MIND DBP: The Analysis of Brain Lesions in Neuropsychiatric Systemic Lupus Erythematosis

H Jeremy Bockholt
The MIND Research Network
Albuquerque, NM

NA-MIC Core 1-3 Meeting
20080522
SCI Institute, Salt Lake City

DBP Objective

- Critical to understanding the etiology of brain lesions in NPSLE (lupus) will be the accurate measurement of their location, size, and time course.
- Lupus brain lesions are known to vary in MRI intensity and temporal evolution and include acute, chronic, and resolving cases.
- Monitoring the time course of image intensity changes in the vicinity of lesions, therefore, may serve to classify them based on their temporal characteristics.
- Evaluation of existing methods to frame the development new tools using the NA-MIC kit for the time series analysis of brain lesions in lupus.

Goals of the DBP

- Use and extend the NA-MIC kit to creation a longitudinal lesion analysis capability optimized for lupus
- **Input data**
  - image data from the T1-weighted, T2-weighted, and FLAIR sequences
- **Output data**
  - will be probability maps for each tissue class, the number of lesions, the volume of each lesion, and the total lesion volume at each time point
  - Changes in lesion size and changes in pixel intensity within the volume of each lesion will be displayed graphically
  - Time course data will also be amenable to time series analysis by statistical tools such as general linear modeling (GLM), independent component analysis (ICA), or potentially Bayesian analysis

Roadmap Project

- Establish an end-to-end tutorial, including sample data-sets
  - (T1, T2, and FLAIR)
  - the scientific community may download tutorial and tool and segment white matter lesions on tutorial then use the framework as a guide to segmentation of their own similar data-sets
  - Data collection Goal:
    - collect 5 lupus and 5 controls with at least 2-3 scanning visits at both 1.5T and 3.0T
      - (T1, T2, FLAIR, and *DTI*)

Technical Requirements

- Co-register, T1, T2, FLAIR
- Classify brain into gray, white, csf, or lesion
- Summarize lesion location, size, and intensity across sequences
- Longitudinal registration
- Characterize lesion changes over time (size and intensity)

Data Collection Progress

- Roadmap Project
  - 3 lupus patients with lesions and 3 controls with T1, T2, and FLAIR from 1.5T and 3.0T, collecting DTI at 3.0T as well (where possible)
    - Some longitudinal data is planned for collection prior to summer programming week
    - We still plan to collect up to 5 lupus and 5 controls
- Clinical Study
  - Total of 40 lupus and controls baseline cases collected so far (1 year followups are started to be scheduled)
    - We do have a 2x2x2mm 12 direction DTI 8Channel coil sequence on these subjects, *limited use*, but should provide reasonable FA maps
  - 14 lupus cases with lesions (indicated by neuroradiological review) have had lesions manually traced by an expert rater

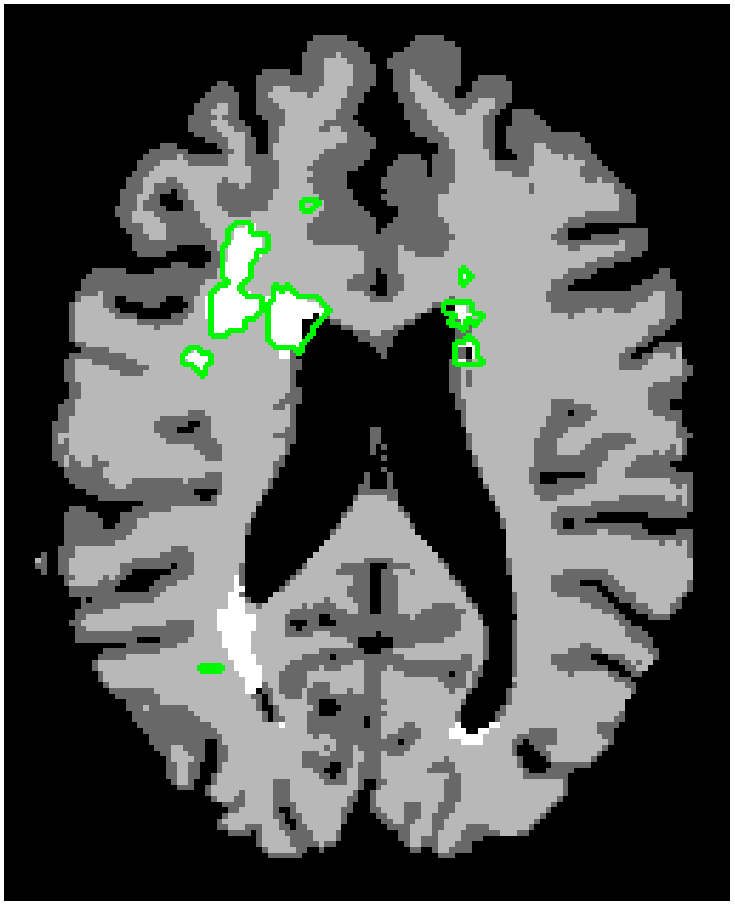
Current Methodology

Manual tracing of white matter lesions hyperintense on FLAIR were performed by an experienced rater.

The NA-MIC kit was used to develop a fully automated two-stage technique that uses a k-means clustering procedure as intensity priors for a bayesian classification upon co-registered T1, T2, and FLAIR image sets. This procedure labels all brain tissue into either gray, white, CSF, or lesion classes.

Current Results

- The automated method closely matches the lesion classification as performed by a manual rater with a relative overlap of 0.8.
- The figure shows an axial slice with csf, gray, and white matter labeled, automated lesions are labeled white, green ROIs indicate manual trace of lesions.
- Perivascular artifacts
- Type I errors
- Type II errors
- Manual classification Errors



Algorithm Challenges

- Longitudinal registration of {T1, T2, FLAIR} -> {T1,T2,FLAIR}
- Longitudinal Identification of same lesions
- Lesion boundary change across time series, size/shape change, intensity changes

Engineering Challenges

- Visualization of clustered lesions, and interface for summarizing the measurements, locations of lesions, and tissue intensities within them
- Visualization of structural time series (T1,T2, FLAIR) with followup (T1,T2,FLAIR)
- Visualization of Lesion boundary changes (show a movie of change)?
- End-to-End wizard within Slicer for full lesion classification from images to statistics on lesions

EM-Segment Status

- Bugs solved (thanks Brad) but not getting usable results
  - 2 channel (T1,T2) segmentation (GM,WM,CSF) works for correct CSF
  - 3 channel (T1,T2,FLAIR) standard EM segmentation works for correct
  - 3 channel (T1,T2,FLAIR) hierarchal EM segmentation (GM, WM{WM,lesion},CSF) does not produce correct white results (GM and CSF ok).
- Mark Scully (MRN DBP engineer) is in communication with Kilian on strategies for getting this to work. Trying sets of different weights, trying with or without intensity normalized, and with different values for intensity normalization.

Comparison Study

- EM-Segment (kilian, brad)
- ITK bayesian (marcel, guido)
- Manual Labeling (chuck, jeremy)
- ITK k-means/bayesian (magnotta)
- JIM (chuck, lisa)
  - This is a commercial tool used extensively in MS lesion work that we are just applying as a contribution to the comparison

Non-DBP Projects

- DTI validation study (MGH 60 direction sequence)
  - Collected under the MIND Clinical Imaging Consortium reliability study
- Competing in 2008 MICCAI lesion segmentation challenge

Project Week Plan

- Complete end-to-end Slicer3 module
  - ITK K-means/Bayesian method
  - Work with Sonja on public tutorial
- Longitudinal analysis phase of project
  - Registration
  - Lesion change
- Compare FA maps to lesion maps
  - Abnormalities are more diffuse than hyperintensities seen on FLAIR

Team

- Jeremy Bockholt, MIND
- Charles Gasparovic, UNM
- Mark Scully, MIND
- Ross Whitaker, Utah
- Steve Pieper, Isomics
- Vincent Magnotta, Iowa
- Marcel Prastawa, Utah
- Guido Gerig, Utah
- Brad Davis, Kitware
- Kilian Pohl, MIT