Segmentation and Analysis of Stroke Images

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Joint work with
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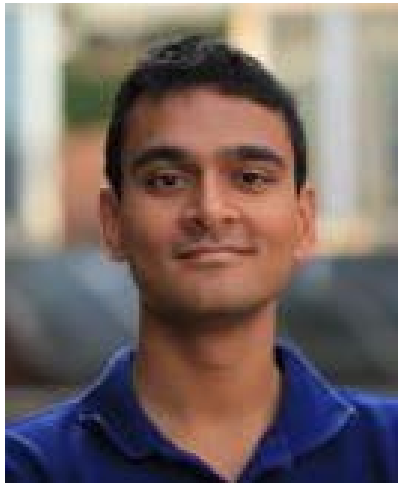

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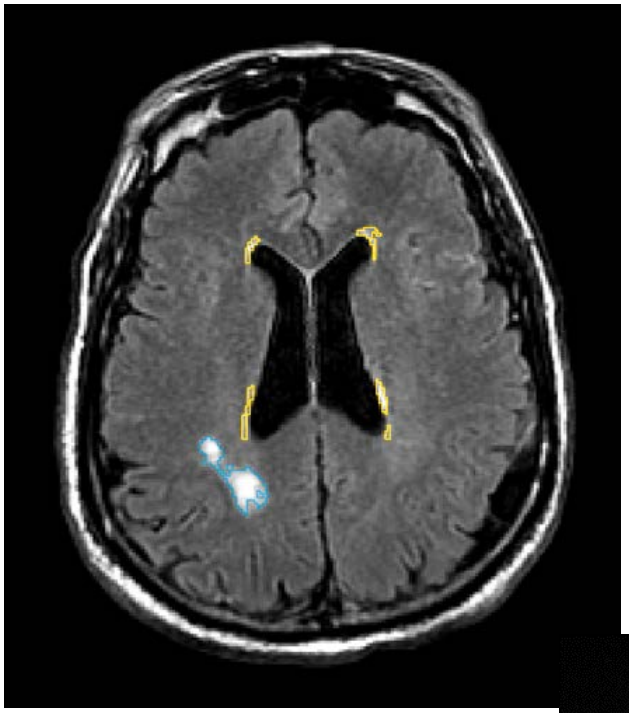
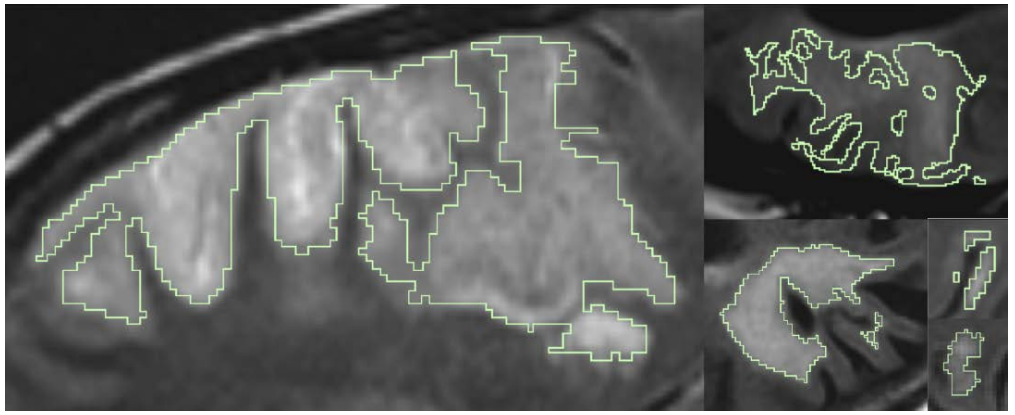
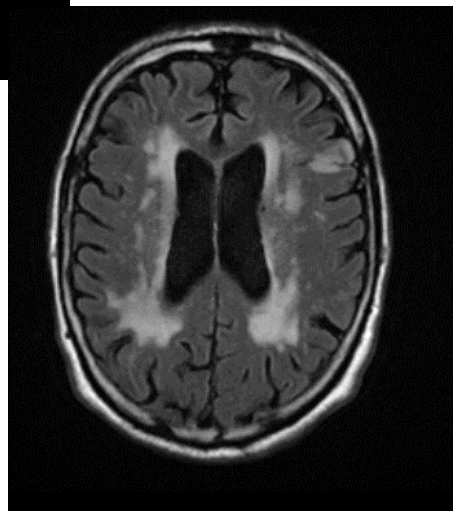
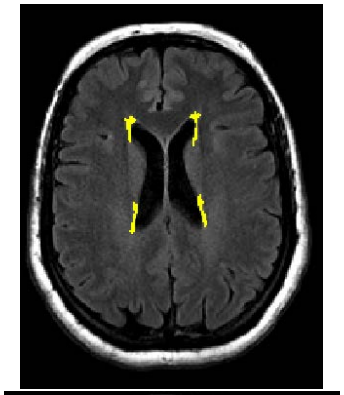
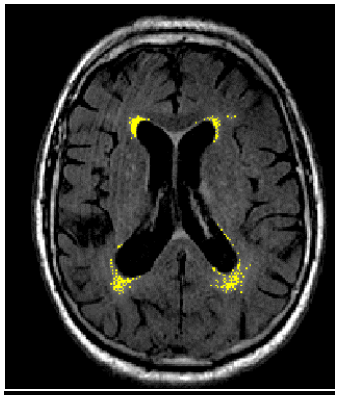
Stroke and Leukoaraiosis

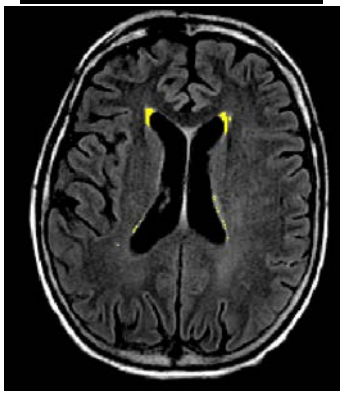


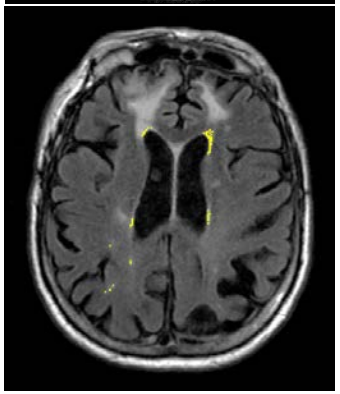












Problem

- Segment white matter hyperintensity in T2-FLAIR MRI
  - Leukoaraiosis vs. chronic stroke
  - Analyze with clinical and genetic information
- What we know
  - Leukoaraiosis occurs roughly symmetrically
  - Both leukoaraiosis and chronic stroke appear hyperintense

Outline

- Our approach
  - Generative model
  - Algorithm
- Results
- Population analysis teaser

Our Approach

- Similar to EM-segmentation
- PCA model on leukoaraiosis segmentation maps
  - Learn from a training set
- If not leukoaraiosis – either stroke or white matter
  - Estimate from the input image

Our Model

- Three tissue classes: **L**eukoaraiosis, **S**troke, **H**ealthy

  C_x is a 3-vector with only one 1

- Given the tissue class, intensity is Gaussian:

  $I_x \mid C_x(c)=1 \sim \mathcal{N}(\mu_c, \sigma_c)$ where c is one of $\{L,S,H\}$

- Generative process:
  - Sample leukoaraiosis from a prior model
  - If not leukoaraiosis, either stroke of healthy
  - Make sure it's all "smooth"

Spatial Priors

- Tissue priors

$$\pi_x = [\, M_x(\alpha) \quad (1 - M_x(\alpha))\beta_x \quad (1 - M_x(\alpha))(1-\beta_x) \,]$$

- Spatial prior model on M_x and β_x:
  - Leukoaraiosis prior: PCA

$$M_x = \mathbf{M_0} + \Sigma_k \alpha_k \mathbf{M_k} \quad \text{where} \quad \alpha \sim \mathcal{N}(\mu_{shape}, \Sigma_{shape})$$

  - Tissue smoothness: Markov Random Field

$$P(C|\alpha,\beta) \sim \Pi_c \pi_x^{C(c)} \Pi_y \exp(C_x' \mathbf{A} C_y)$$

Optimization

- Approximate EM
  - Replace integration over shape parameters **α** with a weighted projection onto the space of the eighenvectors
- Output:
  - In each voxel, posterior probability for each tissue class
  - Parameters of the model:
    - » shape parameters ***α***
    - » intensity parameters for each class ***μ, σ***
- Iterative algorithm
  - Given the current guess (posterior probabilities)
    - » project onto the PCA space => estimate ***α***
    - » estimate image intensity parameters ***μ, σ***
  - Run mean-field on the MRFs
    - » estimate posterior probabilities

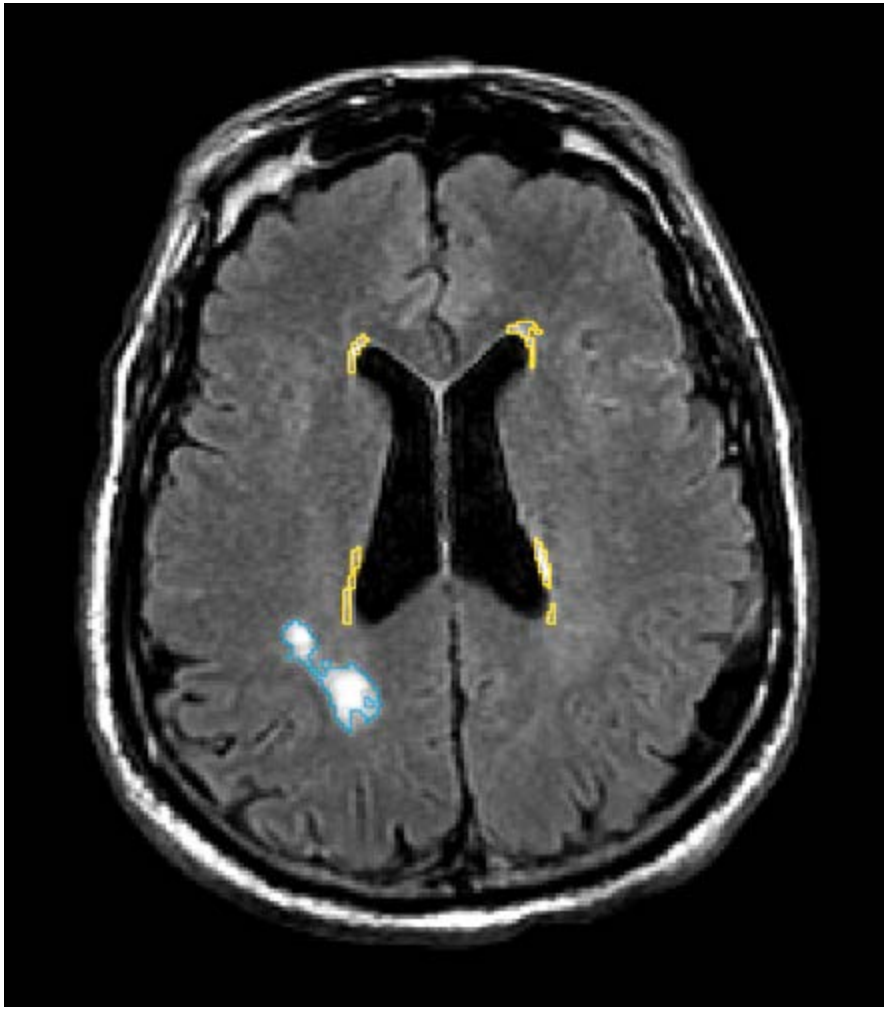
Registration

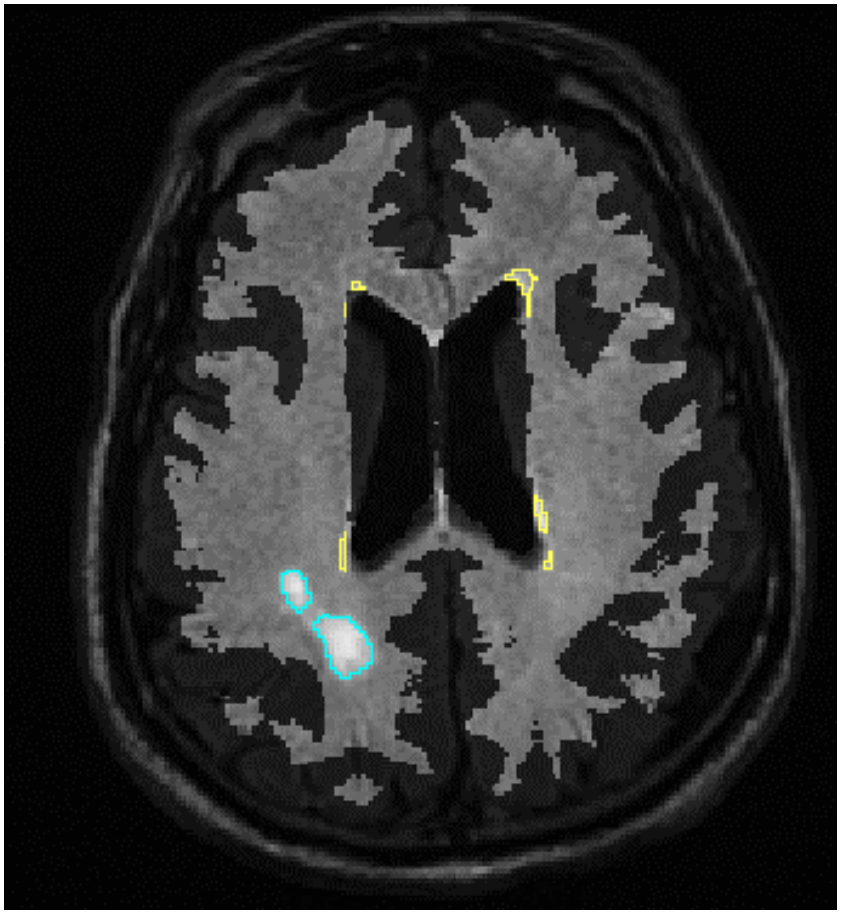
- Original version:
  - Register T2-FLAIR to T1 anatomical
  - Register T1 to the atlas
- Current version:
  - Make a T2-FLAIR atlas
  - Register T2-FLAIR to T2-FLAIR atlas
- Current and future work:
  - Super-resolution to help registration

Data

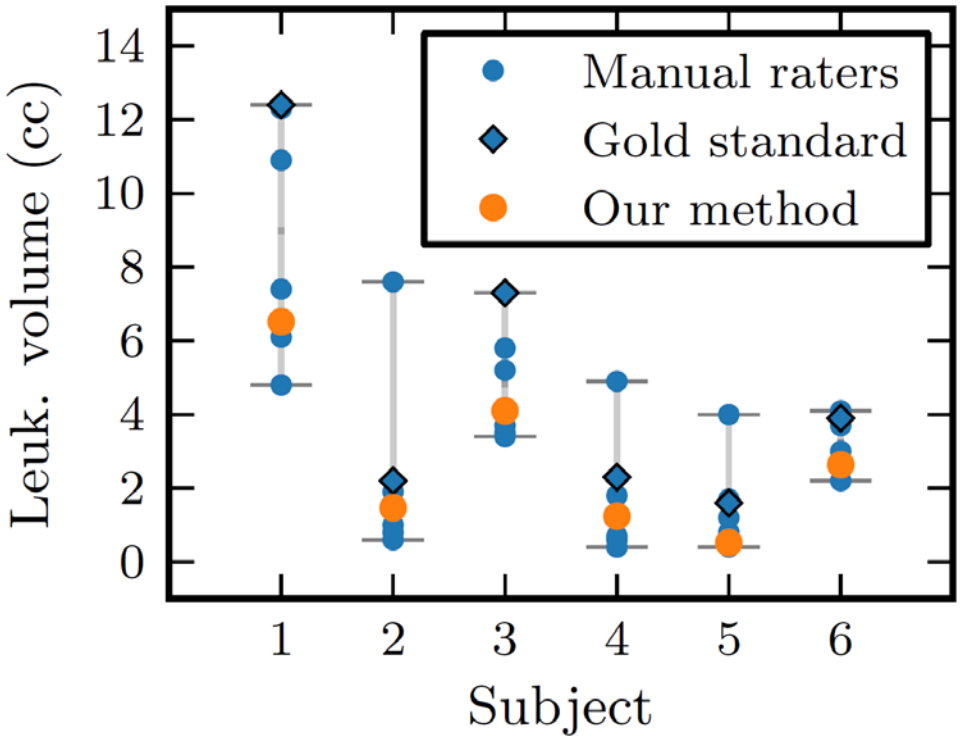
- Close to 1,000 scans of stroke patients
- Training set: 40 of the patients whose scans registered well with the atlas
- Test set: 200 different patients from this data set
- For each patient, we obtain
  - Sagittal T1 scan 1mx1mx7m
  - Axial T2 FLAIR scan 1mx1mx7m
  - Leukoaraiosis was manually segmented in these images, enabling training and validation

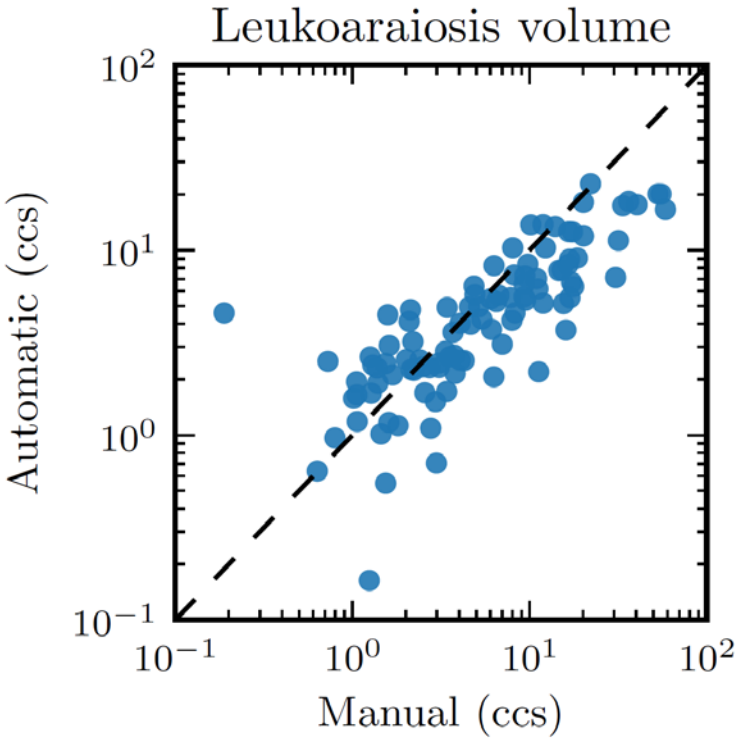
Example Segmentations



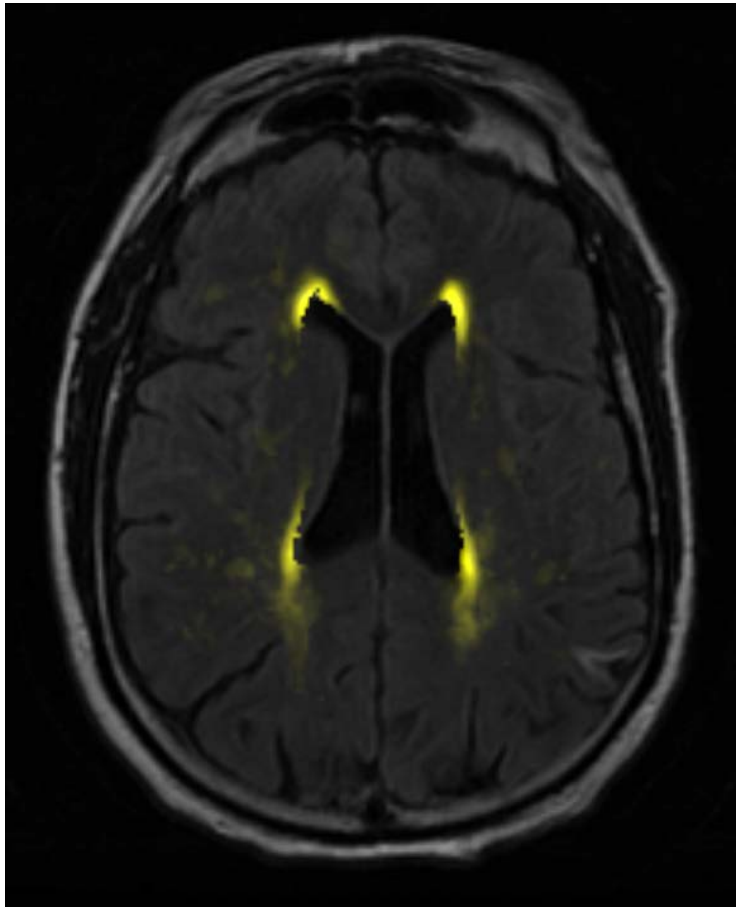


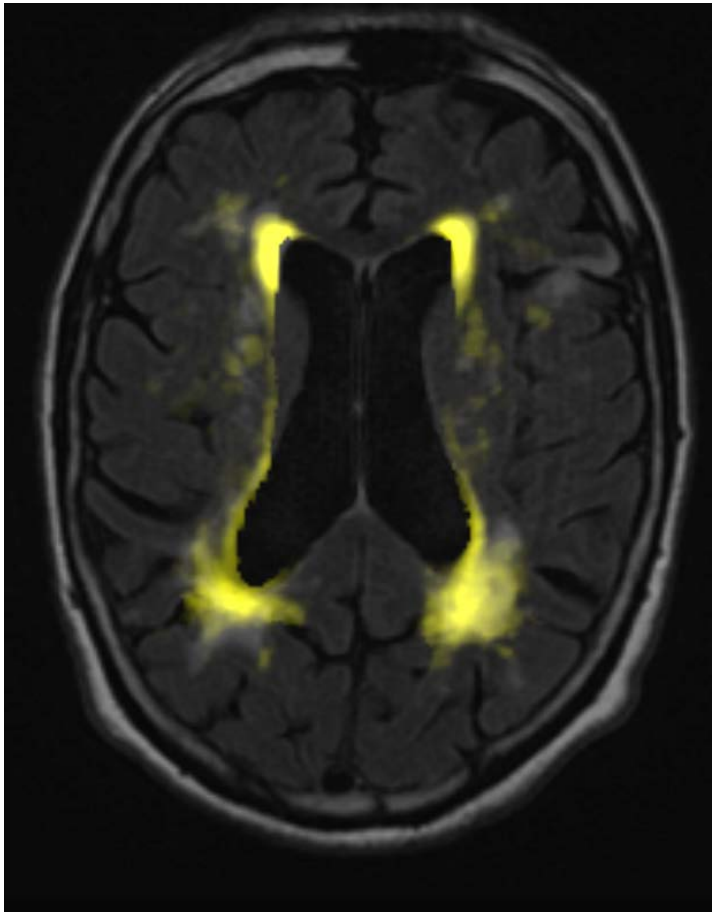
Quantitative Evaluation



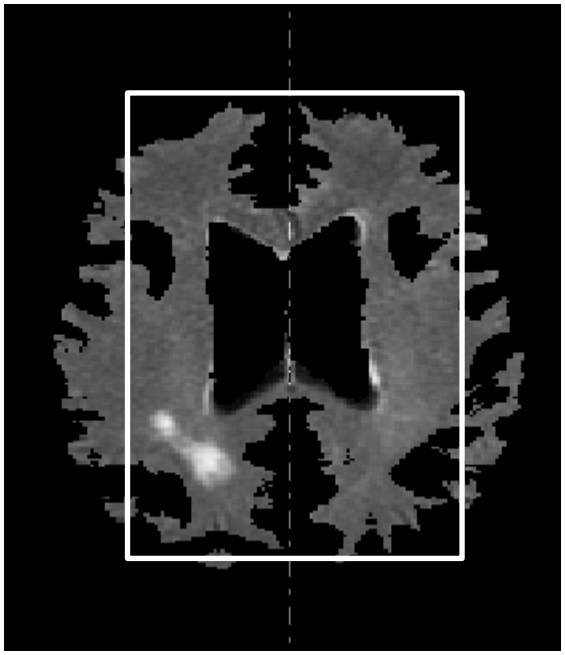


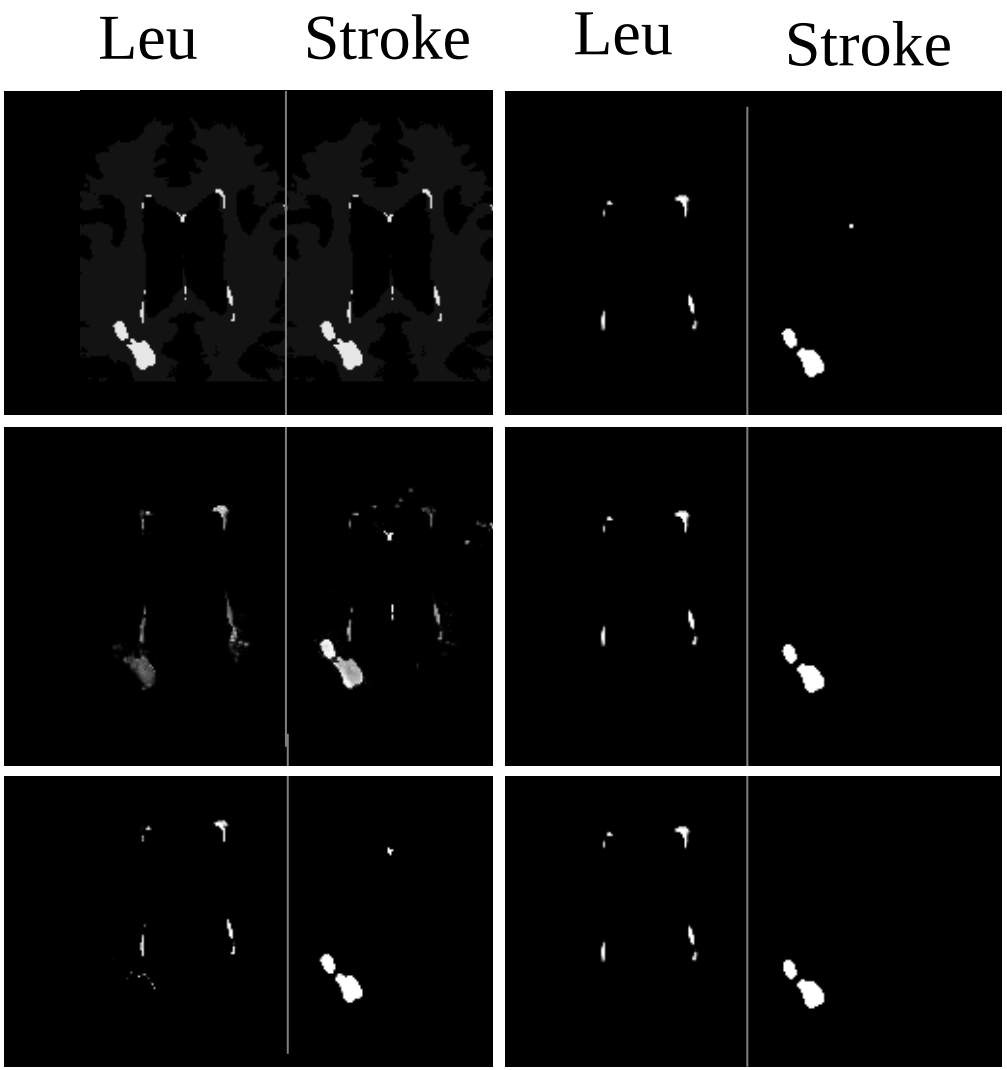
Projections



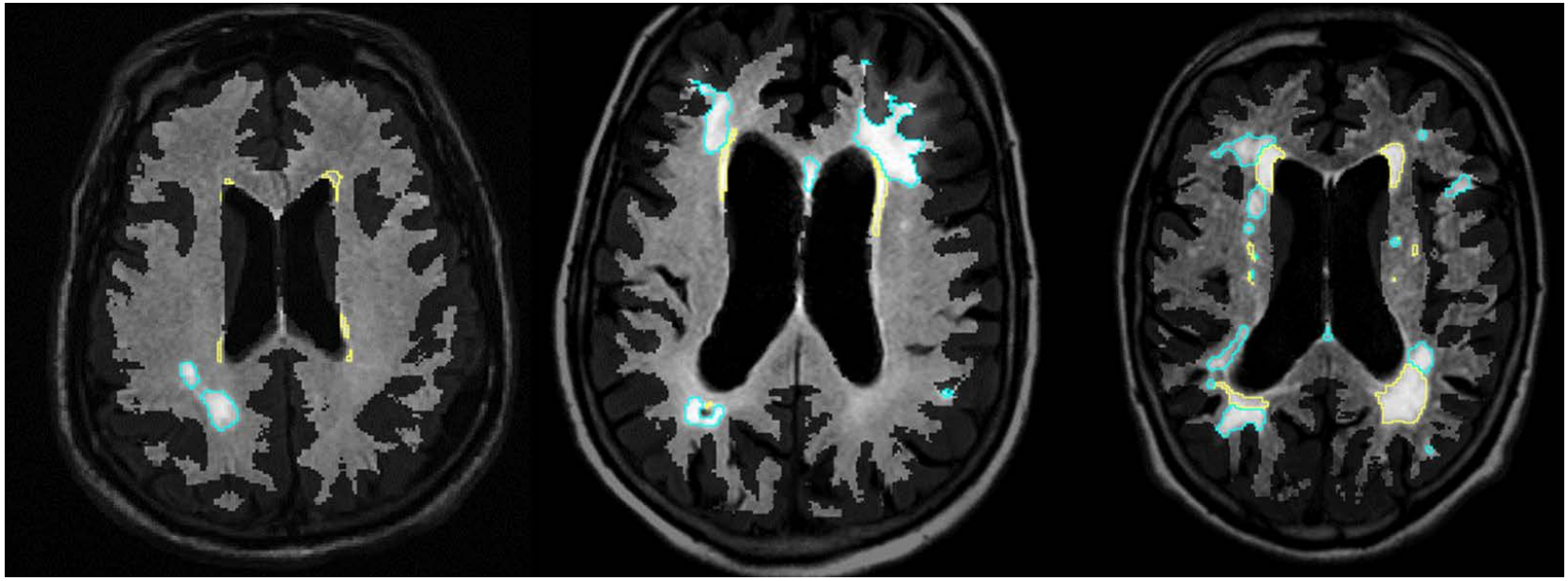


Iterations



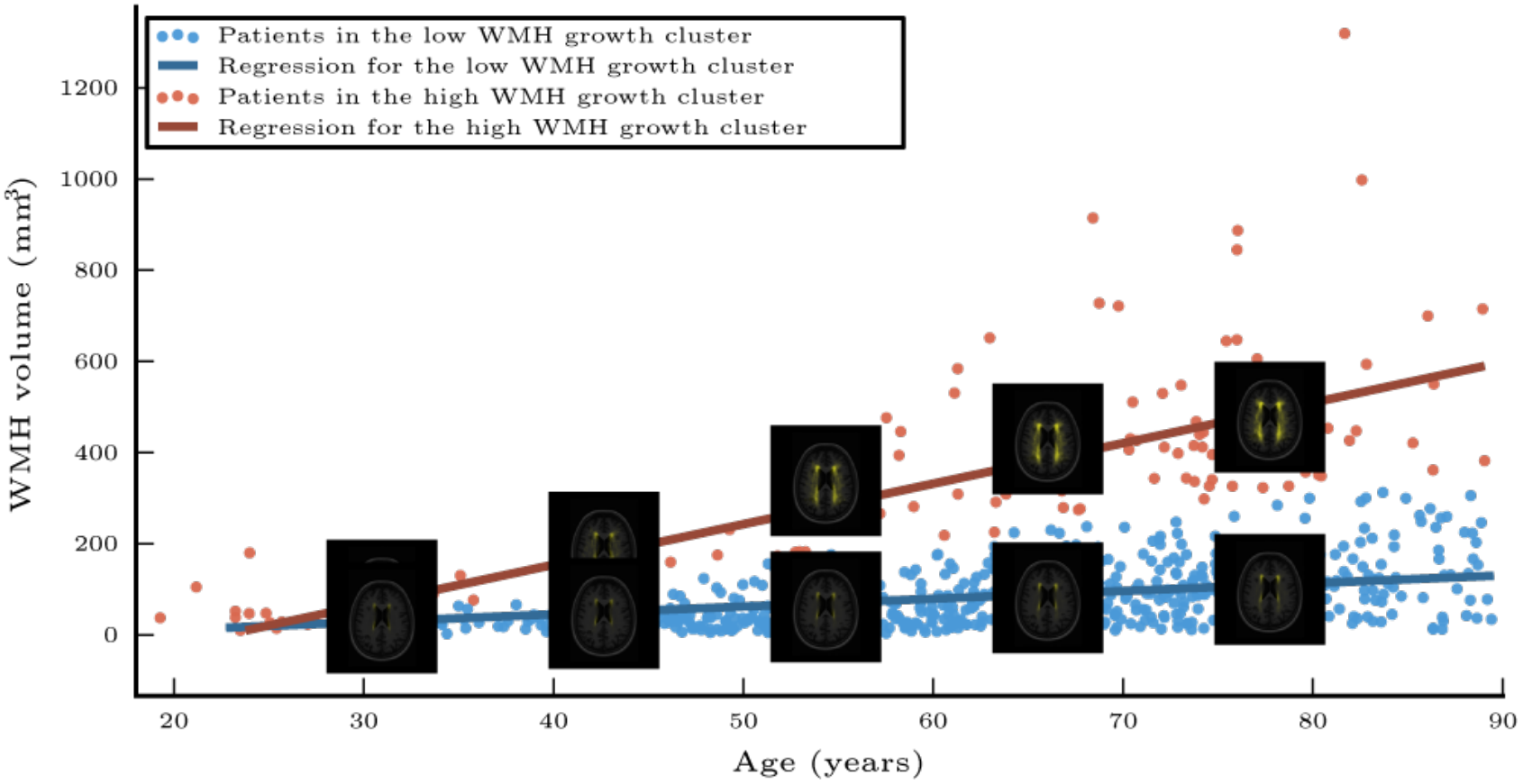


Failure Cases

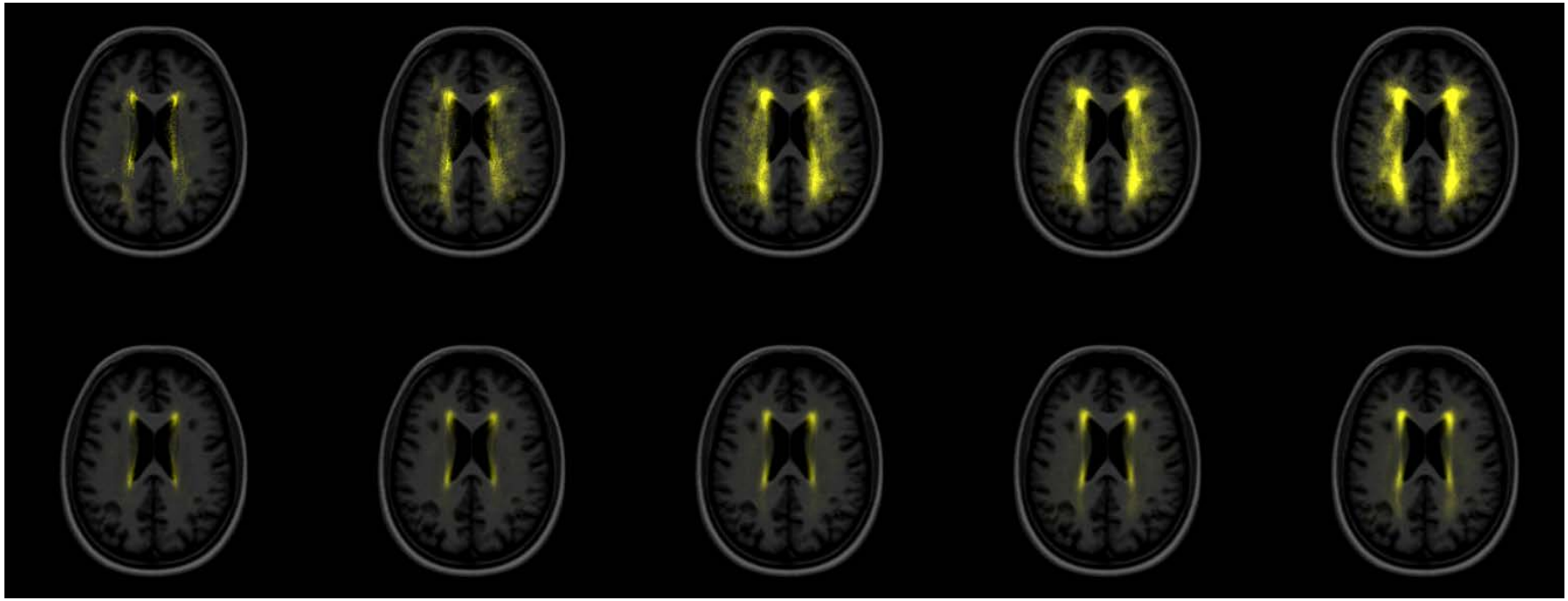


- Problems with registration
- A lot of white matter hyperintensity

Population Analysis



Population Analysis (cont'd)

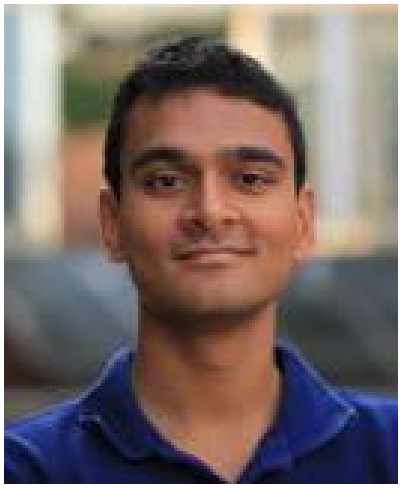


31y 42.5y 54y 65.5y 77y

Thanks

- Adrian Dalca, Ramesh Sridharan
- Our clinical collaborators at MGH: Natalia Rost

- Support:
  - NAMIC: National Alliance for Medical Image Analysis
  - NAC: Neuroimaging Analysis Center



Conclusions

- Accurate model-based segmentation of white matter hyperintensities
  - PCA model captures leukoaraiosis distribution properties
  - MRF regularizes stroke shape
  - Intensity model for each class
- Many clinical applications: stroke, MS, aging, etc.
- Current and future research
  - Registration
  - Multi-site analysis
  - Joint analysis with genetics and clinical information