

MS Lesion Segmentation

Background

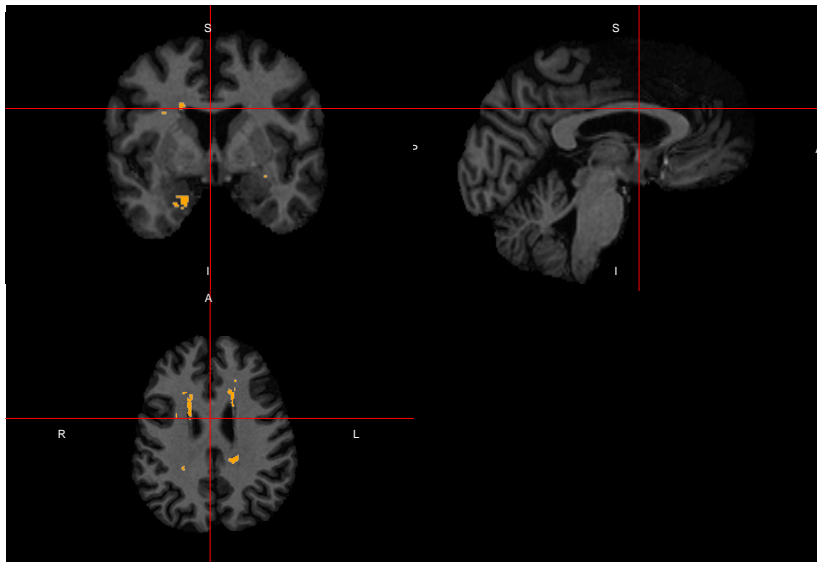
- ▶ Obtaining manual lesion segmentations is often resource intensive.
- ▶ Accurate and efficient methods for automatic segmentation are necessary for scalability and research progress.

Goals of this tutorial

- ▶ Apply OASIS (Sweeney et al. 2013), an automatic lesion segmentation model, to obtain predicted lesion probability maps.
- ▶ Compare the results using the default OASIS settings to those obtained after re-training the model using our data.

Visualization

- ▶ Here's the T1 volume for training subject 05 with a 'gold standard' manual lesion segmentation overlaid.



MS Lesion Segmentation with OASIS

- ▶ OASIS is Automated Statistical Inference for Segmentation (Sweeney et al. 2013).
- ▶ The OASIS algorithm takes FLAIR, T1, T2, and PD images from patients with multiple sclerosis (MS) and produces OASIS probability maps of MS lesion presence, which can be thresholded into a binary lesion segmentation.
- ▶ The OASIS model is based on a logistic regression of the gold standard manual segmentation labels on the images, smoothed versions of the images, and some interaction terms (i.e., supervised learning).

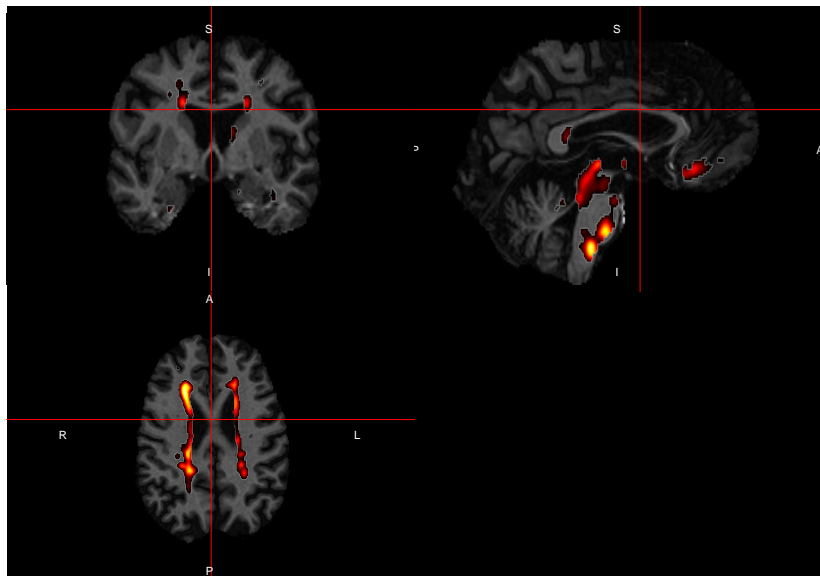
Default OASIS Model

- ▶ The OASIS library comes with default parameters that can be used to generate probability maps for new test subjects.
- ▶ The default model was trained on approximately 100 MS subjects and 30 healthy subjects with manual segmentations.
- ▶ Here we apply the function `oasis_predict` with the default model to obtain OASIS probability maps for the test subjects.

```
library(oasis)
default_predict_ts = function(x){
  res = oasis_predict(
    flair=ts_flairs[[x]], t1=ts_t1s[[x]],
    t2=ts_t2s[[x]], pd=ts_pds[[x]],
    brain_mask = ts_masks[[x]],
    preproc=FALSE, normalize=TRUE,
    model=oasis::oasis_model)
  return(res)
}
default_probs_ts = lapply(1:3, default_predict_ts)
```

Vizualization

- Here's the probability map for test subject 01:

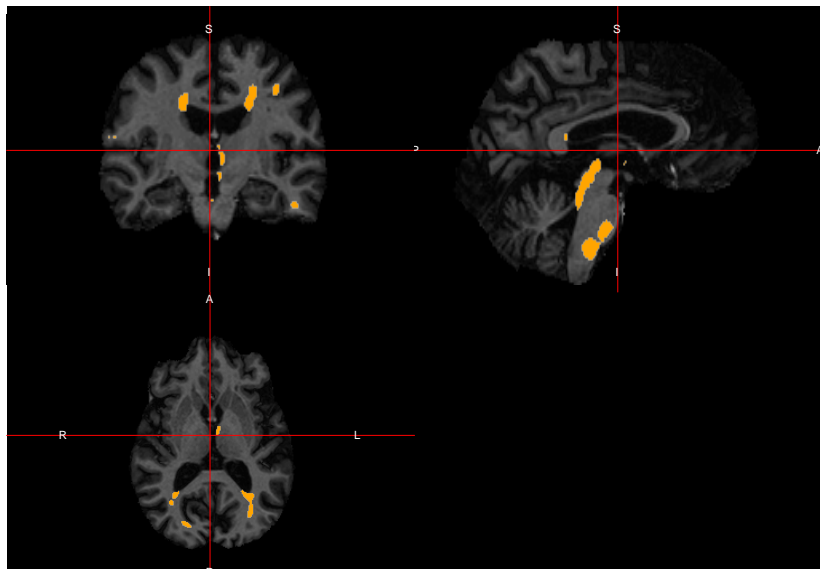


Thresholding

- ▶ To get a final estimated segmentation, we must choose a cutoff to binarize the OASIS probability maps.
- ▶ The `binary` argument in the `oasis_predict` function is `FALSE` by default, resulting in the output being the probability map.
- ▶ Setting `binary=TRUE` will return the thresholded version, using the input to the `threshold` argument (default = 0.16).
- ▶ 0.16 was obtained via a validation set allowing for a 0.5% false positive rate.
- ▶ In practice, we might want to use a grid search over thresholds and cross validation to choose the cutoff.

Visualization

- Here's the binary mask for test subject 01, using the default 0.16 threshold:



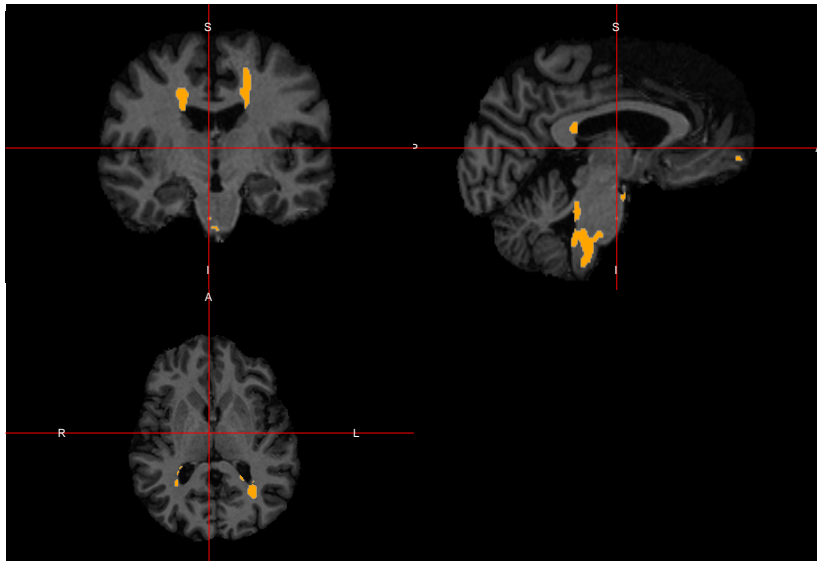
Default OASIS Model

- ▶ To evaluate how the default model performs, we need to compare the predictions to a gold standard.
- ▶ Let's therefore obtain OASIS probability maps for our training subjects.
- ▶ We will use the default threshold to binarize.

```
default_predict_tr = function(x){  
  res = oasis_predict(  
    flair=tr_flairs[[x]], t1=tr_t1s[[x]],  
    t2=tr_t2s[[x]], pd=tr_pds[[x]],  
    brain_mask=tr_masks[[x]],  
    preproc=FALSE, normalize=TRUE,  
    model=oasis::oasis_model, binary=TRUE)  
  return(res)  
}  
default_probs_tr = lapply(1:5, default_predict_tr)
```

Default OASIS Model Results

- Here's the T1 volume for training subject 05 with the OASIS segmentation overlaid.



Default OASIS Model Results

- ▶ The dice coefficients for the training subjects compared to raters 1 (left) and 2 (right) are:

	Rater 1	Rater 2
01	0.4724006	0.4938917
02	0.6900361	0.6860189
03	0.362001	0.4316734
04	0.284585	0.2891665
05	0.3083417	0.2638682

Improving Results

- ▶ The default model is picking up a lot of false positives in the spinal cord.
- ▶ We might improve the results by re-training the OASIS model using our five training subjects.
- ▶ To re-train using new data, binary masks of gold standard lesion segmentations are needed and should be in T1 space.

Making OASIS data frames

- ▶ OASIS requires a particular data frame format, which we create using the function `oasis_train_dataframe`.
- ▶ Includes an option to preprocess your data (`preproc`), which does (1) inhomogeneity correction using `fsl_biascorrect` and (2) rigid coregistration using `flirt` to the T1 space.
- ▶ Includes an option to normalize the intensities of your data using whole-brain normalization (`normalize`).
- ▶ `make_df()` below is a helper function.

```
make_df = function(x){  
  res = oasis_train_dataframe(  
    flair=tr_flairs[[x]], t1=tr_t1s[[x]], t2=tr_t2s[[x]],  
    pd=tr_pds[[x]], gold_standard=tr_golds2[[x]],  
    brain_mask=tr_masks[[x]],  
    preproc=FALSE, normalize=TRUE, return_preproc=FALSE)  
  return(res$oasis_dataframe)  
}  
oasis_dfs = lapply(1:5, make_df)
```

Training OASIS

- ▶ The function `oasis_training` takes the data frames we made and fits a logistic regression using labels and features from a subset of voxels in each subject's brain mask (top 85% in FLAIR intensity).
- ▶ The function `do.call` is a useful R function that applies the function named in the first argument to all elements of the list specified in the second argument.
- ▶ Below, `model` is a `glm` object that stores the estimated parameters from the logistic regression.

```
ms_model = do.call("oasis_training", oasis_dfs)
```

OASIS model object

- ▶ Printing `ms_model` lets us see the model coefficients:

```
print(ms.lesion::ms_model)
```

```
Call: glm(formula = formula, family = binomial, data = tra
```

Coefficients:

(Intercept)	FLAIR_10	FLAIR	FLAIR
-5.6939	4.1041	1.4076	-2.1
PD_10	PD	PD_20	T2
4.7047	0.1739	-17.3328	9.9
T2	T2_20	T1_10	
0.8376	-19.2016	12.5254	1.2
T1_20	FLAIR_10:FLAIR	FLAIR:FLAIR_20	PD_10
-27.9823	-1.0304	-3.4276	0.2
PD:PD_20	T2_10:T2	T2:T2_20	T1_10
-1.1567	-0.9565	1.5197	-1.3

Trained OASIS Model Results

- ▶ Using the same threshold of 0.16.
- ▶ Dice coefficients for the training subjects:

	Rater 1	Rater 2
01	0.6281593	0.6438359
02	0.7088758	0.711435
03	0.5341028	0.6180772
04	0.3621744	0.3594041
05	0.4105148	0.3563922

References

Sweeney, Elizabeth M, Russell T Shinohara, Navid Shiee, Farrah J Mateen, Avni A Chudgar, Jennifer L Cuzzocreo, Peter A Calabresi, Dzung L Pham, Daniel S Reich, and Ciprian M Crainiceanu. 2013. "OASIS Is Automated Statistical Inference for Segmentation, with Applications to Multiple Sclerosis Lesion Segmentation in Mri." *NeuroImage: Clinical* 2. Elsevier: 402–13.