Evaluating Template Generation Methods for Spatially Normalizing Down Syndrome Brain Magnetic Resonance Images

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Introduction

Magnetic resonance (MR) image registration and segmentation algorithms have a higher failure rate for Down syndrome (DS) populations due to anatomical and morphological differences.

Objective

To evaluate three template generation methods, DARTEL, SHOOT, and SyGN on:

- generating a DS cohort-specific template
- spatially matching DS MR images

Dataset

- 138 MR (T1) scans of DS subjects from the NiAD consortium obtained at different sites were employed.

Site	bn	f	uk	wi
Count	9	57	25	47

Methodology

- DARTEL and SHOOT MR templates:
  - Scan- specific grey matter (GM) and white matter (WM) tissue probability maps were generated using SPM12's Unified Segmentation method for DARTEL and SHOOT.
  - Implemented in the SPM12 (v7771) software package
  - Templates generated from tissue segmentation maps.
- SyGN MR template :
  - MR images were skull-stripped for SyGN.
  - Implemented in ANTs software
  - Template generated from MR images.
- All MR images were warped to each template space.
- Average MR images were generated specific to each template method.

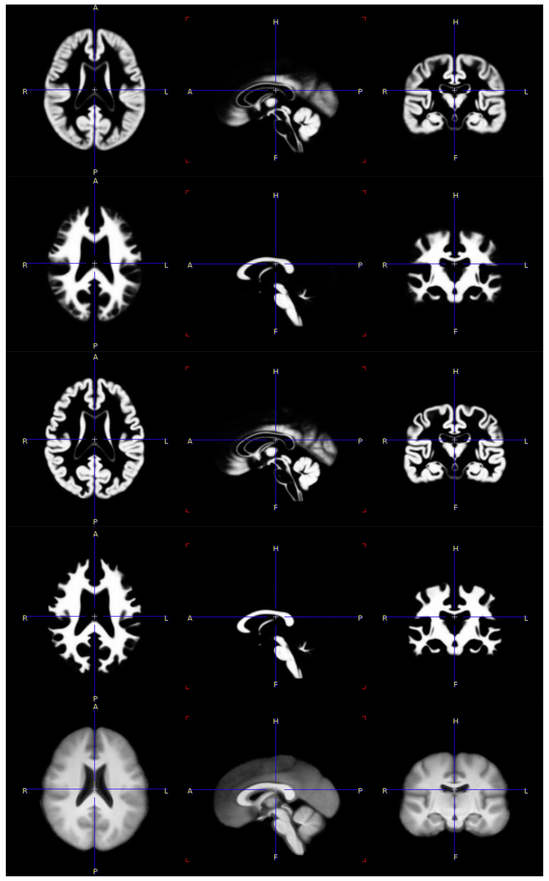

Figure 2: DARTEL template consists of a grey matter probability map (row 1) and white matter probability map (row 2); SHOOT template consists of a grey matter probability map (row 3) and white matter probability map (row 4); SyGN template is a brain MR image (row 5)

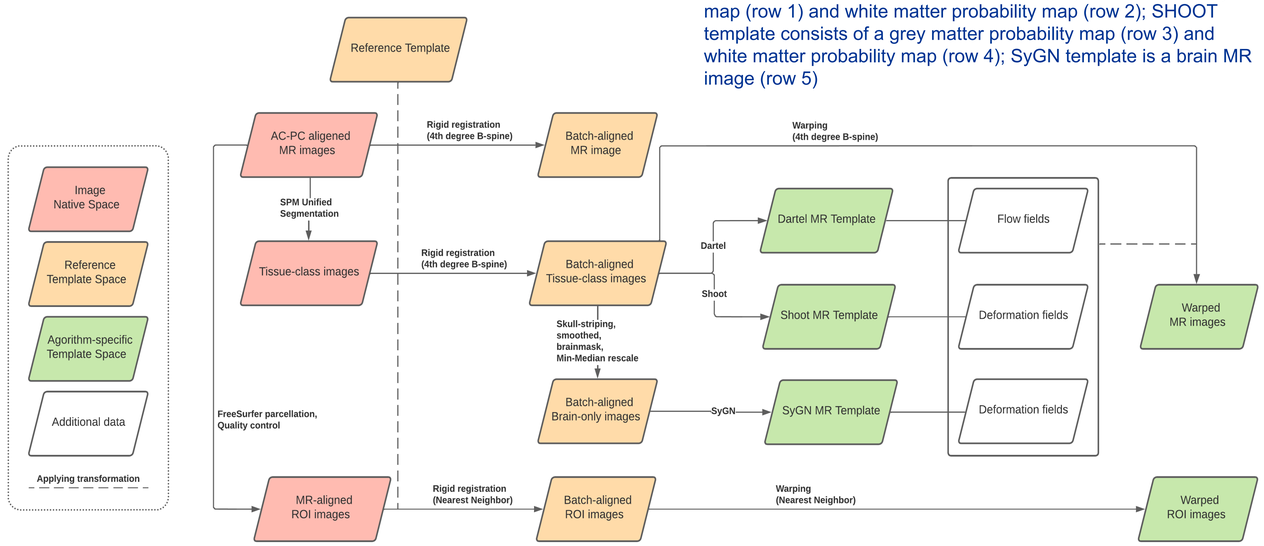

Figure 1: Data pipeline of image registration and template generation

Result

Compared to DARTEL and SHOOT spaces, the average warped MR in SyGN space has

- clearer background-GM boundary,
- lower contrast in GM-WM boundary, and
- less cortical sulci region.

Structural similarity index measure (SSIM) and Normalized Mutual Information (NMI) metrics were calculated between each warped scan and the average MR image for each template method.

- Congruous relationships were observed between SSIM or NMI and the 3 template generation methods.

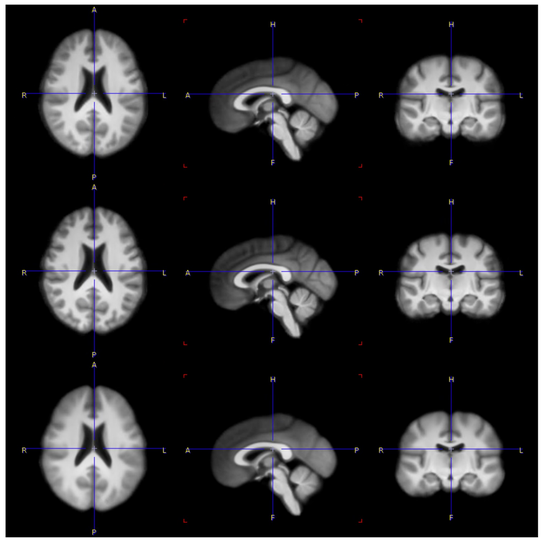

Figure 3: the average of warped MRs in DARTEL space (row 1), SHOOT space (row 2), SyGN space (row 3)

Table 1: Mean, standard deviation (SD), and coefficient of variation (CV) of SSIM and NMI by three methods.

Metric	Method	Mean	SD	CV
SSIM	DARTEL	0.891	0.032	0.036
	SHOOT	0.915	0.033	0.036
	SyGN	0.910	0.026	0.029
NMI	DARTEL	0.421	0.025	0.059
	SHOOT	0.447	0.032	0.072
	SyGN	0.439	0.021	0.048

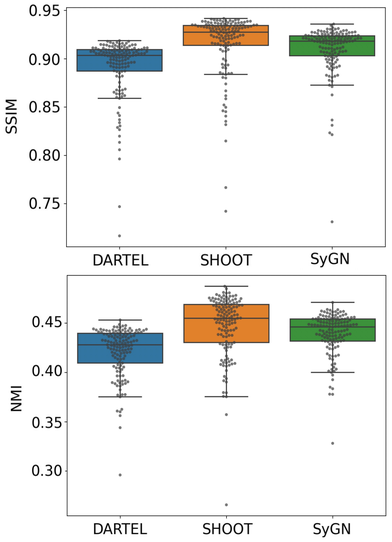

Figure 4: Structural similarity index (top) and Normalized mutual information (bottom) of warped brain MR and their average by three methods. Mean: SHOOT > SyGN > DARTEL. Standard deviation: SyGN < DARTEL < SHOOT.

Conclusion

As quantified by CV-values, SyGN produced robust spatial matching across Down syndrome MRI scans.

- The warped MRs have consistent and accurate background-GM boundary and WM-GM outline.
- Registration precision is improved by not overfitting local features,
- The accuracy of matching at finger-like region of GM-WM boundary is a trade-off.

Future Down syndrome MRI and PET image processing will make use of the SyGN template.

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