Registration

Within and between subjects

Registration

Brain extraction

Estimating spatial transformations

Resampling

Rigid body (Translate, Rotate)

Linear/Affine (Scale, Shear)

Non-affine

Similarity functions

Least Squares

Normalized Correlation

Correlation Ratio

Mutual Information

Interpolation

Nearest neighbor

Trilinear

Sinc

Standard Space

Talairach

MNI

What is Registration?

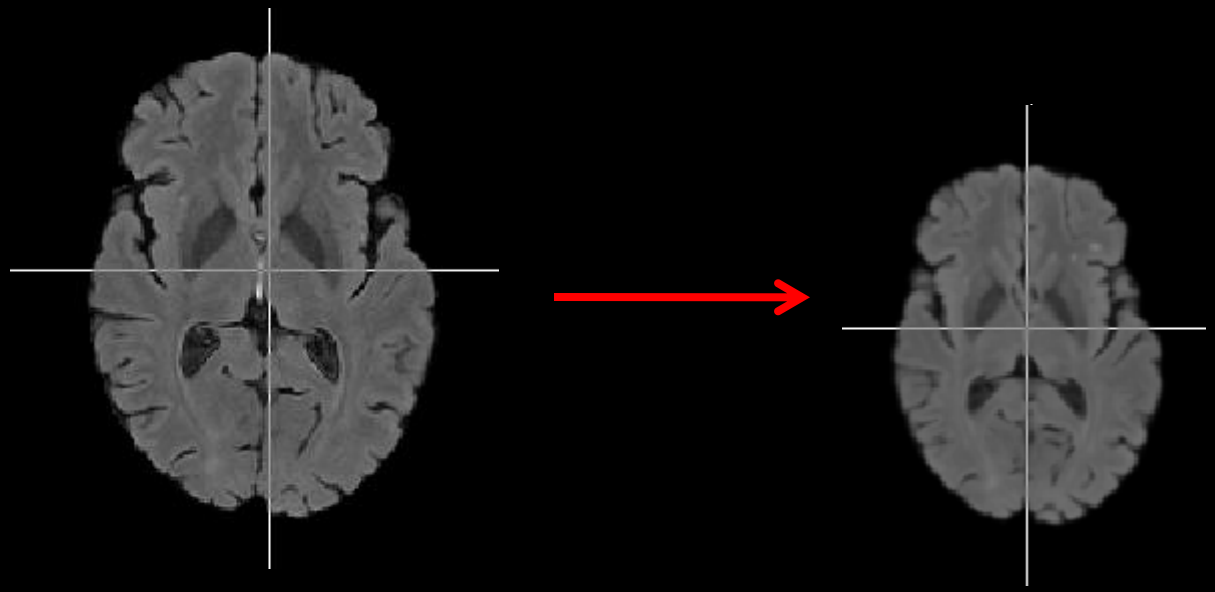
- Registration is the alignment of 2 images.

Registration in Neuroimaging

Make voxel coordinates & intensities in 2 images correspond to the same brain locations.

(Mark Jenkinson 2007 UCLA Summer School)

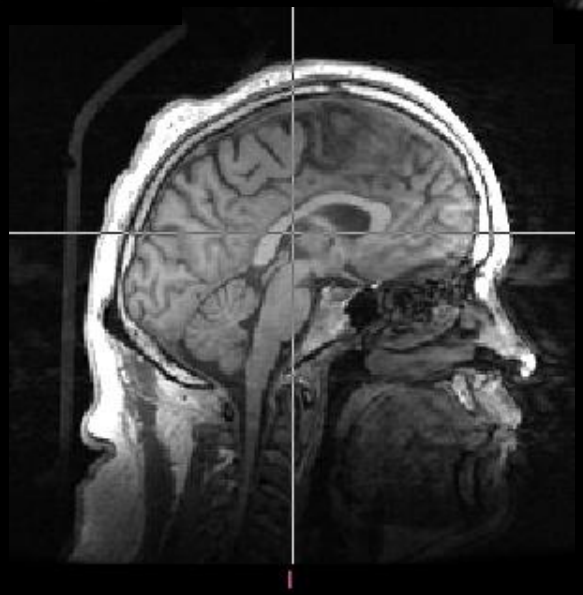
Even if the images are different sizes



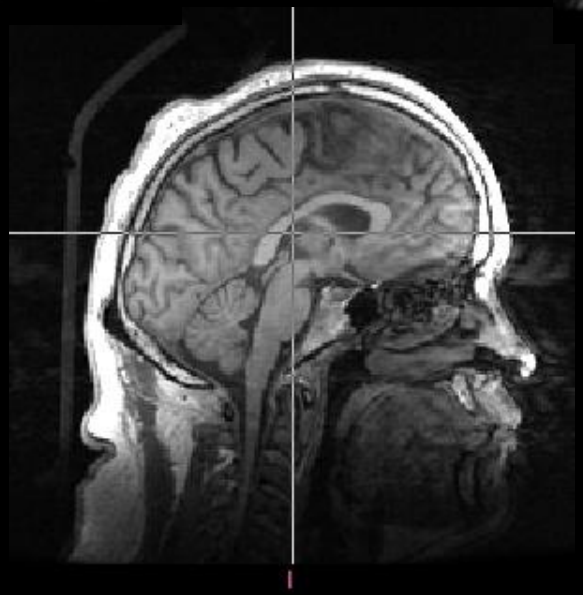
x 128 y 128 z 28

x 68 y 128 z 128

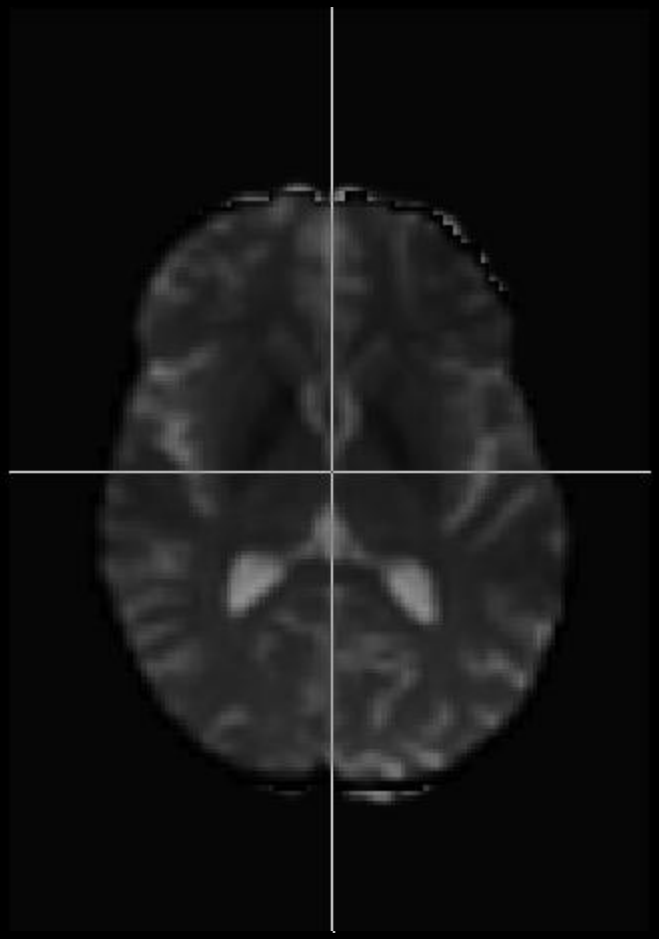
Head shapes vary tremendously, making brain registration harder.



Brain extraction helps registration focus on brain instead of irrelevant tissue.

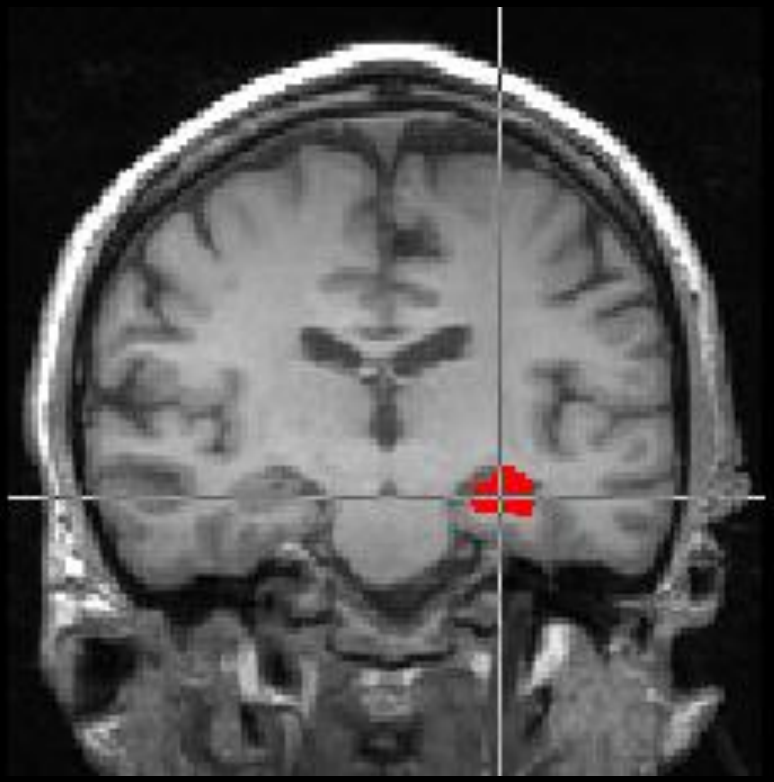


Registration is often pretty good, especially within subject.

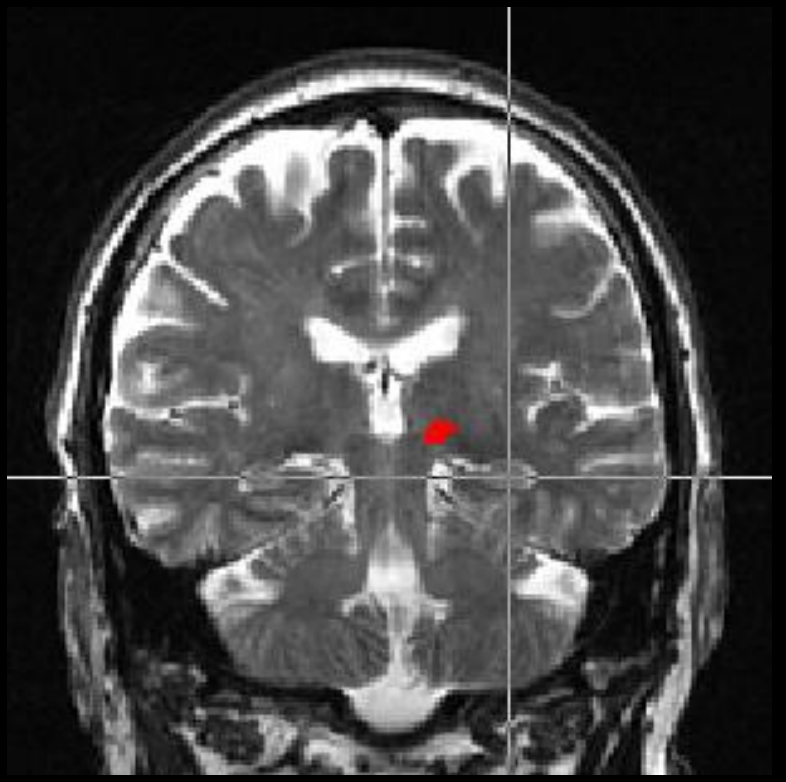


But, registration can definitely fail:

Hippocampus Correct



Hippocampus Wrong



Registration: Two Stages

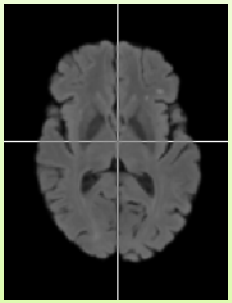
Estimating a spatial transformation:

0 0 0 0
0 0 0 0
0 0 1 0
0 0 0 0

Determining how to move & warp an image into the space of another image.

Result: a 4x4 matrix describing the transform

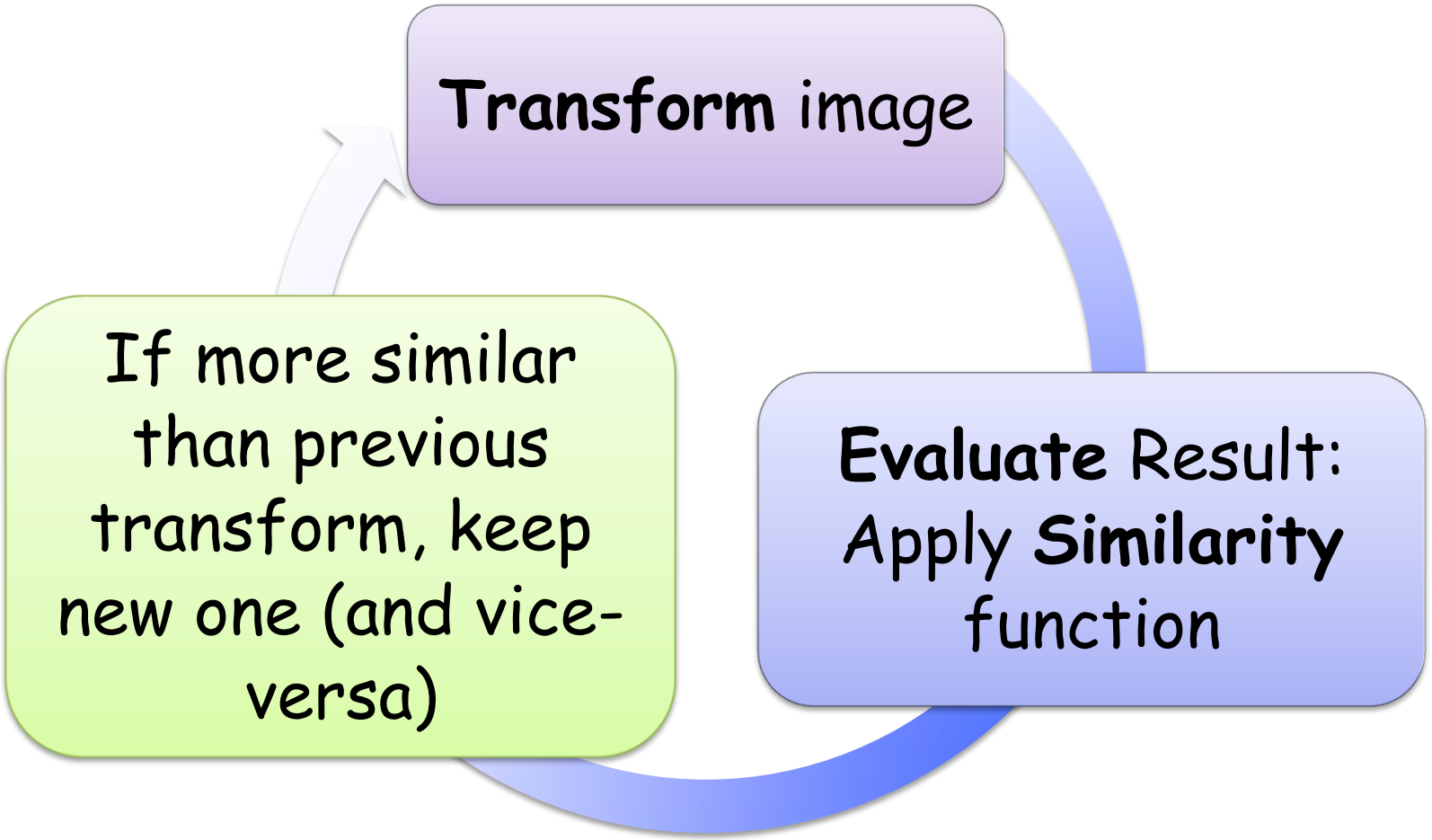
Resampling

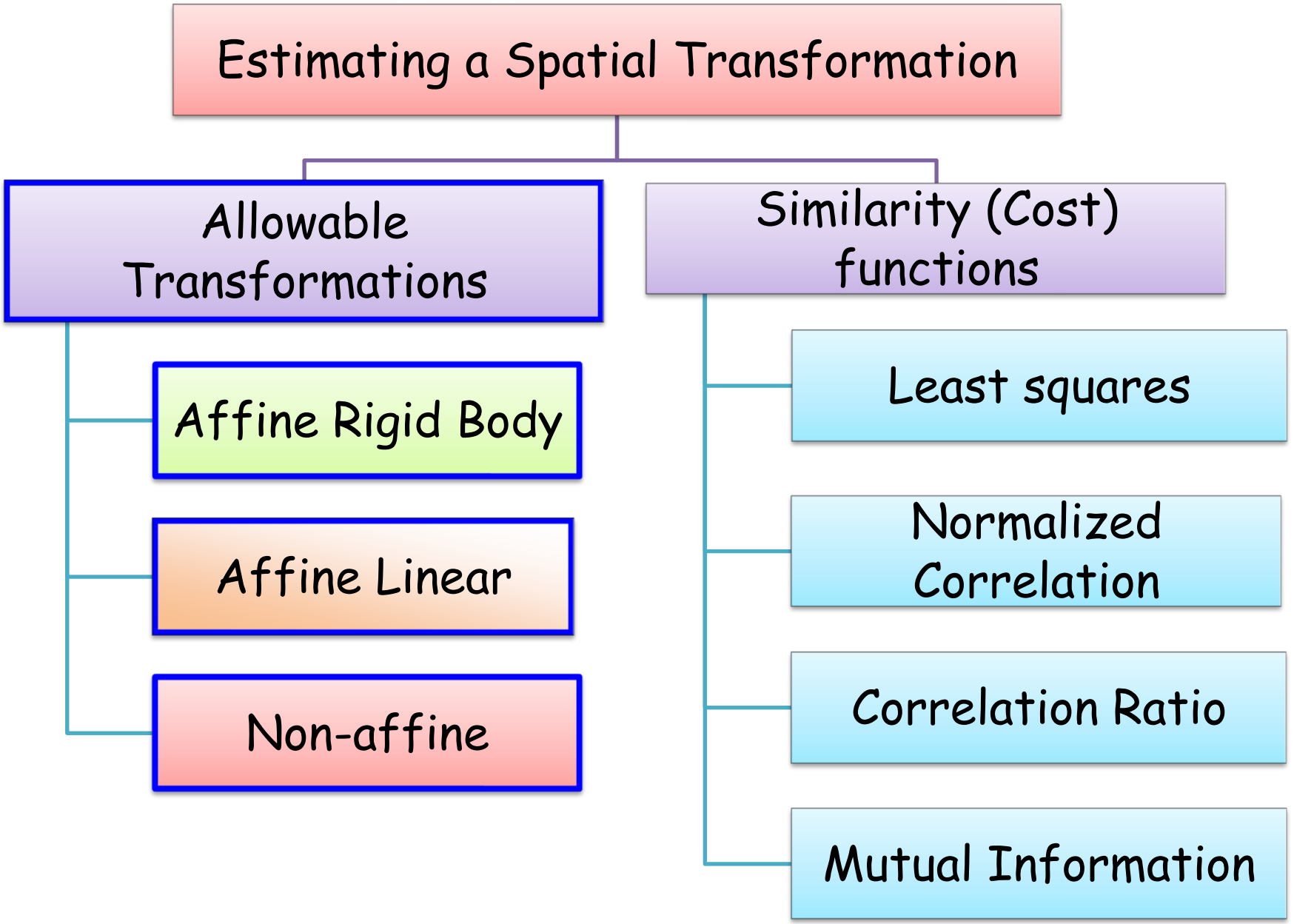


Actually moving and warping the image into the space of the other image.

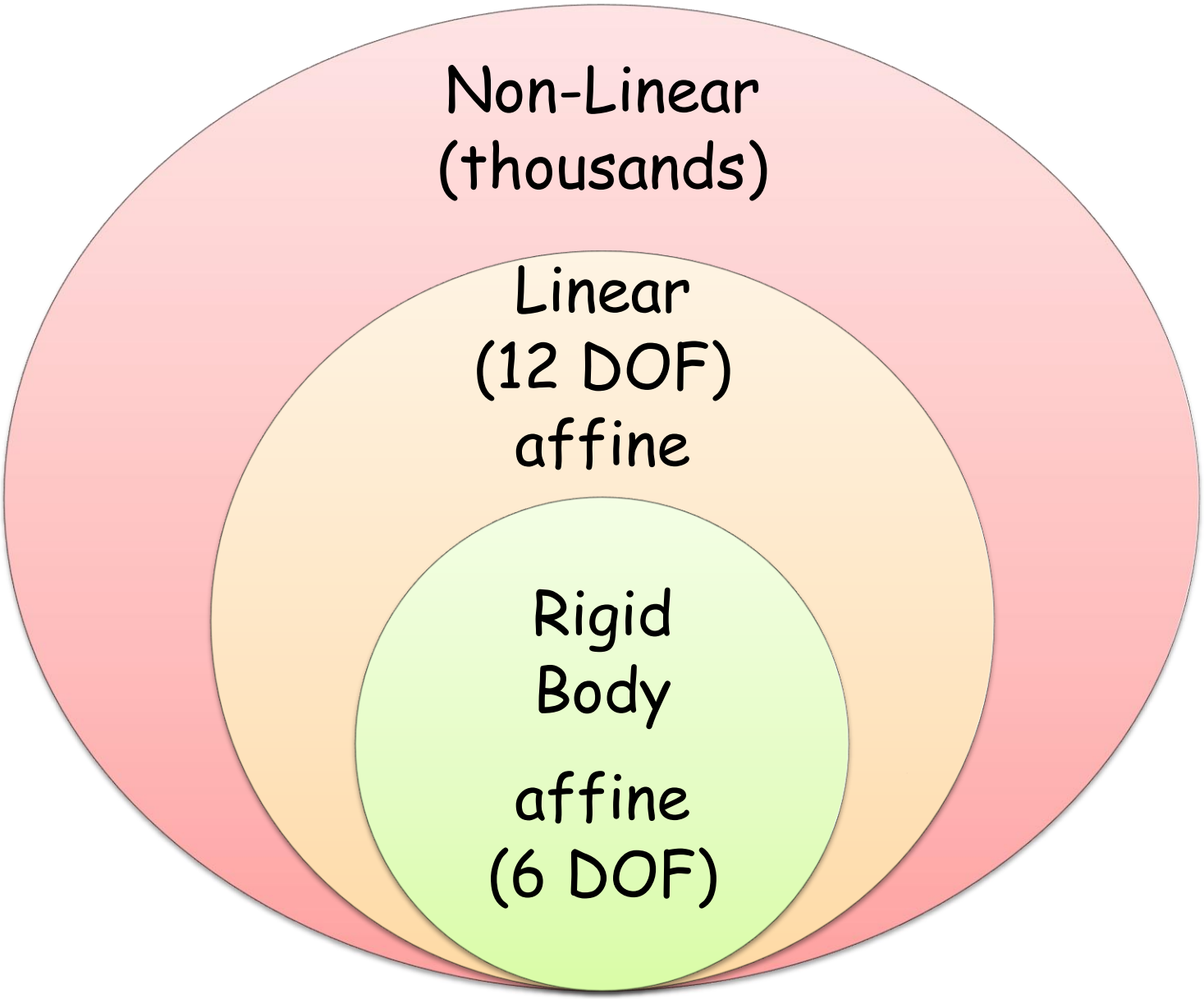
Result: A new image, altered according to the transform

Estimating the Best Transformation




Estimating a Spatial Transformation
Allowable Transformations
Affine Rigid Body
Affine Linear
Non-affine
Similarity (Cost) functions
Least squares
Normalized Correlation
Correlation Ratio
Mutual Information

Allowable Transformations



Allowable Transformations

Affine **Rigid Body** (6 DOF): 3 translations & 3 rotations, (ones you can do yourself)

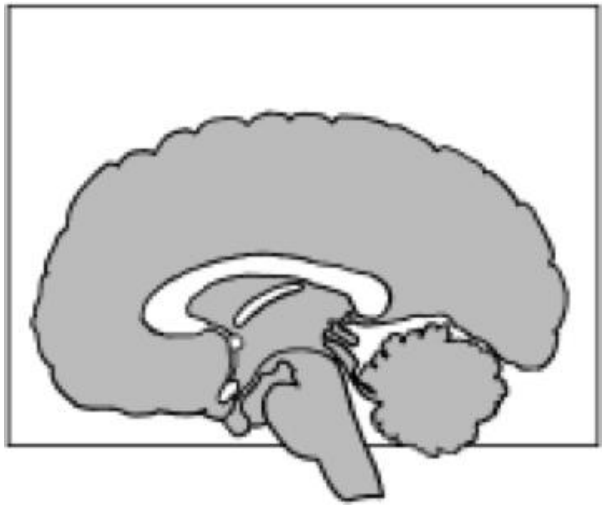
Affine **Linear** (12 DOF): 6 rigid body + 3 scalings +3 shears (preserves collinearity, e.g., points on a line, are still on a line; distance ratios are preserved)

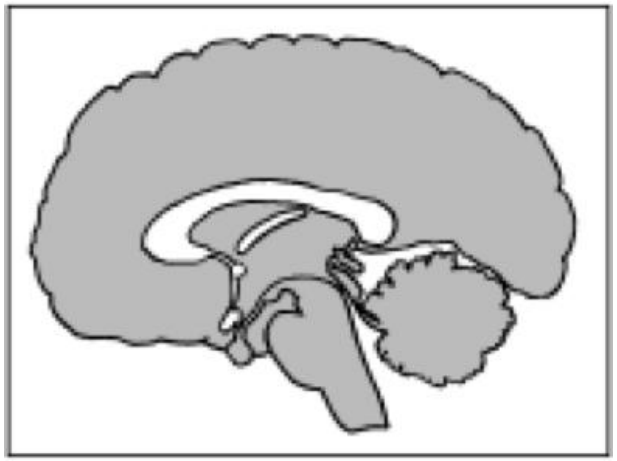
- 7 DOF: Rigid body + global scaling

Non-Affine (Non-linear) thousands…millions of DOF

Translate: 3 directions

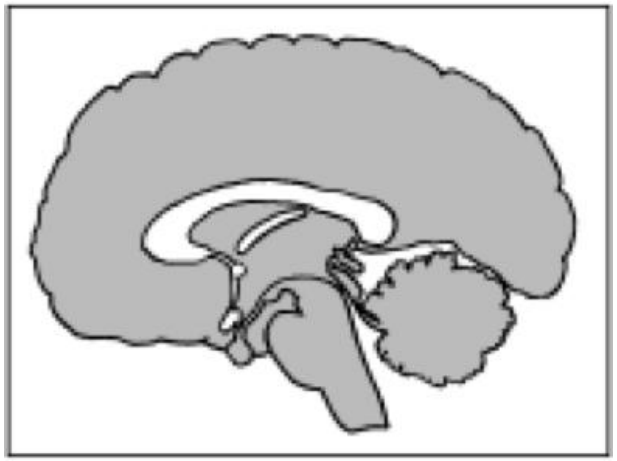
- affine **rigid body** transform
- (e.g. shift up)





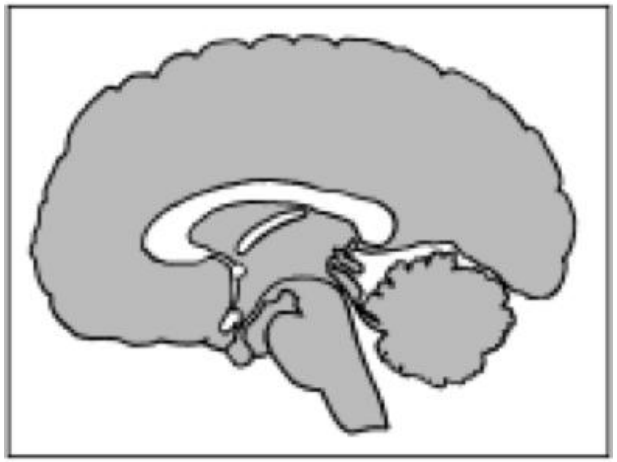
Rotate: 3 directions

- affine **rigid body** transform
- (e.g. pitch down)



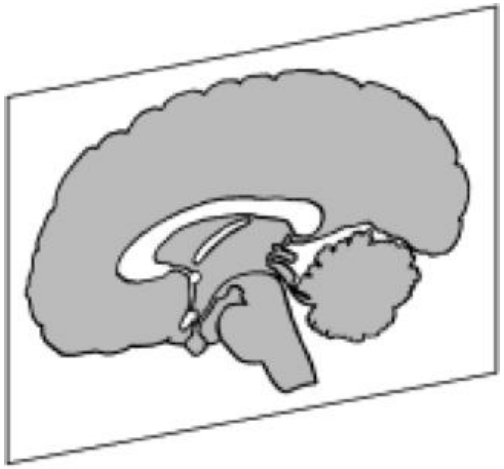
Scaling, (Zoom & Squeeze): 3 directions

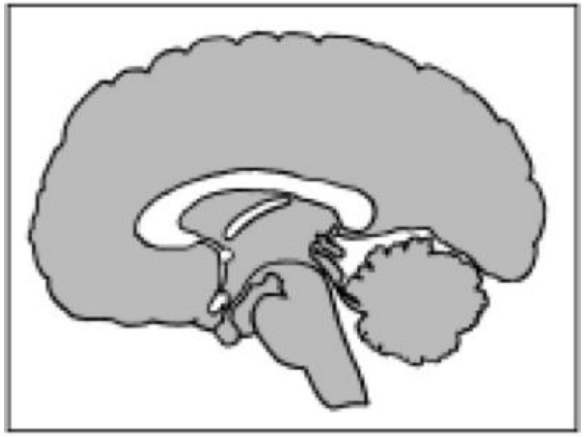
- **linear** affine transforms
- Scaling = global, i.e., all 3 directions at once
- Zoom or squeeze = one direction (e.g. stretch wider)

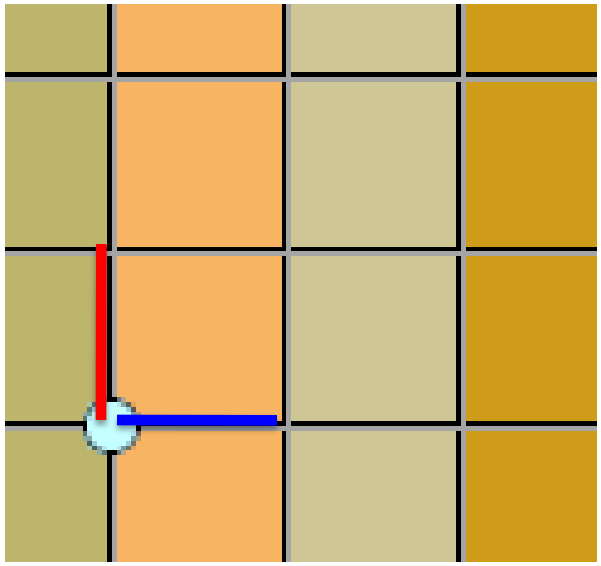


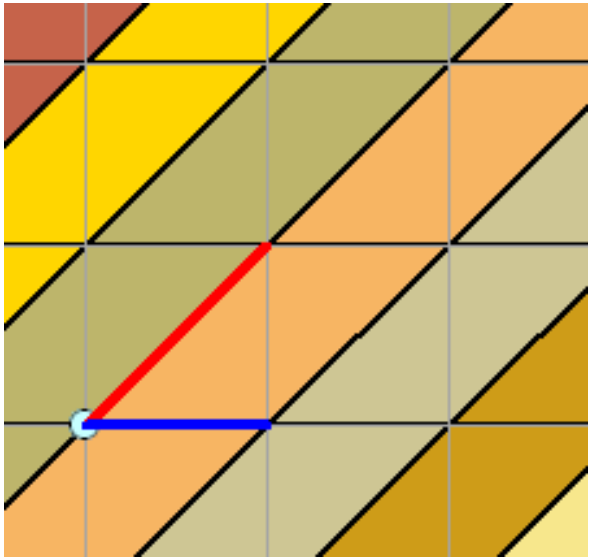
Shear or Skew

- linear affine transform



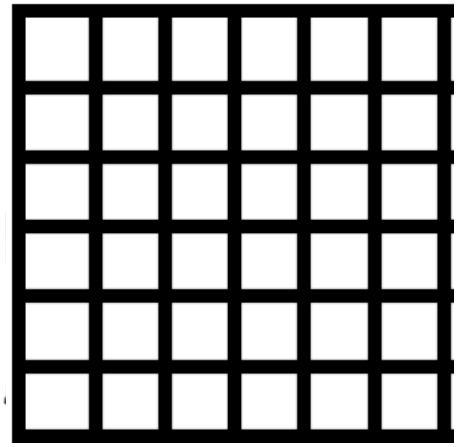


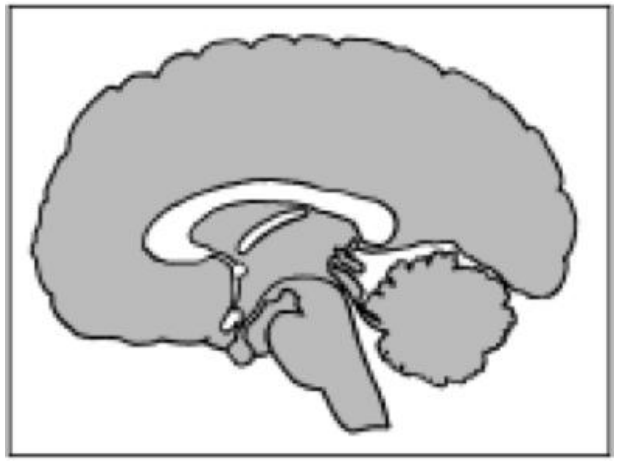


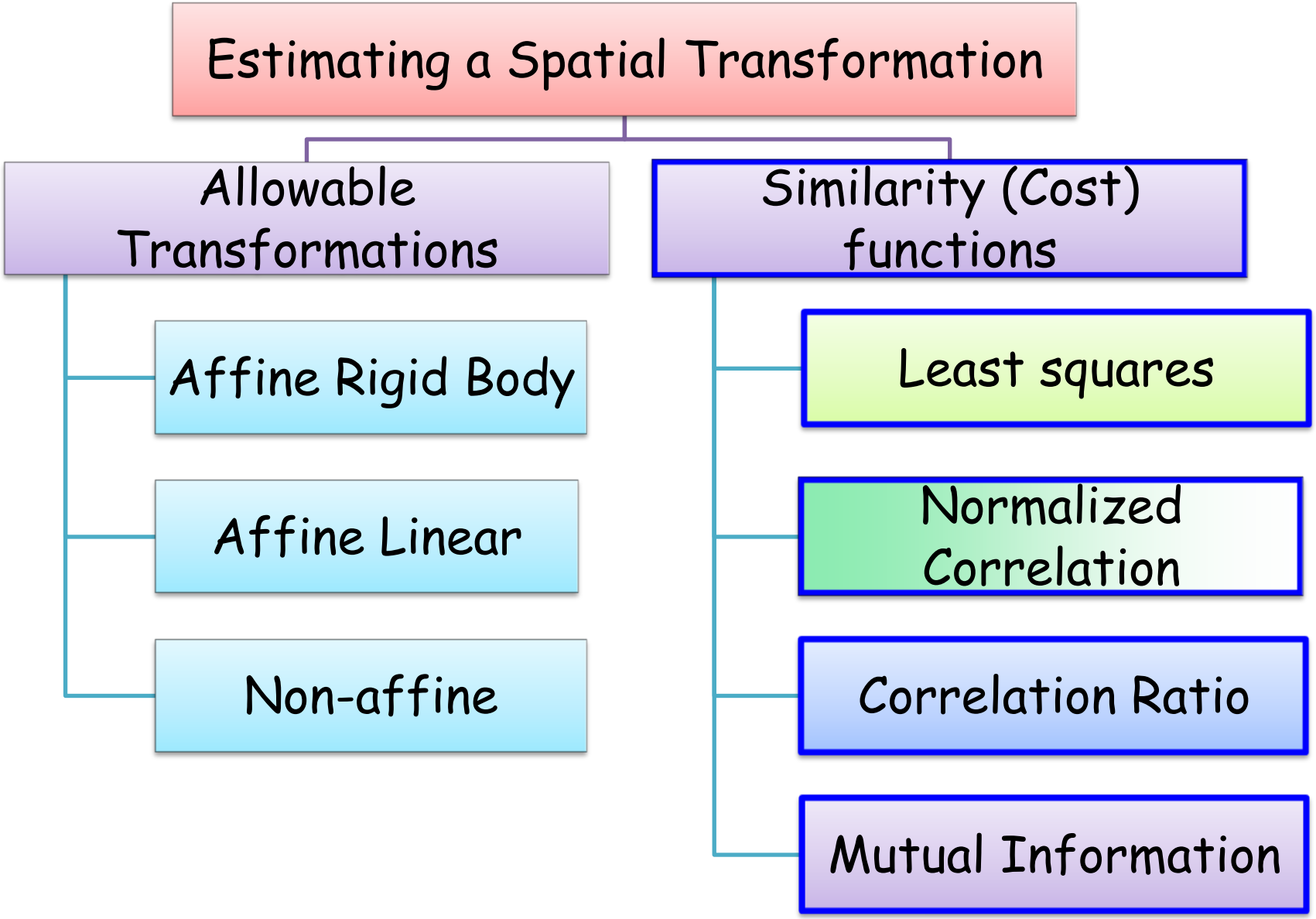


Non-linear (non-affine)

- (e.g., shrink middle; expand edges etc.)



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Mutual Information

Similarity (Cost) functions

Least Squares:

- Intensity matching (only works for images with same contrast/brightness)

Normalized Correlation:

- Intensity matching (with some tolerance for contrast/brightness differences)

Correlation Ratio:

- Handles different MR modalities: Image intensities must have predictable relationship

Mutual Information:

- Handles MR, CT, PET; Uses probability to handle different intensity patterns

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0 0 0 0
0 0 0 0
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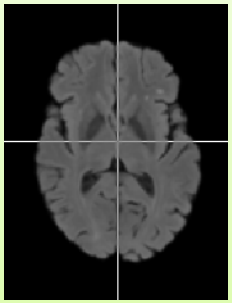
Resampling



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Result: A new image, altered according to the transform

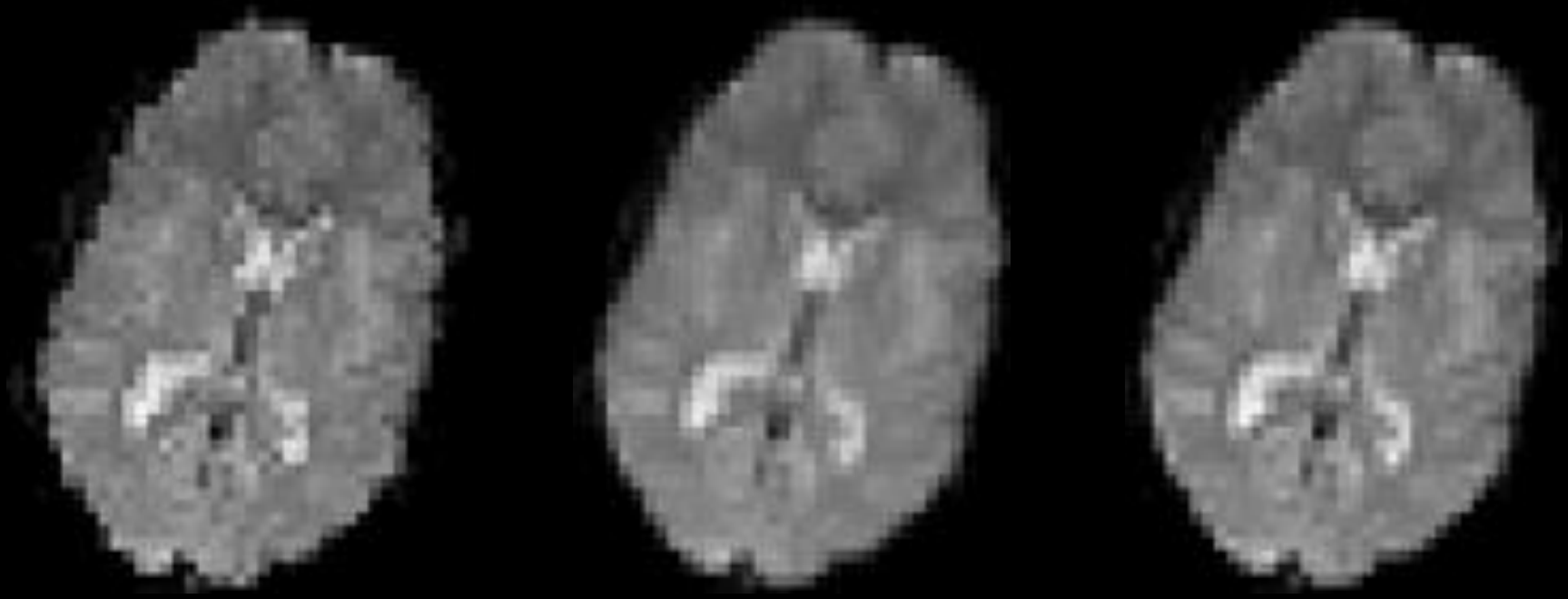
Resampling

Actually transforming an image from one space to another (sometimes reslicing). Each Resampling →Degradation (resampling requires interpolation, i.e., estimating a new voxel intensities)

Types of Interpolation

- Nearest Neighbor: new voxel intensity=nearest neighbor's intensity
- Trilinear: new voxel intensity is weighted average of local neighbors
- Sinc: new voxel intensity is calculated based on large neighborhood…takes more time to run, but is stable (removes tiny spots of noise), & enhances sharpness (by correctly identifying large edge features)

Interpolation



Nearest Neighbor: jagged

Trilinear: blurry

Sinc: best

(Mark Jenkinson 2007 UCLA Summer School)

Registration by any other name…

Realignment, Coregistration & Normalization

Realignment typically applies to a series of volumes (i.e., fMRI series) that may be slightly off because of subject movement.

Coregistration is registration between different images (i.e., T2, spgr, flair etc.)

Normalization is registration to a standard template (necessary for group comparisons)

Standard Space

One reason to register images is to compare subjects.

So, whose brain do you register to?

Several standard brains have been developed, and registering to such a standard is called **spatial normalization.**

The standards continue to evolve.

Although useful for comparing subjects, normalization distorts individual variablility that may be of interest.

Talairach

Talairach defined the first standard (stereotactic) brain coordinate system.

It assumes brains aligned on the AC-PC.

It is based on a single post mortem brain from a woman with a smaller than average cranium.

MNI Standards

The Montreal Neurological Institute improved on the talairach brain by using MR imaging to create the MNI152 brain (an average of 152 normal brains, available as T1, T2 and PD weighted images)

The MNI-152 brain has been replaced by the MNI-305 brain (the "official" standard) and will be replaced by the MNI-450 brain in due time.

Other Atlases

Using one of the standards, atlases have been developed to identify cortical and subcortical structures.

Diffusion Tensor imaging has resulted in new atlases that reveal the location of axon bundles (not distinct in other image modalities).

Online atlases continue to develop that collect functional, architectonic or other data into standards.

Atypical Brains

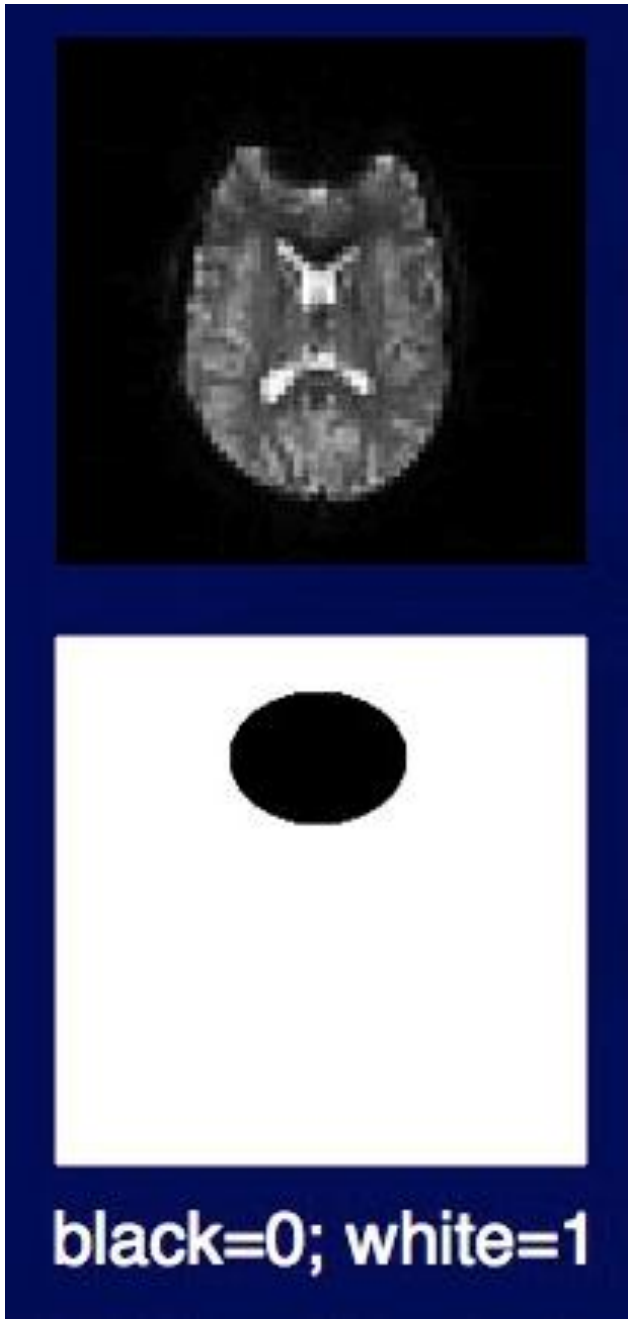
Everything we've considered is for normal young adult brains.

Very young brains, very old brains, & brains with lesions, or atrophy do not register well to standard brains.

If you have lots of brains with similar issues (e.g., age), you can create your own standard for that subgroup.

Abnormalities

It is often better to cover abnormalites with a binary mask, so they are not considered during normalization.



Practical Advice

- Use brain extraction
- Always look at your registrations, to make sure they are decent.
- Always use the best possible image (contrast and resolution) as your reference image.
- Minimize the number of times you resample/interpolate.
- Deweight lesions when normalizing

Summary

To register one image to another, we must move and warp the image, then assess the goodness of fit iteratively.

It is important to choose the correct cost function for the images we are registering.

Estimating the registration transform is distinct from actually applying that transform to an image.

One important function of registration is normalization to a standard.

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