Clinical Application of a Template-free Framework for Analysis of Multi-contrast Anatomical Images

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Introduction

Quantitative analysis of anatomical brain MR images is becoming increasingly important and widely used in clinical medicine. When used for individual patient diagnosis and treatment monitoring, structural MRI has traditionally been interpreted using qualitative criteria (hypo- or hyperintensity) and some basic quantitative measures (number of lesions, lesion diameter, etc.). For more widespread adoption of quantitative measures currently used for research, fully or semi-automated methods of analysis must be adapted for the analysis of individual patients, often with structurally abnormal brains.

The framework developed by Saad et al (1) is a helpful tool. This approach uses a minimal training set to perform tissue classification based on multiple image contrasts without the use of a common atlas or spatial priors. This is a major advance as many of these images cannot be easily registered to an existing atlas. It also creates a framework for easy selection of features of interest using multiple MRI contrasts or textures that can be optimized for the study of an array of brain pathologies in the patient's native brain space.

Methods

Subjects:

- 5 adult healthy volunteers (1 female, ages 21-40, median 31)
- 5 pediatric healthy volunteers (1 female, ages 8-14, median 13)
- 2 patients with abnormal brain anatomy

Acquisition:

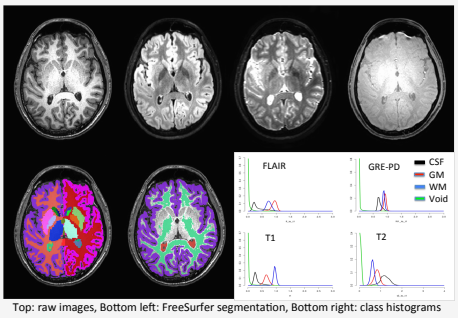
- 3T Philips Achieva MRI at the NIH Clinical Center
- 3D volumetric images (MPRAGE, T2, FLAIR, Gradient Echo with 2 flip angles, water image)

Pre-processing:

- All scans for each subject were registered to the MPRAGE using AFNI and a normalized mutual information cost function
- Field bias adjustment and feature scaling in each sequence was carried out by the procedure described in Saad et al. (1)

Training Class Definition:

- 5 healthy volunteer MPRAGE images were processed with FreeSurfer, inspected for accuracy and corrected as necessary
- In AFNI, 3 masks were created for each subject by combining the FreeSurfer segmentations and eroding as follows: 1) gray matter (GM): left and right hemisphere cortical ribbon, 2) white matter (WM), cerebrospinal fluid (CSF): left and right ventricle masks, 3) void
- Histograms of the scaled image intensity of the voxels in each mask were computed for each contrast and class combination across the 5 adult healthy volunteers



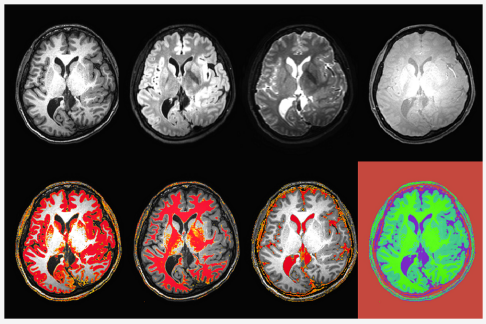
Top: raw images, Bottom left: FreeSurfer segmentation, Bottom right: class histograms

Results:

- Automated classification in individuals presenting challenges for registration to standard atlases
- Top rows (left to right): T1, FLAIR, T2, gradient echo
- Bottom rows (left to right): color overlays indicate likelihood of class membership (gray matter, white matter, CSF respectively). The bottom right panel in each case represents the classification result

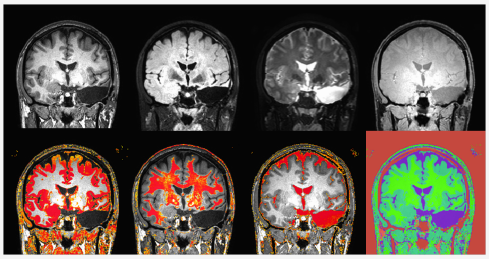
Case 1: Malformation of cortical development

- 42 year old woman with medically refractory epilepsy with complex partial seizures originating from the right temporal region on EEG undergoing evaluation for possible epilepsy surgery. MRI shows extensive areas of dysplastic tissue on the right. Segmentation allows for enhanced visualization of gray matter locations to assist with planning of electrode placement and potential tissue for resection.

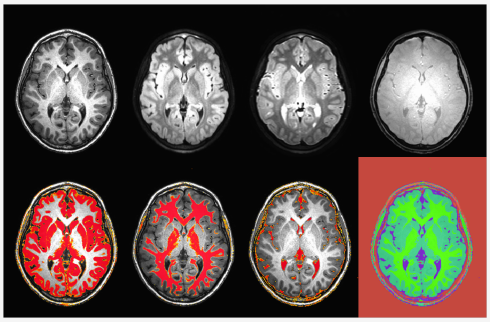


Case 2: Epilepsy patient post temporal lobectomy

- 32 year old man who underwent right anterior temporal lobectomy 4 years ago for refractory epilepsy, now with recurrence of similar seizures, undergoing evaluation for possible re-operation.



Case 3: 8 year old healthy volunteer



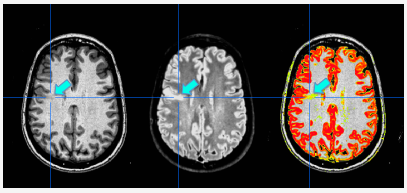
Future Directions:

Focal Cortical Dysplasias

- Often missed by conventional visual analysis; look for hyperintensity on FLAIR, G-W blurring
- In several cases, the lesions show an intermediate probability of belonging to gray matter; may help to identify subtle lesions
- Incorporation of textures such as blurring of the gray white junction using multiple contrasts may also help to identify these lesions

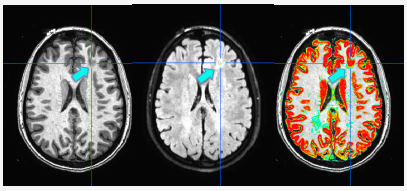
Case 3: Left central focal cortical dysplasia

- 53 year old woman with medically refractory focal seizures with lip and mouth tingling occurring several times daily, undergoing presurgical evaluation.



Case 4: Right frontal focal cortical dysplasia

- 21 year old woman with focal seizures with head turning to the right, rarely with secondary generalization; MRI previously read as normal, seen to have bottom of sulcus subtle dysplasia (yellow/green area encircling bottom of the sulcus).



** Left parietal white matter is also abnormal, clinical significance unknown

Conclusions

- Basis for future investigation of disease states in individual patients in their native anatomy spaces
- Flexible choice of features, can readily include information from different MR contrasts, image textures, and other classes of interest
- Potential examples include
  - Epilepsy (identification of subtle cortical dysplasias, assist with registration of pre to postop)
  - Multiple sclerosis (lesion characterization)
  - Brain tumors (segmentation of tumor compartments)

References

1. Saad, Z et al. (2015), Framework for Generating Class Priors From Multi-Contrast Images Without Group Volume Templates, Poster #4023, OHBM, Honolulu, HI
2. Vovk, A et al. (2011), Segmentation priors from local image properties: without using bias field correction, location-based templates, or registration, Neuroimage, vol. 55, no. 1, pp. 142-52