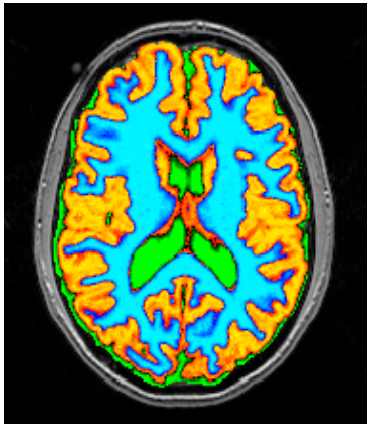
FAST

FMRIB's Automated Segmentation Tool

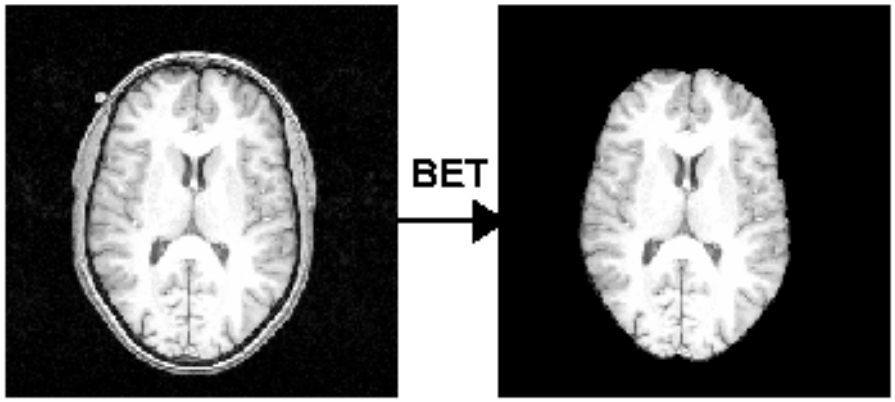
generic tissue-type segmentation and bias field correction

- Input: brain-extracted image(s)
- Segments into different tissue types
- At the same time, estimate bias field
- Robust to noise, because each voxel looks at neighbours



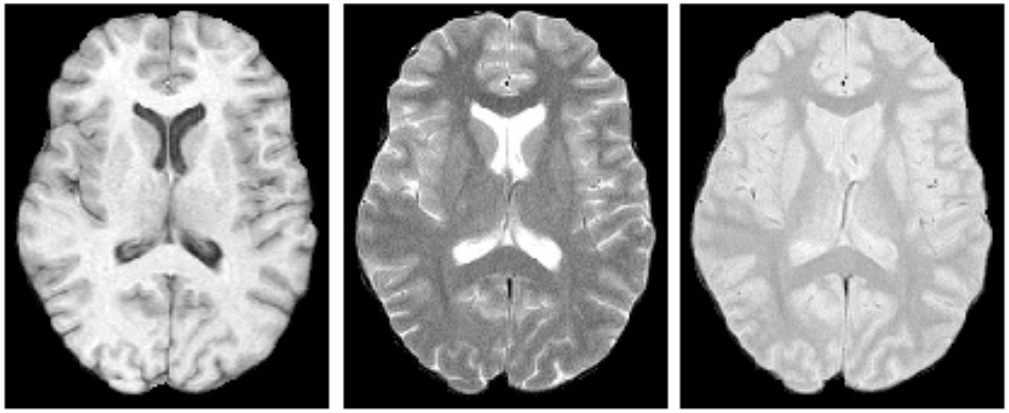
FAST: Input

- First use BET to remove non-brain
  All *volumetric* results are *highly sensitive* to errors here.
  For *bias-field correction alone* the errors do not matter that much



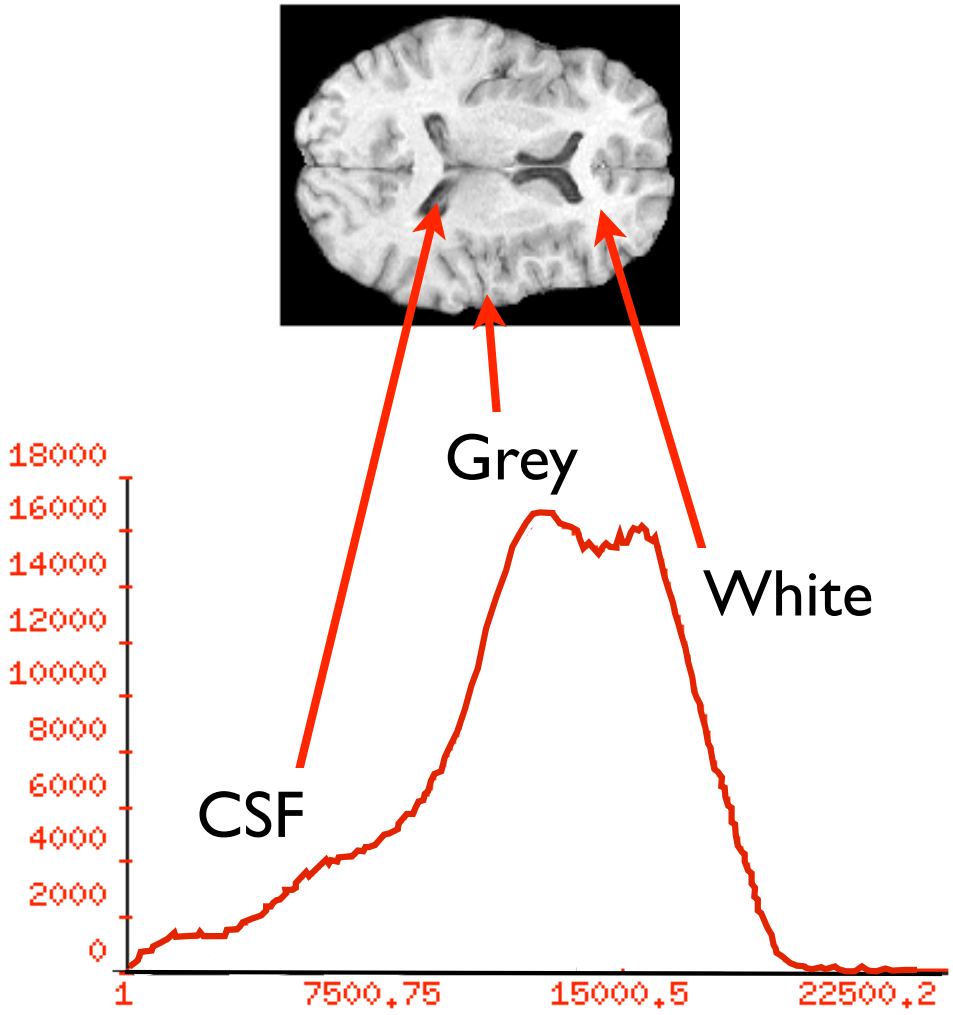
- Input is normally a single image (T1, T2, proton-density....)

- Or several inputs ("multichannel")
- For multi-channel, all must be pre-aligned (FLIRT)



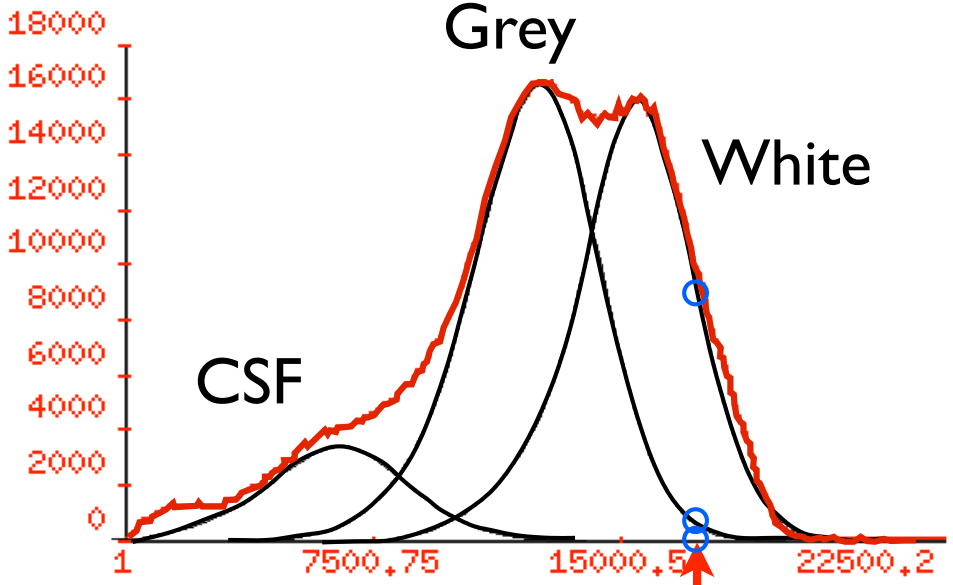
Intensity Model
tissue intensity distributions

- Histogram = voxel count vs. intensity
- Model = mixture of Gaussians
- If well separated, have clear peaks; then segmentation easy
- Overlap worsened by:
  - Bias field
  - Blurring
  - Low resolution
  - Head motion
  - Noise



Probability Model

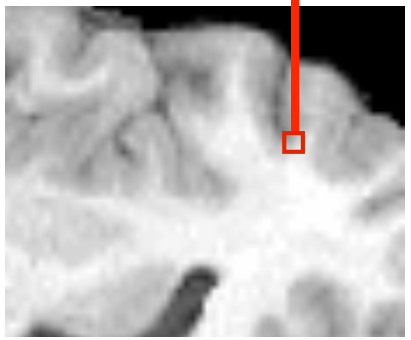
- Histogram = probability distribution function
- Model = mixture of Gaussians
- Probability determined for each tissue class



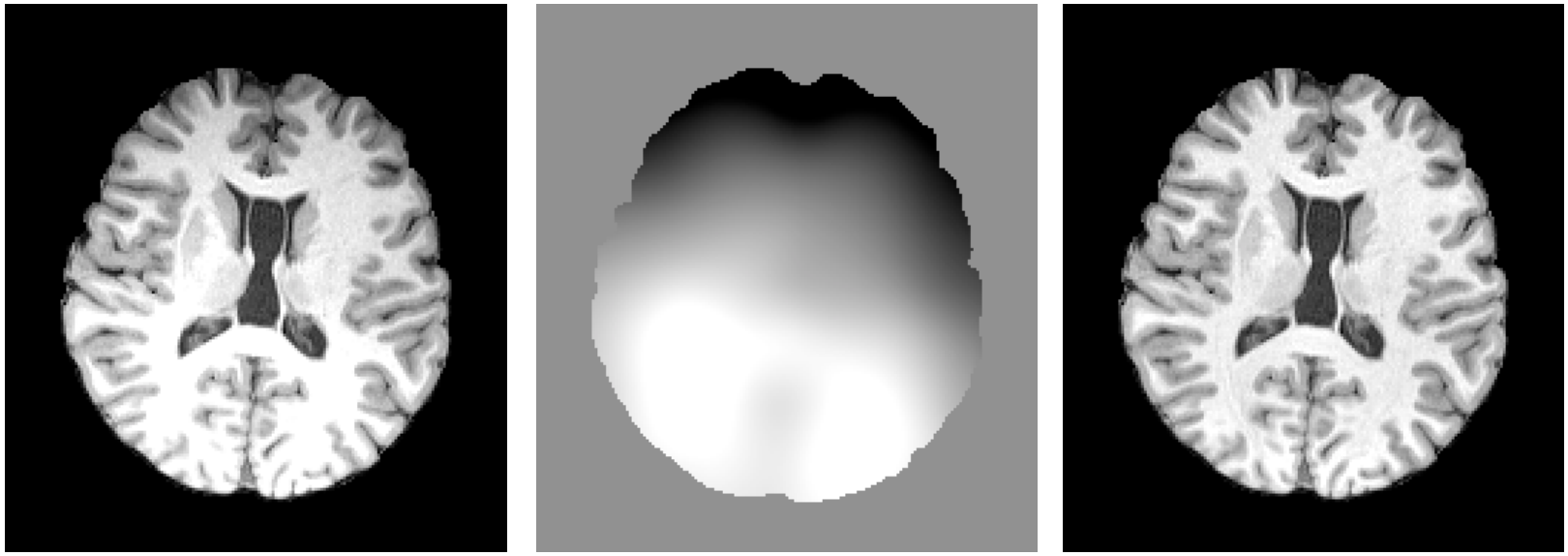
For example:
Voxel near WM/GM border

P(CSF) near zero
P(GM) low
P(WM) moderate

Intensity = 17203



Bias Field Correction

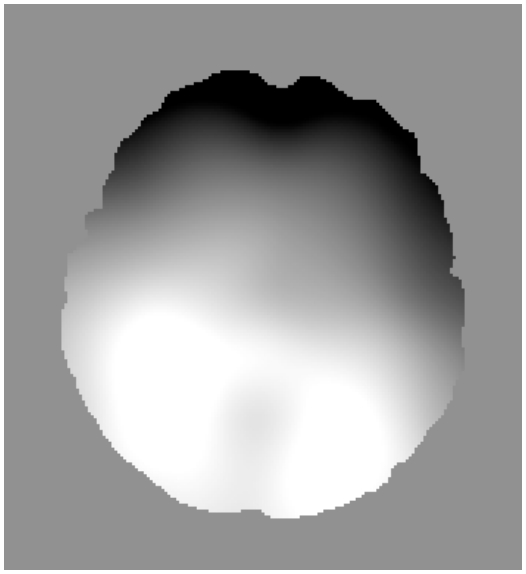


Original Bias Restored

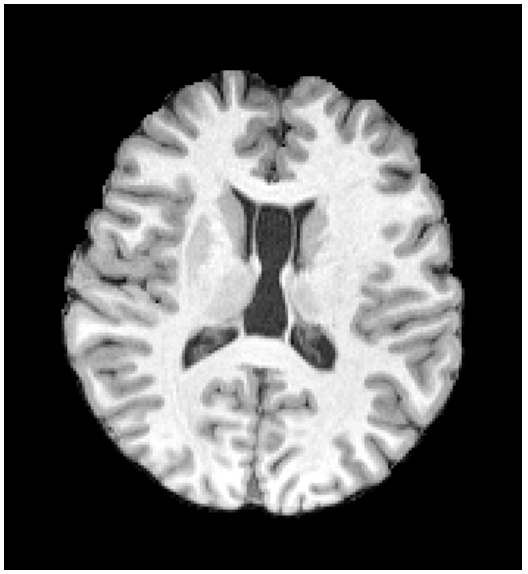
- MRI RF (radio-frequency field) inhomogeneity causes intensity variations across space
- Causes problems for segmentation
- Need to remove bias field before or during segmentation
- Becomes more common and problematic at high field

Bias Field Correction

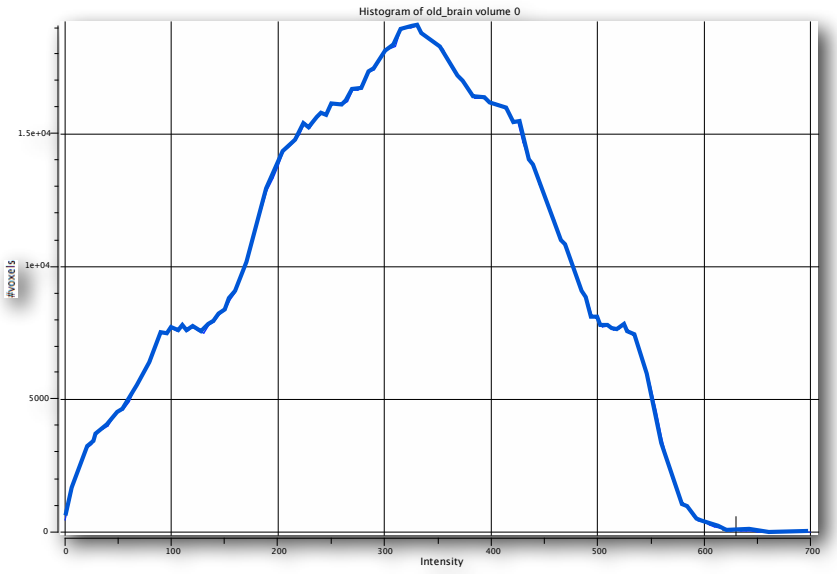
Original

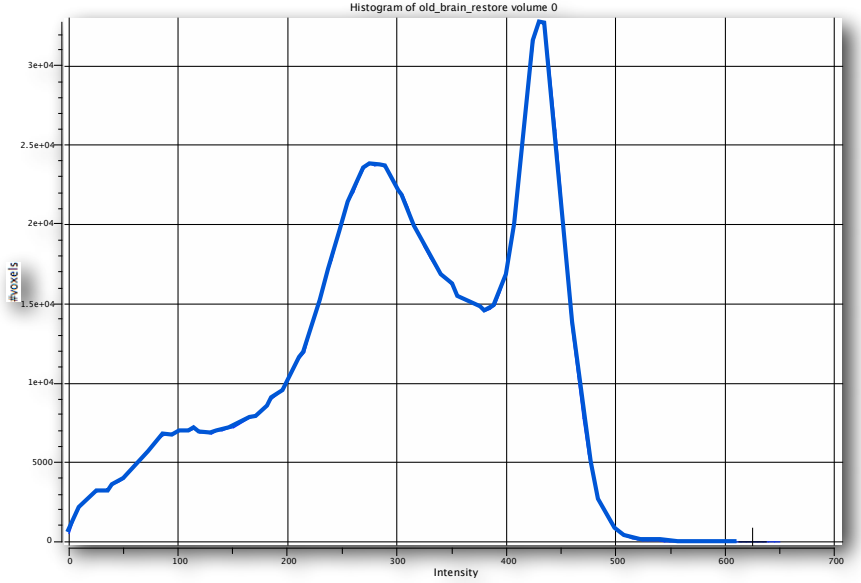


Bias



Restored

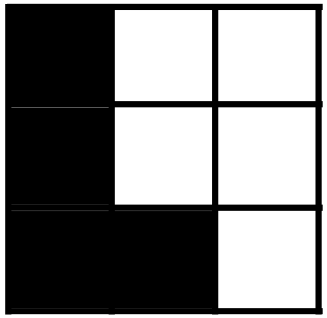




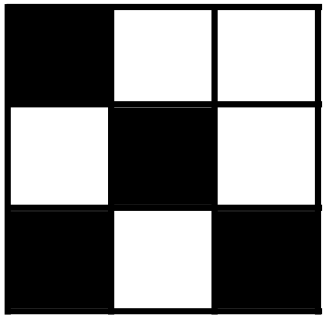
Histograms

Use Spatial Neighbourhood Information (MRF)

- Neighbourhood information: "if my neighbours are grey matter then I probably am too"
- Simple classifiers (like K-means) do not use spatial neighbourhood information
- More robust to noise
- Need the right balance between believing neighbours or intensity



Likely configuration
High probability



Unlikely configuration
Low probability

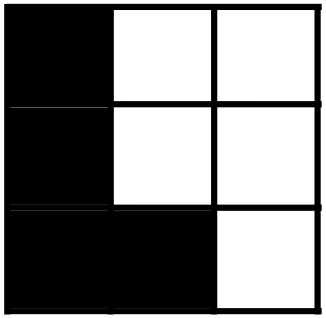
Use Spatial Neighbourhood Information (MRF)

Combine with probability based on Gaussian Mixture Model:

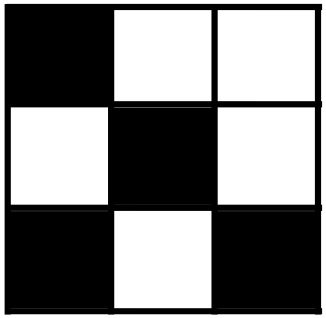
Final log probability =
log p(intensity) + β log p(MRF)

Final result depends on β value

This is user-adjustable



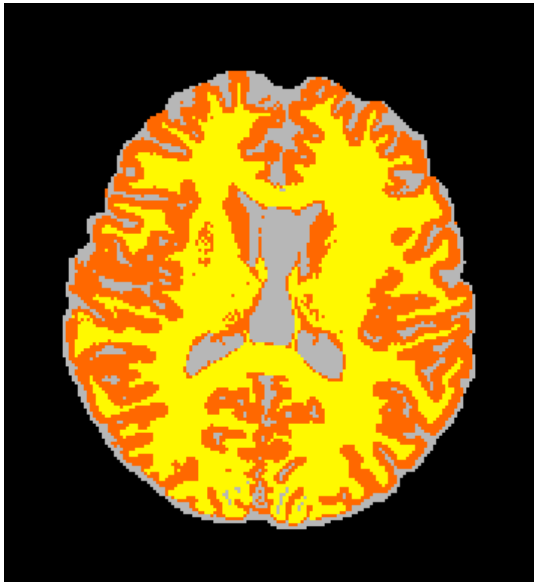
Likely configuration
High probability

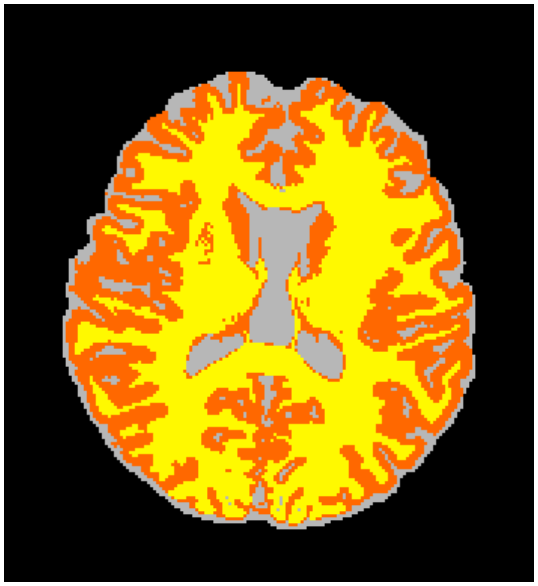


Unlikely configuration
Low probability

Effect of MRF Weighting

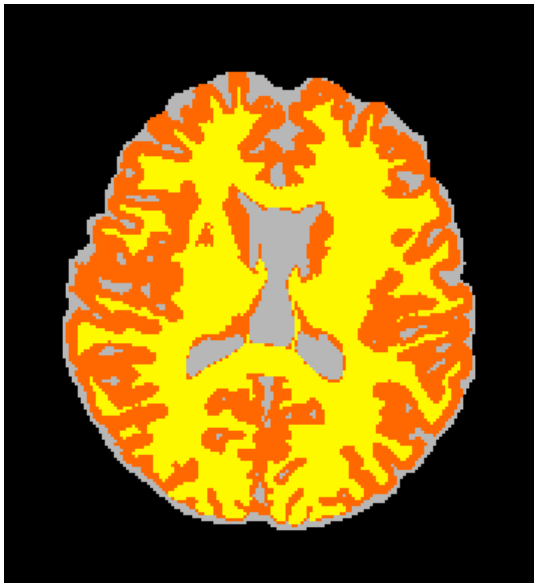
β=0





β=0.1

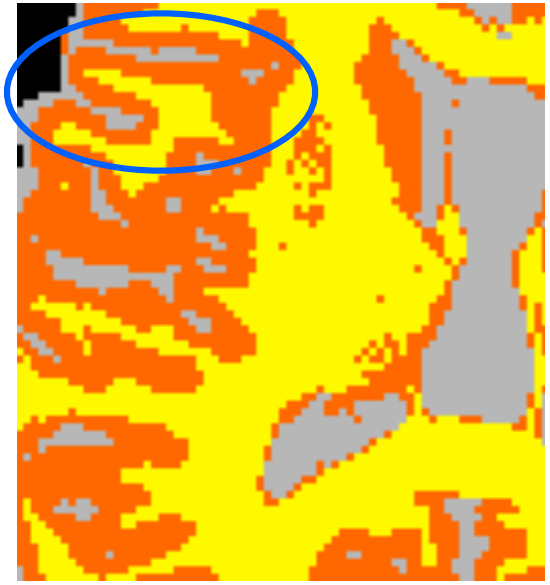
β=0.3

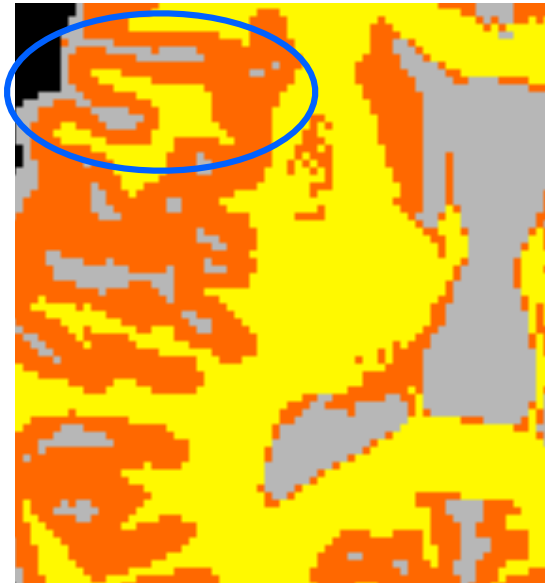


β=0.5

Effect of MRF Weighting

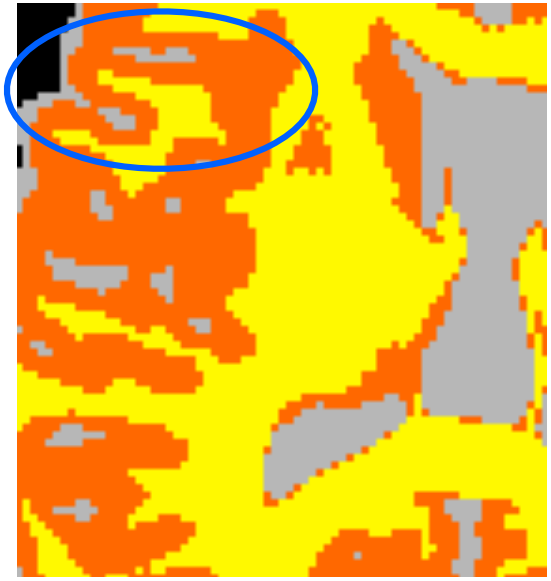
β=0

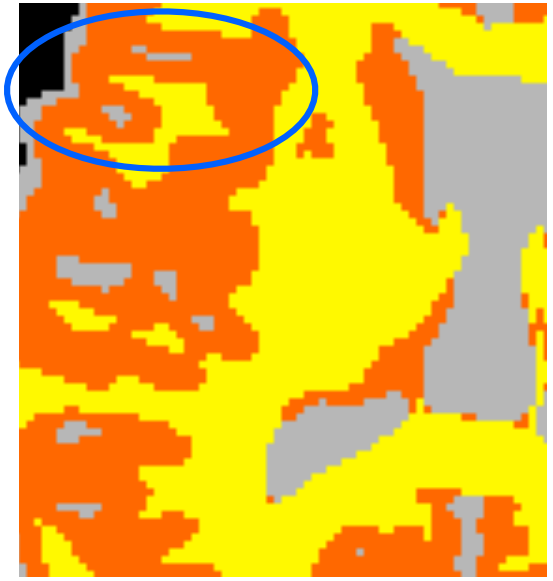




β=0.1

β=0.3



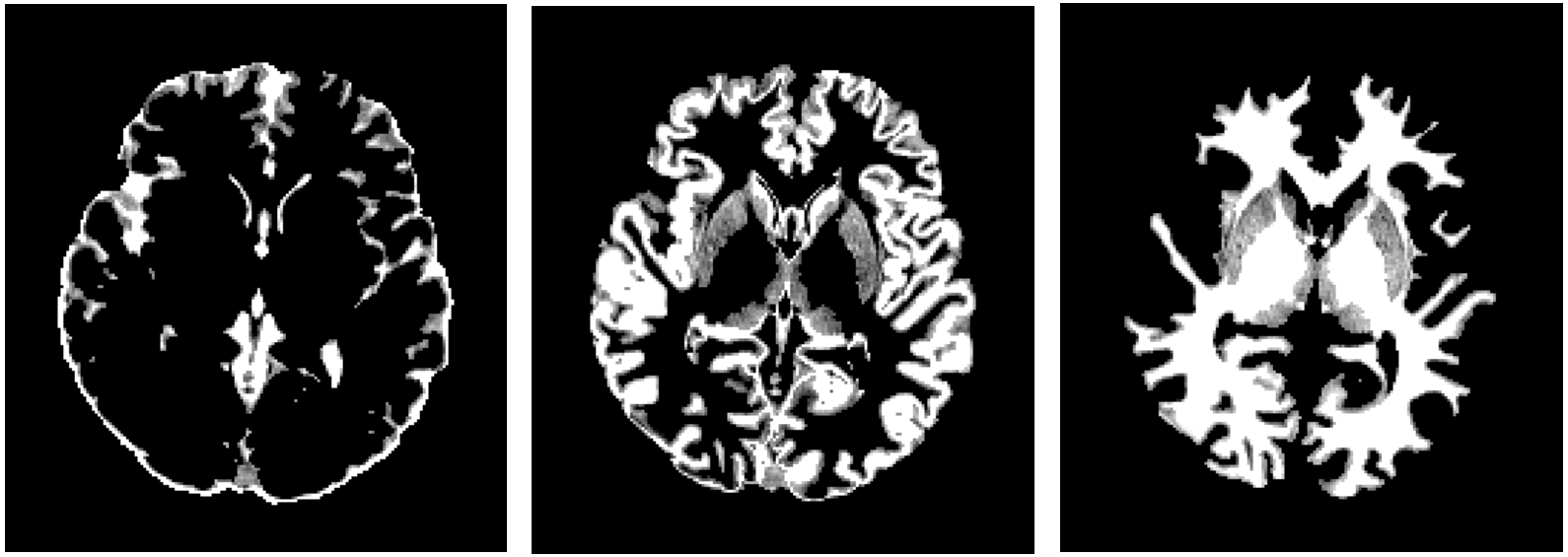


β=0.5

Partial Volume Modelling

- A better model is what fraction of each voxel is tissue X?
- "partial volume" = fraction of CSF, GM or WM

PVE
CSF, GM, WM



Image

"Hard"
Segmentation

PVE (GM)

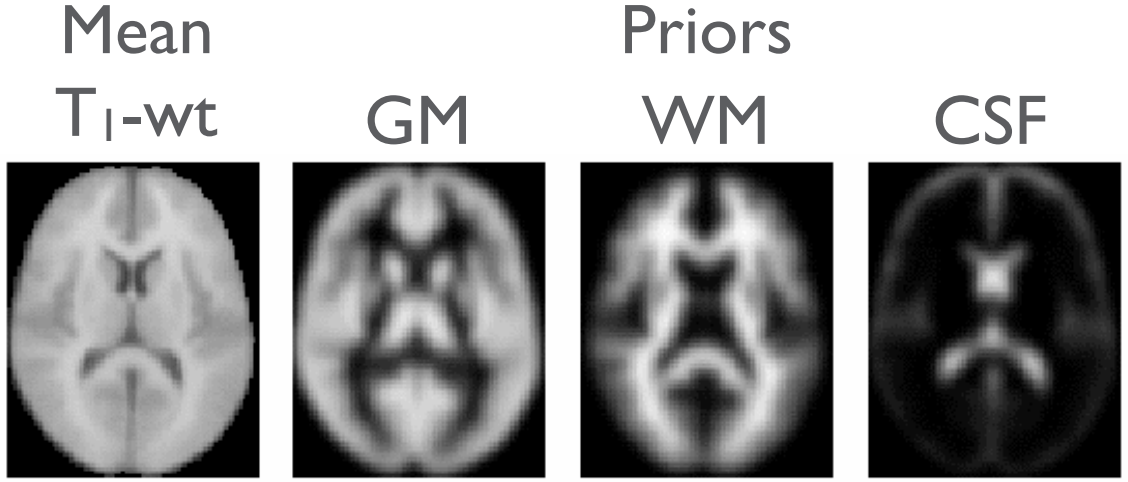
- This substantially improves accuracy of volume estimation

FAST - The Overview

- Initial (approximate) segmentation
  - Tree-K-means
- Iterate
  - Estimate bias field
  - Estimation segmentation; iterate
    - Update segmentation (intensity + MRF)
    - Update tissue class parameters (mean and standard deviation)
- Apply partial volume model
  - MRF on mixel-type (how many tissues)
  - PV Estimation

Optional Use of Priors (tissue probability maps)

- Segmentation priors = average of many subjects' segmentations
- Can use priors to weight segmentation, but can skew results (e.g. due to misalignment)
- FAST does not use priors by default
- If bias field is very bad, priors can be turned on to help initial segmentation (alternatively, do more iterations)
- Can also be turned on to feed into final segmentation (e.g. to aid segmentation of deep grey .... but see FIRST)



Other Options

FAST:

- **Bias field smoothing (-l)**
  - vary spatial smoothing of the bias field
- **MRF beta (-H)**
  - vary spatial smoothness of the segmentation
- **Iterations (-I)**
  - vary number of main loop iterations

fsl_anat:

- This is a new, alternative tool that performs brain extraction and bias field correction (along with other things) in a different way and so is worth trying out too

FAST

FMRIB's Automated Segmentation Tool

Summary

- Typically use a single T1-weighted image
- Multichannel is an option
- Segments into three main tissue-types:
  - Grey Matter, White Matter and CSF
- Models and corrects for bias field
  - Can be used just for bias field correction
- Combines intensity and neighbourhood information
- Partial Volumes Estimates (PVE) are most useful and more accurate for volume calculations
- Can use priors, but can cause bias, so not the default
- Have several adjustable parameters to optimise output