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].

<table>
<thead>
<tr>
<th></th>
<th>FCON (156)</th>
<th>ADHD (597)</th>
<th>ADNI (134)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLIRT ¹</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>FNIRT ²</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hybrid stripping</td>
<td>18 (12%)</td>
<td>112 (19%)</td>
<td>9 (7%)</td>
</tr>
</tbody>
</table>

Number of obvious failures.

¹ Proposed pipeline using only affine registrations.

² Proposed pipeline using also nonlinear registration.

FAILURE OF PROPOSED PIPELINE

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

REGISTRATION

Structural → ICBM 152, FLIRT
Functional → Structural,
FLIRTed brain
Functional → Structural,
FNIRTed brain

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.

<table>
<thead>
<tr>
<th></th>
<th>FCON</th>
<th>ADHD</th>
<th>ADNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLIRT</td>
<td>0.12</td>
<td>0.1</td>
<td>0.16</td>
</tr>
<tr>
<td>FLIRT 2.5 mm</td>
<td>0.07</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>FLIRT 5 mm</td>
<td>0.06</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>FNIRT</td>
<td>0.14</td>
<td>0.13</td>
<td>0.2</td>
</tr>
<tr>
<td>FNIRT 2.5 mm</td>
<td>0.07</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>FNIRT 5 mm</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
</table>

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.

SEGMENTATION

REFERENCES