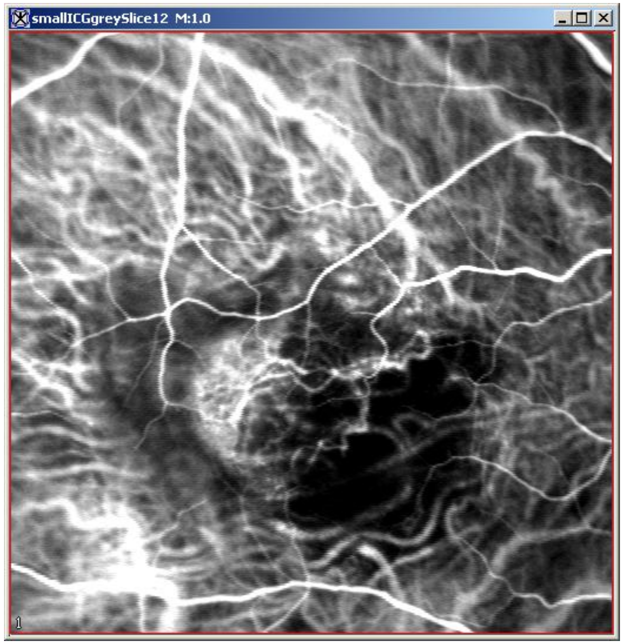
Before



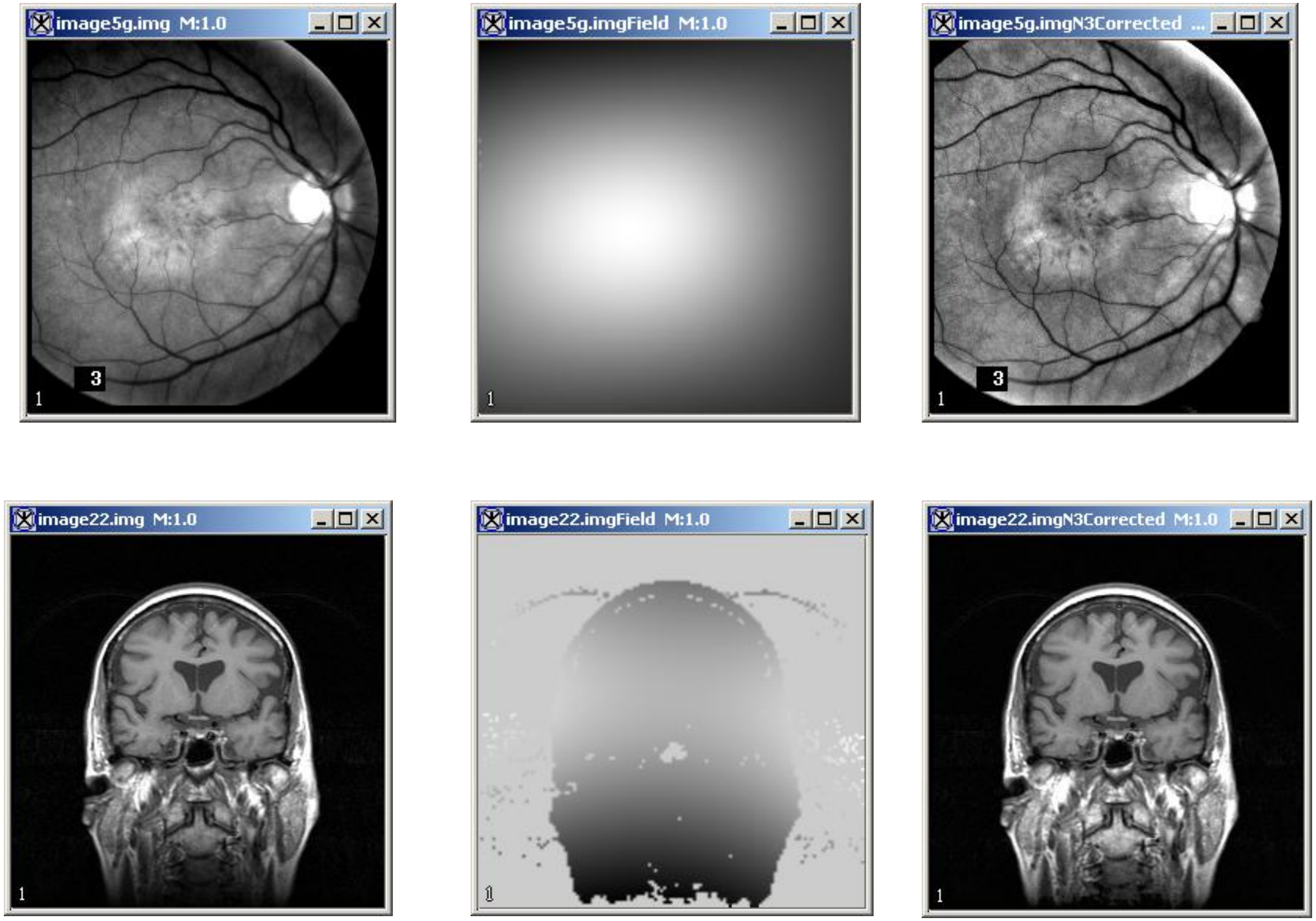
After

Fourier Transform Examples





Shading correction



Registration

REGISTRATION

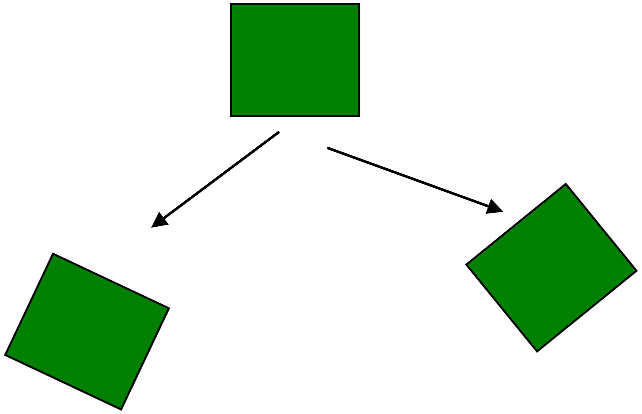
- Two main classes of problems
  - Intra-modality
    - Intra - patient
    - Inter - patient
  - Inter-modality
    - Intra - patient
    - Inter - patient
- Two main methods
  - Extrinsic - landmark methods using surfaces, lines, points.
    - Can be automatic or manual identification of landmarks.
  - Intrinsic – image intensity base using voxel similarity measures (i.e. Cross correlation, mutual information, etc.)

Registration

- Transformation matrix establishes geometrical correspondence between coordinate systems of different images. It is used to transform one image into the space of the other.
- Many different types but generally in biomedical imaging only a few classes are use:
  - Rigid body
  - Global rescale
  - Affine
  - Non-linear

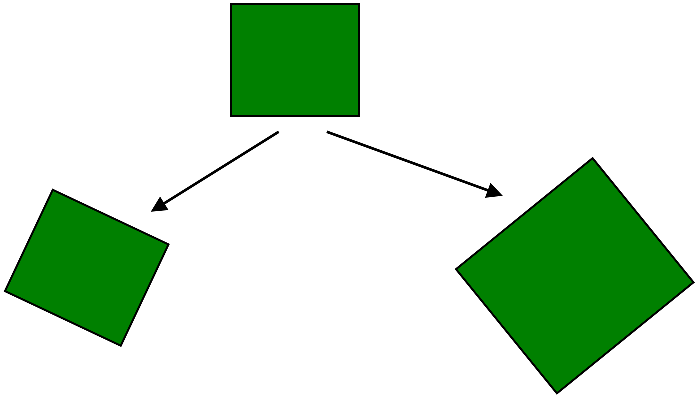
Registration

- Rigid-body transformations include translations and rotations. Preserve all lengths and angles.
  - 2D -> 3 Degrees of Freedom (DOF)
  - 3D -> 6 DOF (3 translation and 3 rotation)



Registration

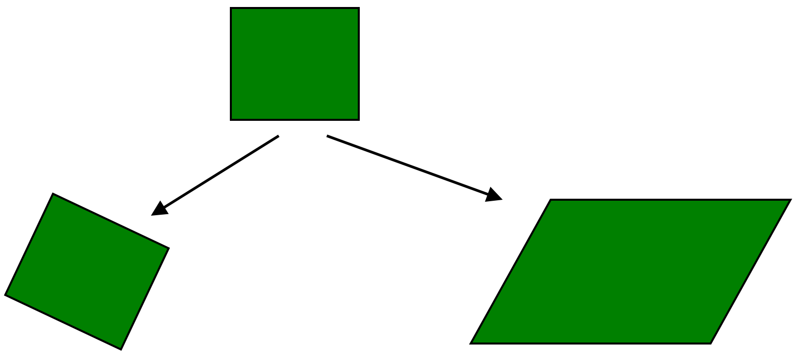
- Global rescale transformations include translations, rotations, and a single scale parameter. Preserve all angles and **relative** lengths.
  - 2D -> 4 DOF (2 translation + 1 rotation + 1 scale)
  - 3D -> 7 DOF (3 translation + 3 rotation + 1 scale)



Registration

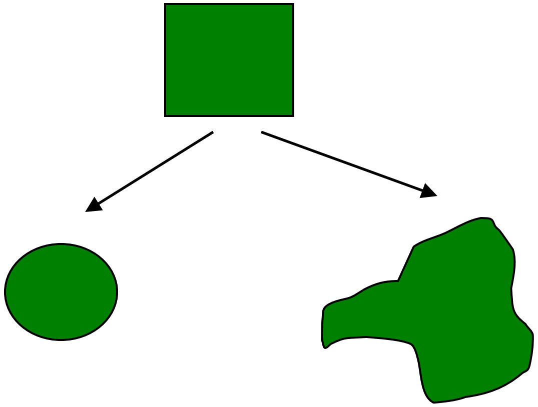
- Affine transformations include translations, rotations, scales, and/or skewing parameters. Preserve straight lines but necessarily not angles or lengths.

  - 2D -> 5 or 7 DOF (2 translation + 1 rotation + 2 scale + 2 skewing)
  - 3D -> 9 or 12 DOF (3 translation + 3 rotation + 3 scale + 3 skewing)



Registration

- Non-linear transformations are local deformations and therefore they are the most general.
  - 2D -> many DOF
  - 3D -> many DOF

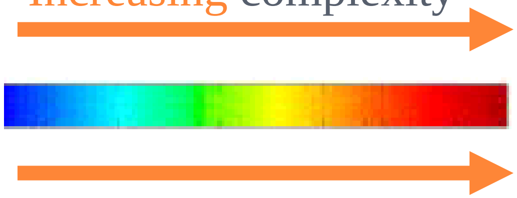


INTERPOLATION OPTIONS

- Trilinear
- Cubic Lagrangian
- Quintic Lagrangian
- Heptic Lagrangian
- Windowed Sinc
- Bspline 3rd Order
- Bspline 4th Order

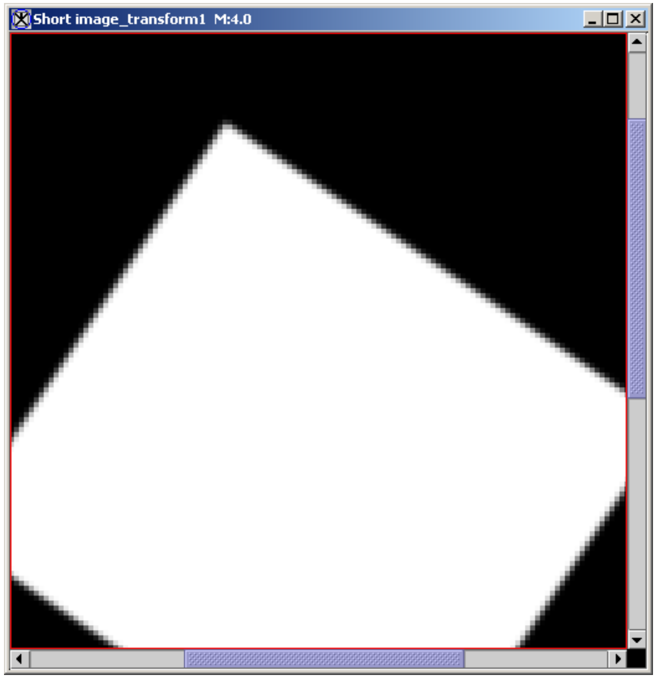
KEY

Increasing complexity

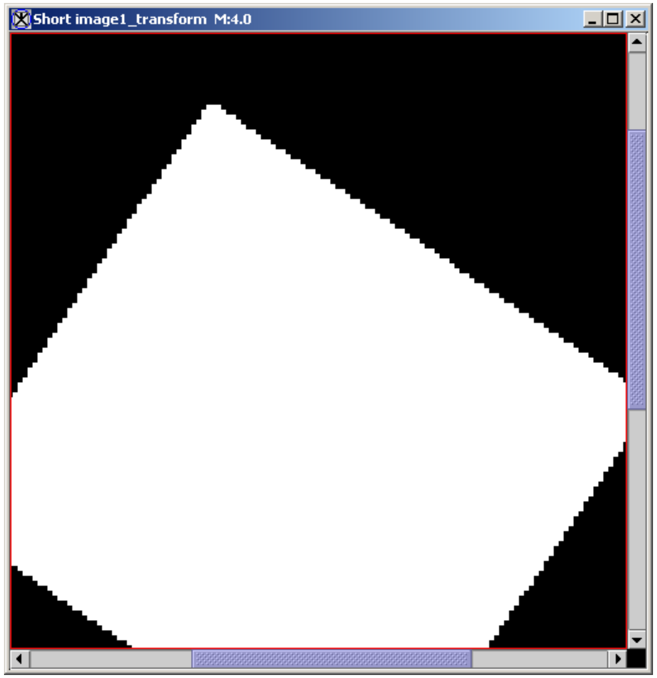


Increasing Process Time

Registration

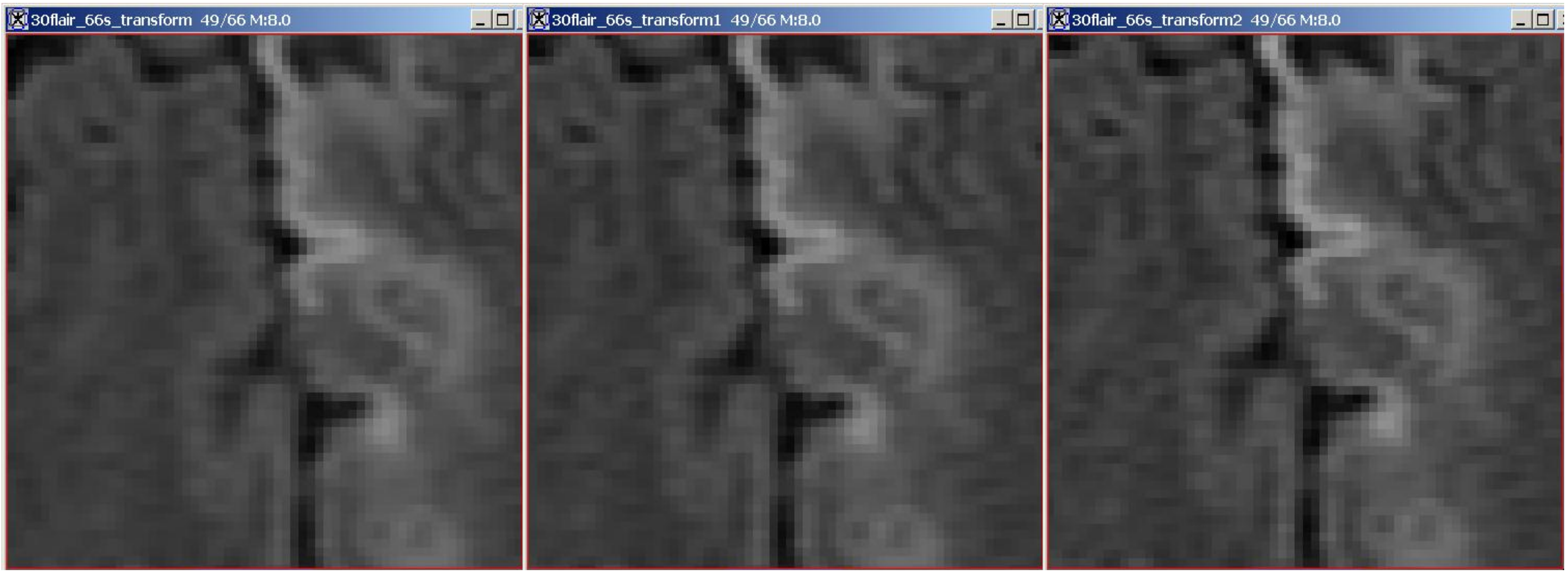


4th Order Bspline interpolation



Nearest neighbor interpolation

Interpolation Differences



Trilinear Cubic Lagrangian Windowed Sinc

Contrast increasing

REGISTRATION

- Extrinsic Landmark based methods
  - can require user interaction
    - Manual identification – user intensive
    - Automatic identification can be problematic but depends on task and modality
  - can be shown to be less reliable and accurate than intensity based methods. Depends on modality and task.
  - once landmarks are identified registration is very fast.

REGISTRATION

- Intrinsic – image intensity at voxels
  - "Best" registration is identified by the minimum of some "cost" function.
  - The cost function is an assessment of how good the alignment between the objects to be registered.
    - A high cost should equate to a poor alignment
    - A low cost should equate to a good alignment
  - Goal
    - Find the transformation (matrix) which minimizes the cost function.

Registration

- Cost functions
  - Intra-modality with consistent mapping of intensity values
    - Least squares
  - Inter-modality or Intra-modality where mapping of intensity values might vary.
    - Normalized correlation
    - Correlation ratio
    - Normalized mutual information

REGISTRATION

- Normalized Mutual Information (NMI) – is base on the entropy of the images (histogram) and the relationship between voxels – joint entropy.

  NMI = (H(x) + H(y)) / H(x,y)   H( ) = entropy

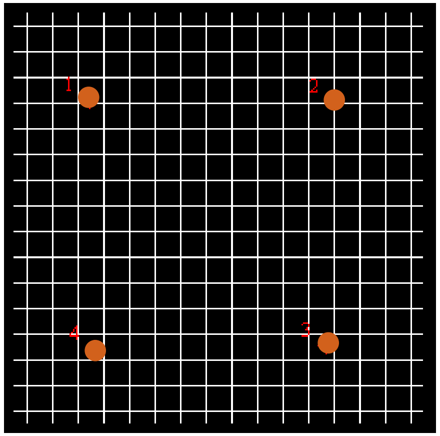
  $= - \sum p_i \log p_i$

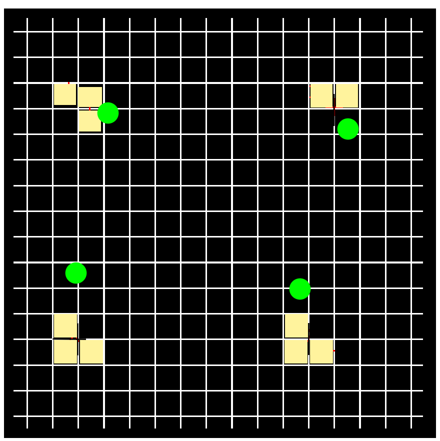
  where p = (histogram count in bin) / total count

- Entropy is a measure of the disorder or unavailability of energy within a closed system.

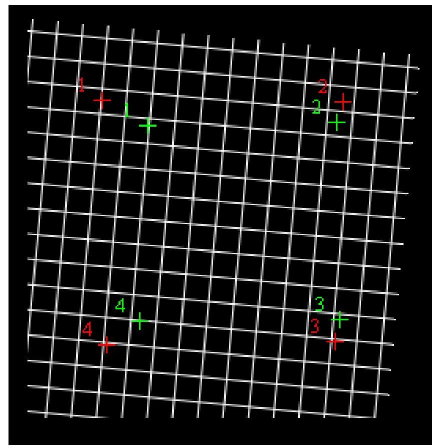
- Entropy will have a maximum value if all values of the histogram have equal probability of occurring (flat histogram) and a minimum when all except one value has a probability of zero.
  - For example, blurring an image reduces noise and thus sharpens the images histogram, resulting in reduced entropy.

Landmark Registration Techniques

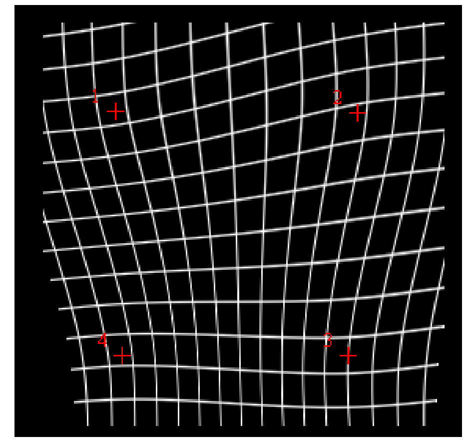




Grid with landmarks points



Least squares registration
(rotation & translation: rigid)



Thin plate splines registration
(rotation, translation and scale: non-linear)

REGISTRATION

Least-Squares Fitting of 2 Point Sets

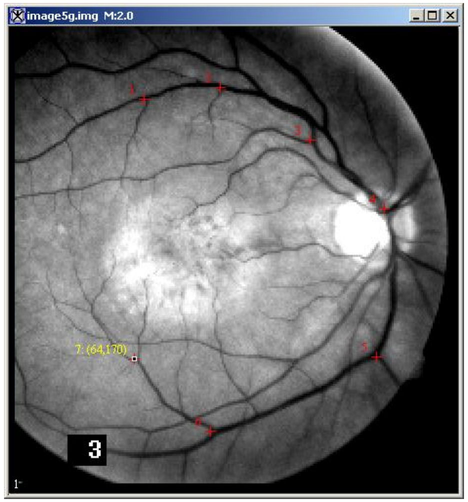


Image A with 7 landmarks

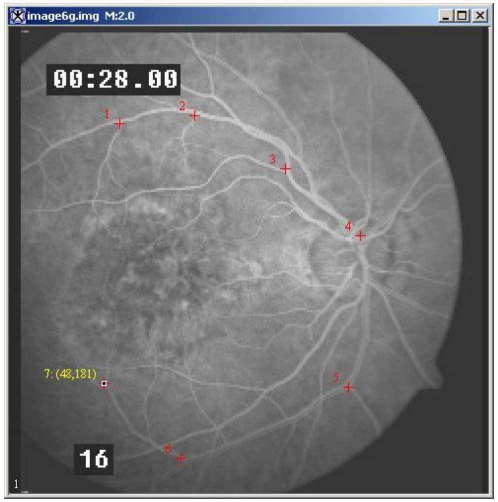


Image B with 7 homologous landmarks

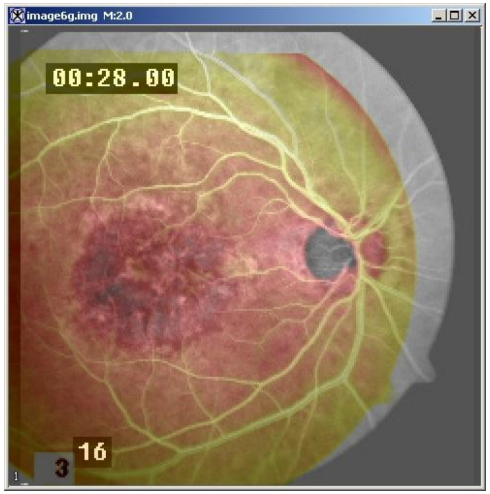
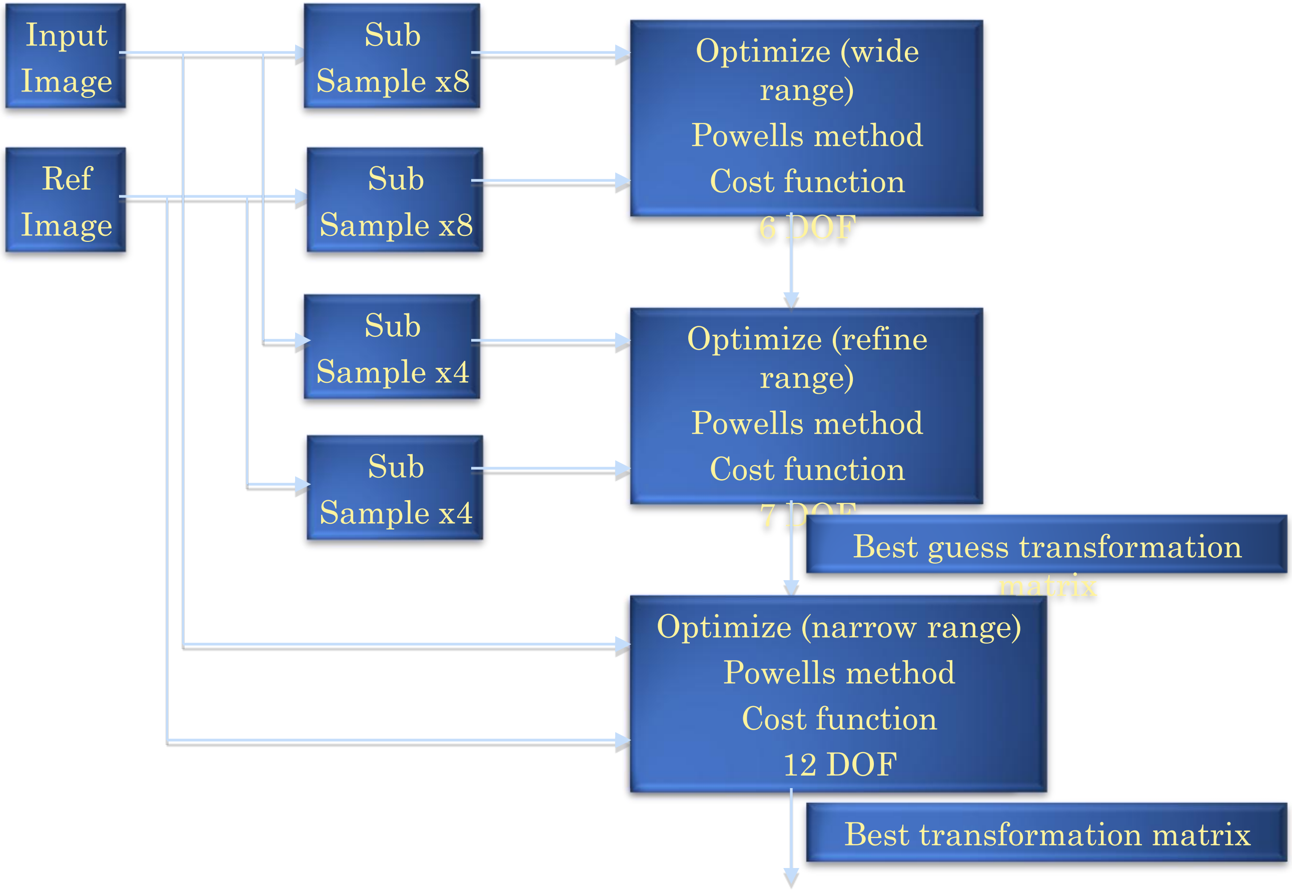


Image A (heated metal LUT) registered and overlaid onto Image B (gray LUT)

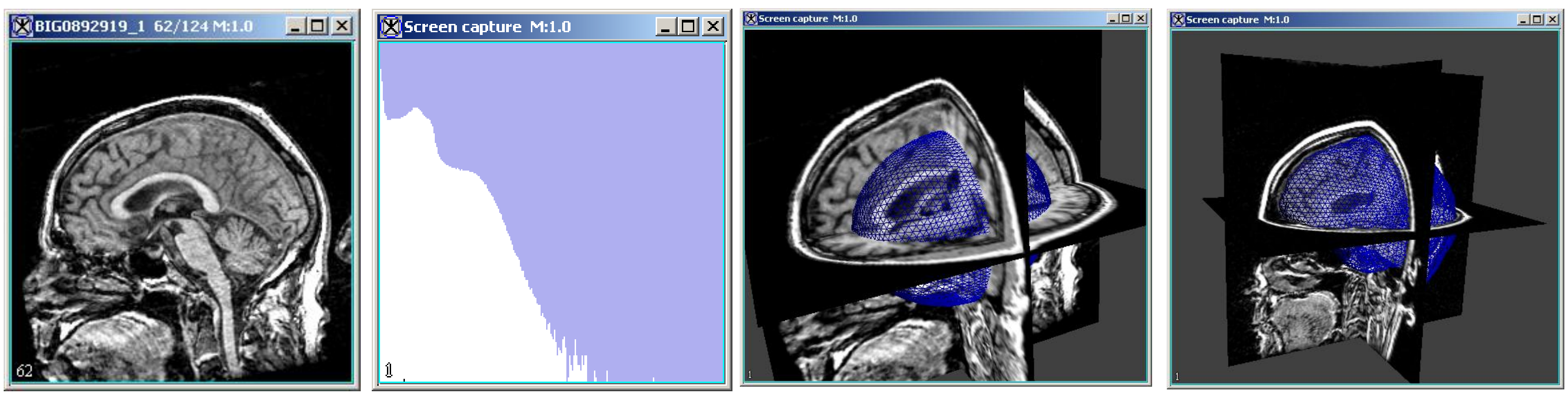
Images supplied by Karl Csaky

Registration



Skull stripping - BET

Input Image → Histogram-based threshold estimation → Estimate ellipsoid used to initialize surface evolution → Evolve surface



Based on: Brain Extraction Tool (BET)

MIPAV Utilities

- Image conversion
  - Gray <==> RGB
  - 4D <==> 3D
  - Between data types
- Image cloning
- Rotation / flipping
- Cropping
- Mask-based quantification
- Intensity projection generation
- Slice extraction / manipulation
- Intensity replacement
- Invert intensity
- Add padding
- Correct spacing
- Image math (operations performed on one image – abs. value, addition, log, etc.)
- Image calculator (operations performed using two source images – difference, multiplication, average, etc.)

Thank you!