FIRST

FMRIB’s Integrated Registration & Segmentation Tool

Segmentation of subcortical brain structures
Sub-Cortical Structure Models

Incorporate prior anatomical information via explicit shape models

Have 15 different sub-cortical structures (left/right separately)
Training Data

- Manual segmentations courtesy of David Kennedy, Center for Morphometric Analysis (CMA), Boston
- 336 complete data sets
- \( T_1 \)-weighted images only
- Age range 4 to 87
  - Adults: Ages 18 to 87, Normal, schizophrenia, AD
  - Children: Ages 4 to 18, Normal, ADHD, BP, prenatal cocaine exposure, schizophrenia.
Model Training: Alignment to MNI152 space

- All CMA data affine-registered to MNI152 space
  - 1mm resolution, using FLIRT

- 2-stage process:
  - Whole head 12 DOF affine
  - 12 DOF affine with MNI-space sub-cortical mask
Deformable Models

- Model: 3D mesh
- Use anatomical info on shape & intensity (from training)
- Deformation: iterative displacement of vertices
- Maintain point (vertex) correspondence across subjects
The Model: Shape

• Model average shape (from vertex locations)

• Also model/learn likely variations about this mean
  - modes of variation of the population; c.f. PCA
  - also call eigenvectors

• Average shape and the modes of variation serve as prior information (known before seeing the new image that is to be segmented)
  - formally it uses a Bayesian formulation
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\[
X = \mu_X + UDBx
\]

- mean
- Eigenvectors (modes)
- Singular values
- Shape parameters
The Model: Intensity

- Intensity is then sampled along the **surface normal** and stored.

- Learn average shape/intensity and “modes of variation” about both.

- Aside: the intensities are re-scaled to a common range and the mode of the intensities in the structure is subtracted.

Intensity

![Diagram showing intensity sampling along a surface normal with modes of variation indicated.]
Boundary Correction

- FIRST models all structures by meshes
- Converting from meshes to images gives two types of voxels:
  - boundary voxels
  - interior voxels
- Boundary correction is necessary to decide whether the boundary voxels should belong to the structure or not
- Default correction uses FAST classification method and is run automatically (uncorrected image is also saved)
  - ensures that neighbouring structures do not overlap

[Diagram showing boundary and interior voxels]
Vertex Analysis

- Use a univariate test at each vertex to measure difference in location (e.g. between means of two groups of subjects)
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Consider each vertex in turn
Vertex Analysis

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Controls

Disease

Consider each vertex in turn

Do a test on distance of these vertices to average shape
Vertex Analysis

• Use a univariate test at each vertex to measure difference in location (e.g. between means of two groups of subjects) using distance along surface normals

• Results are now given as images and statistics done with randomise

• Can do analysis in MNI space or native structural space

• MNI space analysis normalises for brain size
Running FIRST

• Inputs:
  - $T_1$-weighted image
  - Model (built from training data) - provided with FSL

• Applying FIRST
  - A single command: `run_first_all`
    1. registers image to MNI152 1mm template
    2. fits structure models (meshes) to the image
    3. applies boundary correction (for volumetric output)

• Analysis:
  - Use command: `first_utils`
    • volumetric analysis (summary over whole structure)
    • vertex analysis (localised change in shape and/or size)
    • randomise (with multiple comparison correction)
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Summary

• Specific to certain deep grey structures
• Uses broad training set - very general demographics
• Can only work with T1-weighted images
• Models average and variations of shape and intensity
• Represents the boundary as a set of points
• Separate boundary correction step to get voxel labels

• Can perform vertex analysis to look at changes in shape and size