Morphological changes in the corpus callosum: A study using joint Riemannian feature spaces

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Fiber Tracts in the Corpus Callosum
Fiber Tracts: Physical Features
Fiber Tracts: Physical Features

position
orientation
scale
shape
Fiber Tracts: Physical Features

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- shape

These features either individually or in combination can be used to design feature spaces and metrics.
Joint Manifolds

- $S_1$: Shape + scale + orientation + translation
- $S_2$: Shape + scale + orientation
- $S_3$: Shape + scale
- $S_4$: Shape + orientation
- $S_5$: Shape

Joint Manifolds

- $S_1$: Shape + scale + orientation + translation
- $S_2$: Shape + scale + orientation
- $S_3$: Shape + scale
- $S_4$: Shape + orientation
- $S_5$: Shape

<table>
<thead>
<tr>
<th>Manifold</th>
<th>distance metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>shape + scale + orientation + translation</td>
<td>( d(\beta_1, \beta_2) = | h_1 - (h_2, \gamma^*) | )</td>
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<tr>
<td>shape + scale + orientation</td>
<td>( d(\beta_1, \beta_2) = | q_1 - (q_2, \gamma^*) | )</td>
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<td>( d(\beta_1, \beta_2) = | q_1 - O^<em>(q_2, \gamma^</em>) | )</td>
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<td>shape + orientation</td>
<td>( d(\beta_1, \beta_2) = \min_{\gamma \in \Gamma} \left( \cos^{-1} \left( \int_0^1 \langle (q_1, \gamma)(t), (q_2, \gamma)(t) \rangle , dt \right) \right) )</td>
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<td>shape</td>
<td>( d(\beta_1, \beta_2) = \min \left( \cos^{-1} \left( \int_0^1 \langle (q_1, \gamma)(t), O^*(q_2, \gamma)(t) \rangle , dt \right) \right) )</td>
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Illustration: Clustering Fibers in the Corpus Callosum

(a) shape + scale + orientation

(b) shape
Study: Morphological Changes in the Corpus Callosum
Study: Morphological Changes in the Corpus Callosum

Approaches:

1. typically volume-based
   - e.g. divide CC into well-defined partitions; analyze width, thickness

2. tract-based studies:
   - focus on microstructure evaluations
   - studies utilizing geometrical properties of tracts less common
Study: Morphological Changes in the Corpus Callosum
Study: Morphological Changes in the Corpus Callosum
Study: Morphological Changes in the Corpus Callosum
Data Set

- **2 curves**
  - LC: section of the rostrum
  - UC: section of the genu

- **10 control subjects**
  - 22 - 42 years
  - male
  - right handed

- **10 MS subjects**
  - on average, 10 years since onset of disease
  - age-matched
  - primarily female
Mean Curves of a DTI Fiber Bundle: Genu
Mean Curves of a DTI Fiber Bundle: Genu

fiber bundle

shape
Mean Curves of a DTI Fiber Bundle: Genu

fiber

bundle

shape

orientation

shape+i

M. Mani

Feb 2013
Distance Maps
Distance Maps

\begin{center}
\begin{tabular}{|c|c|}
\hline
I & II \\
\hline
LC–LC & LC–UC \\
\hline
III & IV \\
\hline
UC–LC & UC–UC \\
\hline
\end{tabular}
\end{center}
Distance Maps

Shape Manifold

control

MS
Distance Maps

Shape + Orientation Manifold

control
Distance Maps
Shape+Orientation Manifold

control

MS
Distance Maps

shape

shape+ orientation

control MS
Within-group variance for distance distributions

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<td>NC</td>
<td>0.0026</td>
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Within-group variance for distance distributions

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Summary

Using only 10 MS subjects and 10 NC for comparison, we demonstrate an effective new design that uses shape and shape+orientation distances to study shape and morphological changes.

- Variability is suggestive of alterations to callosal shape that accompany illness progression.
- Develop methods to identify and track progressive white matter disease.
- Such tools can improve the clinical evaluation and treatment of patients suffering from MS.