Hippocampus Morphometry Study on Pathology-confirmed Alzheimer's Disease Patients with Surface Multivariate Morphometry statistics

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Abstract
One of the hallmarks of AD is the accumulation of beta-amyloid plaques (Aβ) in human brains. In this work, we study hippocampus morphometry on a cohort consisting of Aβ positive AD (N=151) and matched Aβ negative cognitively unimpaired subjects (N=271) with Aβ positivity determined via florbetapir PET. We compute our surface multivariate morphometry statistics (MMS) from segmented hippocampus structure in structural MR images. With these features, we find statistically significant difference by using Hotelling’s T² tests. Meanwhile, we apply a patch-based analysis of sparse coding system for binary group classification and achieve an accuracy rate of 90.48%. Our results demonstrate that MMS perform better than traditional hippocampal volume measures in classification and it may be applied as a potential biomarker for distinguishing dementia due to AD from age matched normal aging individuals.

Introduction
1. Hippocampus morphometry on Alzheimer’s Disease
2. The Accumulation of beta-amyloid plaques (Aβ)
3. Using MR as an economic way to verify the AD-pathology
4. MRI: Aβ positive AD vs matched Aβ negative cognitively unimpaired subjects
5. Biomarkers: surface multivariate morphometry statistics (MMS)
6. Statistical Group difference study via Hotelling's T² Test
7. Patch-based sparse coding system for binary group classification

Method
Surface Multivariate Morphometry Statistics (MMS)

1. Multivariate tensor-based morphometry (mTBM)
   (a) Two Left Hippocampal Surfaces and their Parameterization with Holomorphic 1-form

   ![Image of hippocampal surfaces](image1)

   Approximate the derive map \( d \) by linearly map from one face \([x_1, x_2, x_3]\) to another face \([y_1, y_2, y_3]\).
   The Jacobian matrix: \( J = \sqrt{\left| \left| \frac{d\mathbf{S}}{d\mathbf{x}} \right| \right|} \)
   Deformation tensor: \( S = (J^T J)^{1/2} \)
   mTBM: a “Log-Euclidean metric”[1] on the set of deformation tensors (3 x 1 feature vector on each vertex)

2. Radial Distance
   Radial Distance[2]: distance between each surface point to its medical center. (a scalar on each vertex)

   ![Image of radial distance](image2)

   Group Difference Study with Surface MMS
   Hotelling’s T² Test [3]
   2 groups of 4-dimensional vectors: \( P_i, i = 1, \ldots, m \) and \( N_j, j = 1, \ldots, n \)
   Mahalanobis distance: \( M = (\bar{P} - \bar{N}) \sum^{-1}(\bar{P} - \bar{N}) \)
   Permutation test: 15,000 times
   Statistical threshold: \( p < 0.05 \)

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Reference