

An open-source framework for multi-modal pulmonary image analysis

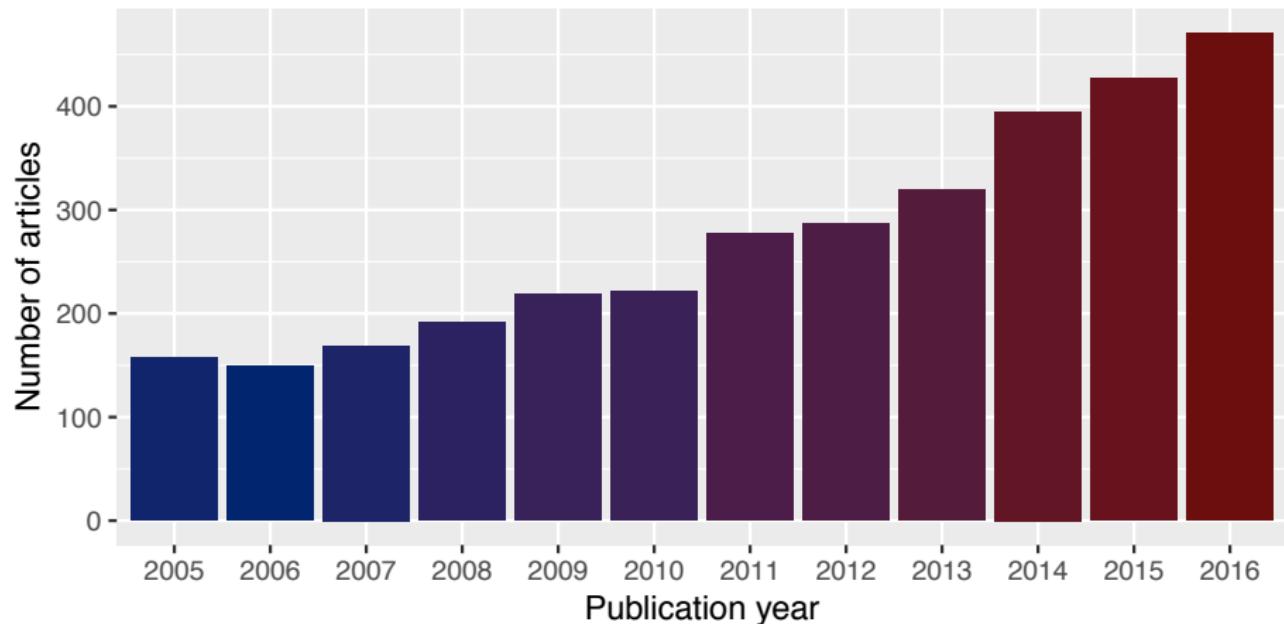
Nick Tustison

What does the neuroimaging community offer?

Great packages such as:

- AFNI
- FSL
- FreeSurfer
- SPM
- ANTs

Public & robust software → research output



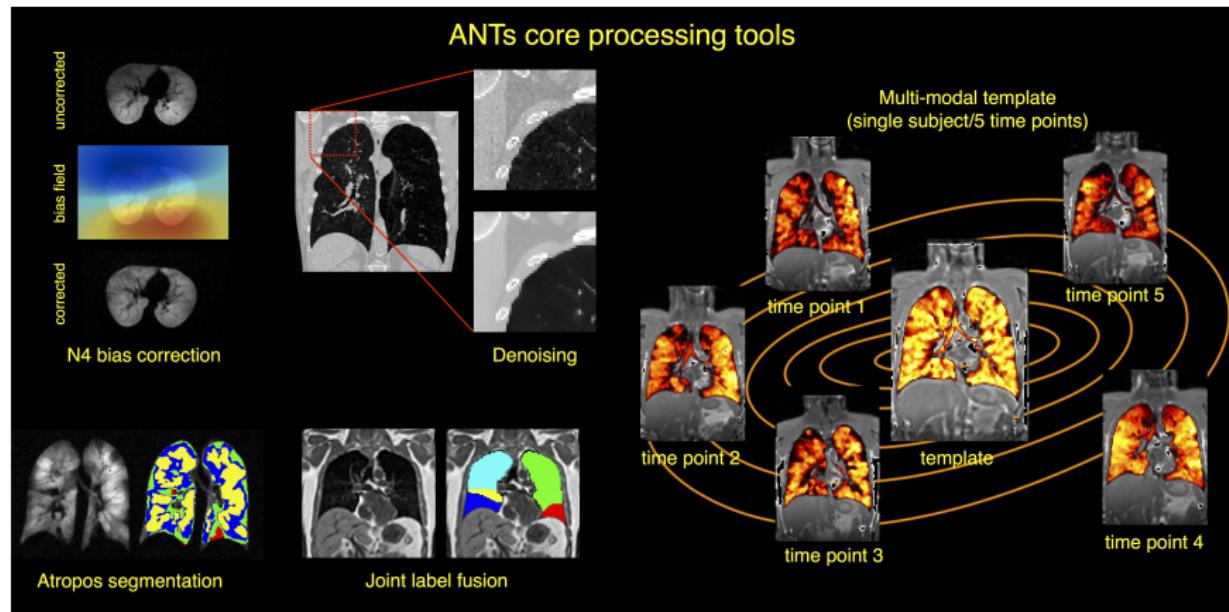
Benefits of open-source:

- Motivates community-based support:
 - bug fixes (*“Given enough eyeballs, all bugs are shallow.”*),
 - new features,
 - reproducibility verification, and
 - community tech support.
- Learn directly from journal manuscripts *and* implementations.
- Tremendous cost-savings.

E. A. Hoffman et al., JMRI 2015.

*“More widespread use of all [pulmonary] imaging biomarkers has been limited for a number of key reasons, including: 1) lack of support to harmonize image acquisition software; 2) **universally available image analysis software**; 3) regulatory boundaries for emerging approaches; and 4) historically weak links between respiratory and radiology clinical programs.”*

ANTs core tools for lung image analysis



Proposed core functionality

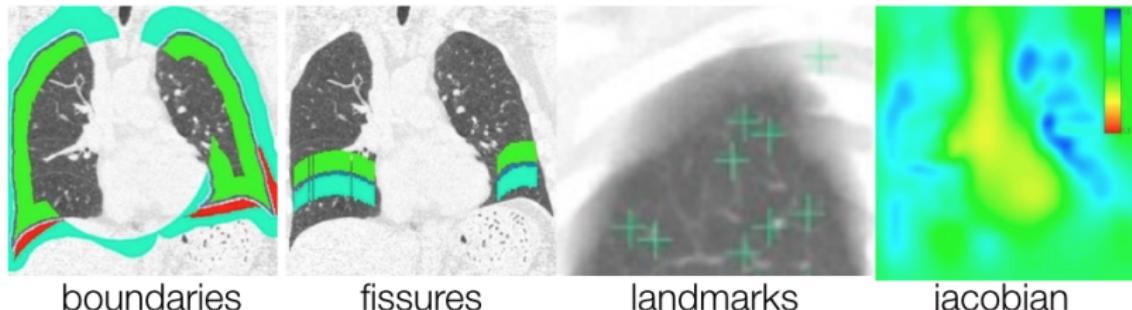
| Functionality | CT | 1H MRI | 3He MRI | PET |
|-------------------------|----|--------|---------|-----|
| registration | ○ | ○ | ○ | ○ |
| template generation | ○ | ○ | ○ | ○ |
| lung segmentation | ○ | ○ | ‡ | ‡ |
| lobe segmentation | ○ | ○ | ‡ | ‡ |
| airway segmentation | ○ | — | — | — |
| vessel segmentation | ○ | — | — | — |
| functional segmentation | * | — | ○ | * |
| feature indices | ○ | — | * | * |

'○': previously published work

'*': cross-modality functionality

'‡': simultaneous structural acquisitions

EMPIRE 2010



boundaries

fissures

landmarks

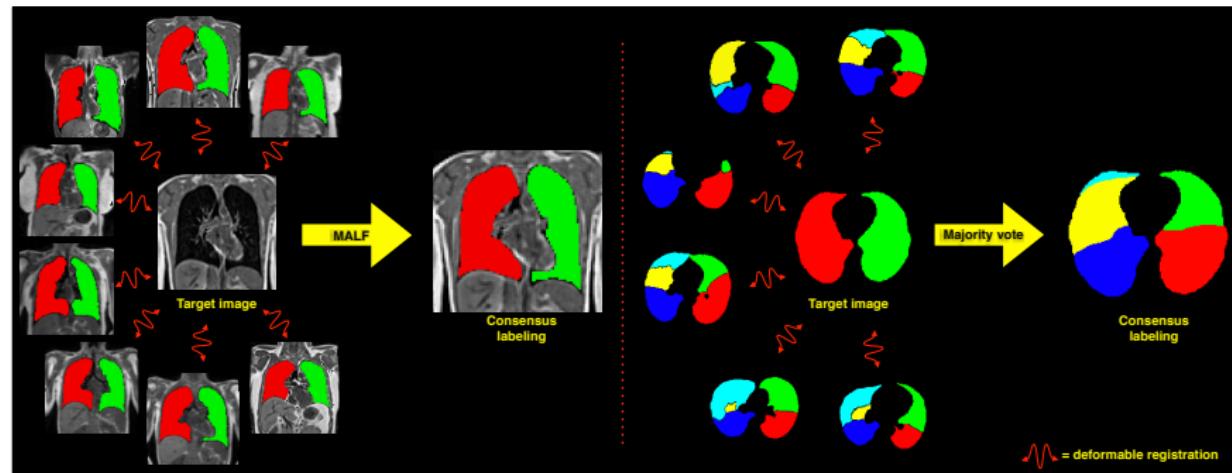
jacobian

| | Lung Boundaries | | Fissures | | Landmarks | | Folding | | Overall | | | |
|----------------------|-----------------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|--------|-------------|-------------|
| Team Name | Avg Score | Avg Rank | Avg Score | Avg Rank | Avg Score | Avg Rank | Avg Score | Avg Rank | Avg Score | Placed | Last Update | Method Type |
| picsl gsyn | 0.12 | 8.00 | 0.03 | 9.52 | 0.75 | 3.65 | 0.00 | 13.77 | 8.73 | 1 | 25 Jun 2010 | Fully Auto |
| Nifty Reggers | 0.00 | 7.57 | 0.27 | 12.30 | 0.75 | 7.25 | 0.00 | 12.50 | 9.90 | 2 | 26 Jun 2010 | Fully Auto |
| Iowa sstvd | 0.00 | 10.00 | 0.00 | 10.07 | 0.70 | 6.05 | 0.00 | 10.00 | 10.75 | 0 | 26 Jun | Fully |

Registration github examples

- <https://github.com/ntustison/antsCtLungRegistrationExample>
- <https://github.com/ntustison/ProtonCtLungMaskRegistration>

Atlas-based lung and lobe estimation



Good results on 1H MRI

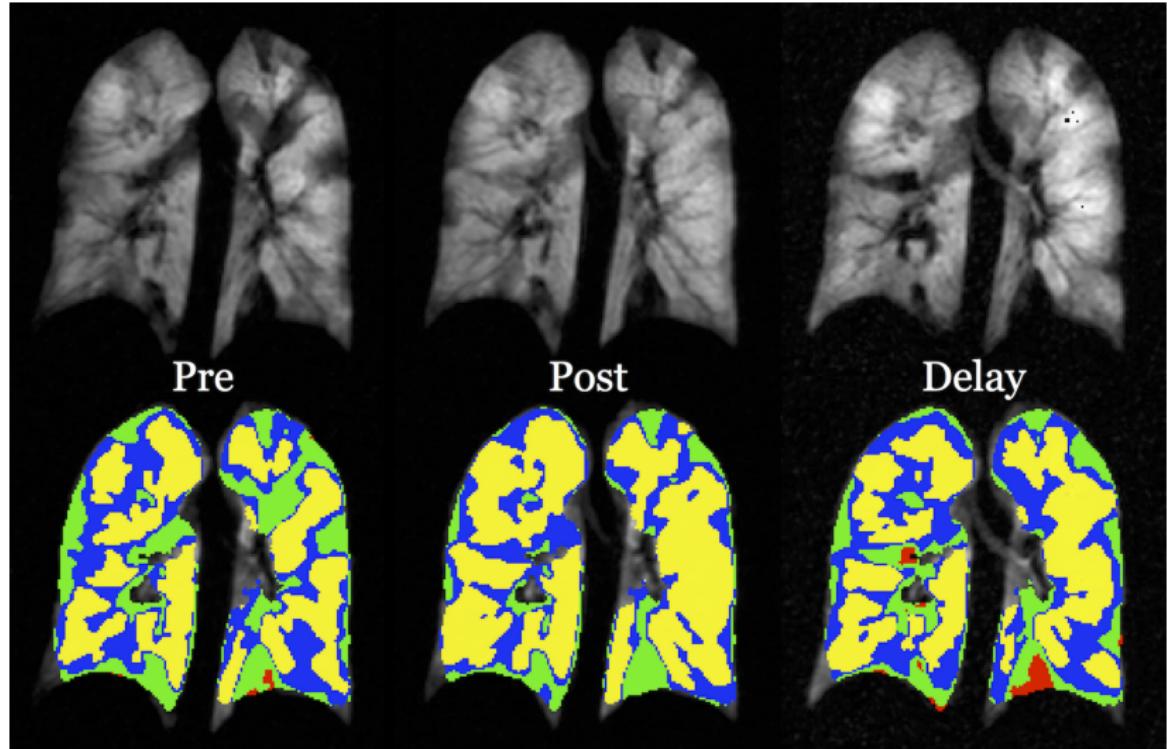
| | Mean | SD | Median |
|---------------------|---------------|---------------|---------------|
| Left lung | 0.963 (0.974) | 0.013 (0.097) | 0.964 (0.992) |
| Right lung | 0.968 (0.972) | 0.012 (0.135) | 0.970 (0.996) |
| Left upper | 0.882 (0.922) | 0.059 (0.163) | 0.894 (0.978) |
| Left lower | 0.868 (0.885) | 0.06 (0.229) | 0.892 (0.964) |
| Right upper | 0.852 (0.921) | 0.067 (0.088) | 0.875 (0.96) |
| Right middle | 0.657 (0.765) | 0.130 (0.299) | 0.696 (0.886) |
| Right lower | 0.873 (0.914) | 0.063 (0.176) | 0.900 (0.968) |

(*) Comparison with state-of-the-art

Lung and lobe estimation github example

<https://github.com/ntustison/LungAndLobeEstimationExample>

Functional ventilation



Functional segmentation github example

```
https:  
//github.com/ntustison/LungVentilationSegmentationExample
```

Combining ANTs lung functionality

Longitudinal voxelwise analysis of ventilation data

