Pattern classification of hippocampal shape analysis in a study of Alzheimer's Disease

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Objective: A pipeline that permits processing of several brain datasets via applications on multiple sites has been implemented under the auspices of the Brain Morphometry Biomedical Informatics Research Network. To test this, pattern classification of metric distances between hippocampal structures was used to classify shapes in a study of Alzheimer's Disease. These metric distances give a precise mathematical description of what shapes are similar and different.

Methods: 45 subjects (21 nondemented controls, 18 very mild Alzheimer's Disease, 6 semantic dementia) were scanned using high resolution T1-weighted structural MRI at Washington University. Then the anonymized scans were analyzed at MGH's Martinos Center using Freesurfer [1]. The resulting segmented data sets were aligned and processed at JHU's Center for Imaging Science (CIS) using the Large Deformation Diffeomorphic Metric Mapping (LDDMM) tool [2]. Briefly, LDDMM computes the velocity vectors that transform one binary image I_0 to another I_1 giving the metric distance $d(I_0, I_1) = \sqrt{\int_0^1 \|v\|_V^2 \, dt}$ where the norm $\|\bullet\|_V^2$ ensures smoothness in the space of velocity vector fields that are generated by the group of infinite dimensional diffeomorphisms (which is the generalization of rotations, translations and scale group), the necessary group for studying shape.

From the 4050 LDDMM comparisons of left and right hippocampal shapes, we conducted statistical analysis of two 45x45 matrix of metric distances. First, these distances were non-linearly mapped to R^d space by a multidimensional scaling (MDS) [3] to minimize the interpoint distance distortion in Euclidean space. The classical MDS produced a d_L+d_R dimensional feature matrix, which was used to perform classification via linear discriminant analysis [4]. The performance criteria of the classification measures the instances of misclassification with leave-one-out cross validation.

Results & Discussion: The figure below shows a 2-dimensional scatter plot generated by LDA. Class labels are represented by Nondemented controls (1), Alzheimer's Disease (2) and Semantic Dementia (3). Thus there is class-specific information in the LDDMM matrix.

Conclusions: Pattern classification of metric distances provides a powerful means of distinguishing shapes and providing the neuroanatomist an increased understanding of diseases and disorders with greater statistical power.

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