Whole brain image registration using multi-structure confidence-weighted anatomic constraints

Ali R. Khan, Mirza Faisal Beg

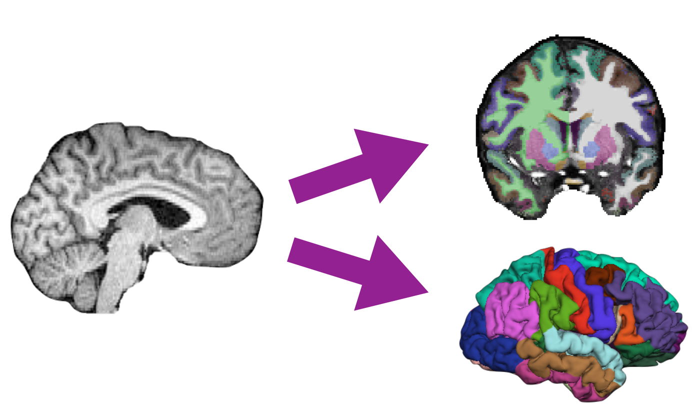
Simon Fraser University, Canada

Introduction

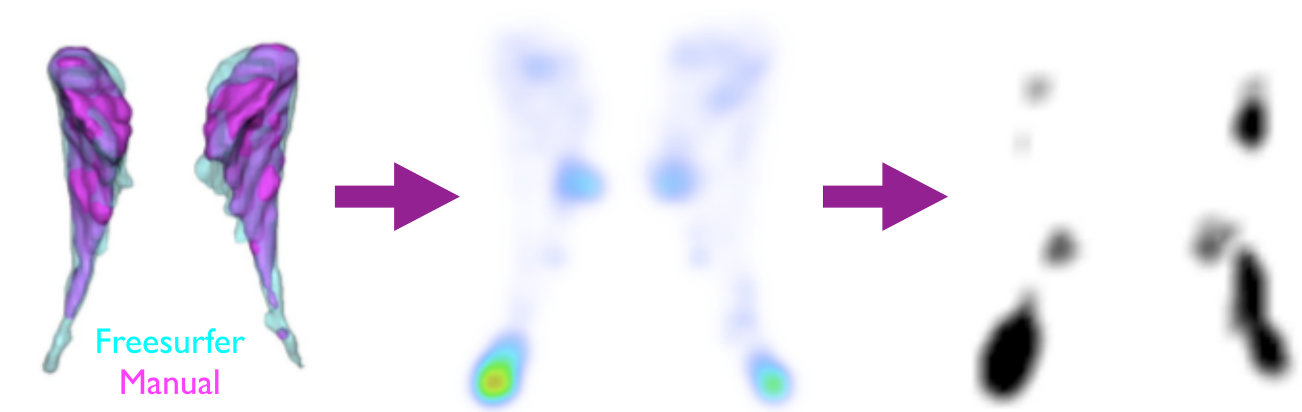
- Inter-subject registration of whole brain magnetic resonance images
  - Challenging: high anatomical variability, convoluted folding of the cortex
  - Applications: morphometry, functional localization, atlas creation
- Our approach:
  - Use automated Freesurfer [1] segmentations of multiple brain structures as simultaneous anatomic constraints (multi-structure registration), instead of as initialization [2]
  - Weight these using trained segmentation confidence maps (SCMs)
  - Large deformation diffemorphic framework for registration (LDDMM [3])

Methods

1. Run Freesurfer
   - Subcortical and cortical
     - Fully automated segmentation
   - Segmentation errors?
     - Train confidence maps

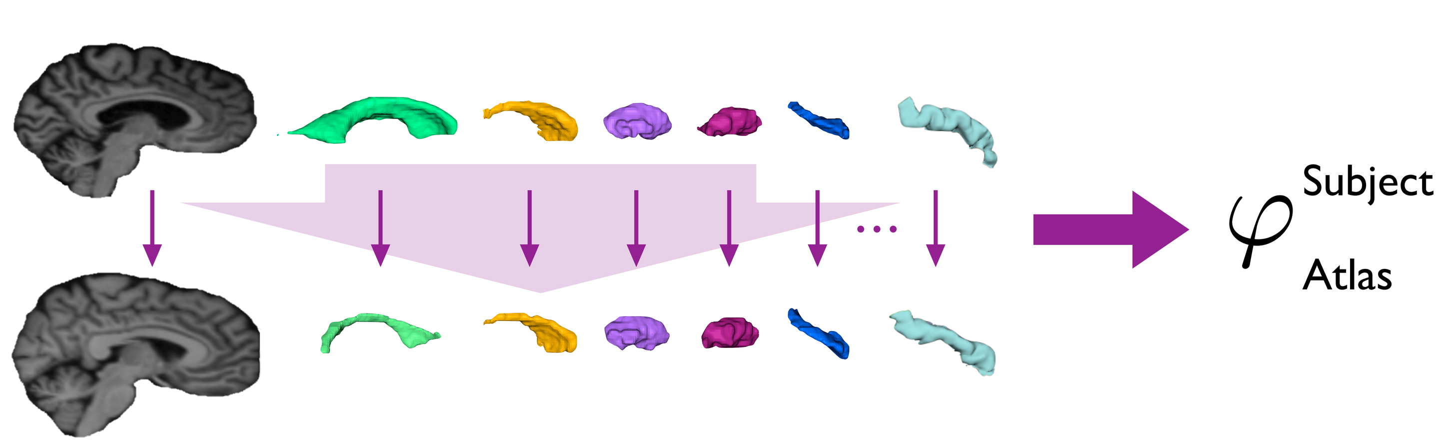


2. Train segmentation confidence maps for each brain structure
   - For each training subject:
     a. Find local errors between manual and automated structure
     b. Spatially normalize these to the atlas
     c. Compute SCM as probability of accuracy



Segmentations   Error map   SCM

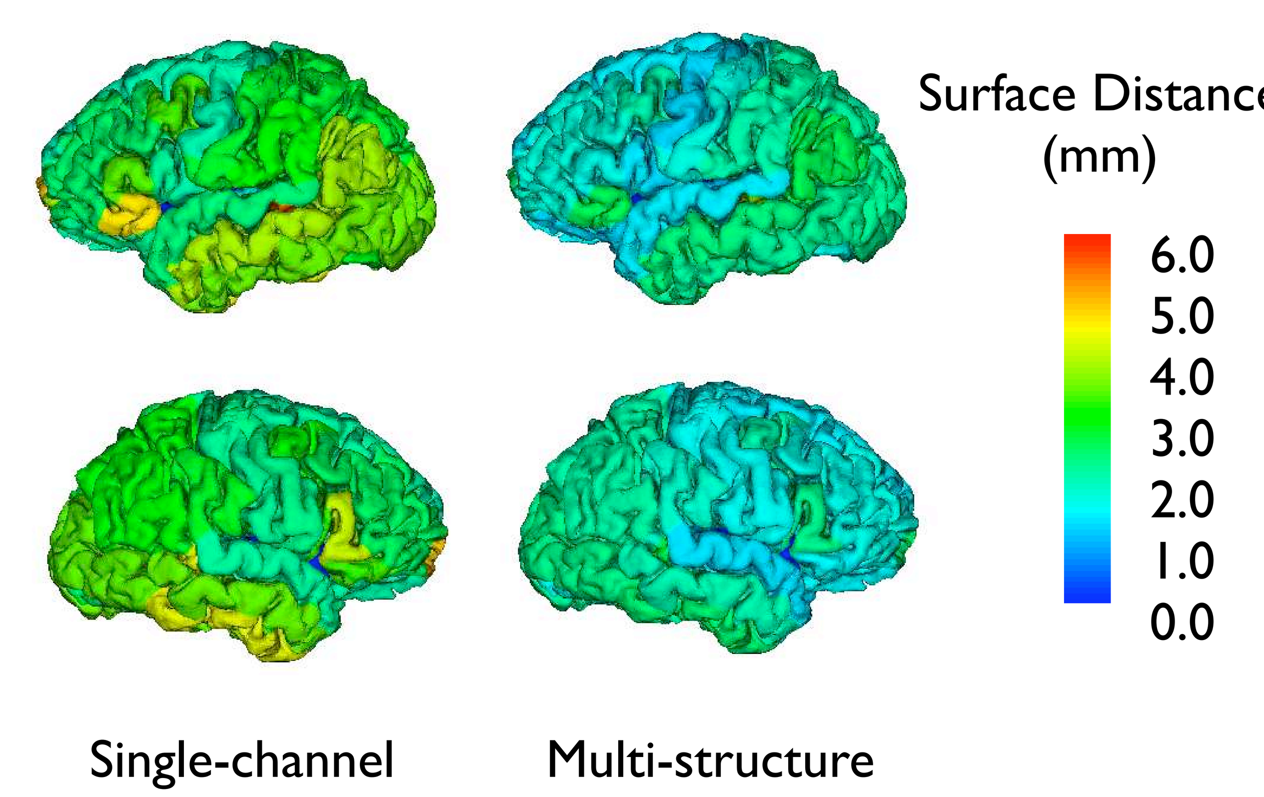
3. Perform multi-structure confidence-weighted LDDMM registration to atlas
   - 16 subcortical, and 35 cortical structures used in the multi-structure registration
   - Provides anatomical constraints to help guide the high-dimensional registration



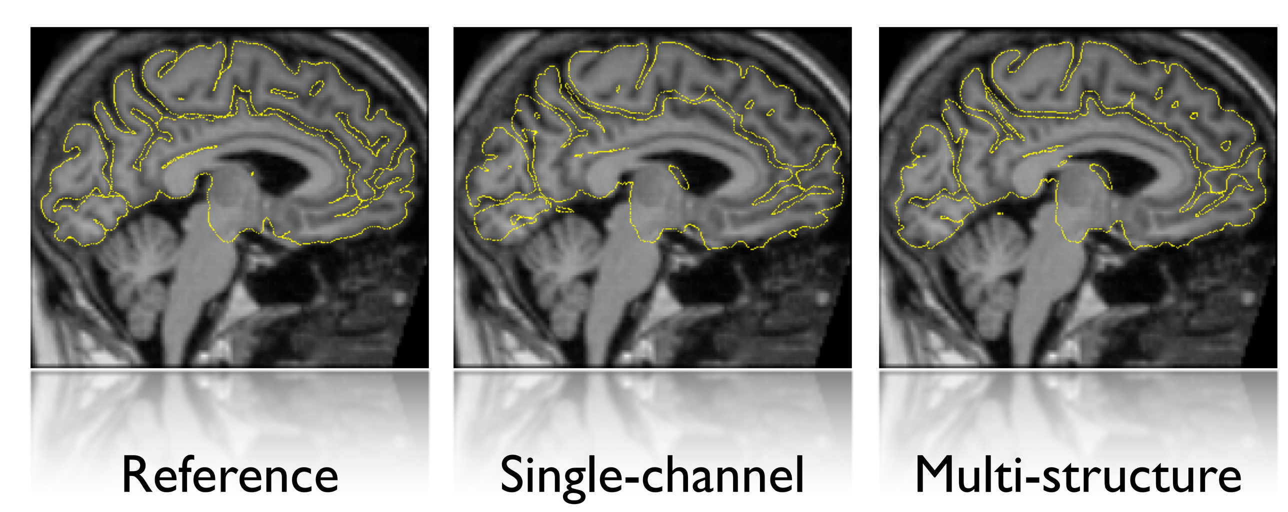
Results

- Multi-structure confidence-weighted LDDMM registration compared against:
  - Free-form Deformation B-splines, IRTK [4]
  - Single channel LDDMM
- 1.5T brain MR scans brains from the Internet Brain Segmentation Repository (IBSR) [5]
  - 9 brains used for training SCMs, other 9 brains used for testing image registration

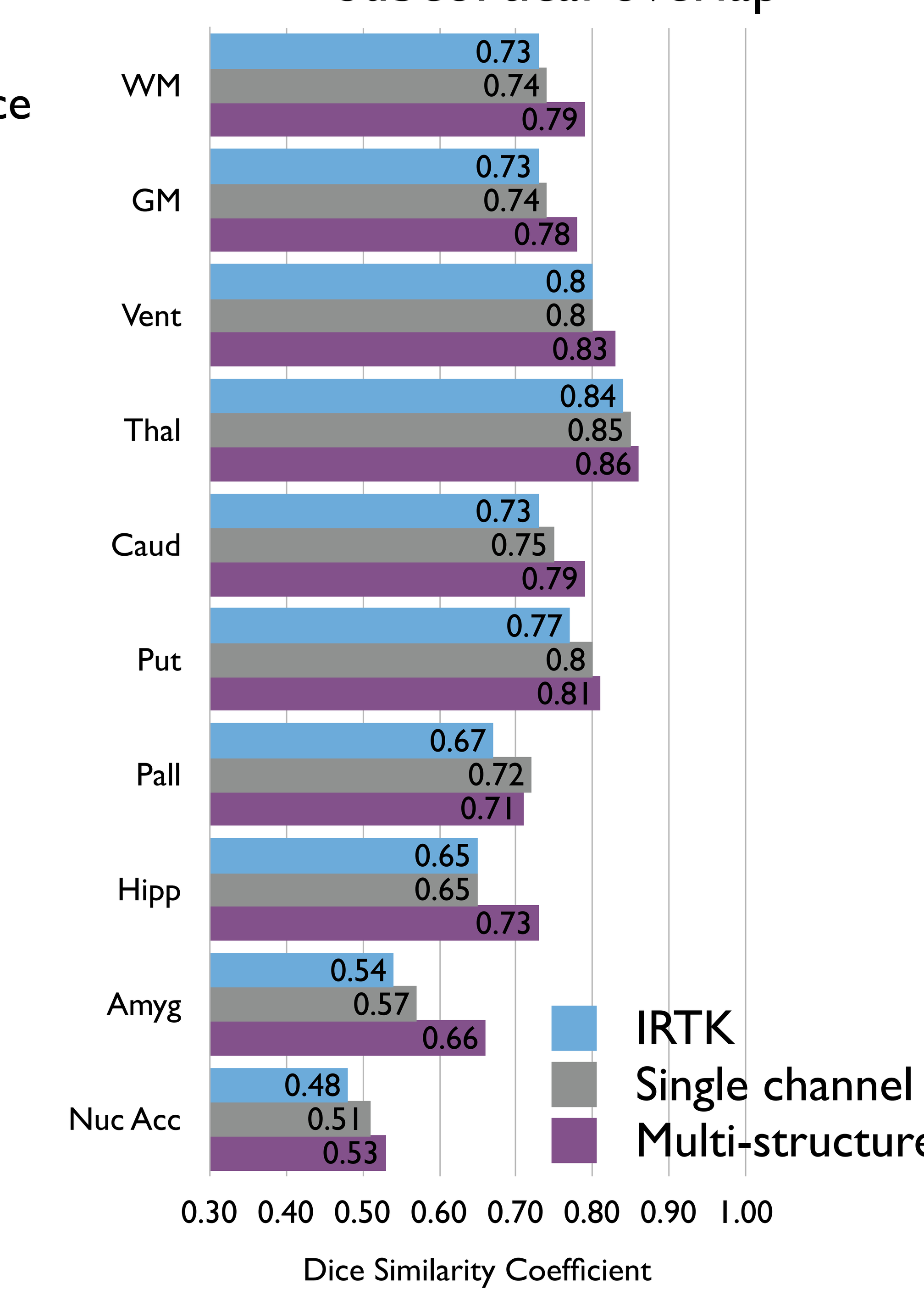
Cortical surface distances



Propagated cortical surfaces



Subcortical overlap



Conclusions

- Anatomical constraints, in the form of automated segmentations, can improve brain registration
  - More accurate volumetry, morphometry, or functional localization in brain mapping studies
- Limitations:
  - SCMs generated for subcortical structures only; future work will include cortical SCMs
  - High computational cost with LDDMM; requires high-performance computing machines

SFU SIMON FRASER UNIVERSITY THINKING OF THE WORLD

MIAL Medical Image Analysis Lab

NSERC CRSNG

References

[1] B. Fischl, et al., "Whole brain segmentation automated labeling of neuroanatomical structures in the human brain," Neuron, vol. 33 (3), pp. 341–55, 2002.

[2] A. R. Khan et al., "Freesurfer-initiated fully-automated subcortical brain segmentation in MRI using large deformation diffeomorphic metric mapping," Neuroimage, vol. 41 (3), pp. 735–46, 2008.

[3] M. F. Beg, et al., "Computing large deformation metric mappings via geodesic flows of diffeomorphisms," International Journal of Computer Vision, vol. 61 (2), pp. 139–57, 2005.

[4] Rueckert et al., "Nonrigid registration using free-form deformations: application to breast MR images," IEEE Transactions on Medical Imaging, vol. 18 (8), pp. 712–21, 1999.

[5] IBSR data was provided by the Center for Morphometric Analysis at Massachusetts General Hospital and is available at http://www.cma.mgh.harvard.edu/ibsr/.

Medical Image Analysis Lab, School of Engineering Science
Simon Fraser University, 8888 University Dr, Burnaby, BC, V5A 1S6, Canada

Ali R. Khan (akhanf@sfu.ca), Mirza Faisal Beg (mfbeg@ensc.sfu.ca)
Website: http://www.autobrainmapping.com