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

\[ P(\text{CSF}) \text{ near zero} \]
\[ P(\text{GM}) \text{ low} \]
\[ P(\text{WM}) \text{ moderate} \]

Intensity = 17203
Bias Field Correction

• 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

Histogram of old_brain volume 0

Histogram of old_brain_restore volume 0
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:

$$\text{Final log probability} = \log p(\text{intensity}) + \beta \log p(\text{MRF})$$

Final result depends on $\beta$ value

This is user-adjustable

Likely configuration
High probability

Unlikely configuration
Low probability
Effect of MRF Weighting

\[ \beta = 0 \]

\[ \beta = 0.1 \]

\[ \beta = 0.3 \]

\[ \beta = 0.5 \]
Effect of MRF Weighting

$\beta=0$

$\beta=0.1$

$\beta=0.3$

$\beta=0.5$
Partial Volume Modelling

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

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
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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