

MRI Image Analysis Guide for Outcome Brain Markers in Parkinson's Disease

This repository provides an overview of basic MRI image analysis tools for evaluating brain markers relevant to Parkinson's disease, including:

- Total Brain Volume
- Atrophy Rates
- Deep Grey Matter Volumes
- Cortical Thickness Measures

The tools described here are widely used and well-established in the majority of neuroimaging studies, both in healthy and neurological populations, including Parkinson's disease research. They are recognized for their reliability, accuracy, and extensive validation in scientific literature.

There is no single “best” tool for these analyses; the choice largely depends on user preference and familiarity. For example, FSL is known for its ease of use and integration with other neuroimaging tools, while SPM with CAT12 provides advanced surface-based analyses and seamless integration with MATLAB. Similarly, FreeSurfer is widely recognized for its robust cortical thickness measures. Users are encouraged to choose the tools that best fit their workflow and expertise.

Note:

There might be slight variance in results when using these different tools. This variability is related to several factors, including:

- Image Quality and Resolution
- Preprocessing Pipelines and Parameters
- Algorithmic Differences between Tools
- Software Version and Updates

For a detailed discussion on these variances and their implications in neuroimaging studies, refer to Droby et al., 2021 <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0254597>

Prerequisites

Ensure you have the following installed on your system:

- **SPM** (Statistical Parametric Mapping)– Installation Guide: <https://www.fil.ion.ucl.ac.uk/spm/software/spm12/>
- CAT12 (Computational Anatomy Toolbox) –Installation Guide: <http://www.neuro.uni-jena.de/cat/>
- FSL (FMRIB Software Library)– Installation Guide <https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FslInstallation>
- ANTs (Advanced Normalization Tools) – Installation Guide: <https://stnava.github.io/ANTs/>
- MATLAB– Required for running SPM and CAT12

1. Total Brain Volume

FSL - FAST

FAST (FMRIB's Automated Segmentation Tool) is used for tissue segmentation (gray matter, white matter, and CSF) to estimate total brain volume.

Example Command:

```
``bash
fast -t 1 -n 3 -H 0.1 -l 4 -l 20.0 -g -o output_prefix input_image.nii.gz
``

- `t 1`: Image type (1 = T1-weighted)
- `n 3`: Number of tissue types (CSF, GM, WM)
- `o`: Output prefix
```

Alternative: CAT12 in SPM

CAT12 provides an automated pipeline for tissue segmentation and volume estimation.

1. Launch SPM in MATLAB and select CAT12 -> Segmentation.
2. Load the T1-weighted image.
3. Run the pipeline to obtain gray matter, white matter, and CSF volumes, as well as total intracranial volume.

2. Atrophy Rates

FSL – SIENA(X)

SIENA (Structural Image Evaluation, using Normalization, of Atrophy) is used to measure brain volume changes (atrophy rates) between two time points.

Example Command:

```
```bash
siena baseline_image.nii.gz followup_image.nii.gz -o output_directory
```

- `baseline_image.nii.gz`: Baseline T1-weighted image
- `followup_image.nii.gz`: Follow-up T1-weighted image
- `-o`: Output directory for the results
```

Alternative: CAT12 Longitudinal Analysis

CAT12 supports longitudinal data analysis for estimating atrophy rates.

1. In SPM, go to **CAT12 -> Longitudinal Data Analysis**.
2. Load paired images for each subject.
3. The pipeline estimates individual atrophy rates and generates statistical outputs.

3. Deep Grey Matter Volumes

FSL - FIRST

FIRST (FMRIB's Integrated Registration and Segmentation Tool) is used for segmenting subcortical structures, including deep grey matter regions relevant in Parkinson's disease (e.g., putamen, caudate, thalamus).

Example Command:

```
``bash
run_first_all -i input_image.nii.gz -o output_prefix
``

- `-i`: Input T1-weighted image
- `-o`: Output prefix
```

Alternative: CAT12

CAT12 provides segmentation of subcortical structures using advanced surface-based methods.

1. In SPM, go to CAT12 -> ROI Analysis.
2. Select the regions of interest for deep grey matter structures.
3. The output includes volume estimates for each structure.

4. Cortical Thickness Measures

CAT12 in SPM

CAT12 provides robust cortical thickness estimation using surface-based methods, offering more accurate measurements compared to traditional voxel-based approaches.

1. Launch SPM and navigate to CAT12 -> Surface Estimation.
2. Load T1-weighted images.
3. The pipeline includes:
 - Cortical surface extraction
 - Smoothing and thickness estimation

- Statistical analysis and visualization options

Output:

- Cortical thickness maps
- Statistical comparison maps (e.g., group differences)

Alternative: FreeSurfer

FreeSurfer is another widely used tool for cortical thickness estimation.
<https://surfer.nmr.mgh.harvard.edu/fswiki/DownloadAndInstall>

Example Command:

```
```bash
recon-all -i input_image.nii.gz -s subject_id -all
```
```

- `-i`: Input T1-weighted image
- `-s`: Subject ID
- `-all`: Run the full pipeline including cortical thickness estimation

References

- FSL Documentation: <https://fsl.fmrib.ox.ac.uk/fsl/fslwiki>
- SPM Documentation: <https://www.fil.ion.ucl.ac.uk/spm/>
- CAT12 Documentation: <http://www.neuro.uni-jena.de/cat/>
- FreeSurfer Documentation: <https://surfer.nmr.mgh.harvard.edu/>

Contact

For questions, issues, or collaboration inquiries, please contact:

Amgad Droby

Email: amgadd@tlvmc.gov.il