Skull-stripping Free Preprocessing Pipeline for Functional Magnetic Resonance Imaging

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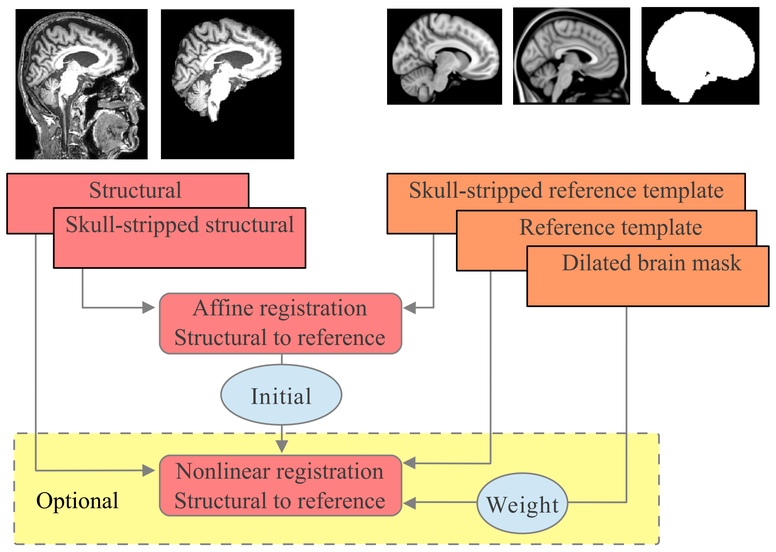
Introduction

Several preprocessing pipelines for functional magnetic resonance images are available in the literature: FSL [1] FEAT, the Neuro Bureau Athena pipeline [2], and others. Skull-stripping is used as a preprocessing step for important tasks like registration and segmentation. Commonly used skull-stripping approaches [3] include: hybrid stripping [4], FSL BET [5], and skull-stripping in AFNI [6]. Unfortunately, manual inspection and possibly parameter tuning are required in skull-stripping which hinders an automatic preprocessing of large databases.

Contribution

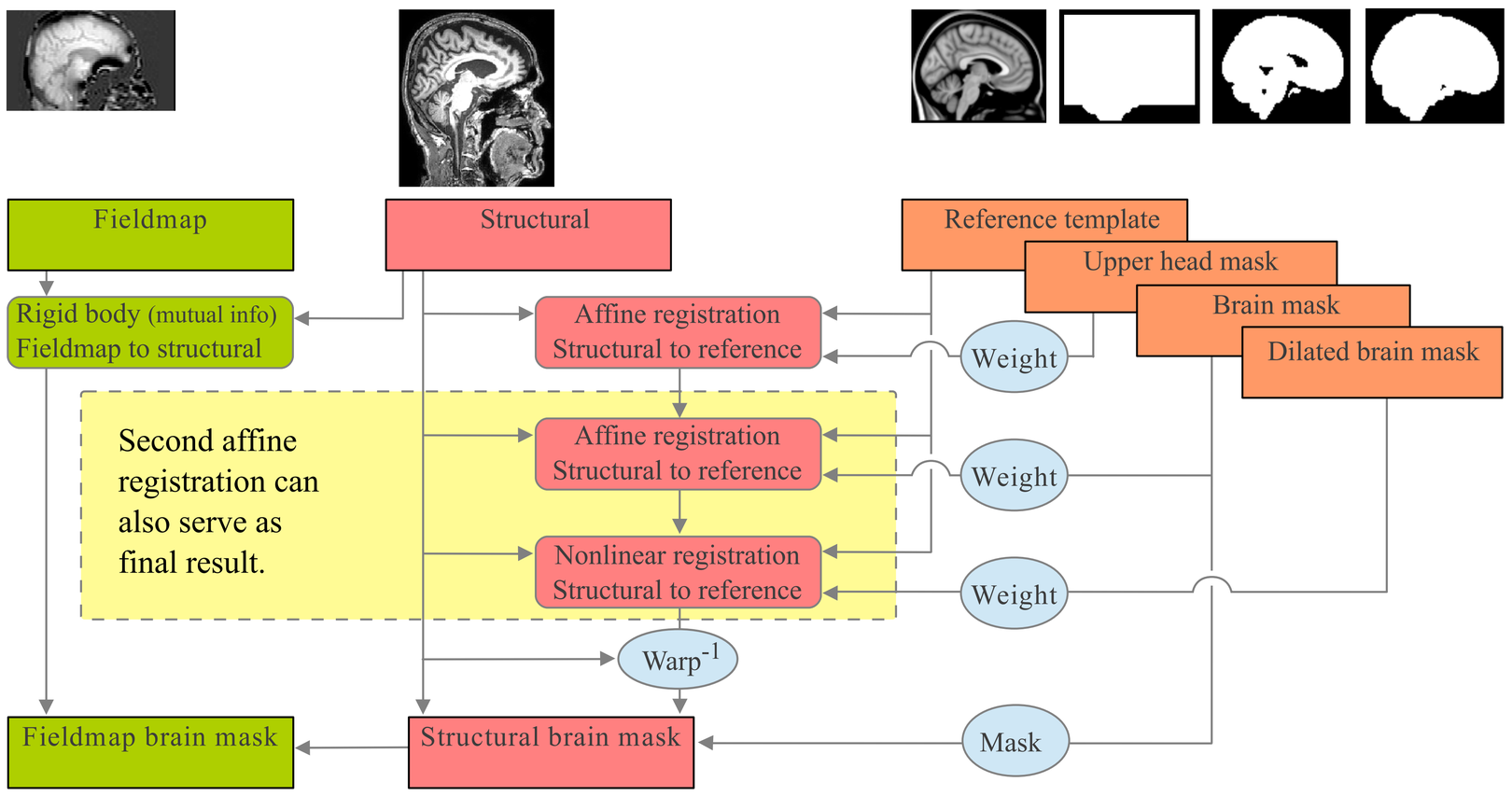
We propose a pipeline which drops skull-stripping. It was evaluated on three standard datasets containing together more than 880 subjects. The results show that our pipeline is a more robust alternative to the classical skull-stripping based pipeline.

Classical pipeline



Preprocessing pipeline as implemented in FSL [1] FEAT or the Neuro Bureau Athena pipeline [2].

Proposed pipeline



Registration
(1.) Affine registration of structural image to reference template, weighted by upper head mask. (2.) Result initializes second affine registration, weighted by brain mask. This result can initialize a nonlinear registration. The upper head mask allows for robustly registering datasets which have the face removed for anonymization.

Brain extraction
Apply inverse of affine registration or nonlinear registration to template brain mask.

Datasets / Robustness

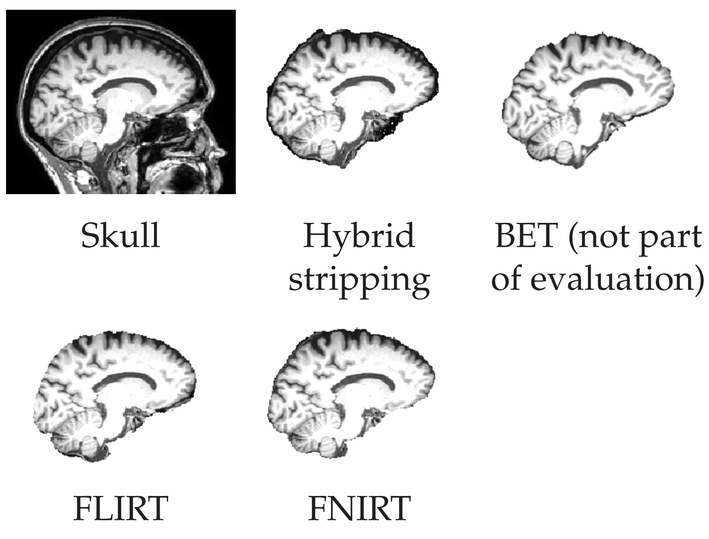
Affine registration tool: FSL FLIRT.
Nonlinear registration tool: FSL FNIRT.
Reference template: ICBM 152 [7].

	FCON (156)	ADHD (597)	ADNI (134)
FLIRT [1]	0	0	1
FNIRT [2]	0	0	1
Hybrid stripping	18 (12%)	112 (19%)	9 (7%)

Number of obvious failures.

[1] Proposed pipeline using only affine registrations.
[2] Proposed pipeline using also nonlinear registration.

Qualitative comparison

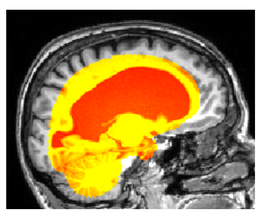


Skull | Hybrid stripping | BET (not part of evaluation)

FLIRT | FNIRT

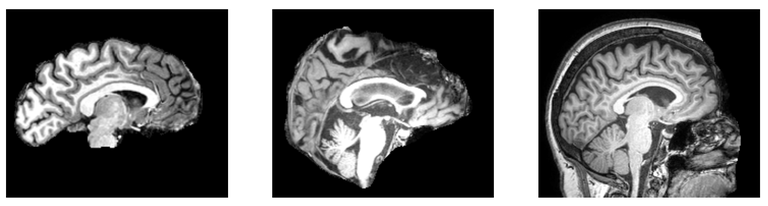
LONI image ID 234922

Failure of proposed pipeline



The figure shows the only subject for which the second, masked linear registration with FLIRT failed (due to strongly enlarged ventricles). The extracted brain mask is overlayed in yellow onto the dataset. FNIRT succeeded when the second linear registration was omitted.

Hybrid stripping failures



Baltimore sub19738 | LONI image ID 279186 | LONI image ID I243872

Some incorrect hybrid stripping results.

Registration

	FCON	ADHD	ADNI
Structural → ICBM 152, FLIRT	2.1	1.9	1.9
Functional → Structural, FLIRTed brain	0.23	0.46	0.42
Functional → Structural, FNIRTed brain	0.23	0.41	0.45

Mean value (in mm) of the maximum difference between the registration of the proposed pipeline and the classical pipeline. FSL FLIRT with boundary-based registration was used.

Segmentation

	FCON	ADHD	ADNI
FLIRT	0.12	0.1	0.16
FLIRT 2.5 mm	0.07	0.06	0.08
FLIRT 5 mm	0.06	0.08	0.09

	FCON	ADHD	ADNI
FNIRT	0.14	0.13	0.2
FNIRT 2.5 mm	0.07	0.07	0.11
FNIRT 5 mm	0.06	0.06	0.06

Square root of average squared differences in grey matter segmentation. The brain mask was dilated by 2.5 mm in the second row and by 5 mm in the third row of the table.

References

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