Automating SPECT Reconstruction for Dementia Research Initiatives

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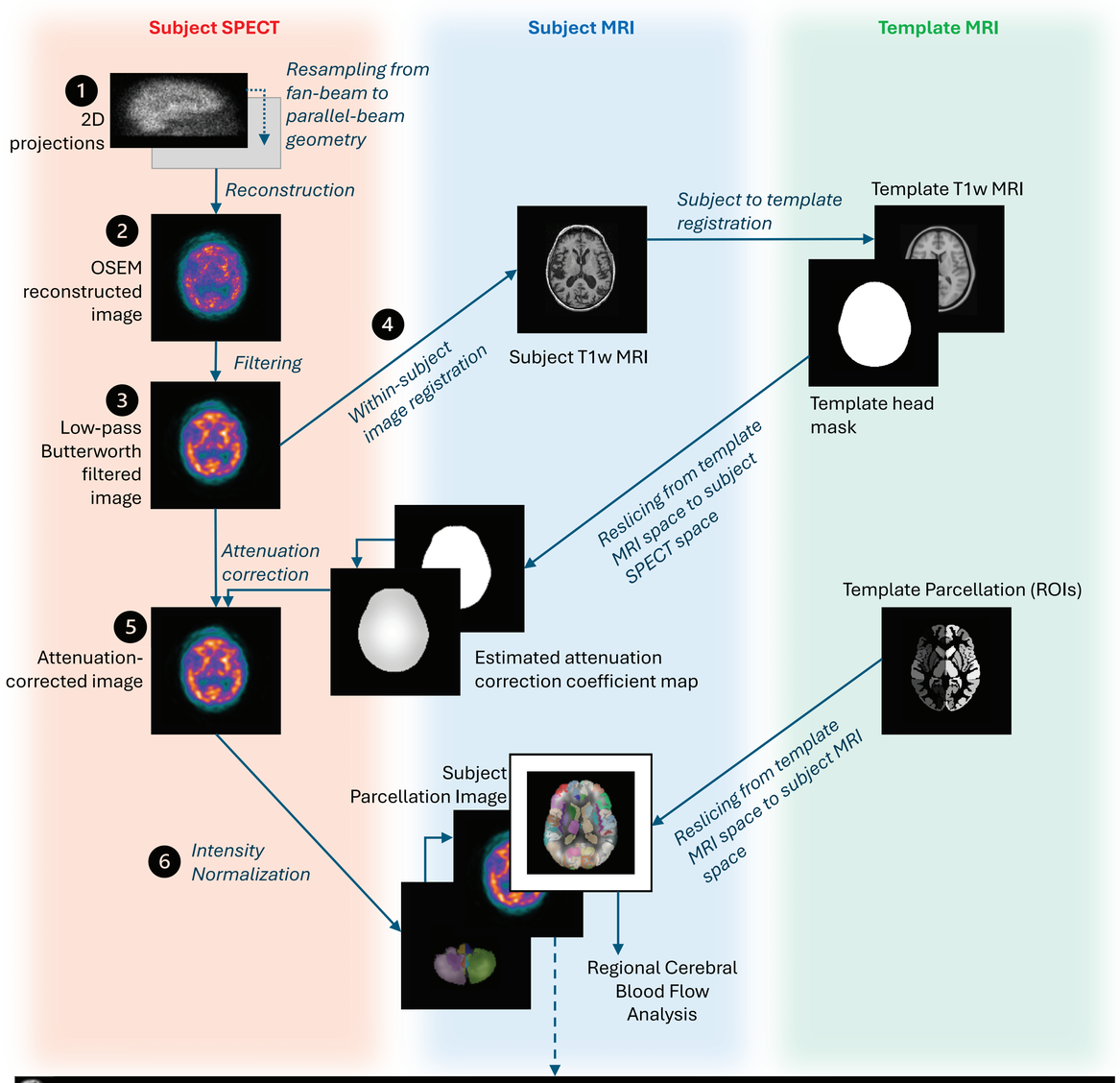
Introduction

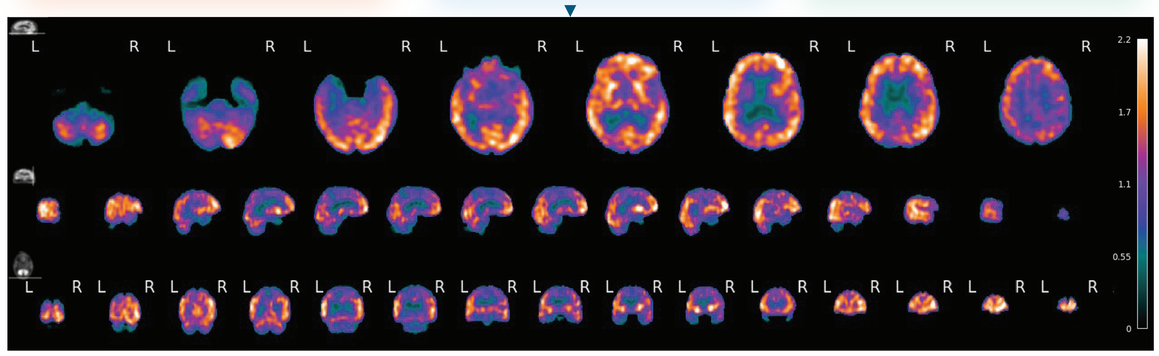
- Single Photon Emission Computed Tomography (SPECT) can show abnormalities in cerebral blood flow within key brain regions (e.g., basal ganglia & temporal lobes).
- Brain perfusion SPECT offers a potential biomarker for personalized therapeutic strategies.
- Dementia initiatives acquiring multiple SPECT scans in numerous participants greatly benefit from automated image processing pipelines.
- **Goal:** Develop an automated workflow for SPECT reconstruction, attenuation correction, and regional analysis.

Methods

1. Dataset: SPECT scans of 5 participants were used to develop an initial version of the pipeline. Fan-beam projections were resampled to parallel-beam geometry.
2. Reconstruction: SPECT data were iteratively reconstructed into 3D volumes using the Ordered Subset Expectation Maximization (OSEM)[1] algorithm.
3. Filtering: 3D low-pass Butterworth filter was applied to reduce image noise.
4. Image Registration: Within-subject inter-modal image registration, in conjunction with anatomical template registration, was used to obtain an approximate head mask as well as regions of interest (ROIs) in subject SPECT and subject MRI spaces.
5. Attenuation correction was applied using coefficients[2] estimated from the resliced head mask in subject SPECT space, as adapted from Lange et al. (2015)[3].
6. Intensity normalization: Intensity values within each SPECT reconstruction were normalized using the mean intensity value of the ROI corresponding to the more perfused cerebellar hemisphere[4].
7. Parameter Selection: Several image reconstructions corresponding to a range of parameter choices were assessed using pairwise Structural Similarity Index Measure (SSIM)[5] to determine the influence of specific combinations.

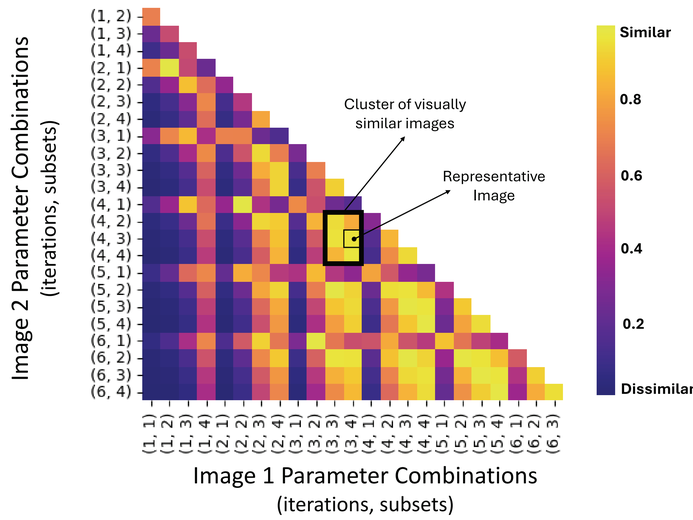
Results





To establish an automated workflow, an initial version of the pipeline was piloted using a dataset consisting of brain perfusion SPECT and structural MRI scans of 5 participants. Optimal reconstruction parameter values were selected from candidates identified using SSIM based on expert visual assessment of the corresponding images (as shown above with orthogonal views of an attenuation-corrected, intensity-normalized SPECT volume in subject MRI space).

- OSEM reconstruction with 4 iterations and 3 subsets, followed by 3D low-pass Butterworth filtering with a 0.6 cm^{-1} cutoff frequency and a filter order of 10, resulted in the preferred image quality with minimal noise and artifacts.
- This pilot development has shown promise in establishing the foundations of the scalability and robustness required for processing an additional ~2500 subject SPECT scans from the Sunnybrook Dementia Study.



- The heatmap of pairwise SSIM values revealed clusters of reconstruction parameters producing visually similar images.
- A representative image from each cluster was selected for further visual assessment.

Discussion

- The development of this pipeline focuses on the automation of processing brain perfusion SPECT data in patients with cognitive issues.
- The workflow supports large-scale, standardized analysis, enabling integration into personalized dementia therapy programs.
- The pipeline will be applied to dementia research initiatives including the existing dataset of the Sunnybrook Dementia study, such that comparison of clinical cognitive function with cerebral perfusion can be assessed.

References

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