An Isometry-Invariant Descriptor for Detection of Brain Surface Deformation Affected by Alzheimer's Disease

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Introduction

This poster represents our recent work on encoding the area and angle changes on brain surface deformation. It is based on a novel area-preserving mapping and Beltrami coefficient [1]. Experiment results have demonstrated the efficacy and efficiency of our method on selecting the most affected brain functional areas by Alzheimer's disease (AD).

Methodology

1. Area-preserving mapping

There is a unique conformal mapping between a simply connected surface ***S*** and a unit disk ***D***, such that the Riemannian metic is:

$$g = e^{2\lambda}\left(dx^2 + dy^2\right)$$

On ***D***, the conformal factor defines a measure:

$$\mu = e^{2\lambda} dxdy$$

Then there exists a unique Brenier mapping:

$$\tau : (D, dxdy) \rightarrow (D, \mu)$$

Thus, the composition mapping,

$$\tau^{-1} \circ \phi : S \rightarrow D$$

is an area-preserving mapping.

2. Isometry Invariant Shape Descriptor

The distortion of a surface is

$$K = \frac{1+|v|}{1-|v|}$$

where v is the Beltrami coefficient, which contains rich information of surface deformation. In our work, we compute the area-preserving mapping and angle preserving mapping and use Beltrami coefficient to measure the difference between the two mapping results.

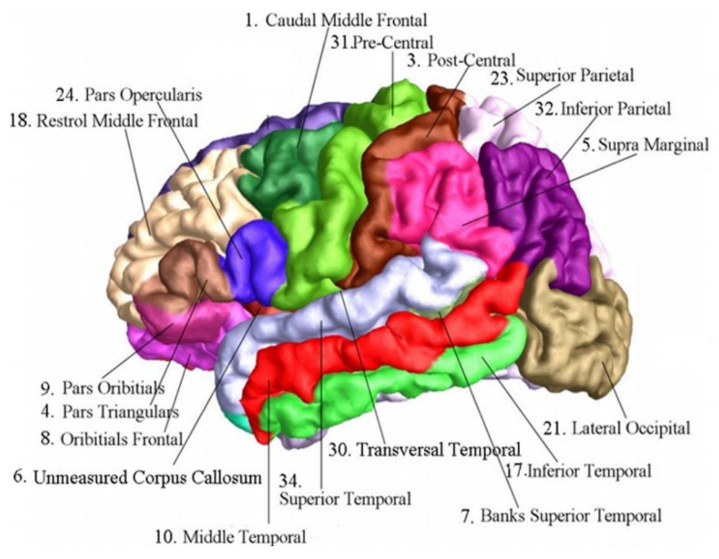
Experiments and Results

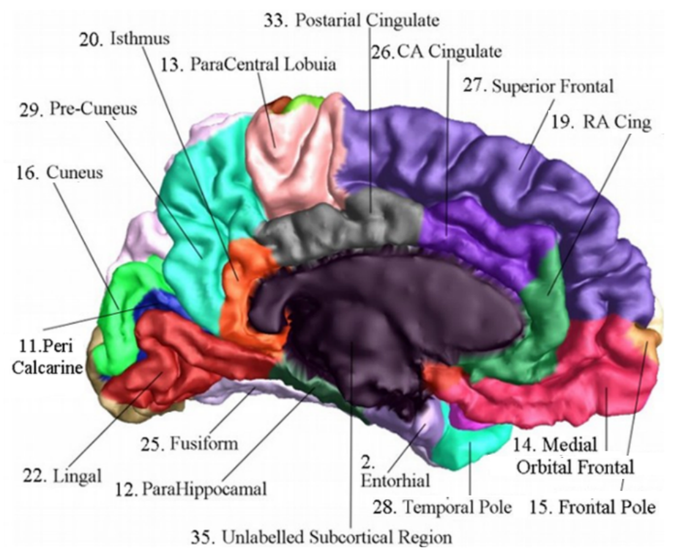
1) Compute the are-preserving mapping and conformal (angle preserving) mapping of the brain surfaces.

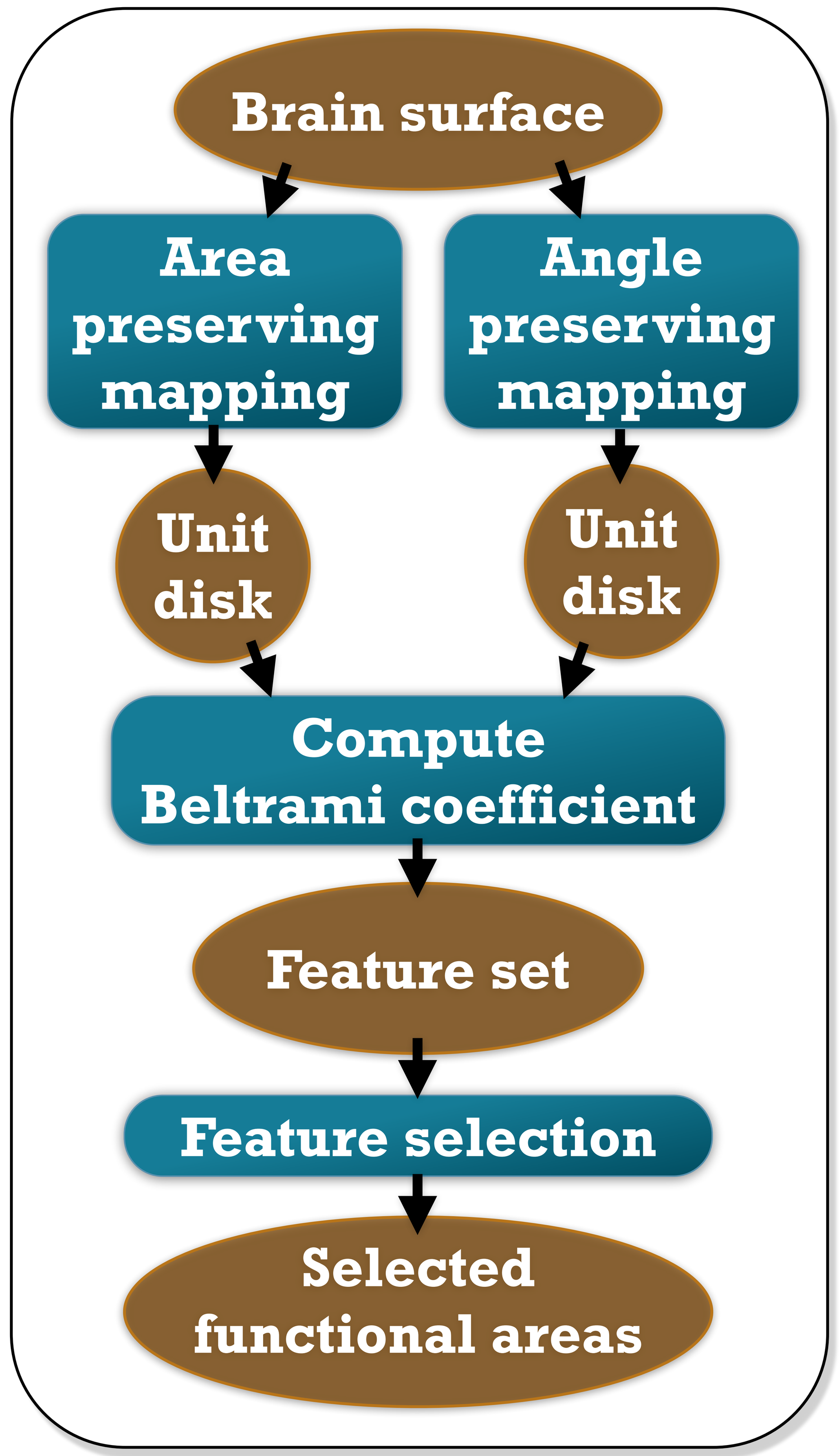
2) Compute the Beltrami coefficients between the two mappings and use the norm of the Beltrami coefficient to construct the feature set.

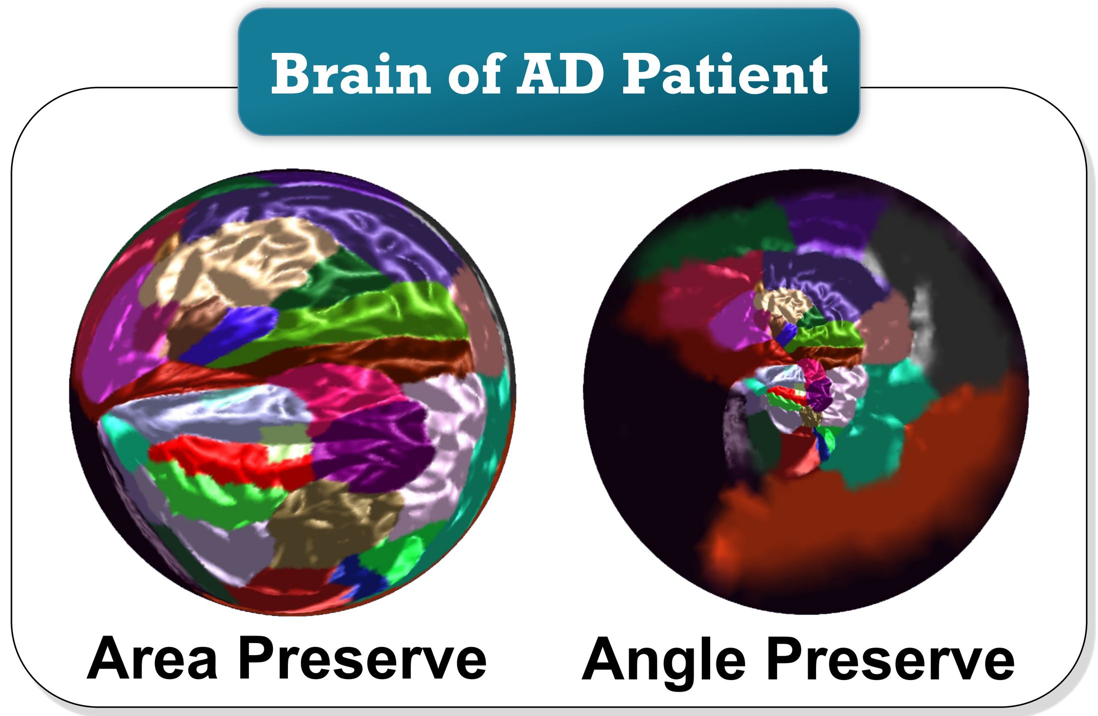
3) Use feature-selection method to discover the feature with the highest norm of the Beltrami coefficient.

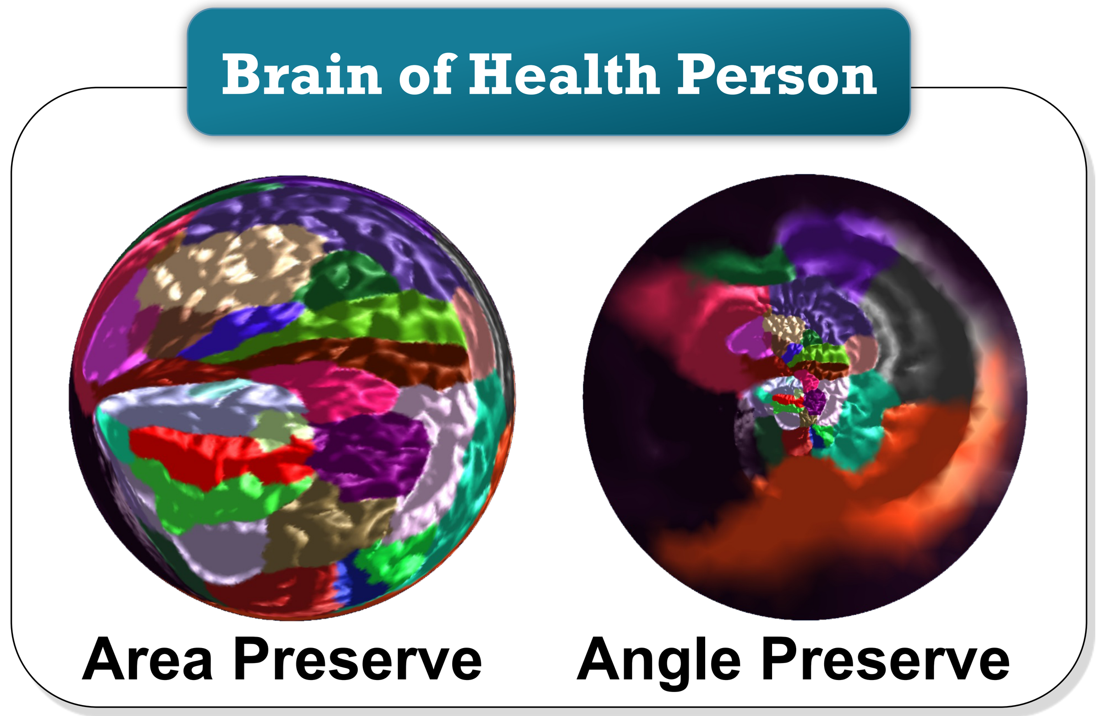
As the result, 10-Middle Temporal, 25-Fusiform, 27-Superior Frontal, 32-Inferior Parietal and 34-Superior Temporal are selected as the functional areas that are most affected by AD, as shown below.

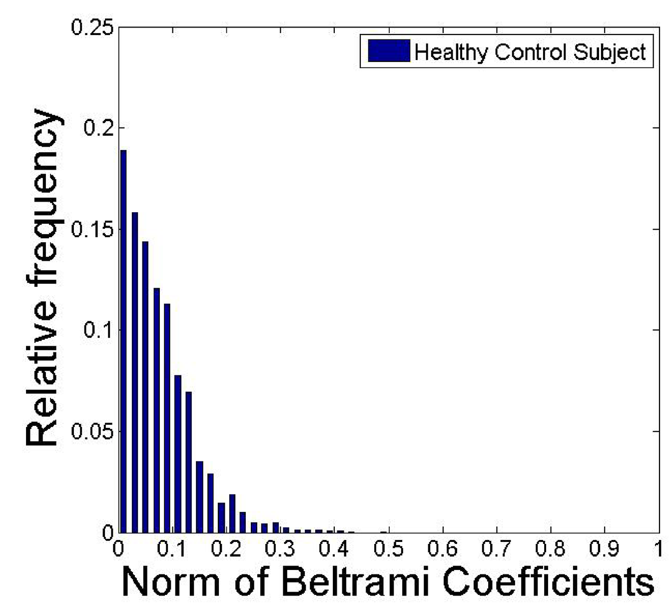


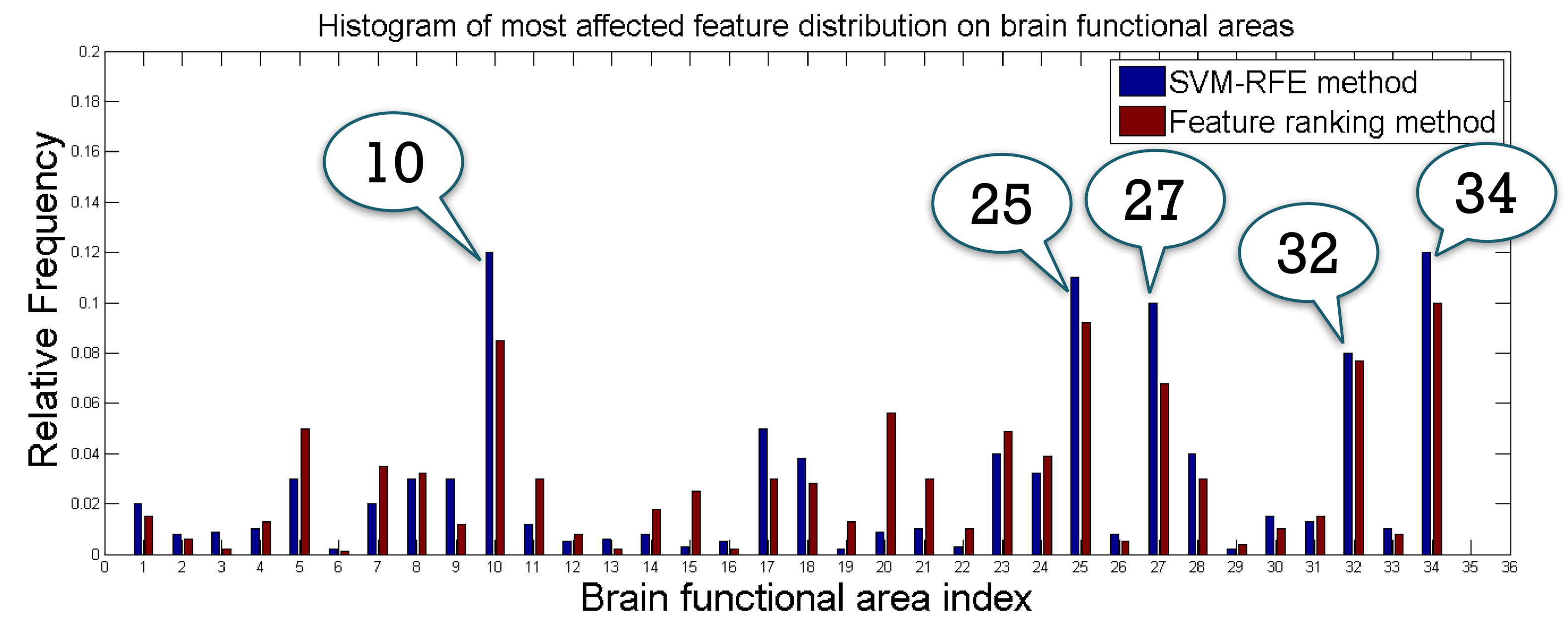












Contribution

The thickness of brain surface is always considered as an essential morphometric feature in the analysis of the MRI of human brain [2]. Our methods, however, shows that the area of brain surface is also a potential morphometric feature.

Dataset

The data come from Alzheimer's Disease Neuroimaging Initiative (ADNI) [2]. It contains baseline T1-wighted MRI images from 100 AD subjects and 100 non-AD subjects. We used Free-surfer to generate brain surfaces from the MRI.

Conclusion

1. We propose an isometry-invariant descriptor for comparing surface deformation between two groups.

2. By applying our method on brain surfaces of persons with and without AD, we discovered 5 brain functional areas that are statistically rated to AD.

References

[1] F.Gardiner and N. Lakic, "Quasiconformal Teichmüller theory, Mathematical Surveys and Monographs", vol. 76, American Mathematical Society, 2000.

[2] CRJ Jack, et al, The Alzheimer's Disease Neuroimaging Initiative (ADNI): MRI methods. J Magn Reson Imaging. 2008a Apr;27(4):685.

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