SuBGELS: Subtraction-Based Gadolinium Enhancing Lesion Segmentation

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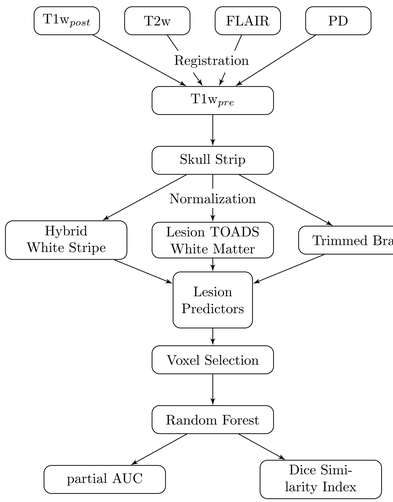
Goals and Methods

Compare gold standard, manual segmentation of gadolinium-enhancing lesions in head MRI images to an automated method using:

- Voxel selection methods
- Random forests
- Smoothing

Data were from 14 patients with multiple sclerosis, with 5.8 per patient. There were 24 scans with lesions; the average (SD) total lesion volume was 201.1mm^3 (196.1).

Image Processing Pipeline



References

[1] Andy Liaw and Matthew Wiener. "Classification and Regression by randomForest". In: *R News* 2.3 (2002), pp. 18–22.
[2] Leo Breiman. "Random forests". In: *Machine learning* 45.1 (2001), pp. 5–32.
[3] Lee R. Dice. "Measures of the amount of ecologic association between species". In: *Ecology* 26.3 (1945), pp. 297–302.

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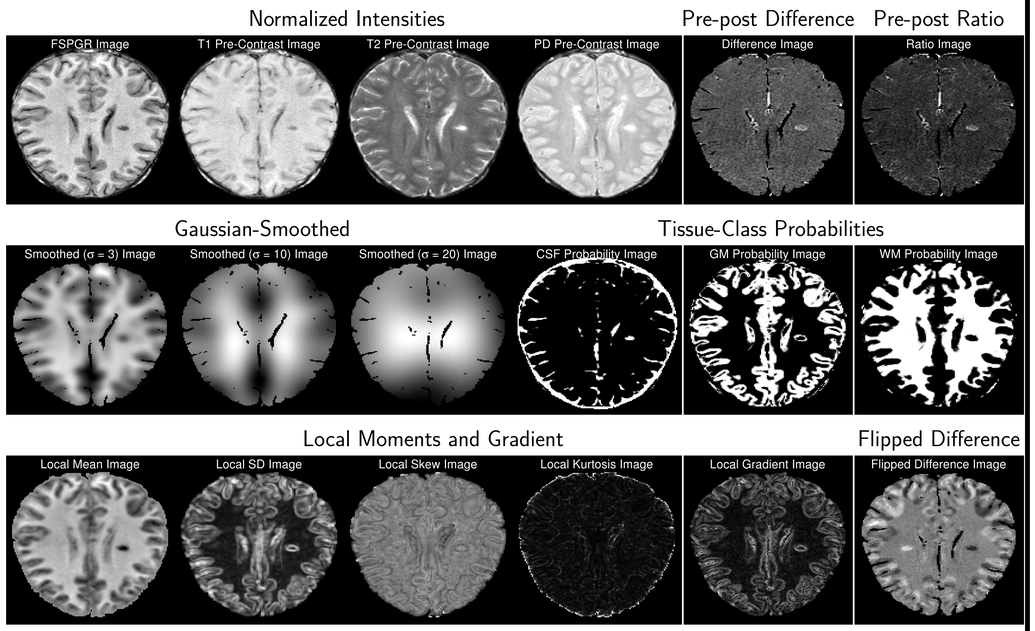
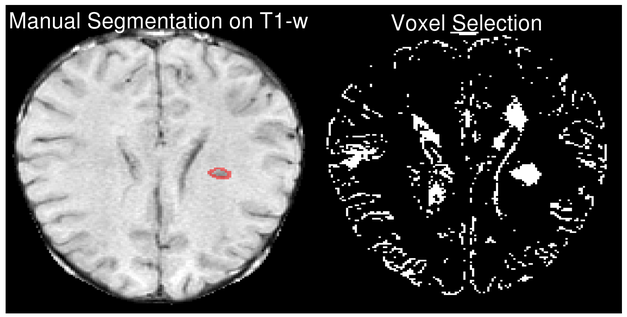
Imaging Predictors



Imaging Model: a Random Forest

Notation: Let i denote scan, v: voxel, and $X(v)$: value of images X for voxel v. We denote the indicator manual segmentation classified a voxel as enhancing lesion as $Y_i(v)$. For each fold in 10-fold cross validation, we estimated $\hat{P}(Y_i(v) = 1|X(v))$ using a random forest [1, 2], where $\hat{P}(Y_i(v) = 1|X(v))$ is the probability a voxel is an enhancing lesion given the predictors X.

Voxel Selection



We estimated the 90% quantile of the FLAIR voxel intensity distribution for each scan. We only modeled voxels above this threshold. All other voxels are set to $\hat{Y}_i(v) = 0$, where $\hat{Y}_i(v)$ is the predicted Y for voxel v for scan i.

Measuring Prediction Performance

For each fold testing set, we estimated a the partial area under the curve (pAUC) for predicting enhancing lesions, at a cutoff of 1% false-positive rate. We also calculated a 2×2 table comparing to the manual segmentation for each threshold:

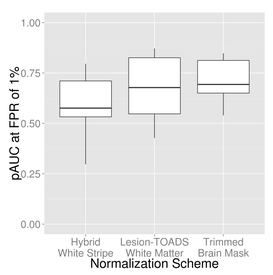
		Manual segmentation	
		0	1
Model Prediction	0	TN	FN
	1	FP	TP

We used the Dice Similarity Index (DSI) [3] to estimate performance:

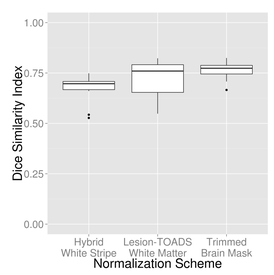
$$\text{DSI} = \frac{2\times\text{TP}}{2\times\text{TP}+\text{FN}+\text{FP}}$$

where TN/TP refer to true negative/positive voxels, and FN/FP: false negative/positive voxels. We calculated the maximum DSI over all cutoffs for that specific fold.

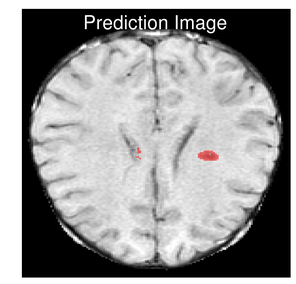
Prediction Results



Distribution of Dice Similarity Index (DSI) for 10 folds. The folds had a median DSI of 0.67, 0.72, and 0.76 for the hybrid White Stripe, Lesion TOADS white matter mask, and trimmed brain mask normalizations, respectively.



Similarly, the partial area under the curve (pAUC) is depicted with the same normalizations, with median pAUCs: 0.60, 0.67, and 0.71, respectively.



The predicted lesion mask has a high overlap between the manual segmentation, with some incorrect predictions near the ventricles.

Conclusions

These results indicate that the approach described can achieve moderately accurate segmentation of gadolinium-enhancing lesions in a small sample of patients with MS. Improvements must be made on the method, especially in areas near the ventricles.