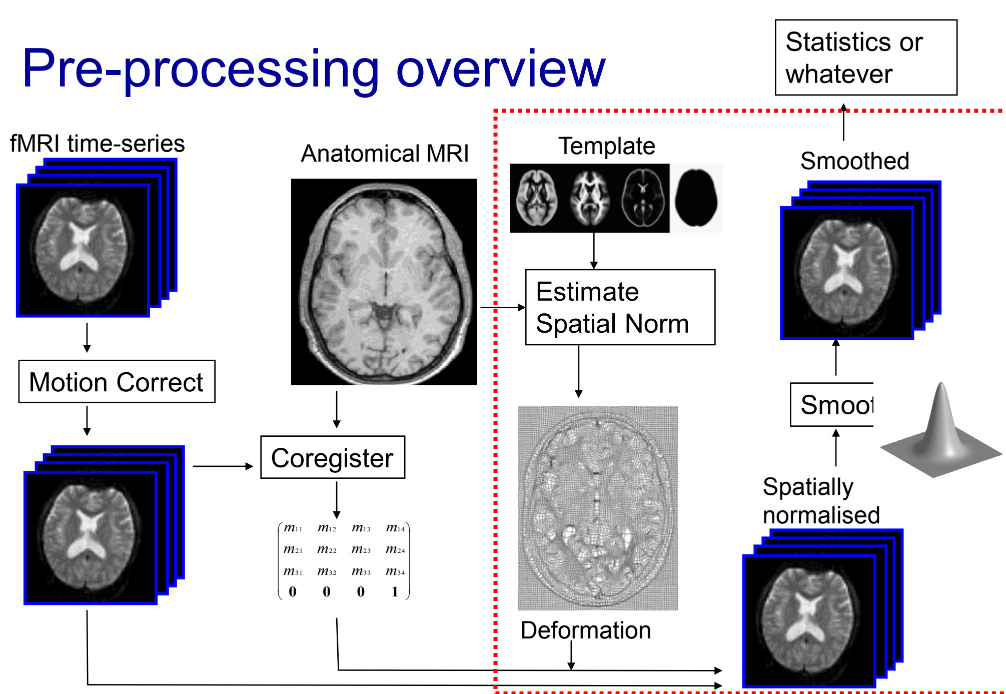
Preprocessing II: Between Subjects

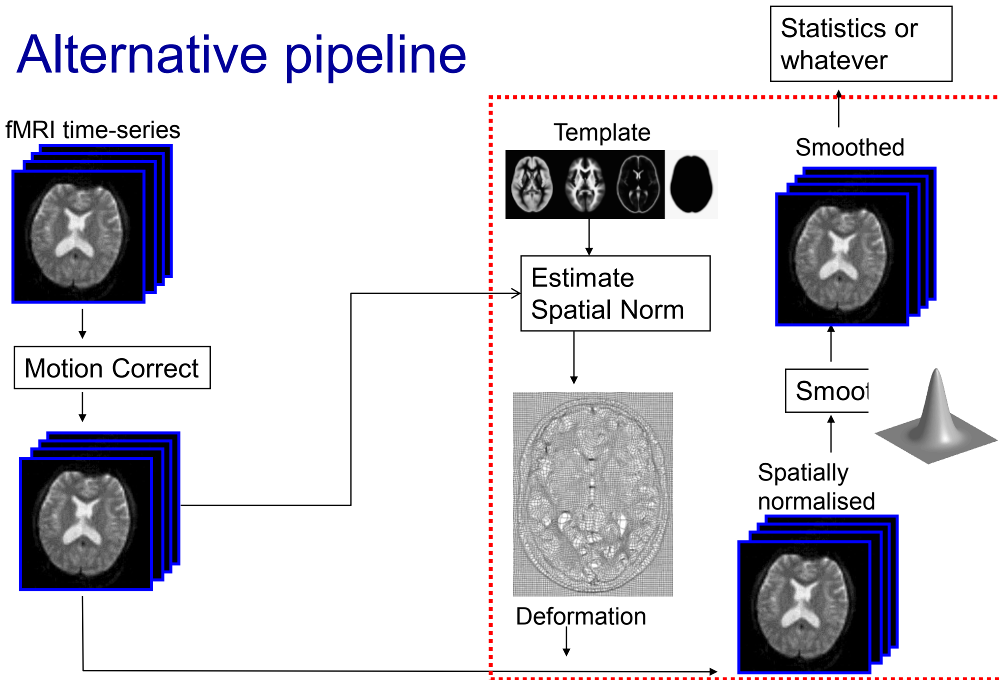
John Ashburner

Wellcome Trust Centre for Neuroimaging,
12 Queen Square, London, UK.

Pre-processing overview



Alternative pipeline



Contents

* **Normalise/Segment**
  Use segmentation routine for spatial normalisation
  * **Gaussian mixture model**
  * **Intensity non-uniformity correction**
  * **Deformed tissue probability maps**
* Dartel
* Smoothing

Spatial normalisation

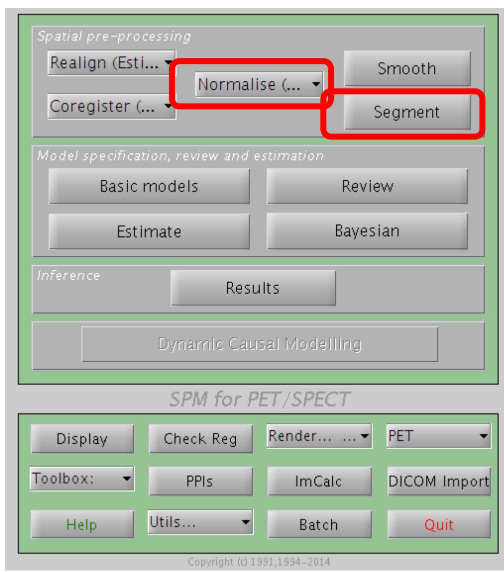
* Brains of different subjects vary in shape and size.
* Need to bring them all into a common anatomical space.
  * Examine homologous regions across subjects
    * Improve anatomical specificity
    * Improve sensitivity
  * Report findings in a common anatomical space (eg MNI space)

* In SPM, alignment is achieved by matching grey matter with grey matter and white matter with white matter.
  * Need to segment.

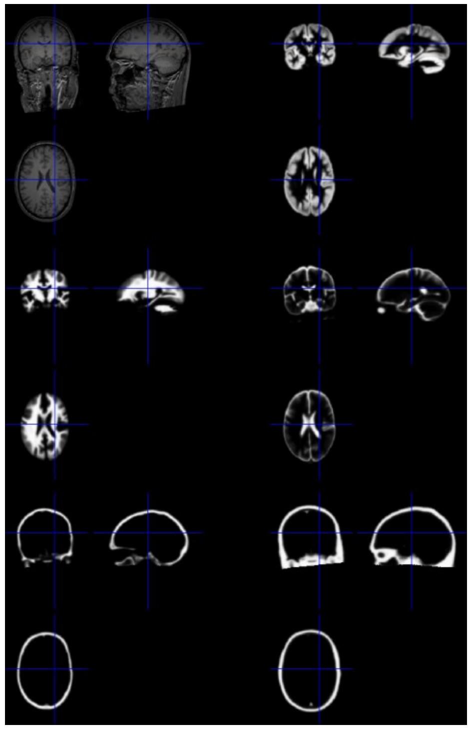
Normalise/Segment

* This is the same algorithm as for tissue segmentation.

* Combines:
  * Mixture of Gaussians (MOG)
  * Bias Correction Component
  * Warping (Non-linear Registration) Component

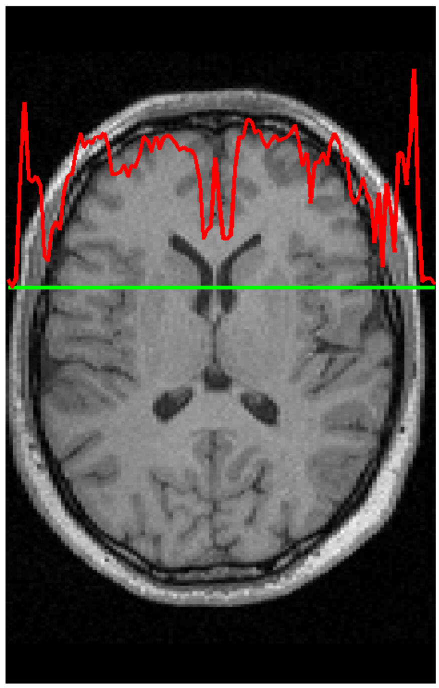


Spatial normalisation

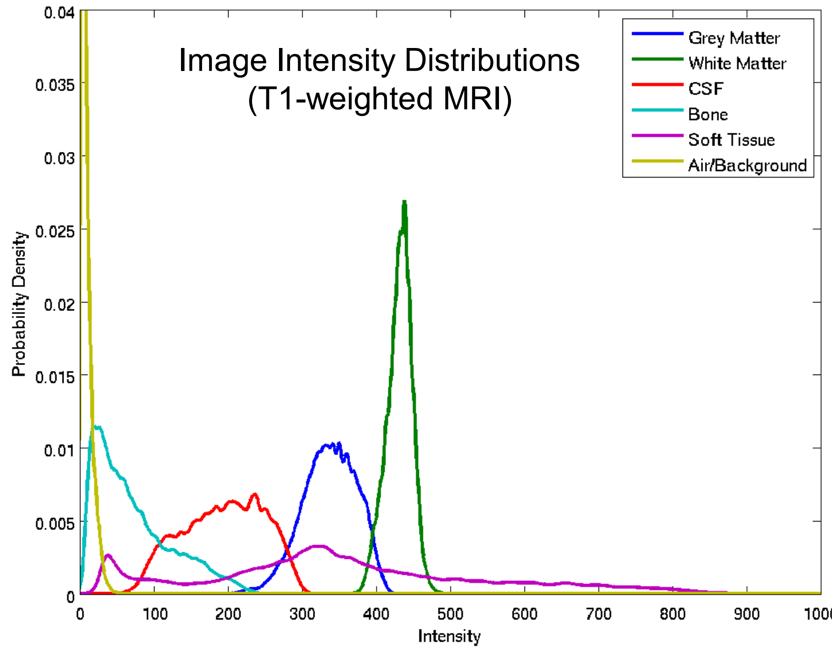


* Default spatial normalisation in SPM12 estimates nonlinear warps that match tissue probability maps to the individual image.
* Spatial normalisation achieved using the inverse of this transform.

Segmentation

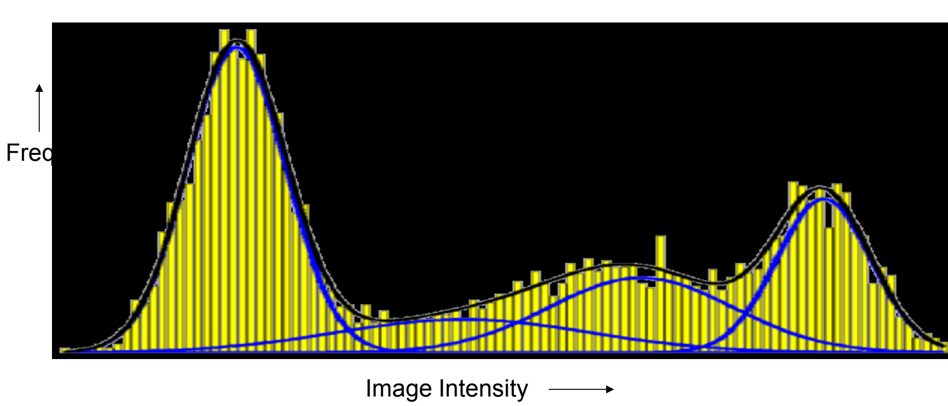


* Segmentation in SPM12 also estimates a spatial transformation that can be used for spatially normalising images.
* It uses a generative model, which involves:
  * Mixture of Gaussians (MOG)
  * Warping (Non-linear Registration) Component
  * Bias Correction Component

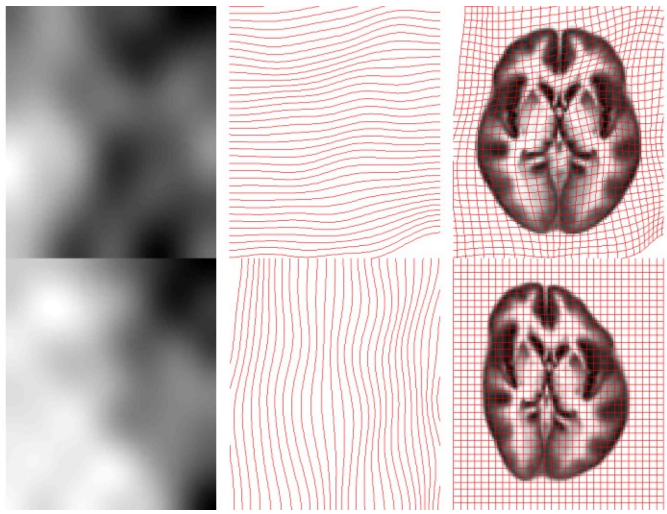


Modelling tissue intensities

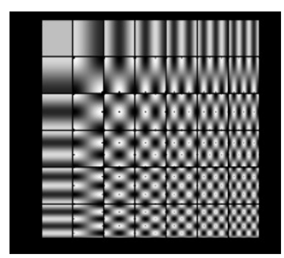
* Classification is based on a ***Mixture of Gaussians*** model (MOG), which represents the intensity probability density by a number of Gaussian distributions.

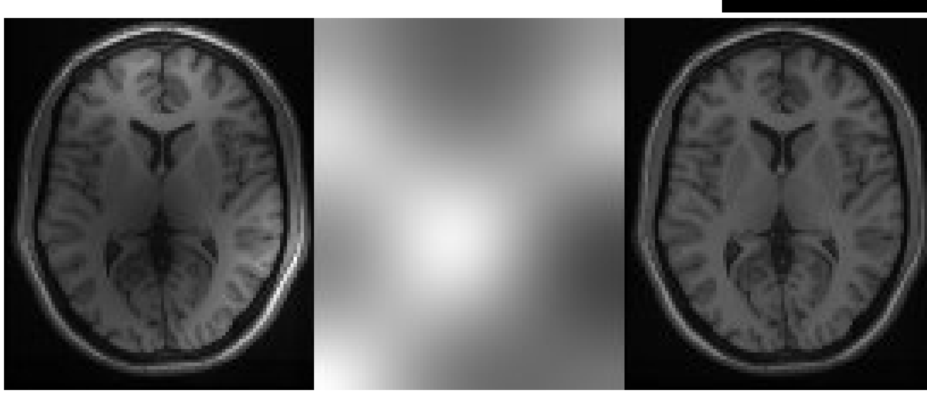


Modelling deformations



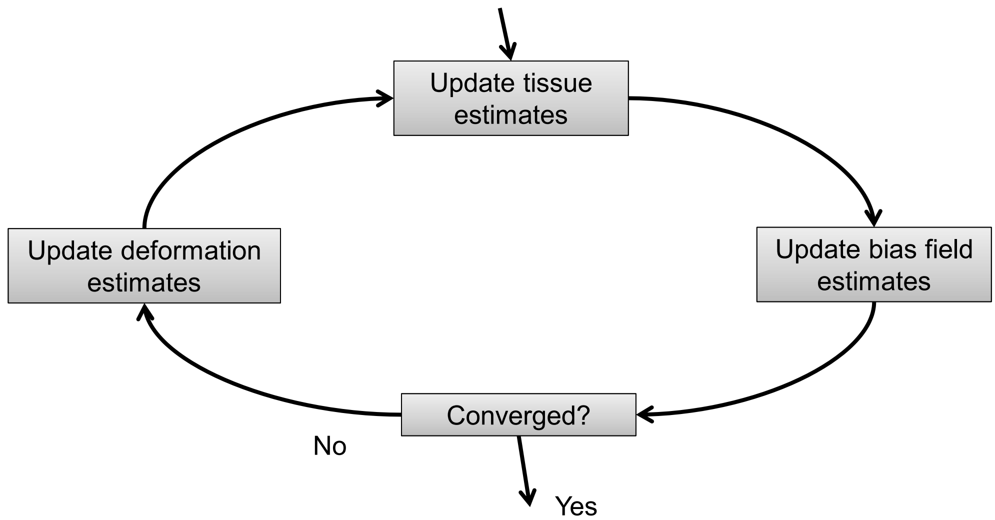
Modelling a bias field



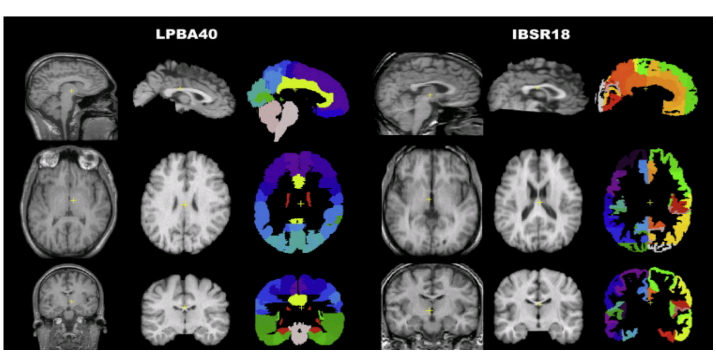


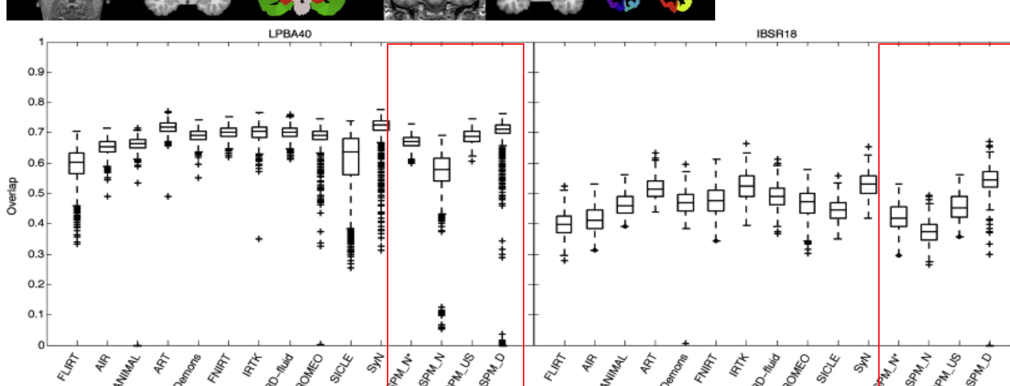
Corrupted image Bias Field Corrected image

Iterative optimisation scheme



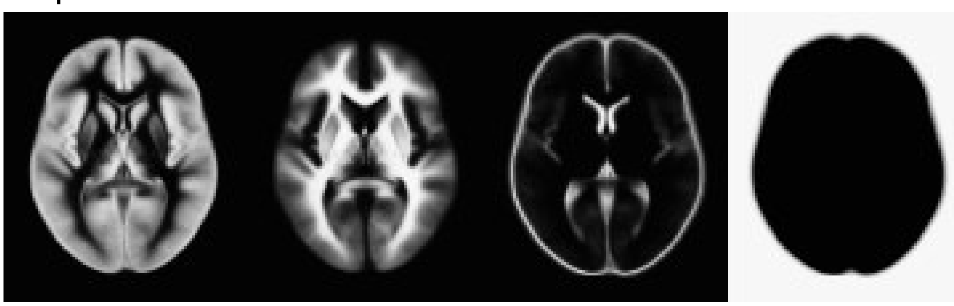
Evaluations of nonlinear registration algorithms





Old tissue probability maps

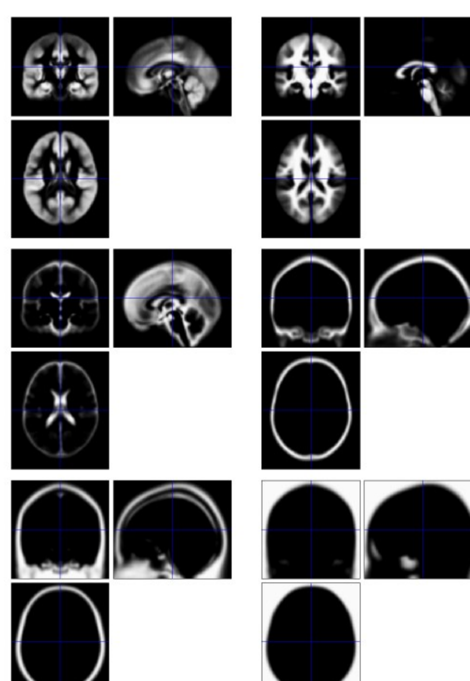
* Tissue probability maps (TPMs) are used instead of the proportion of voxels in each Gaussian as the prior.

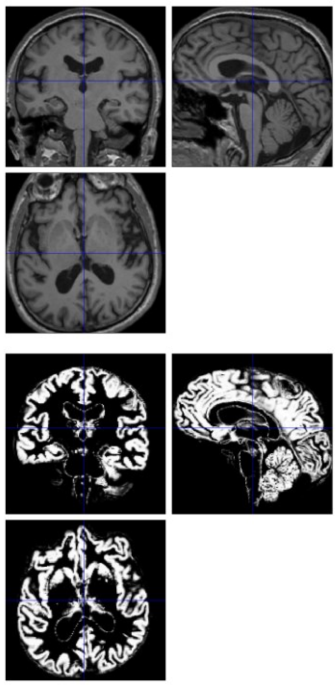


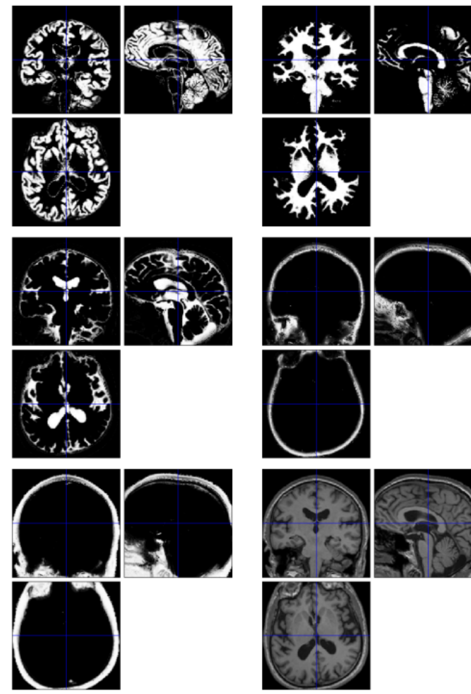
ICBM Tissue Probabilistic Atlases. These tissue probability maps are kindly provided by the **International Consortium for Brain Mapping**, John C. Mazziotta and Arthur W. Toga.

Tissue probability maps in SPM12

Includes additional non-brain tissue classes (bone, and soft tissue)





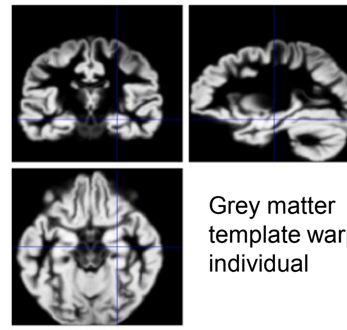


Contents

* Normalise/Segment
* **Dartel**
  * **Velocity field parameterisation**
  * **Objective function**
  * **Template creation**
  * **Examples**
* Smooth

Dartel image registration

* Uses fast approximations
    * Deformation integrated using scaling and squaring
* Uses Levenberg-Marquardt optimiser
    * Multi-grid matrix solver
* Matches GM with GM, WM with WM etc
* Diffeomorphic registration takes about 30 mins per image pair (121×145×121 images).



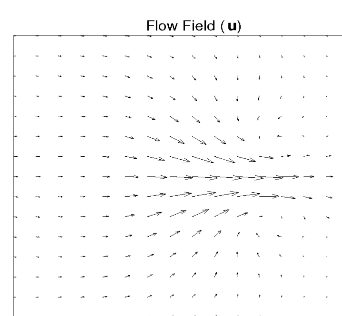
Grey matter template warped to individual

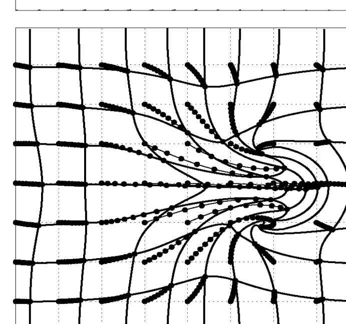
Individual scan

Dartel

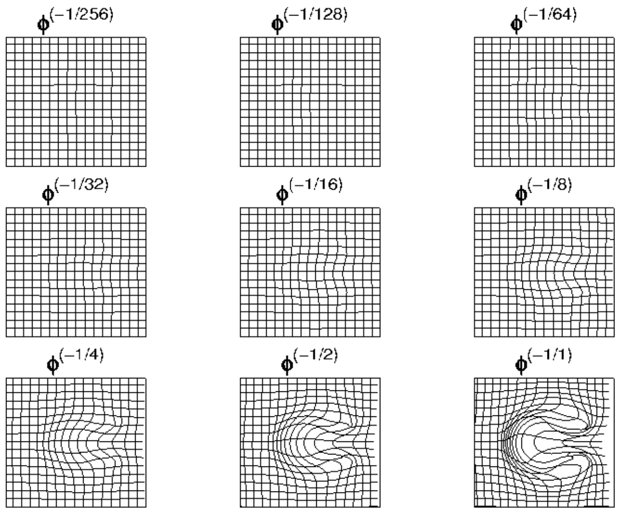
* Parameterising the deformation
* $\boldsymbol{\varphi}^{(0)}$ = Identity
* $\boldsymbol{\varphi}^{(1)} = \int_{t=0}^{1} \mathbf{v}(\boldsymbol{\varphi}^{(t)})dt$
* $\mathbf{v}$ is an estimated velocity field.

* Scaling and squaring is used to generate deformations.





Scaling and squaring example

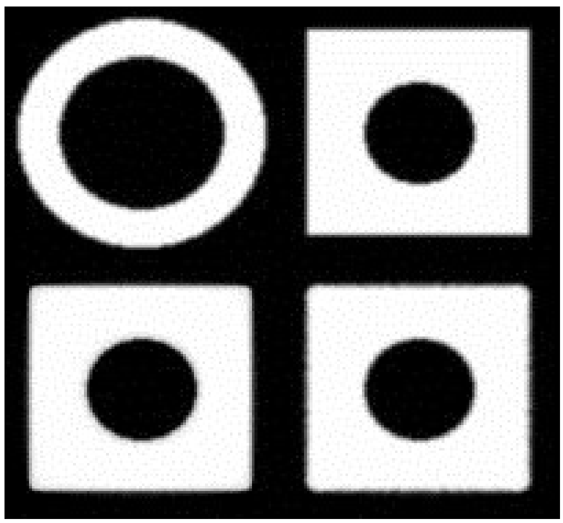


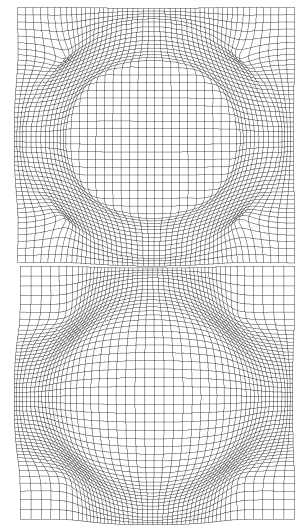
Registration objective function

* Simultaneously minimize the sum of:
  * **Matching Term**
    * Drives the alignment of the images.
    * Multinomial assumption
  * **Regularisation term**
    * A measure of deformation roughness
    * Keeps the warps spatially smooth.

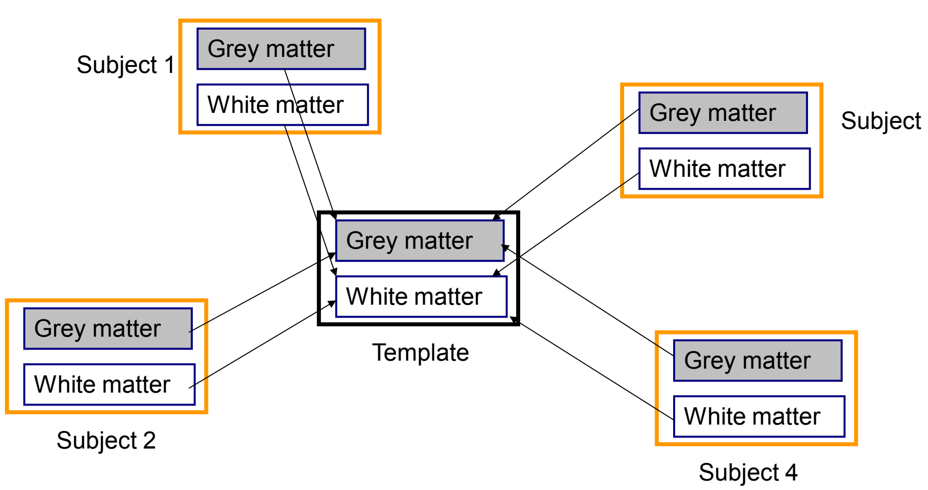
* A balance between the two terms.

Effect of different forms of regularisation





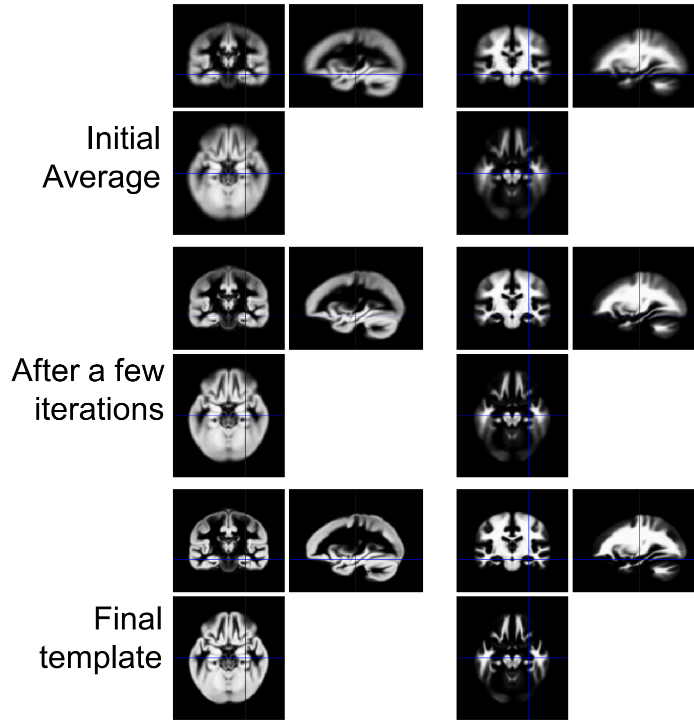
Simultaneous registration of GM to GM and WM to WM

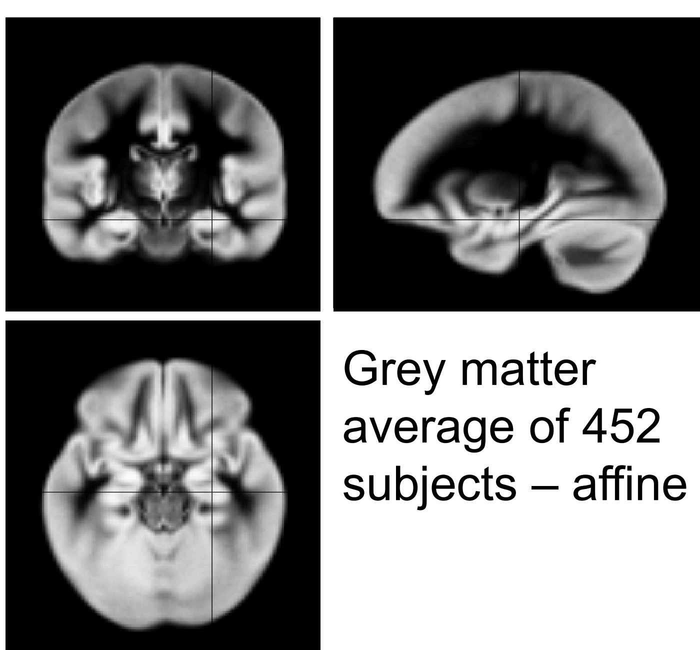


Template

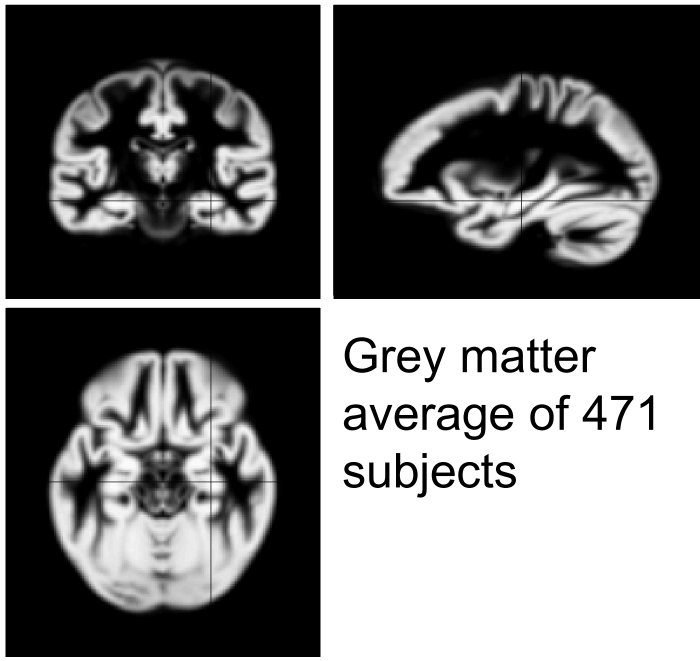
Iteratively generated from 471 subjects

Began with rigidly aligned tissue probability maps



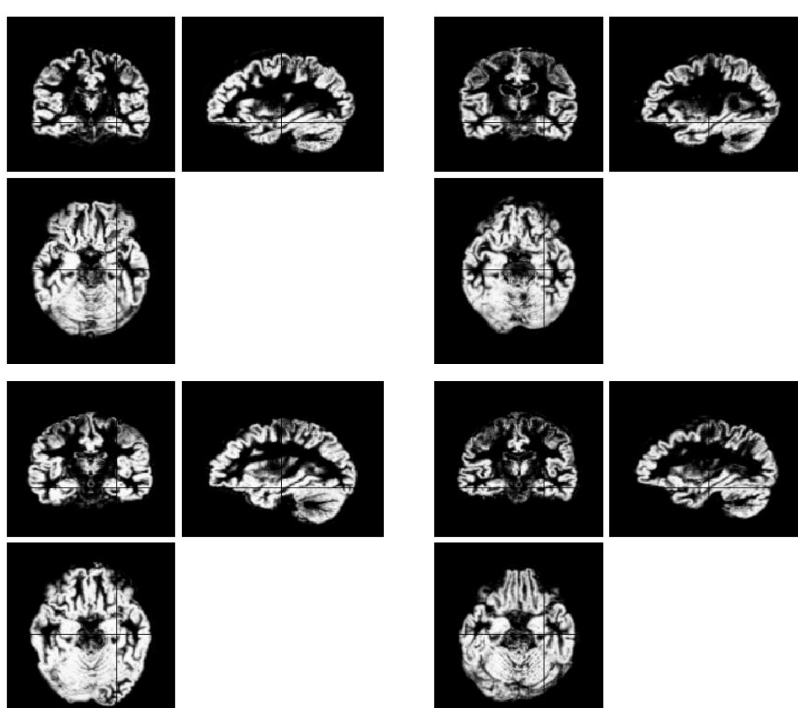


Grey matter average of 452 subjects – affine

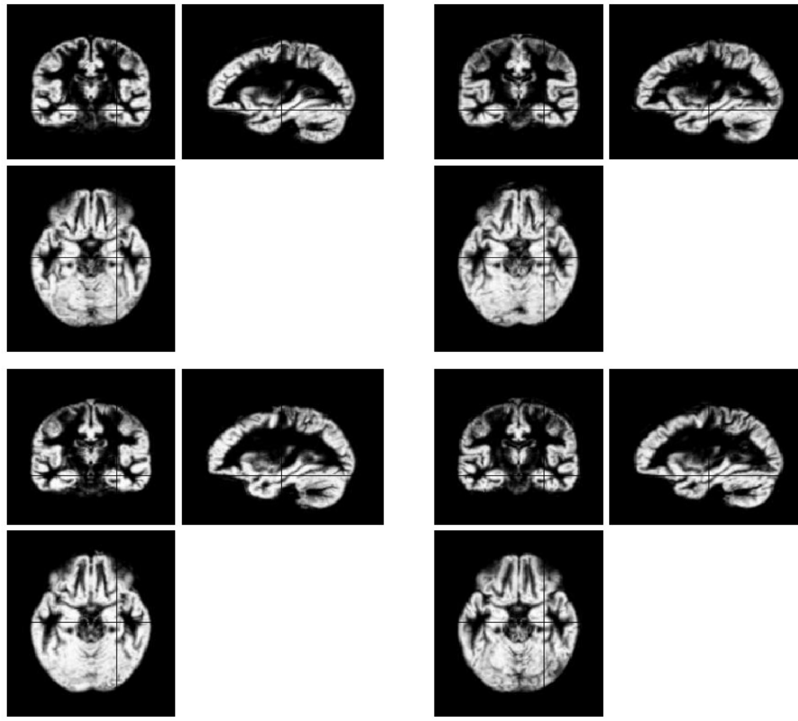


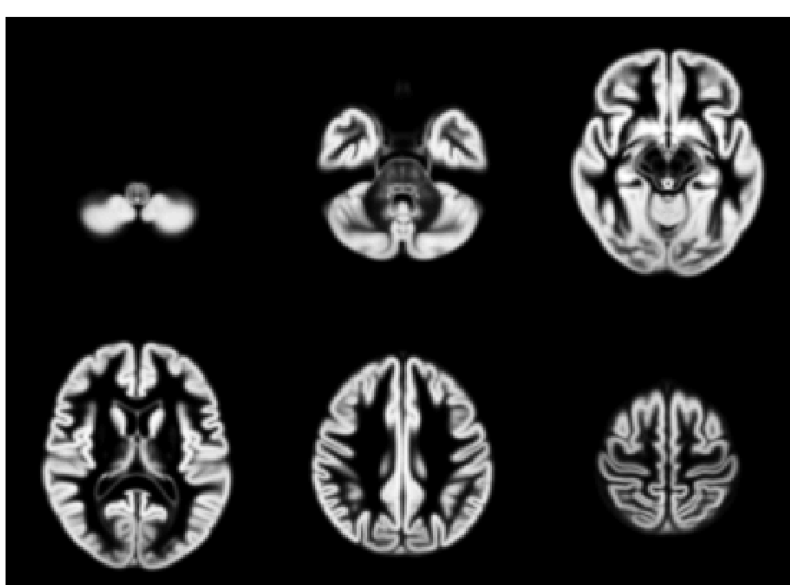
Grey matter average of 471 subjects

Initial GM images

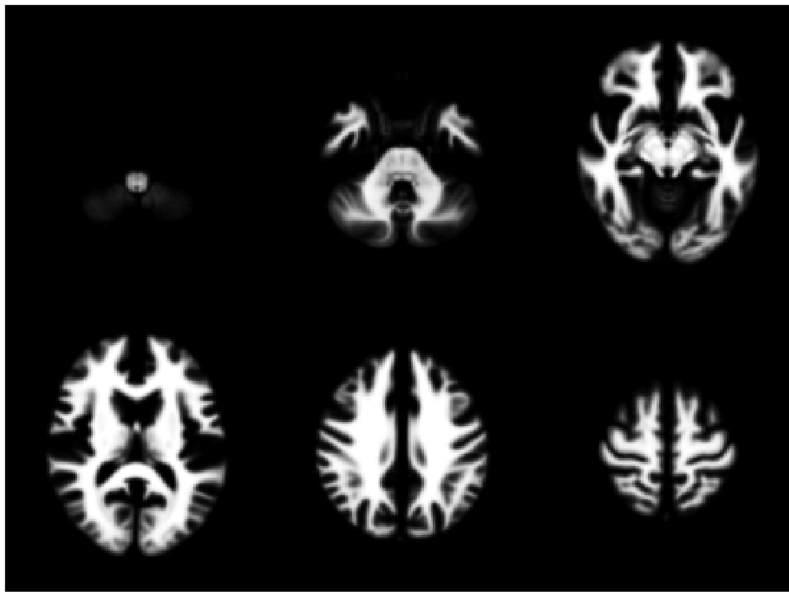


Aligned
GM images

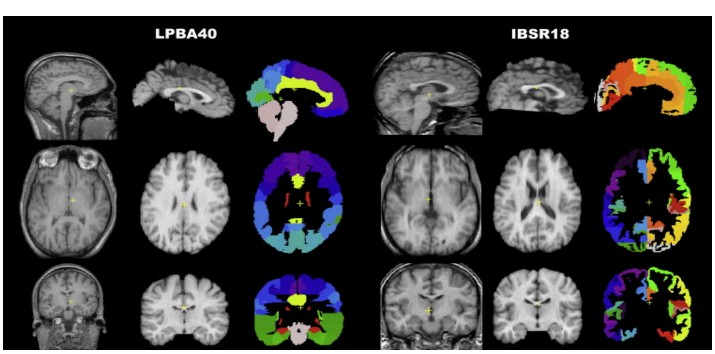




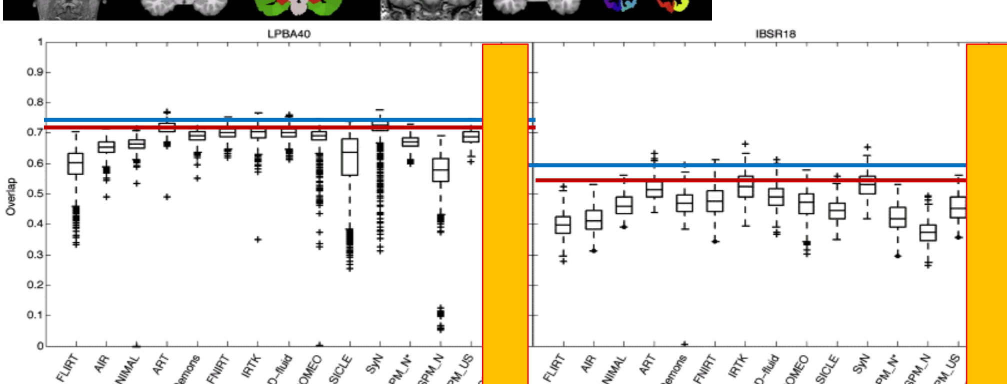
471 Subject Average



471 Subject Average



Evaluations of nonlinear registration algorithms

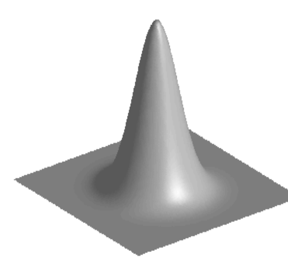


Contents

* Normalise/Segment
* Dartel

* **Smoothing**
  * **Compensating for inaccuracies in inter-subject alignment**

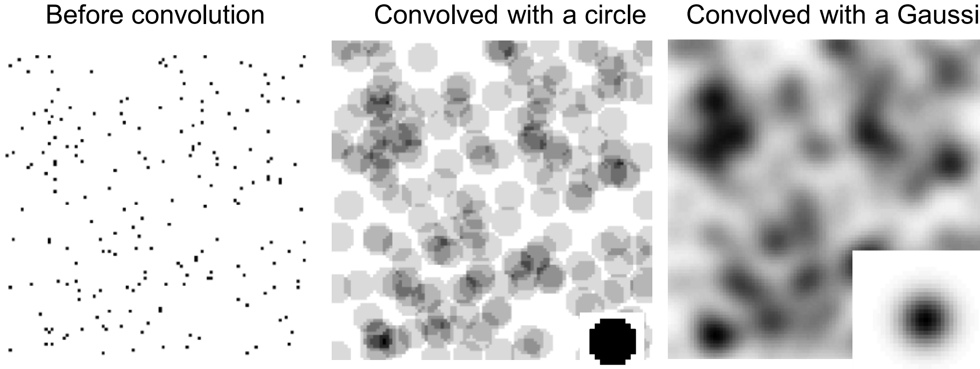
Smooth



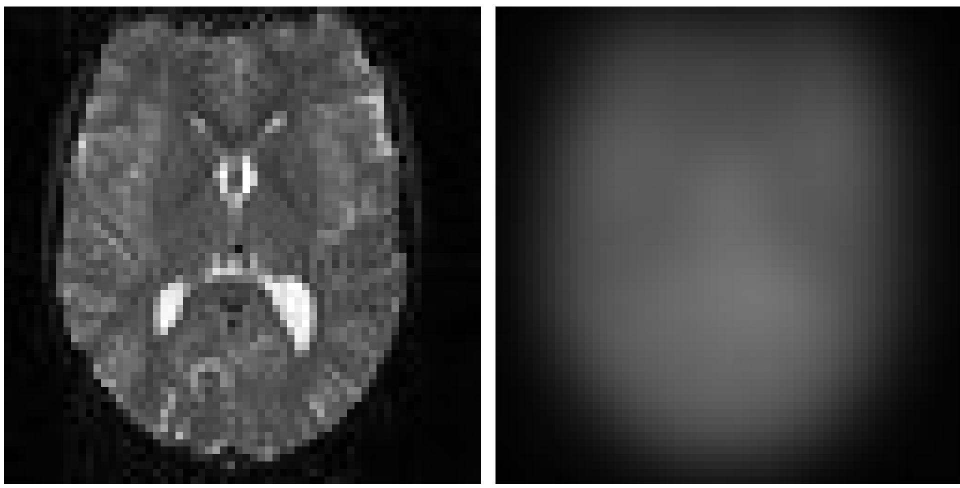
Blurring is done by convolution.

Each voxel after smoothing effectively becomes the result of applying a weighted region of interest (ROI).

Before convolution | Convolved with a circle | Convolved with a Gaussian



Smooth



References

* Ashburner & Friston. *Unified Segmentation*. NeuroImage 26:839-851 (2005).
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