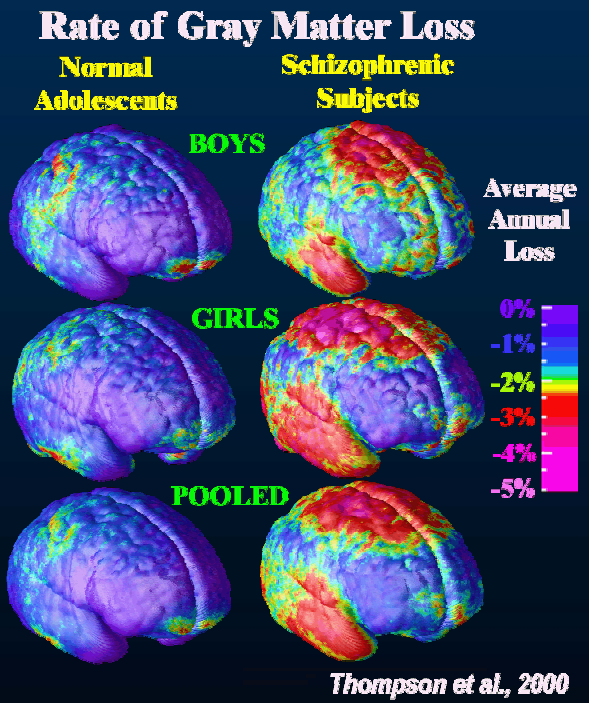
Center for
Computational
Biology (CCB)

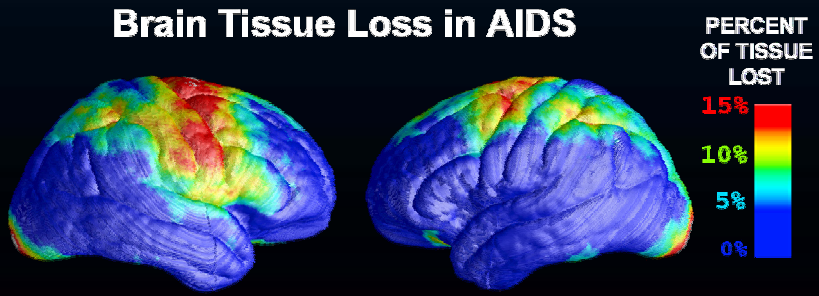
CCB Computational Tool: Automated Cortical Feature Extraction and Modeling

Duygu Tosun

“Human Brain Mapping”



Thompson et al., 2000

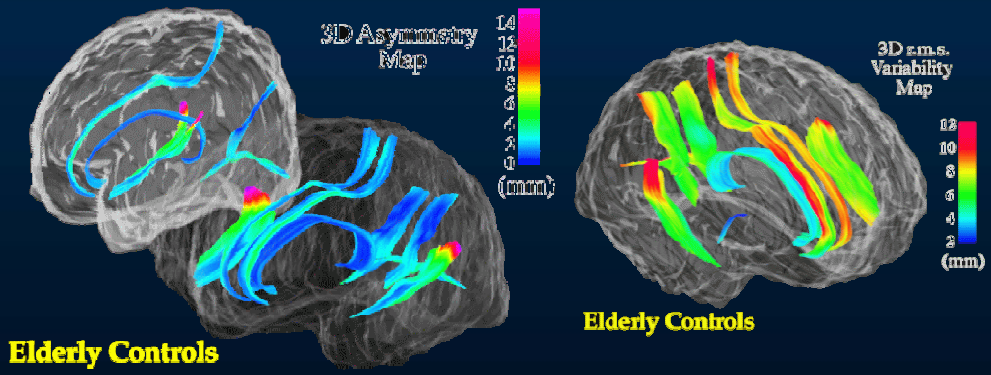


Thompson et al., 2005

- Explore the spatial and temporal organization of the neural systems supporting human behaviour
- Both normal and clinical populations
- Variability within a population

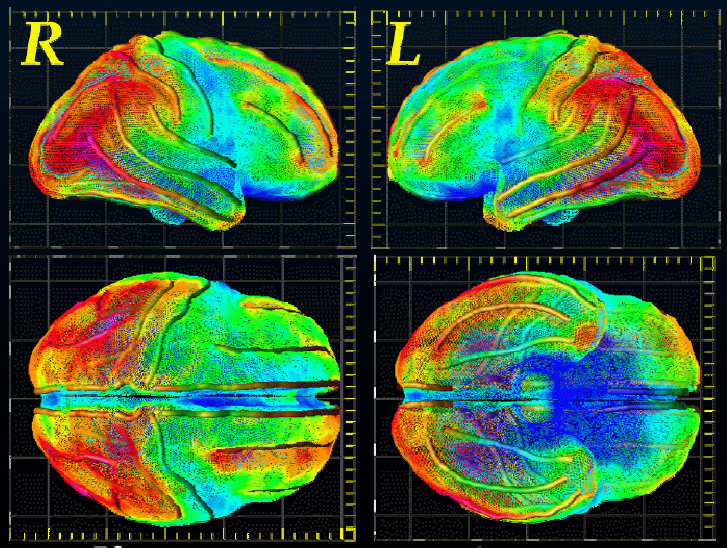
“Human Brain Mapping”

Cortical Variability and Asymmetry



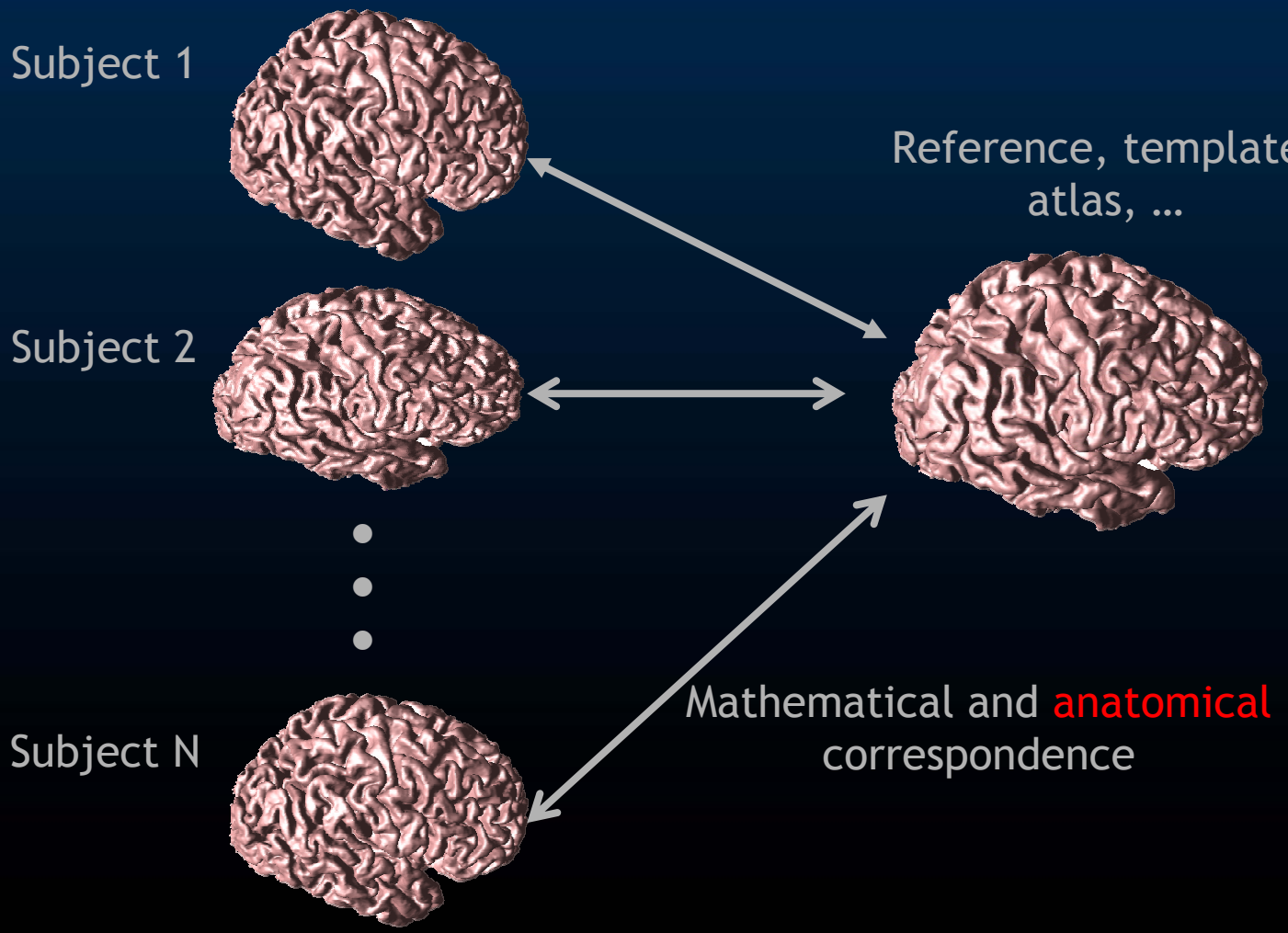
- Explore the spatial and temporal organization of the neural systems supporting human behaviour
- Both normal and clinical populations
- Variability within a population

Alzheimer



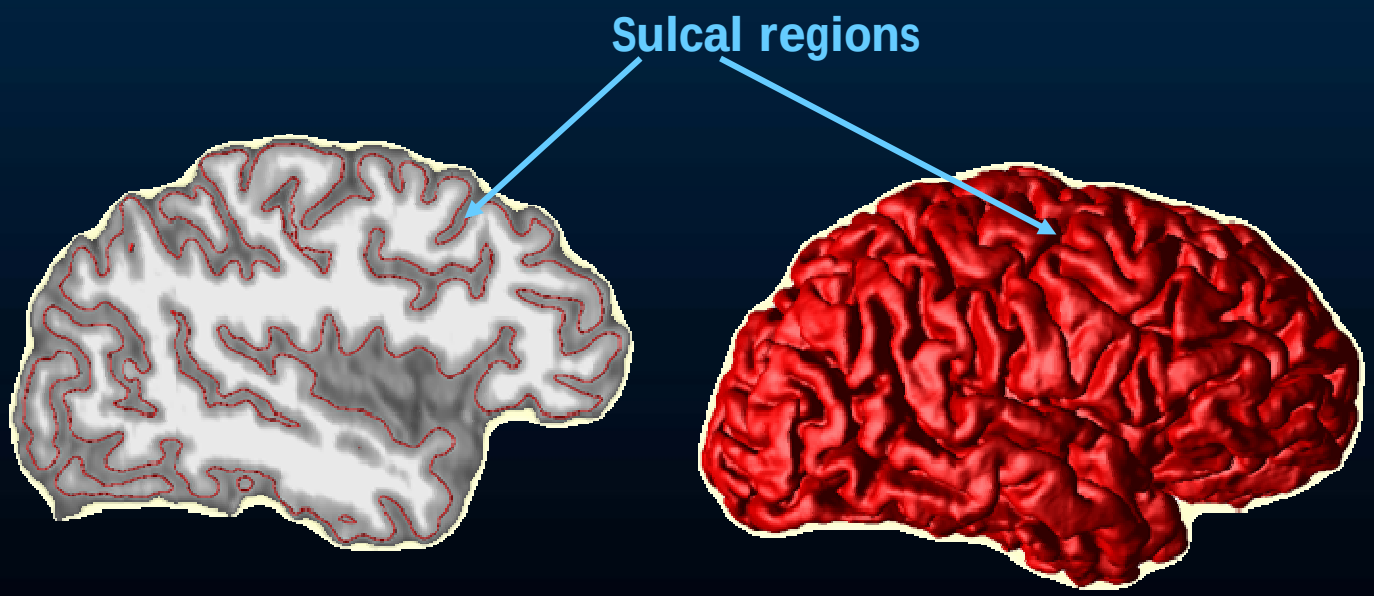
A Framework for Computational Anatomy

Compare, pool, and average data within and across populations

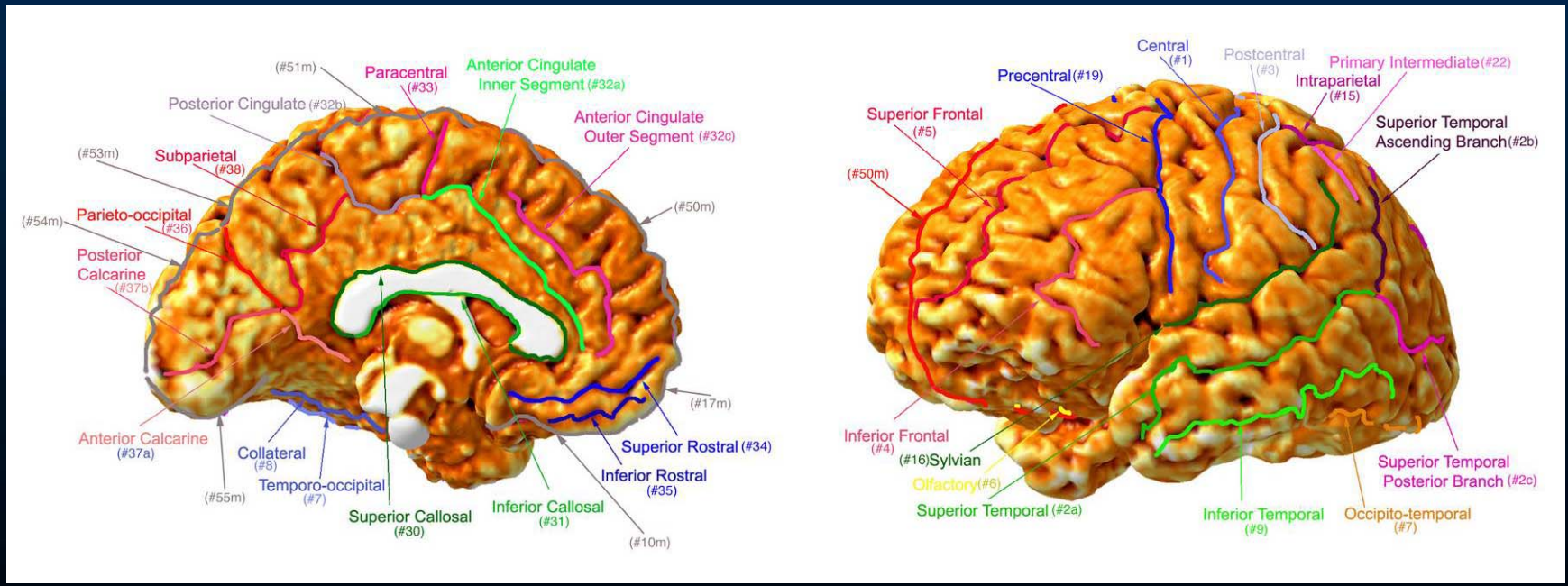


What are the Key Cortical Features?

•The most unique morphological features of the human cerebral cortex are its 3-D folds

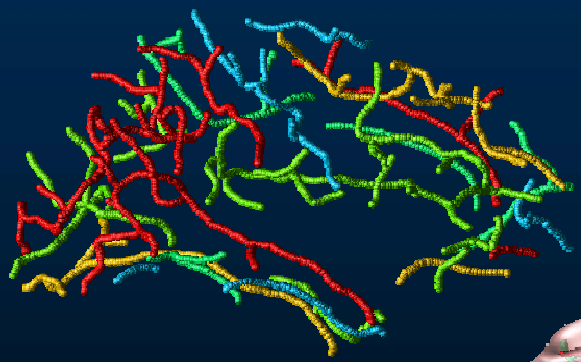


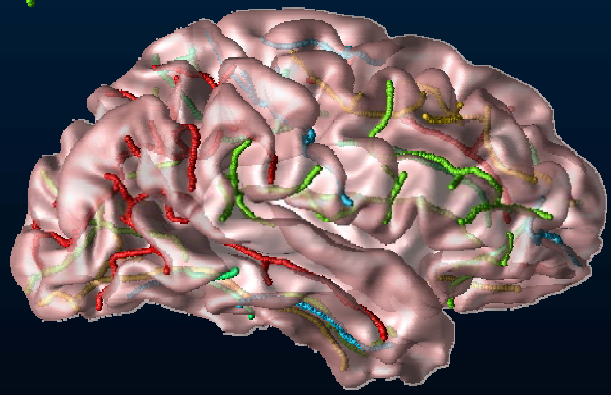
Imposing Anatomical Homology via Landmark Points/Curves

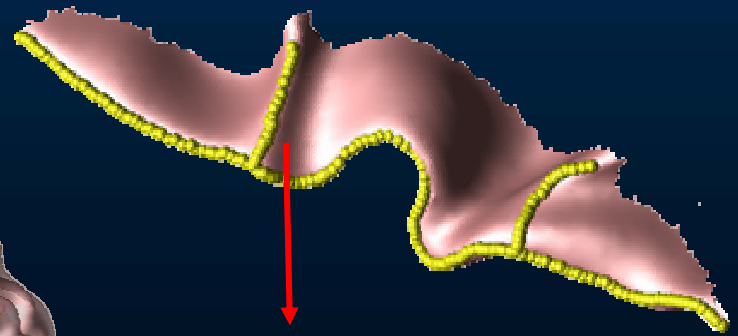


An example protocol to manually identify the cortical curves

Identification and Representation of Sulcal Regions







How to extract cortical features automatically?

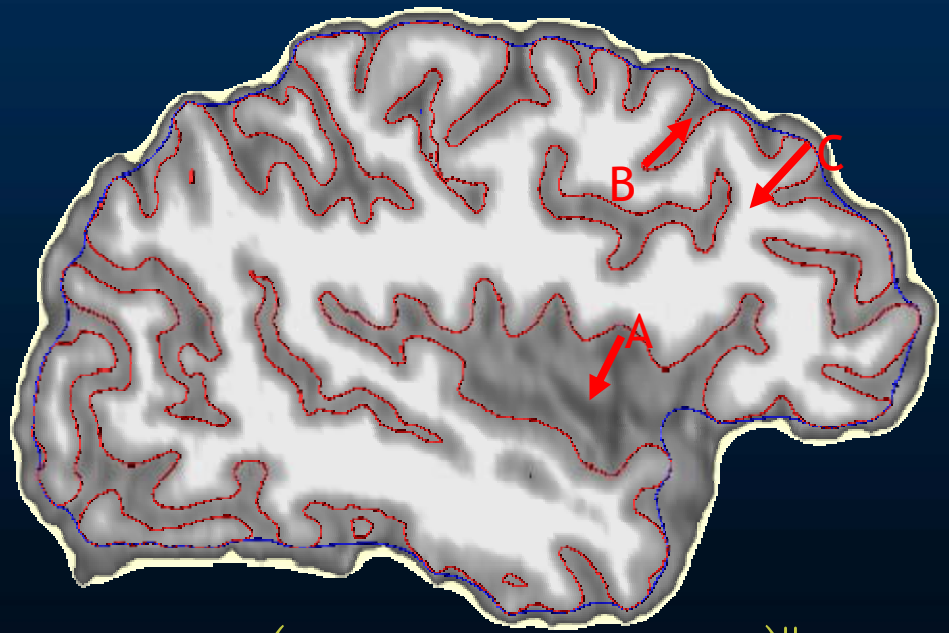
1. Segment sulcal region
2. Find curves of sulcal fundus

Software Tool

- Developed in C++
- Integrated into SHIVA as plugins
- http://www.loni.ucla.edu/Software/
- Mobile AMD Athlon 64 Processor 4000+, 1.00 GB RAM
- Suse Linux 10.1
- < 5 mins run time (segment 20-30 sulcal regions and identify curves of sulcal fundi)

1. Segment Sulcal Regions

Mean Curvature Flow with Barrier Force



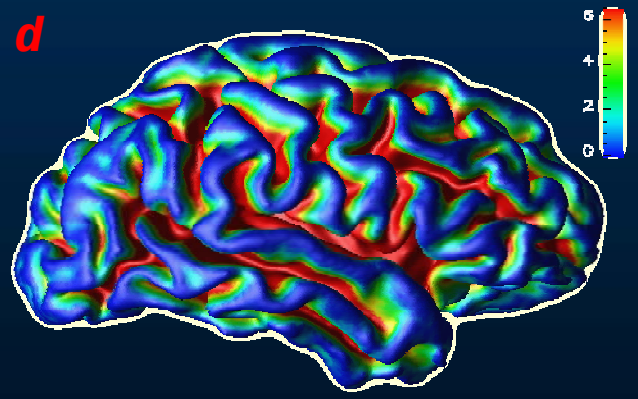
$$\phi_t(x,t) = \left(w_\kappa \kappa(x) + w_R R(x)\right)\left\|\nabla \phi(x,t)\right\|$$

Implicit representation of cortical surface (3-D)

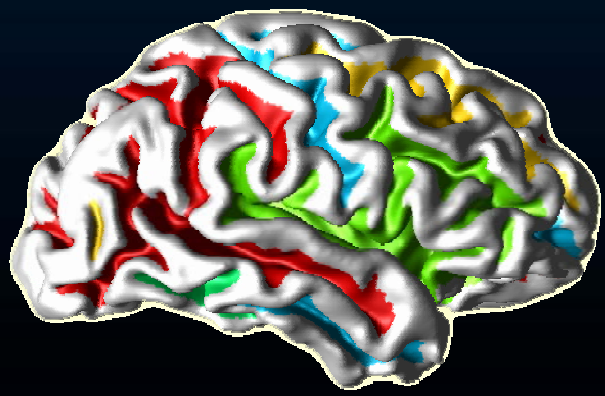
Mean curvature (unfolds cortical foldings)

Barrier force (anchors gyral crown points)

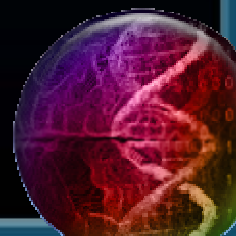
Geodesic Sulcal Depth From Outer Surface & Segmenting Sulcal Regions



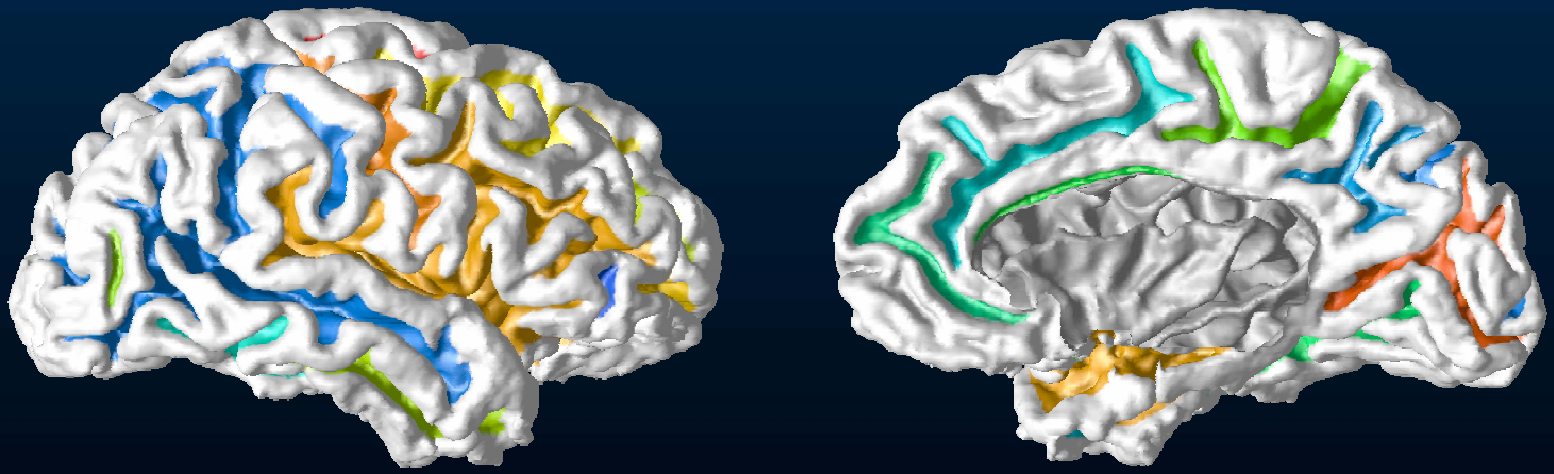
d>3mm



Segmented sulcal regions



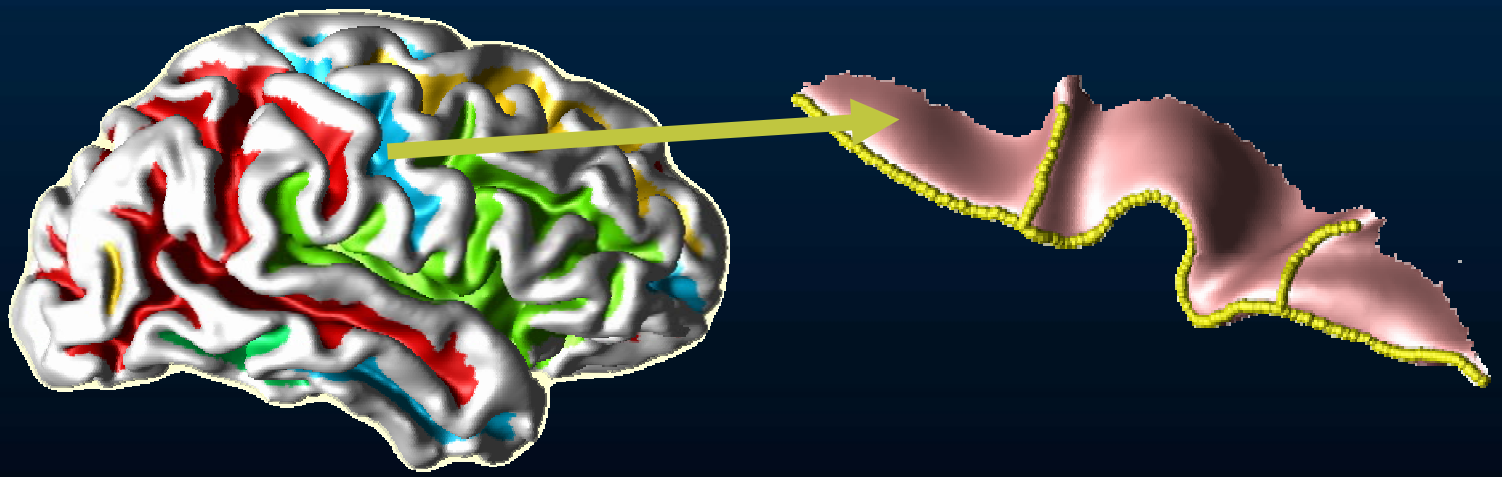
Segmented Sulcal Regions



Process left & right hemisphere separately in order to identify the sulcal regions in the medial surface.

2. Curves of Sulcal Fundi

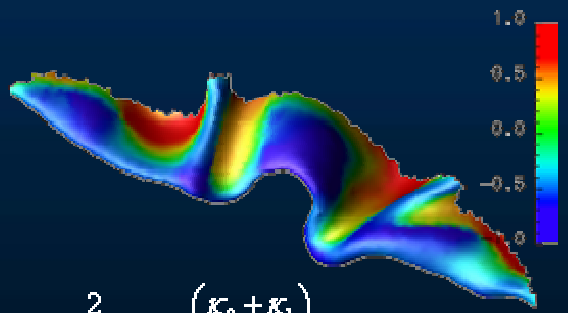
Sulcal Fundi Network



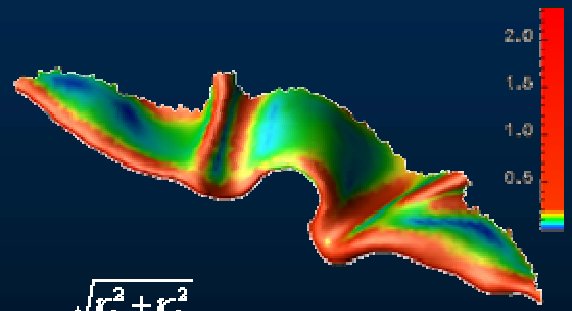
Process each connected component separately.

Automated Sulcal Fundus Extraction

Sulcal morphometry: Shape index (SI) and curvedness (C)



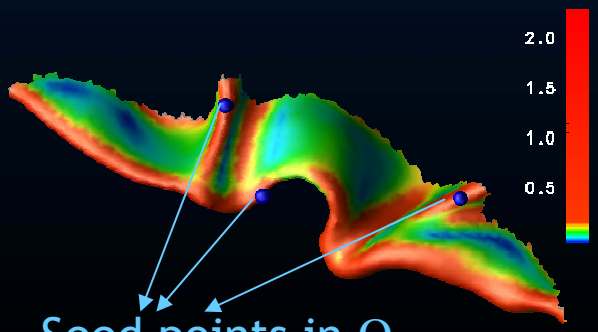
$$SI = \frac{2}{\pi}\arctan\left(\frac{\kappa_2 + \kappa_1}{\kappa_2 - \kappa_1}\right)$$



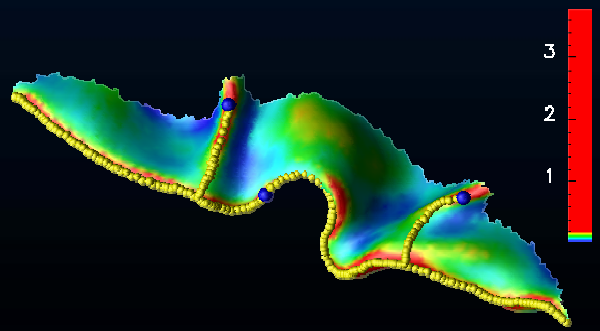
$$C = \frac{\sqrt{\kappa_1^2 + \kappa_2^2}}{2}$$

Fundal morphometry: Highly outward folding

i.e., Ω = {SI < 0 and C is maximal}



Seed points in Ω



Speed func. favoring high curvedness

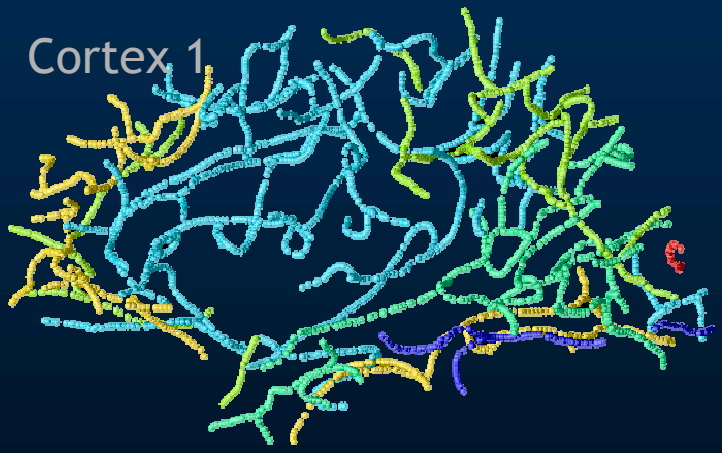
$$|\nabla T(x)| f(x) = 1$$

$$x \in Cortex$$

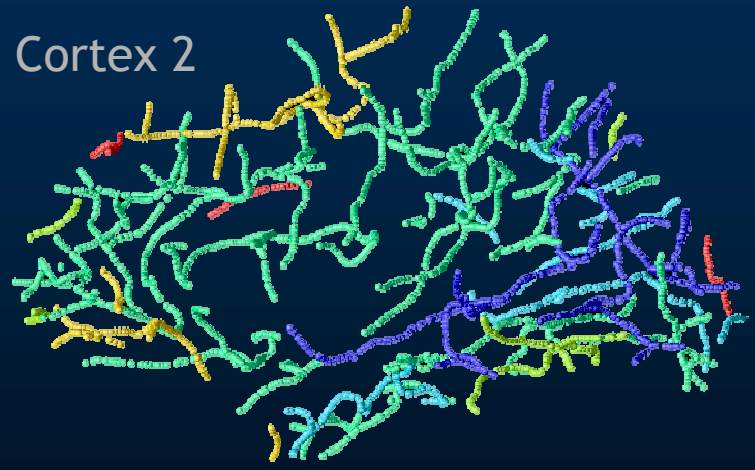
Track fundal curve following the fastest path to sulcal boundary

Examples

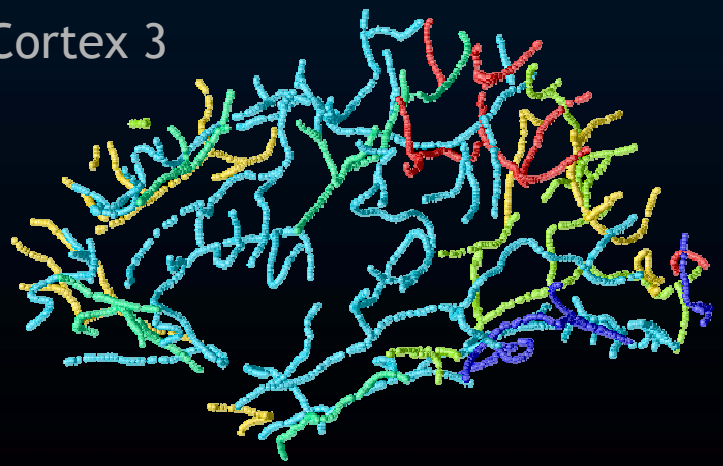
Cortex 1



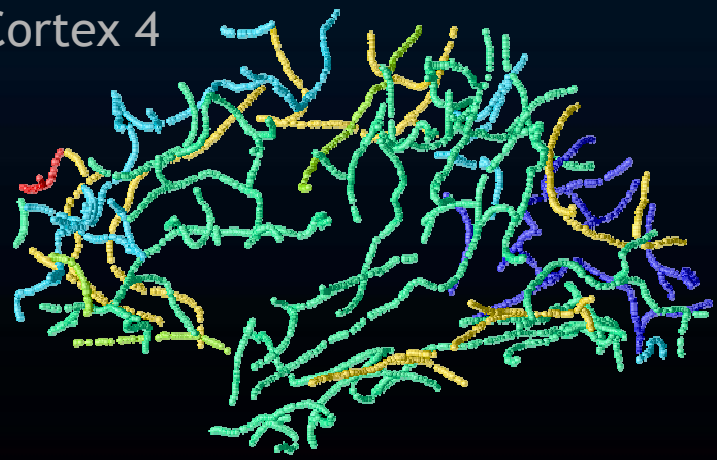
Cortex 2

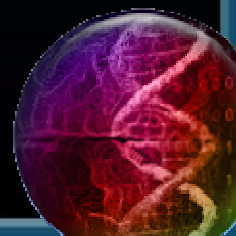


Cortex 3



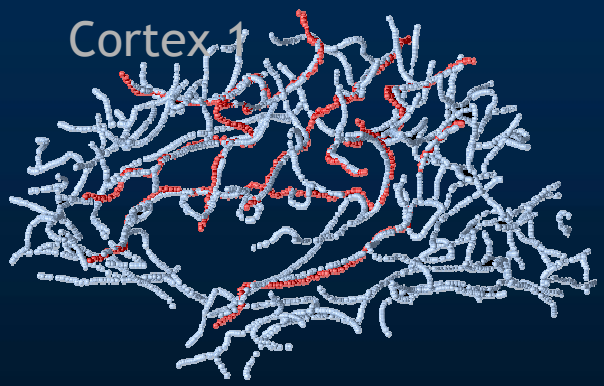
Cortex 4



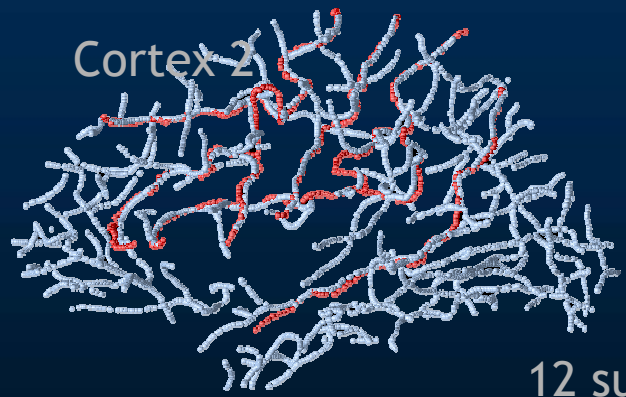


Manual vs Automated

Cortex 1



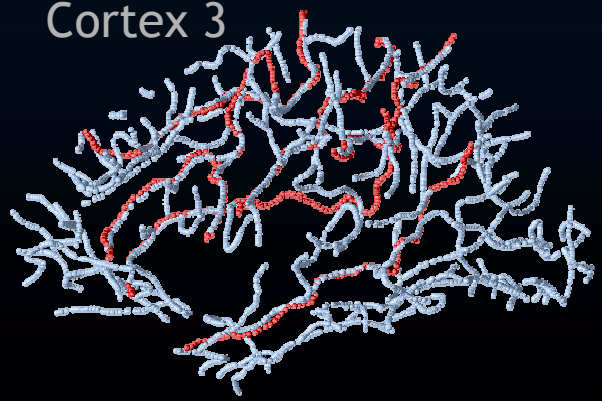
Cortex 2



12 subjects (50-80 years old)
(mean ± stdev in mm)

Central: 0.171 ± 0.509
Pre-central: 0.343 ± 0.779
Superior frontal: 0.605 ± 1.966
Inferior frontal: 0.774 ± 1.354
Superior temporal: 0.369 ± 1.249

Cortex 3



Cortex 4