

## Brain Extraction/Segmentation

# Brain Extraction 3 Different Attempts

In this tutorial we will discuss performing brain segmentation using:

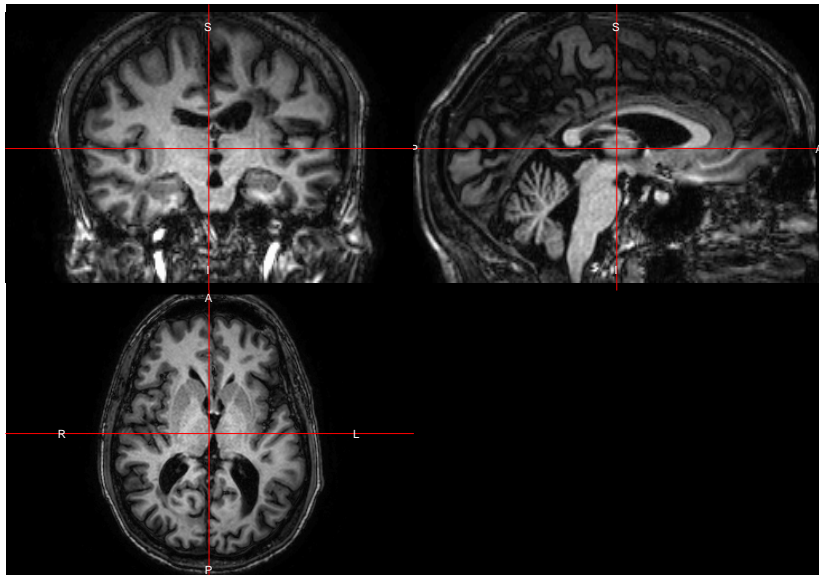
- ▶ the brain extraction tool (BET) (Smith 2002) in FSL (Jenkinson et al. 2012)
  - ▶ without bias correction (method 1) and with (method 2)
- ▶ a multi-atlas approach, called “multi-atlas label fusion” with the `malf` command (method 3).
- ▶ (extra slides) a robust version using a wrapper function in `extrantsr`, `fslbet_robust`

## Loading Data from ms.lesion

```
library(ms.lesion)
library(neurobase)
files = get_image_filenames_list_by_subject()$training01
t1_fname = files["MPRAGE"]
t1 = readnii(t1_fname)
rt1 = robust_window(t1);
red0.5 = scales::alpha("red", 0.5)
```

# T1-weighted MPRAGE Image

`ortho2(rt1)`



# Attempt 1: Brain Extraction of T1 image using BET

Here we will use FSL's Brain Extraction Tool (BET) to extract the brain tissue from the rest of the image (general overview):

- ▶ 2nd and 98th percentiles are calculated.  $(98\text{th} - 2\text{nd}) * 10\% + 2\text{nd percentile}$  used to threshold out background
- ▶ From non-thresholded voxels - calculate center of gravity (COG)
- ▶ Calculate radius of brain and median intensity of all points within "spherical brain" (used in last step)
- ▶ Perform region growing and iterating to get brain surface
- ▶ Smooth surface
- ▶ Use median intensity to shrink surface to the "real" surface

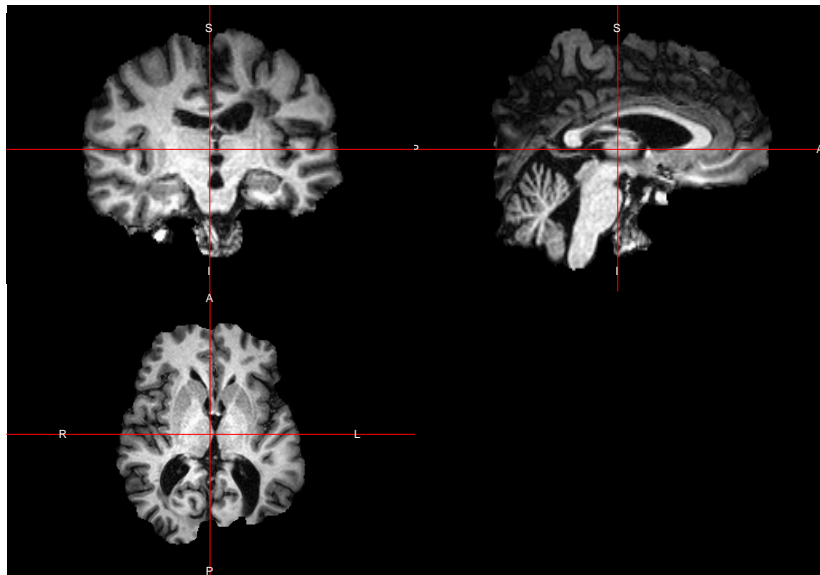
## Attempt 1: Brain Extraction of T1 image using BET

`fslr` - wraps FSL commands to use in R - registration, image manipulation

`fslr::fslbet` - takes in a filename/nifti and calls FSL bet function - additional options can be passed to FSL command in using `opts`

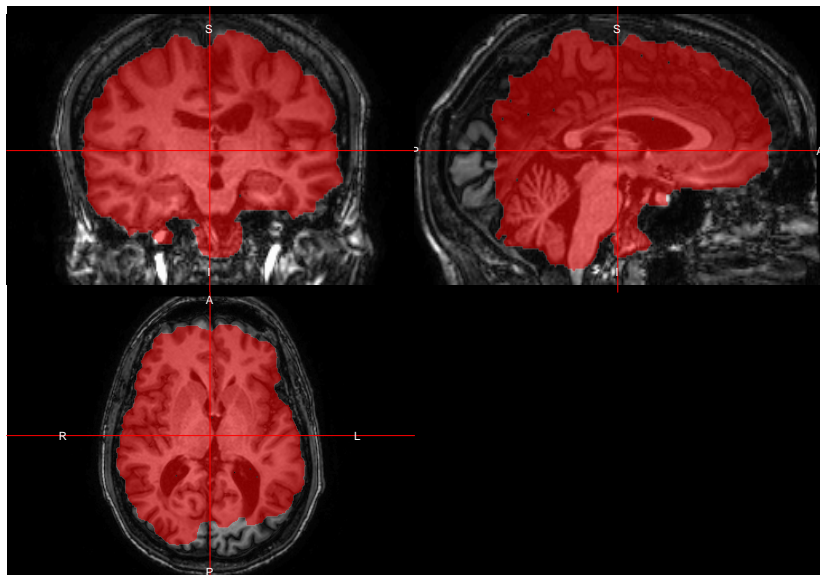
```
library(fslr)
ss = fslbet(infile = t1_fname)
```

## FSL BET Results - Missing Brain Tissues (Posterior)



## FSL BET Results not Satisfactory

```
ortho2(rt1, ss > 0, col.y = red0.5)
```





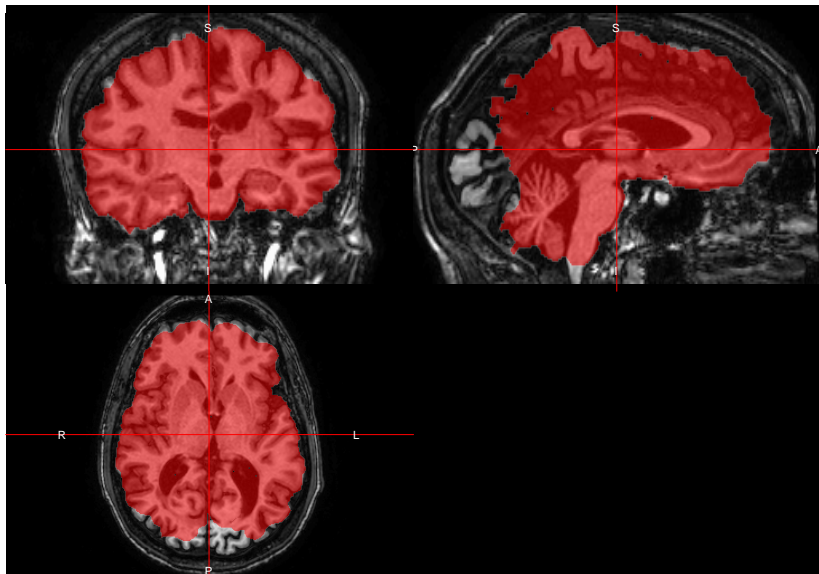
## Attempt 2: Bias Correct before BET (recommended)

Before doing skull-stripping/brain extraction, we would do bias correction:

```
library(extrantsr)
bc_img = bias_correct(file = t1, correction = "N4")
```

## BET on N4 Corrected Image Unsatisfactory

```
bc_bet = fslbet(bc_img); ortho2(bc_img, bc_bet > 0, col.y =
```



## Attempt 3: Brain Extraction of T1 image using MALF

Figure from Multi-Atlas Skull Stripping method paper (Doshi et al. 2013):

## Attempt 3: Brain Extraction of T1 image using MALF

Figure from Multi-Atlas Skull Stripping method paper (Doshi et al. 2013):

- ▶ Register templates to an image using the T1 for that subject
- ▶ Apply transformation to the label/mask
- ▶ Average each voxel over all templates
  - ▶ there are “smarter” (e.g. weighted) ways
- ▶ `malf.templates` package has templates provided by Neuromorphometrics, Inc.  
(<http://Neuromorphometrics.com/>) from MICCAI 2012 Challenge on Multi-atlas Labelling (Bennett Allan Landman et al. 2012)
  - ▶ hand segmentations of the brain and brain structures

# Attempt 3: Brain Extraction of T1 image using MALF

## Multi-Atlas Fusion:

- ▶ Register templates to an image using the T1 for that subject
- ▶ Apply transformation to the label/mask
- ▶ Average each voxel over all templates
  - ▶ there are “smarter” (e.g. weighted) ways
- ▶ `malf.templates` package has templates provided by Neuromorphometrics, Inc.  
(<http://Neuromorphometrics.com/>) from MICCAI 2012 Challenge on Multi-atlas Labelling (Bennett Allan Landman et al. 2012)
  - ▶ hand segmentations of the brain and brain structures

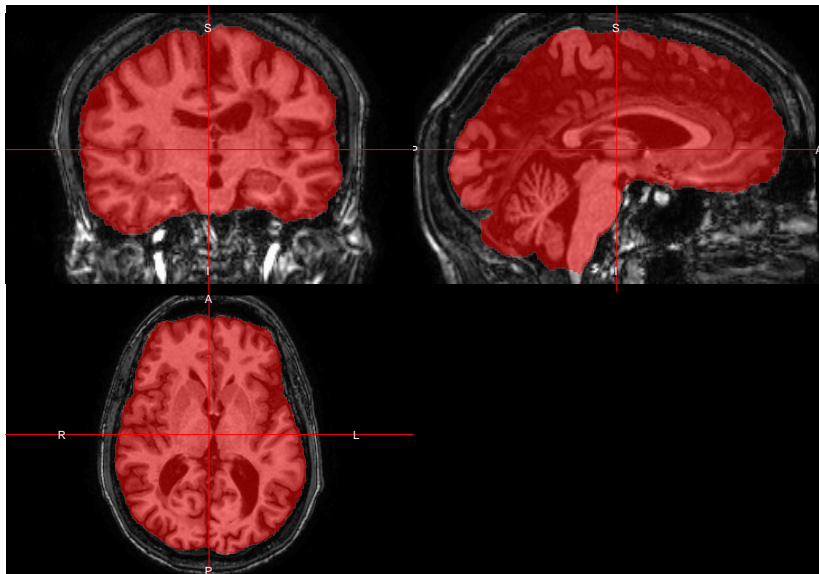
## MALF - use `extrantsr::malf`

- ▶ Function requires arguments: `template.images` (T1-weighted images in this case) and `template.structs` (labels/structures/masks, brain masks here)
- ▶ Performs non-linear registration using Symmetric Normalization (SyN) (B. B. Avants et al. 2008), a form of diffeomorphic registration:

```
library(malf.templates) # load the data package
library(extrantsr)
timgs = mass_images(n_templates = 5) # let's register 5 templates
ss = extrantsr::malf(
  infile = bc_img,
  template.images = timgs$images,
  template.structs = timgs$masks,
  keep_images = FALSE # don't keep the registered images
)
```

## MALF performs well

```
ortho2(bc_img, ss > 0, col.y = red0.5)
```



## Processed Results Available in ms.lesion

In the `ms.lesion` package, we have the brain masks for each subject located in the `coregistered` folder. You can access this data using the `type = "coregistered"`:

```
files = get_image_filenames_list_by_subject(  
  type = "coregistered")$training01  
files["Brain_Mask"]
```

```
[1] "library/ms.lesion/extdata/coregistered/training01/brain_masks"
```



# Conclusions from the MS data

- ▶ FSL BET can perform brain extraction (additional ex shows when it works)
  - ▶ It did not work sufficiently here
  - ▶ There are options you can change for performance
- ▶ Bias-correction before brain extraction is a good idea
  - ▶ Especially if the method depends on intensities
- ▶ MALF/MASS is a good option, but needs templates and is computationally expensive
  - ▶ weighted templates or local weighting is done in other software (not discussed)

Extra Slides are showing additional BET options

## Additional Example

FSL BET did not work in the previous data set. It works in many cases, though. We will look at a subject from the kirby21 dataset (Bennett A Landman et al. 2011).

## Kirby21

```
library(kirby21.t1)
t1_fname = get_t1_filenames()[1]
t1 = readnii(t1_fname)
```

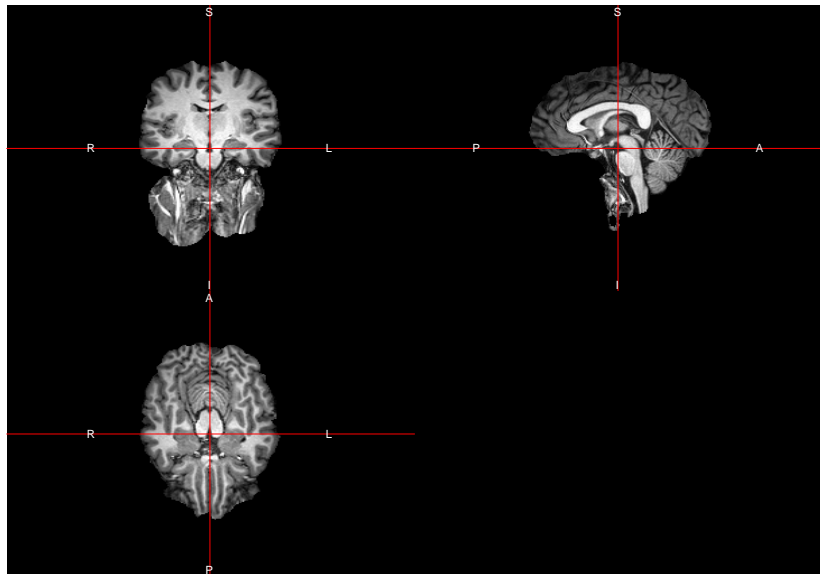
T1 image has the neck!

```
ortho2(robust_window(t1))
```



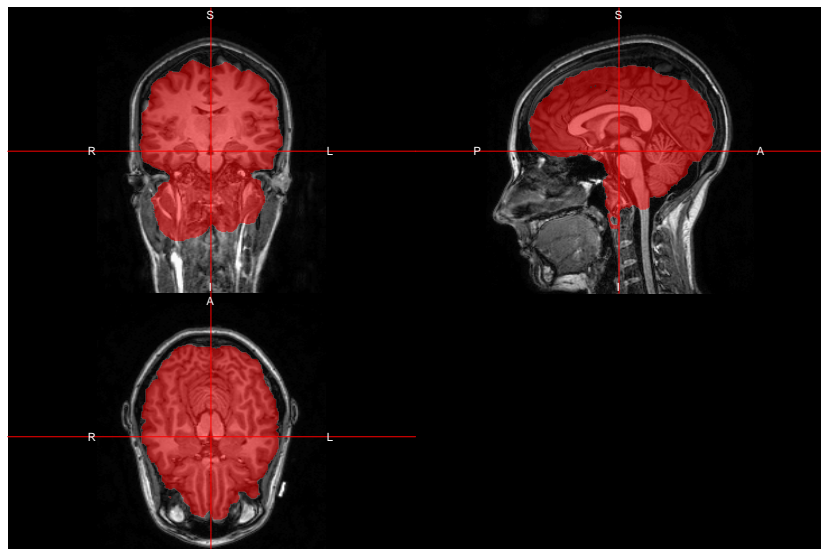
## Neck messes up BET

```
ss = fslbet(infile = t1_fname); ortho2(robust_window(ss))
```



## Recommend to Bias Correct first: not fixed

```
bc_img = bias_correct(t1, correction = "N4"); bc_bet = fslb  
ortho2(robust_window(t1), bc_bet > 0, col.y = red0.5)
```



# BET with neck removal

We use the modification of BET in `extrantsr`, which is called through `fslbet_robust`. `fslbet_robust`:

- ▶ bias correct image
- ▶ remove neck (`double_remove_neck` performs 2 registration steps, more robust than one (which is the default).)
- ▶ run BET
- ▶ estimate center of gravity (COG)
- ▶ run BET again with new COG

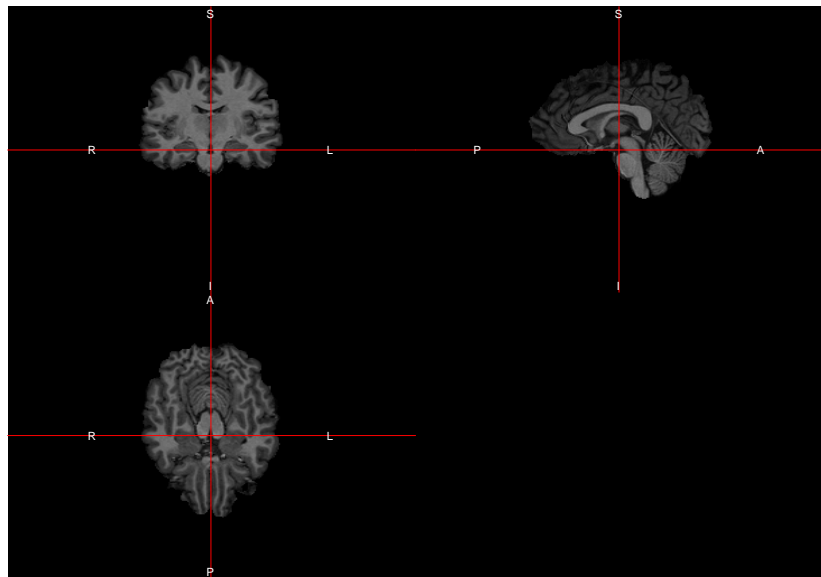


## fslbet\_robust syntax

```
ss = extrantsr::fslbet_robust(  
  t1,  
  remover = "double_remove_neck",  
  correct = TRUE,  
  correction = "N4",  
  recog = TRUE)
```

## BET with neck removal - works well!

```
ortho2(ss)
```



# Conclusions

- ▶ Brain extraction allows you to analyze the brain only
  - ▶ Important for tissue segmentation/registration
- ▶ BET may work (look at your data!)
  - ▶ Should bias correct first
  - ▶ May need to remove neck
  - ▶ High values may affect results - may need to remove/Winsorize them

## References

- Avants, B. B., C. L. Epstein, M. Grossman, and J. C. Gee. 2008. "Symmetric Diffeomorphic Image Registration with Cross-Correlation: Evaluating Automated Labeling of Elderly and Neurodegenerative Brain." *Medical Image Analysis*, Special issue on the third international workshop on biomedical image registration - WBIR 2006, 12 (1): 26–41. doi:10.1016/j.media.2007.06.004.
- Doshi, Jimit, Guray Erus, Yangming Ou, Bilwaj Gaonkar, and Christos Davatzikos. 2013. "Multi-Atlas Skull-Stripping." *Academic Radiology* 20 (12). Elsevier: 1566–76.
- Jenkinson, Mark, Christian F. Beckmann, Timothy E. J. Behrens, Mark W. Woolrich, and Stephen M. Smith. 2012. "FSL." *NeuroImage* 62 (2): 782–90. doi:10.1016/j.neuroimage.2011.09.015.
- Landman, Bennett A, Alan J Huang, Aliya Gifford, Deepti S Vikram, Issel Anne L Lim, Jonathan AD Farrell, John A Bogovic, et al. 2011. "Multi-Parametric Neuroimaging Reproducibility: A 3-T Resource Study." *Neuroimage* 54 (4). Elsevier: 2854–66.  
<https://www.nitrc.org/projects/multimodal/>.