

PREPROCESSING – COREGISTRATION AND SPATIAL NORMALISATION

Methods for Dummies 2023

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RECAP

Realignment of volumes over the course of a scan

- Allows the changes over time to be compared

Unwarping of volumes due to B0 inhomogeneities

- Corrects for signal drop off and image distortion

COREGISTRATION



Problem: Functional scans have low spatial specificity



Solution: Align the functional images with a high-resolution structural image



Process: Maximize the mutual information between the functional and spatial images



Issues: Poor starting estimates lead to local minima

PROBLEM





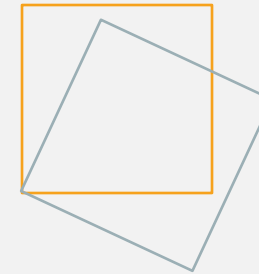
SOLUTION



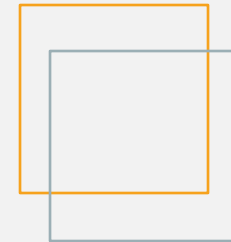


PROCESS - TRANSFORMS

- Realignment uses 6 transforms
 - 3 rotation
 - 3 translation
- Coregistration uses a further 6 transforms
 - 3 shear
 - 3 scales



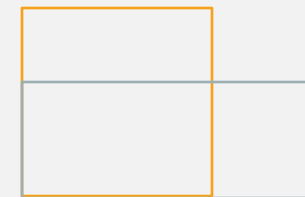
Rotation



Translation



Shear



Scaling

PROCESS - MUTUAL INFORMATION

- Maximize the mutual information (Shannon information)
 - $MI = \text{Entropy of the two images} - \text{joint entropy}$
 - The lower the joint entropy, the higher the mutual information
- The mutual information is often represented in the joint histogram

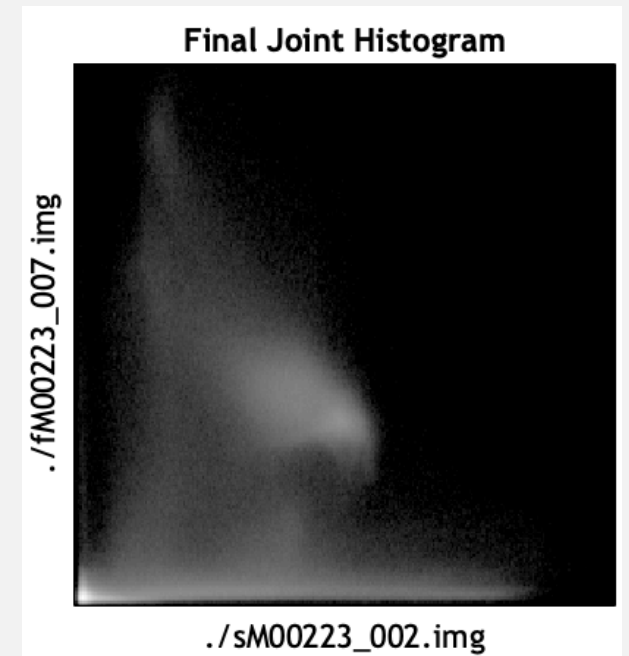
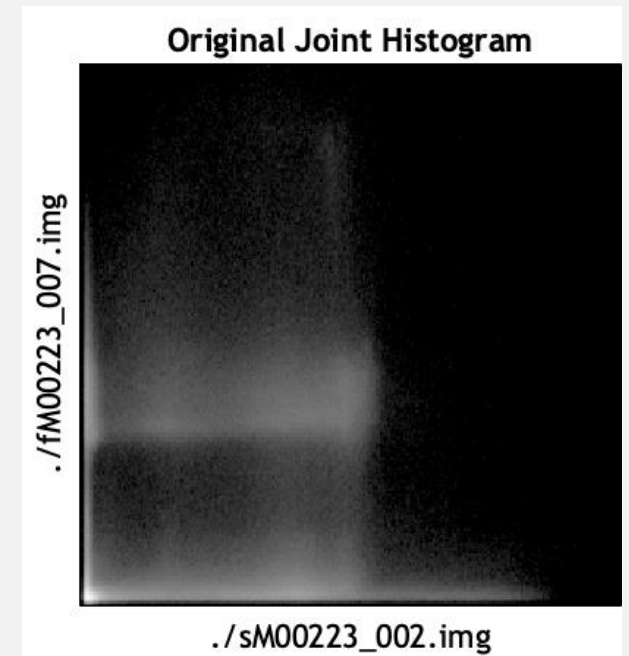




Image 1

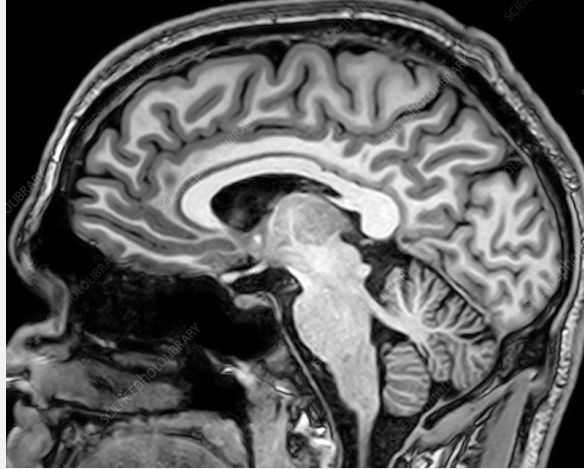
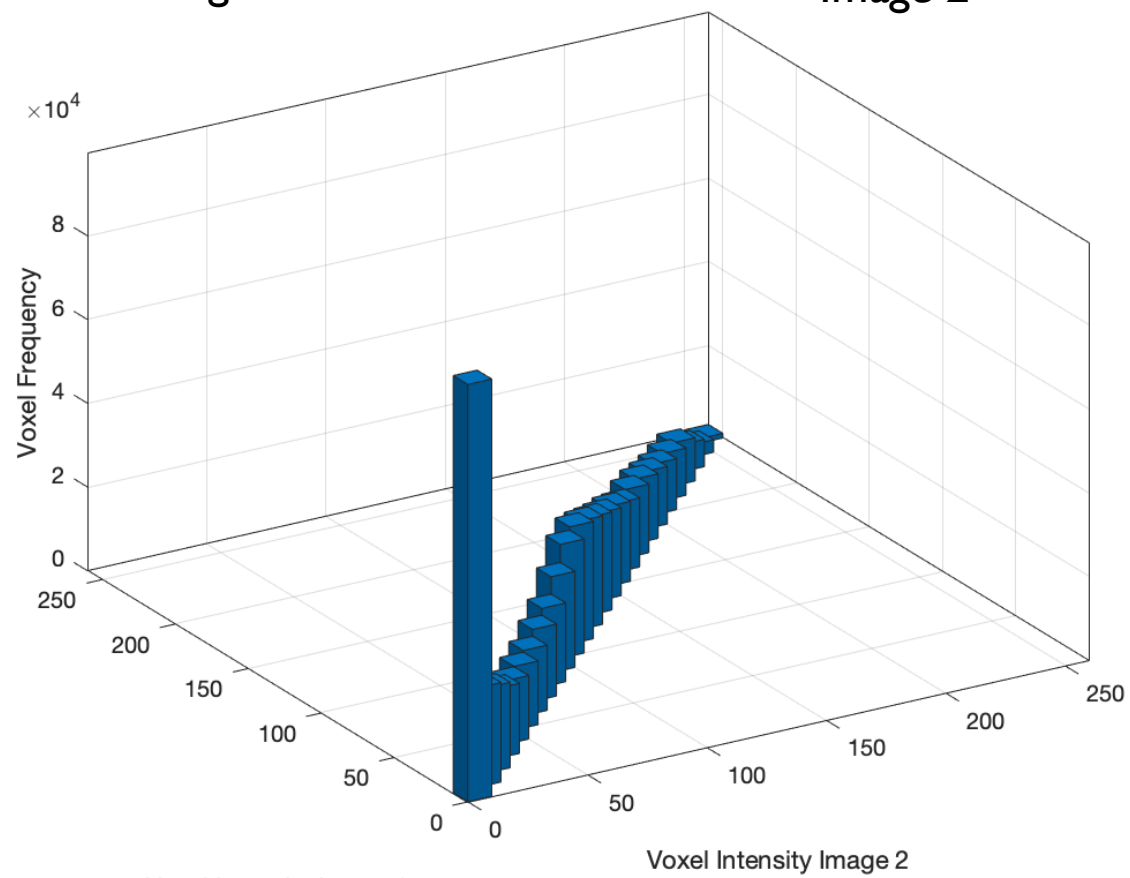


Image 2



Voxel Intensity Image 1

Voxel Intensity Image 2



Image 1

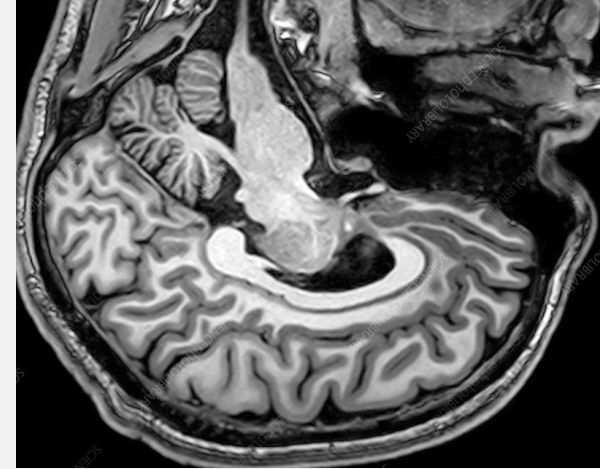
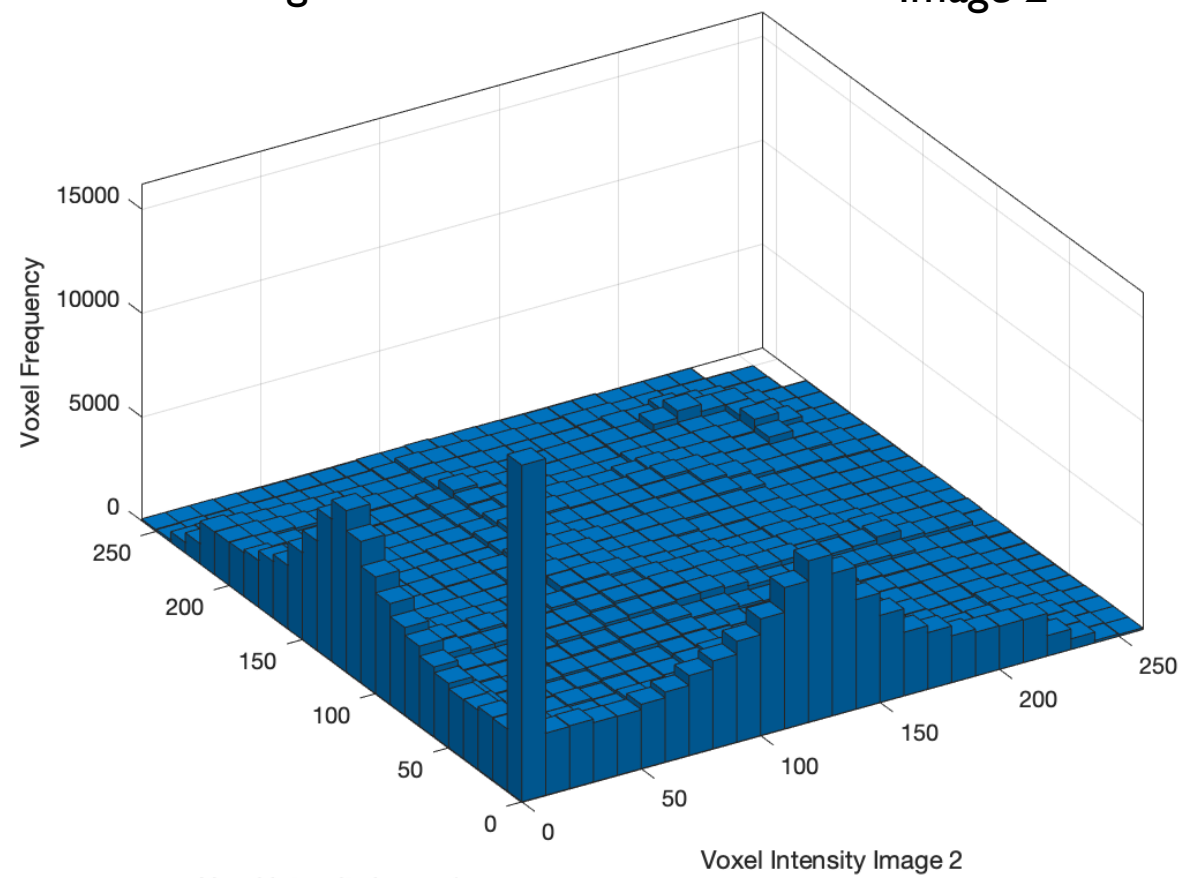


Image 2



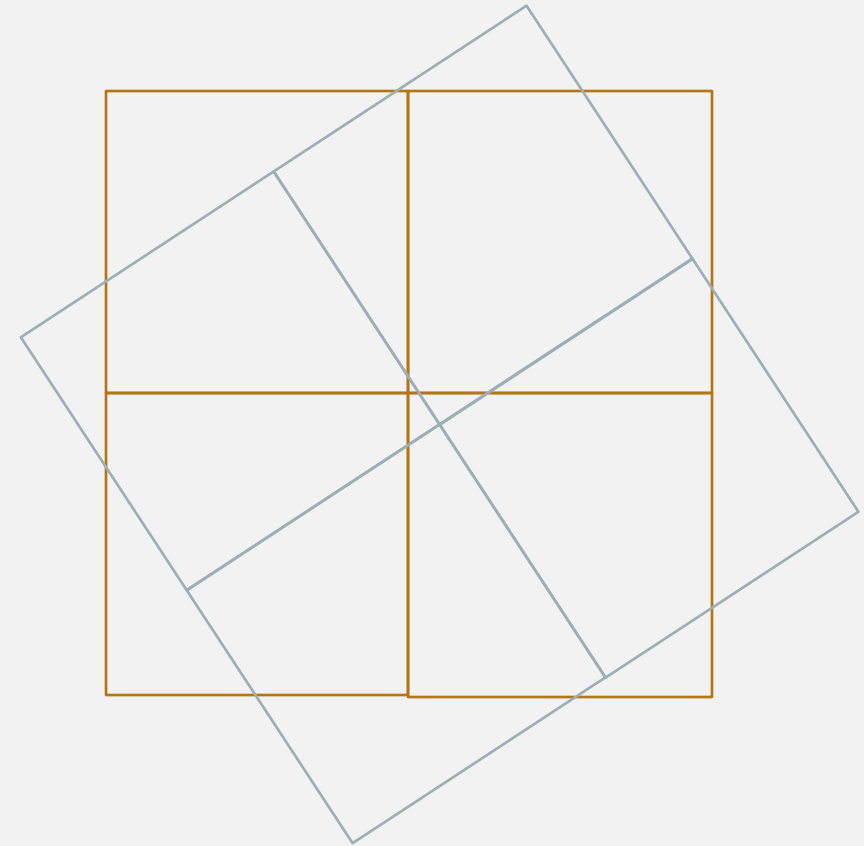
Voxel Intensity Image 1

Voxel Intensity Image 2



PROCESS– VOXEL INTERPOLATION

- The image voxels cannot be perfectly aligned after transformation
- Interpolation techniques are used to approximate the values at each location between voxels
- Often done with generalized interpolation using B-splines



SPATIAL NORMALISATION



Problem: We can't compare across brains of different shapes and sizes



Solution: Register all images to a 'standard' image



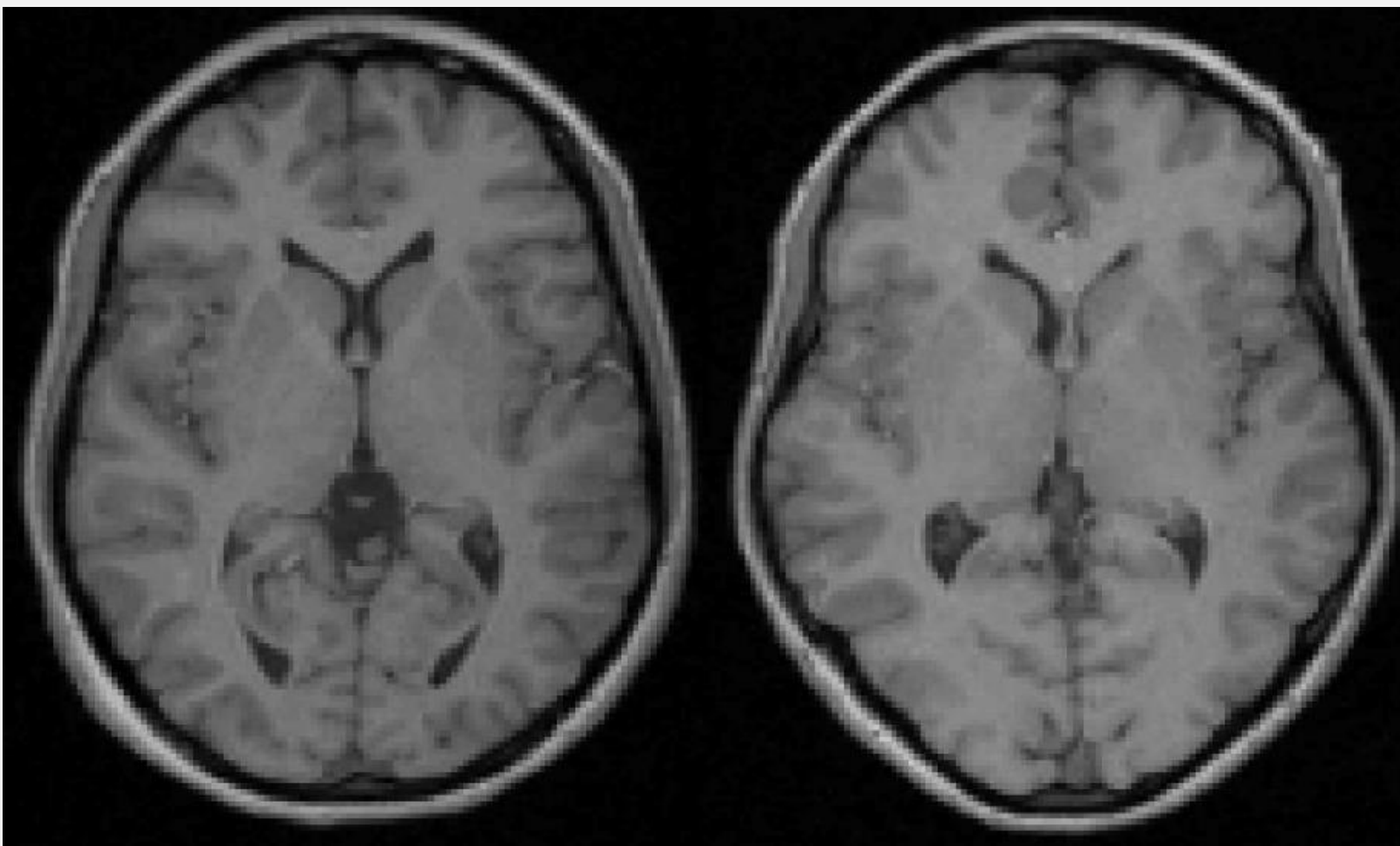
Process: Coregister the images to find an approximate match
Use non-linear transformations to allow for changes in head shape



Issues: Potential over-warping of images

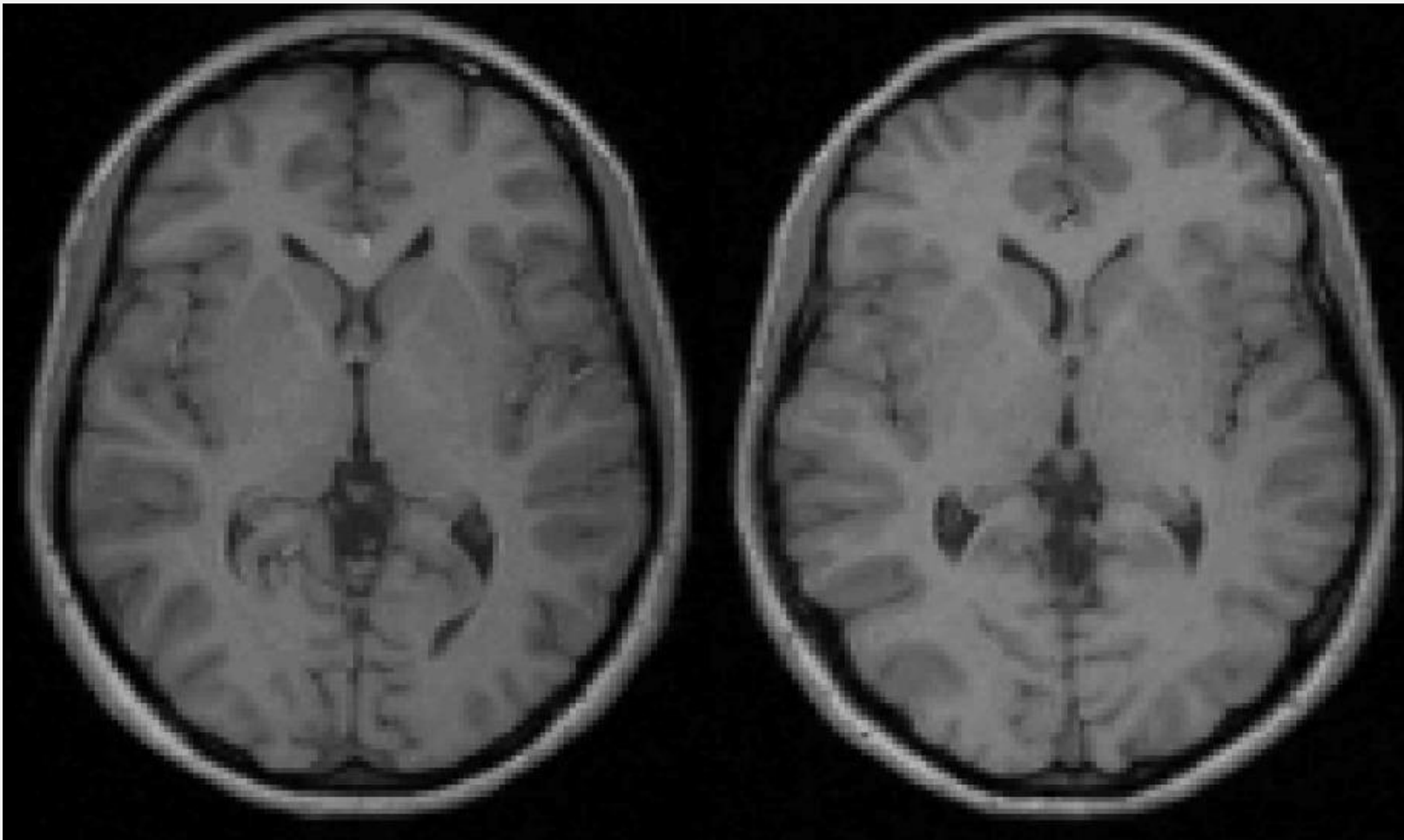


PROBLEM



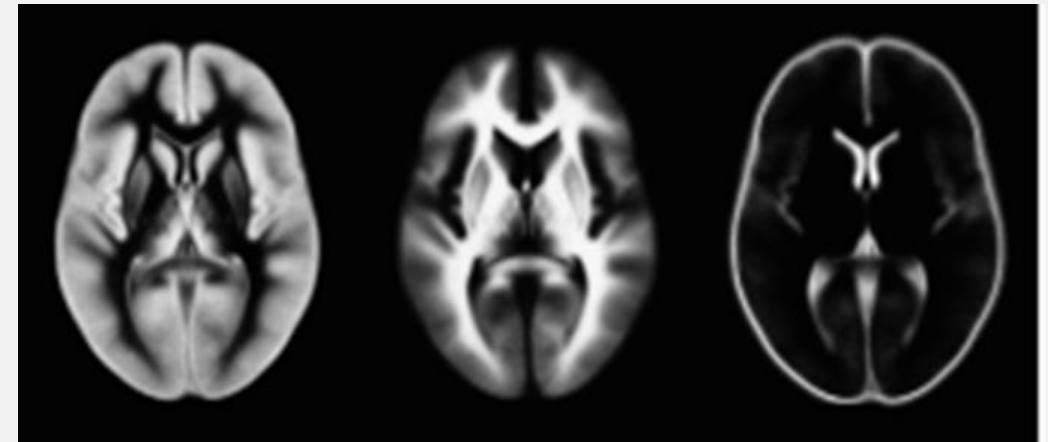
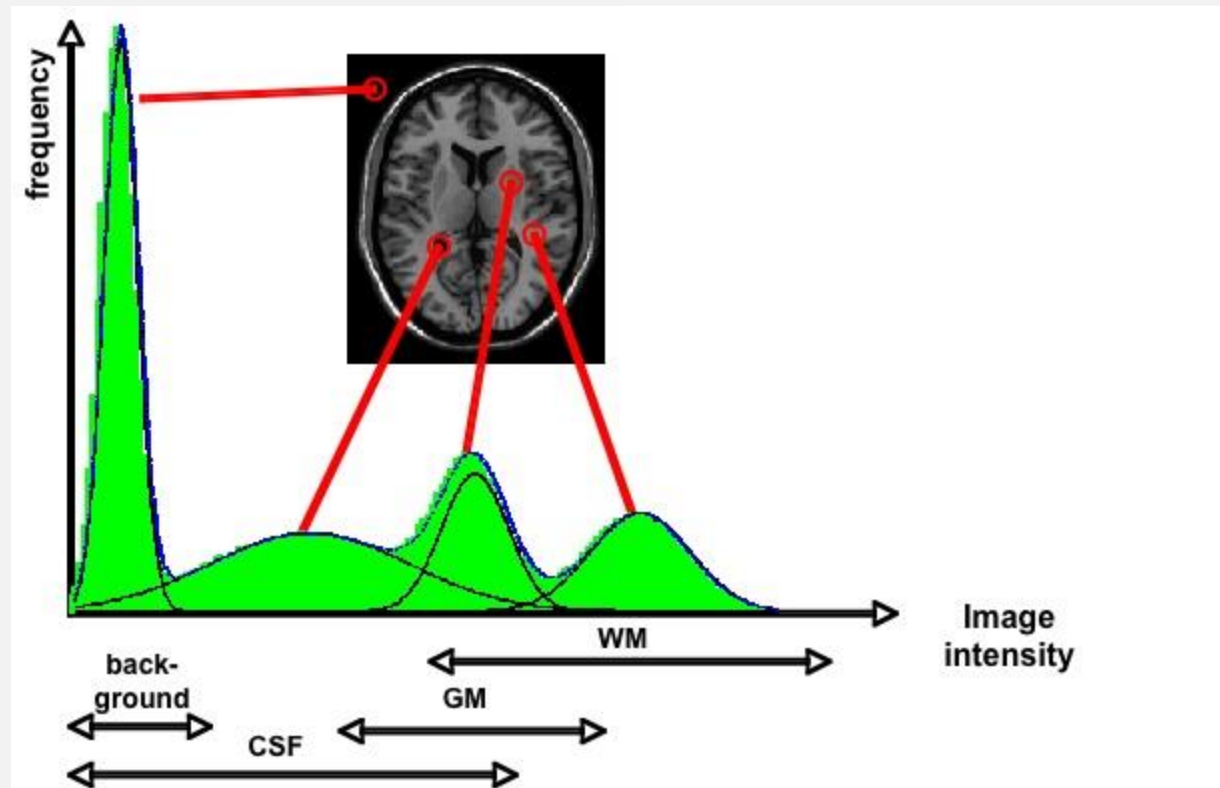


SOLUTION





PROCESS - SEGMENTATION





PROCESS - WARPING

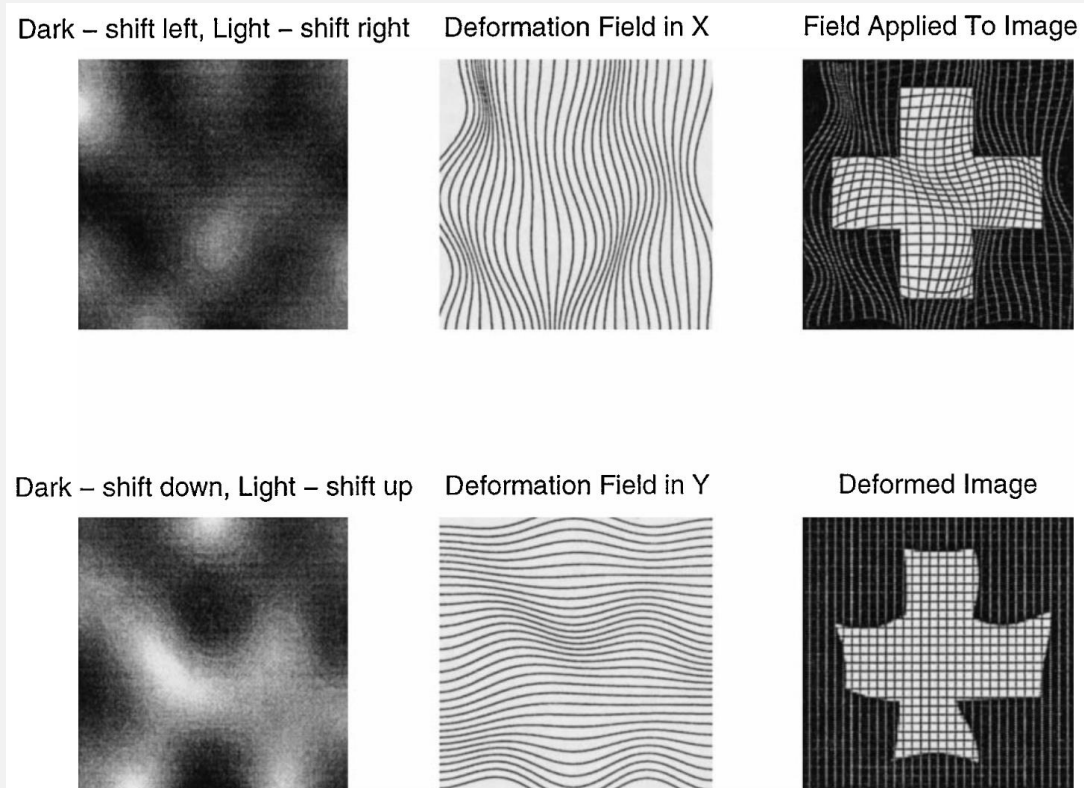


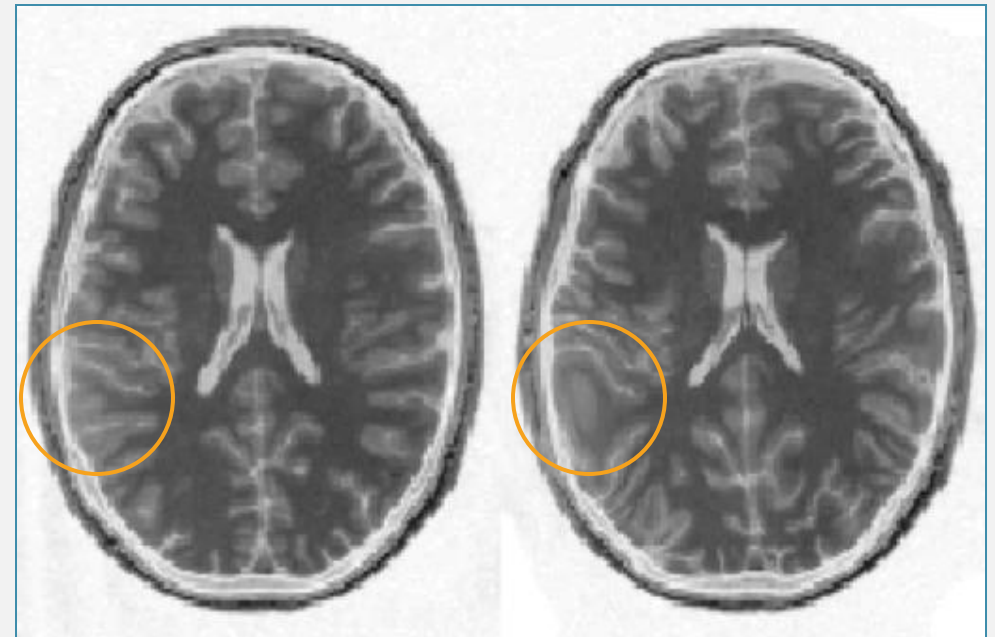
Figure 2.

For the two-dimensional case, the deformation field consists of two scalar fields: one for horizontal deformations, and the other for vertical deformations. Images at left show the deformation fields as a linear combination of the basis images (see Fig. 1). Center column: Deformations in a more intuitive sense. The deformation field is applied by overlaying it on the object image, and resampling (right).



ISSUES

- Overfitting of images can introduce non-present features
- Find the best parameters to match the source image to the template *whilst simultaneously* minimizing the deviation of the parameters from expected values.
- Regularization uses constraints to reduce the possibility of overfitting



Constrained

Unconstrained

SMOOTHING



Problem: Registration cannot be perfect



Solution: Remove high frequency components that constitute residual anatomical and registration differences



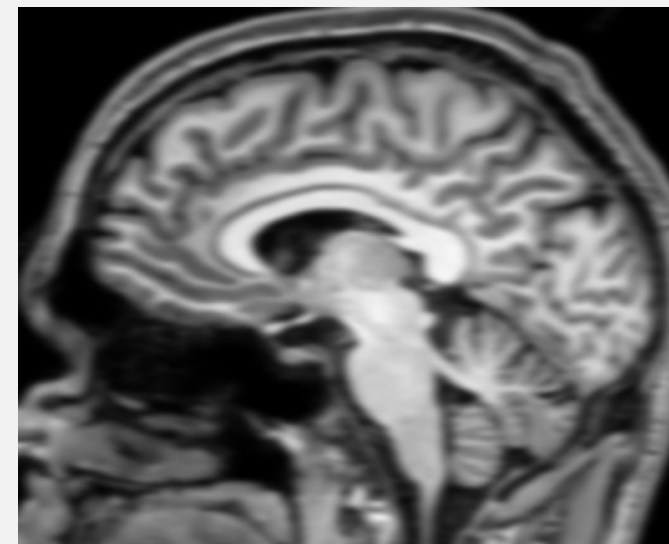
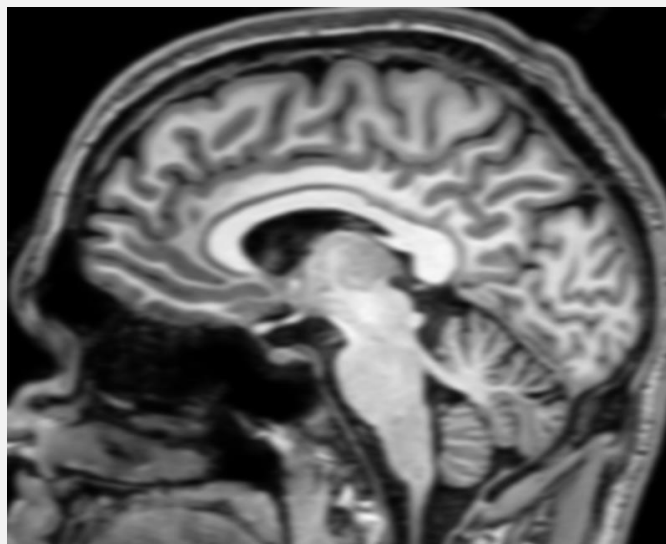
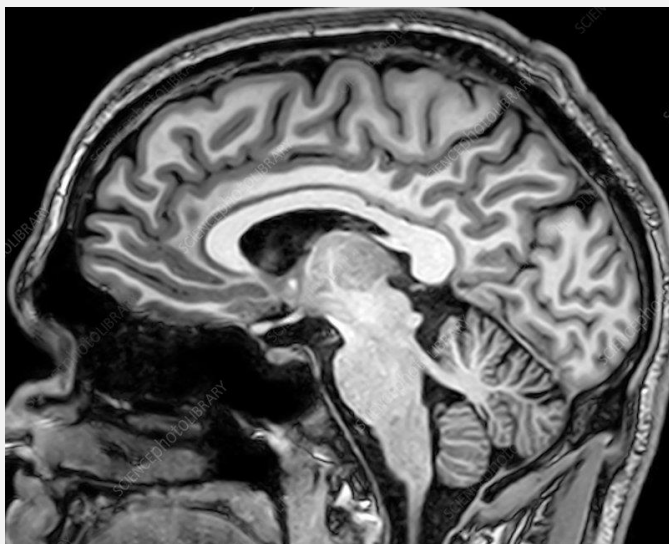
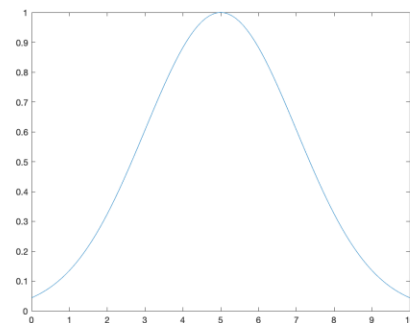
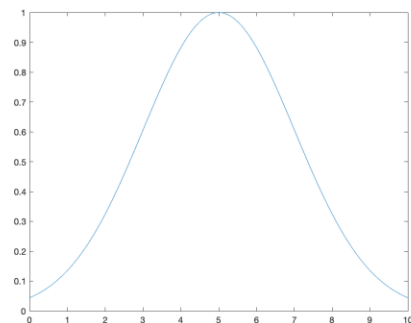
Process: Apply a Gaussian kernel



Issues: Reduces spatial localisation



PROCESS



DEMO

