Novel surface-smoothing based local gyrification index and its use in localizing changes in cortical folding in Alzheimer's Disease

Evgeniy Lebed, Eli Gibson, and Mirza Faisal Beg

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

elebed@sfu.ca egibson@sfu.ca mfbeg@sfu.ca

Introduction

Neurodegeneration

- Disruptions in cytoarchitecture at the micro and macroscopic scales due to disruptions in fetal development, or due to neurodegenerative diseases such as Alzheimer's can be manifested in the changes in the brain's folding patterns.
- Quantification of the folding patterns is an important task in the full computational pipeline as it has the potential to flag the onset of developmental changes or neurodegenerative pathologies.

Gyrification

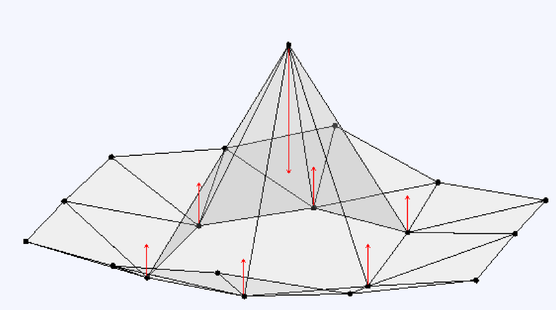
- A measure that quantifies the degree of folding of a cortical surface
- Used in conjunction with *intrinsic curvature index, folding index, roundness* and *average/mean curvature*.
- In 2D , Gyrification is defined as the ratio of lengths of the original curve, and a curve that defines the convex/semiconvex hull.
- In 3D (a 2D manifold in $\mathbb{R}^3$) Gyrification is defined as the ratio of surface areas.
- A convex hull may not provide anatomically-meaningful information, and semiconvex hull is usually created manually. We propose a fully automatic way of computing the semiconvex hull.
- Can be used as a local or a global measure

Methods

Laplacian mesh smoothing

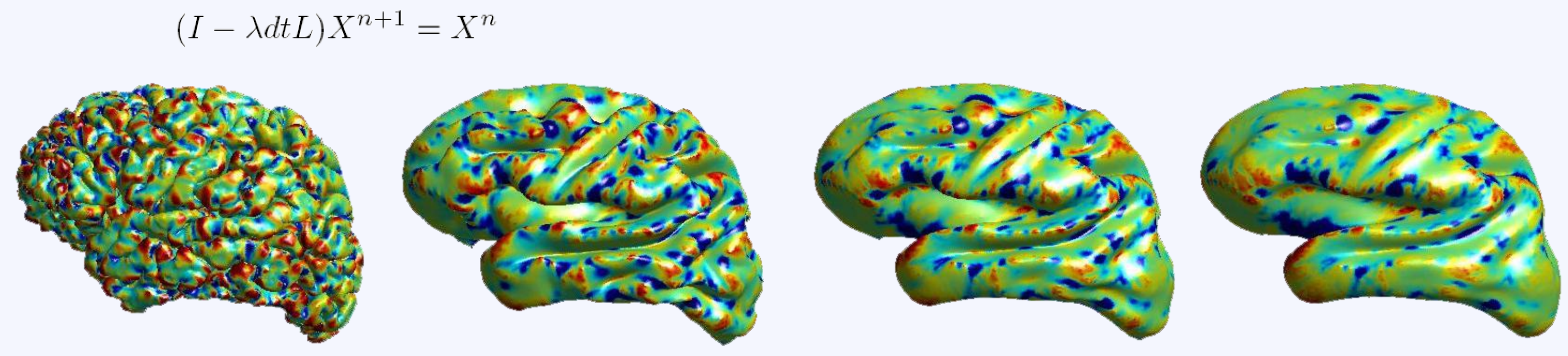
- Analogous to solving the heat equation

$$\frac{\partial X}{\partial t} = \lambda L(X) \quad \text{where} \quad L(x_i) = \frac{2}{\sum_{j \in N_1(i)} |e_{ij}|} \sum_{j \in N_1(i)} \frac{x_j - x_i}{|e_{ij}|}$$



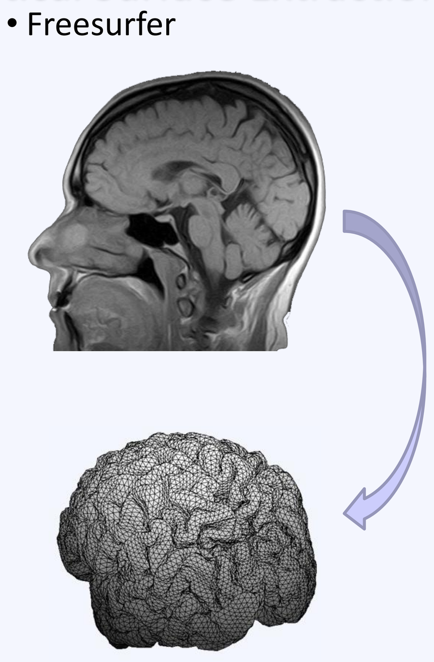
- Backward Euler numerical approximation

$$(I - \lambda dt L)X^{n+1} = X^n$$

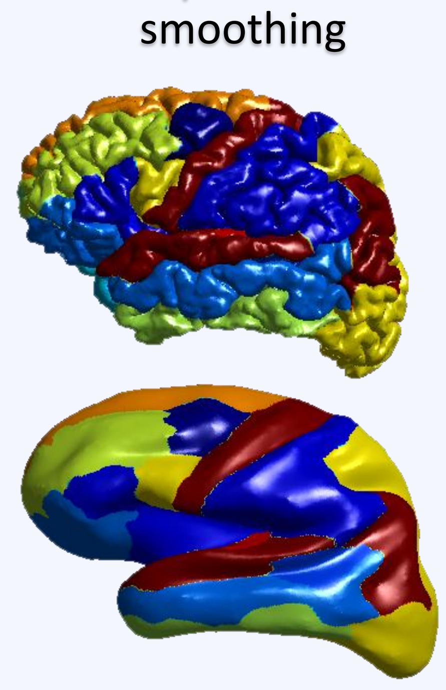


Cortical Surface Extraction

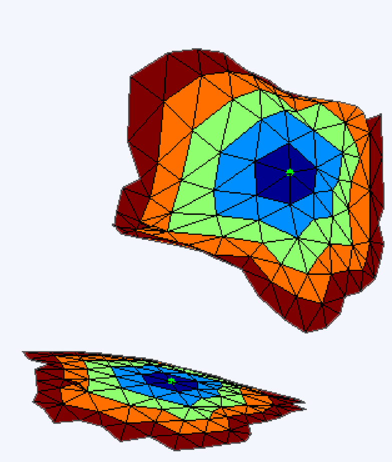
- Freesurfer



Mesh preservation smoothing



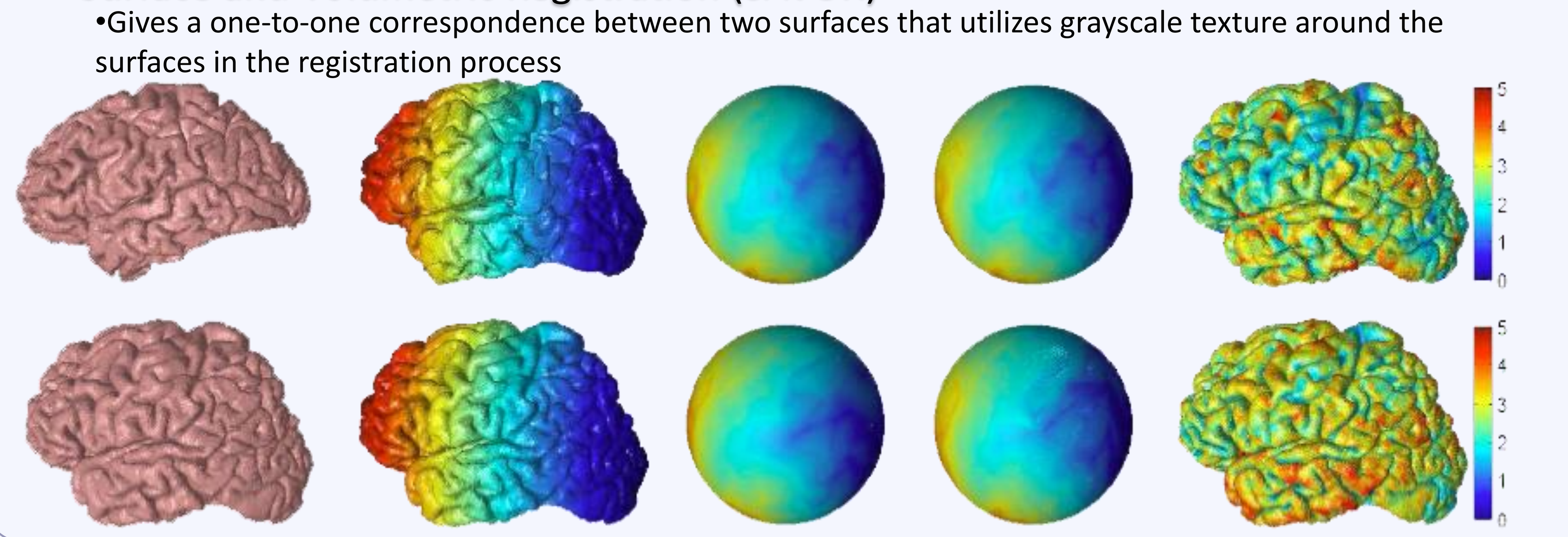
Surface area computation



$$A(x_i) = \sum_{j \in N_1(i)} \frac{((x_j^1 - x_j^2) \times (x_j^1 - x_j^3))}{2}$$

Surface and Volumetric Registration (SAVOR)

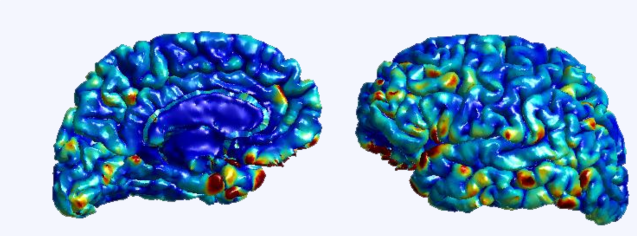
- Gives a one-to-one correspondence between two surfaces that utilizes grayscale texture around the surfaces in the registration process



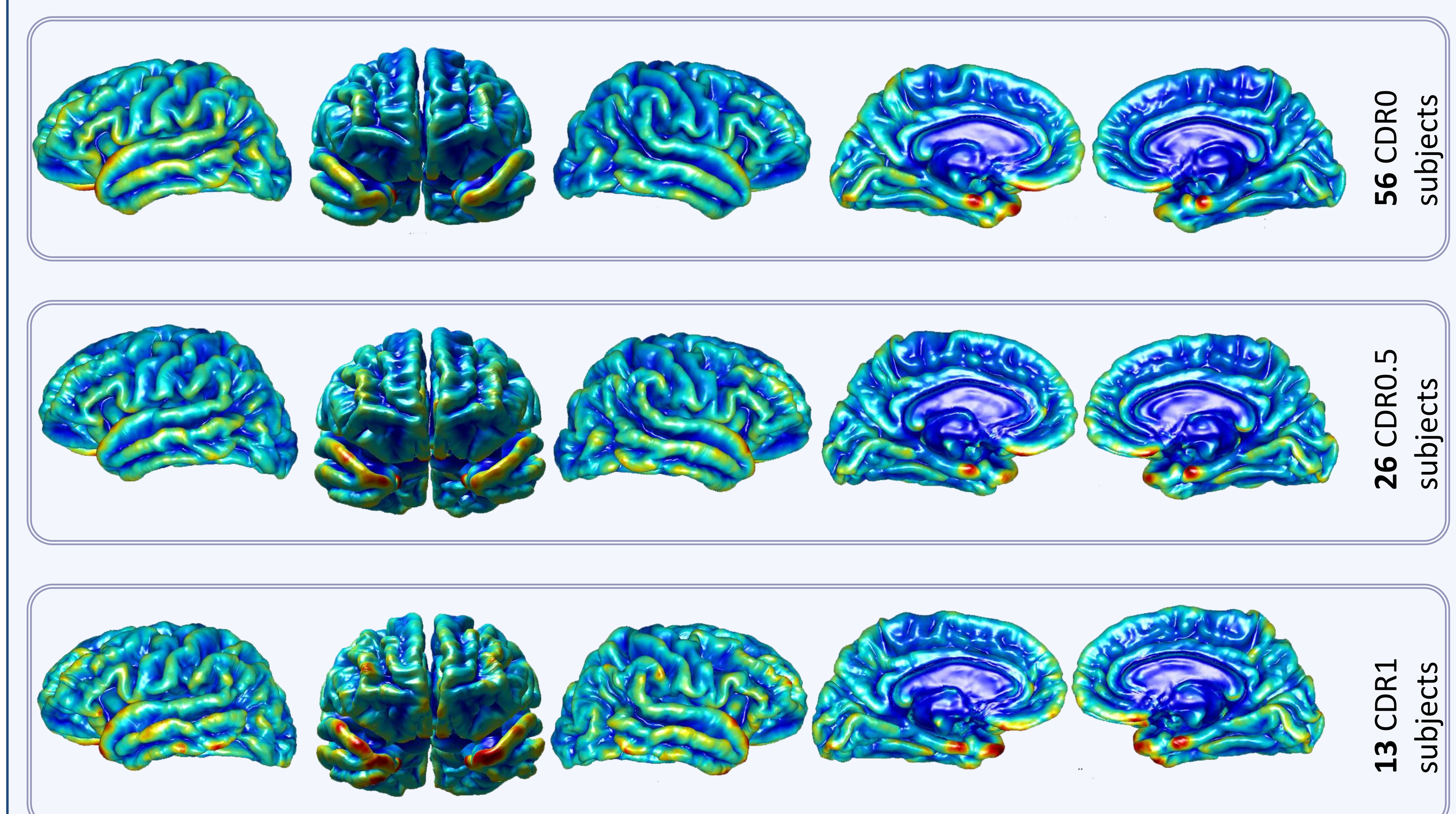
Results

OASIS dataset

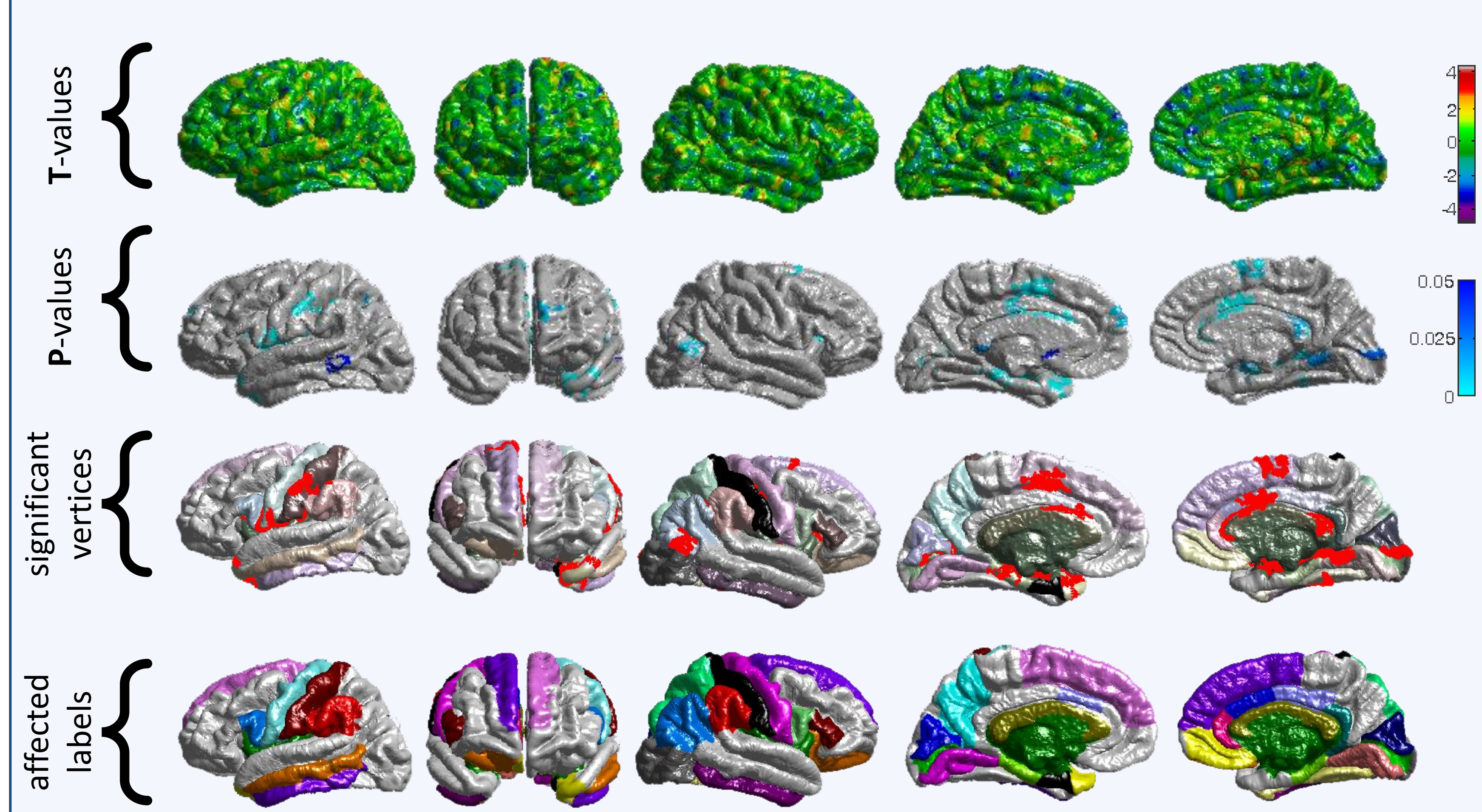
- Collection of MRI scans of controls and Alzheimer's subjects at various stages of the disease. Three prominent groups – Clinical Dementia Rating 0, 0.5 and 1.
- Computation of local Gyrification of each subject.
- Registration of each subject onto a common template.
- Transforming the subjects' Gyrification values on to a common template.



Single subject local Gyrification



Statistical Analysis : CDR0 – CDR0.5 group differences



Conclusions

- Fully automatic algorithm for computing local and regional changes in the cortical folding pattern.
- Mesh preserving Laplacian smoothing allows the vertex wise correspondence to be retained between original and smoothed surface.
- Can be used for classification and finding group differences among healthy and diseased subjects.

References

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