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

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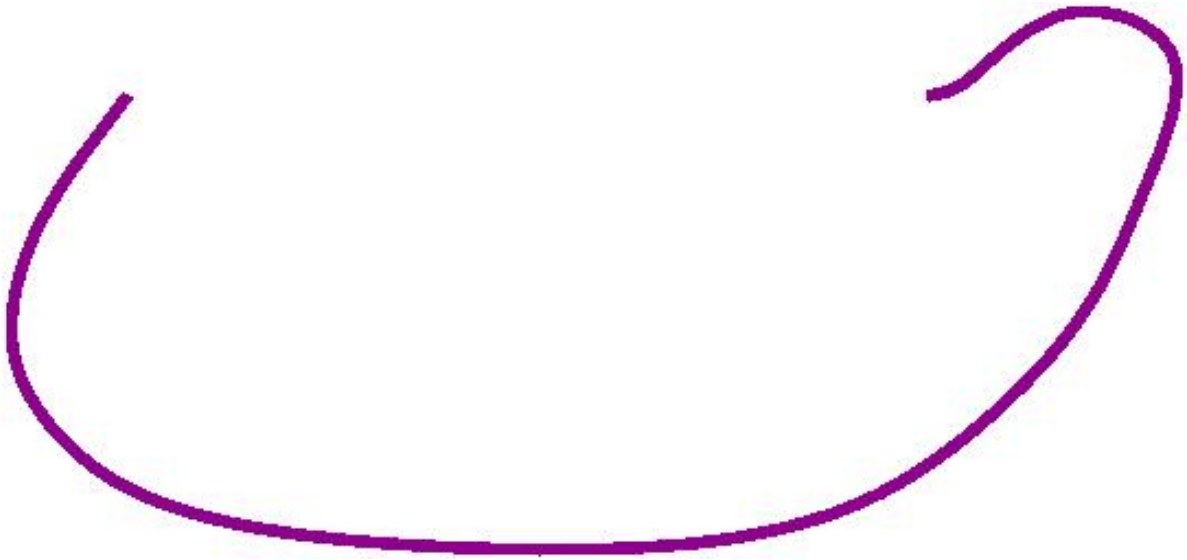
Fiber Tracts in the Corpus Callosum

Fiber Tracts: Physical Features



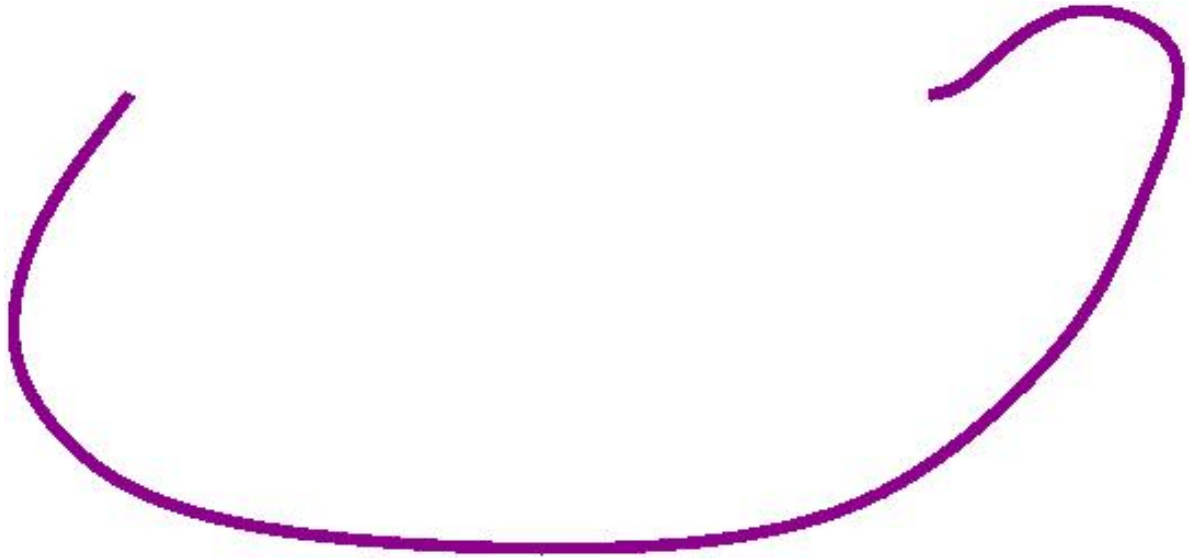
Fiber Tracts: Physical Features

position

orientation

scale

shape



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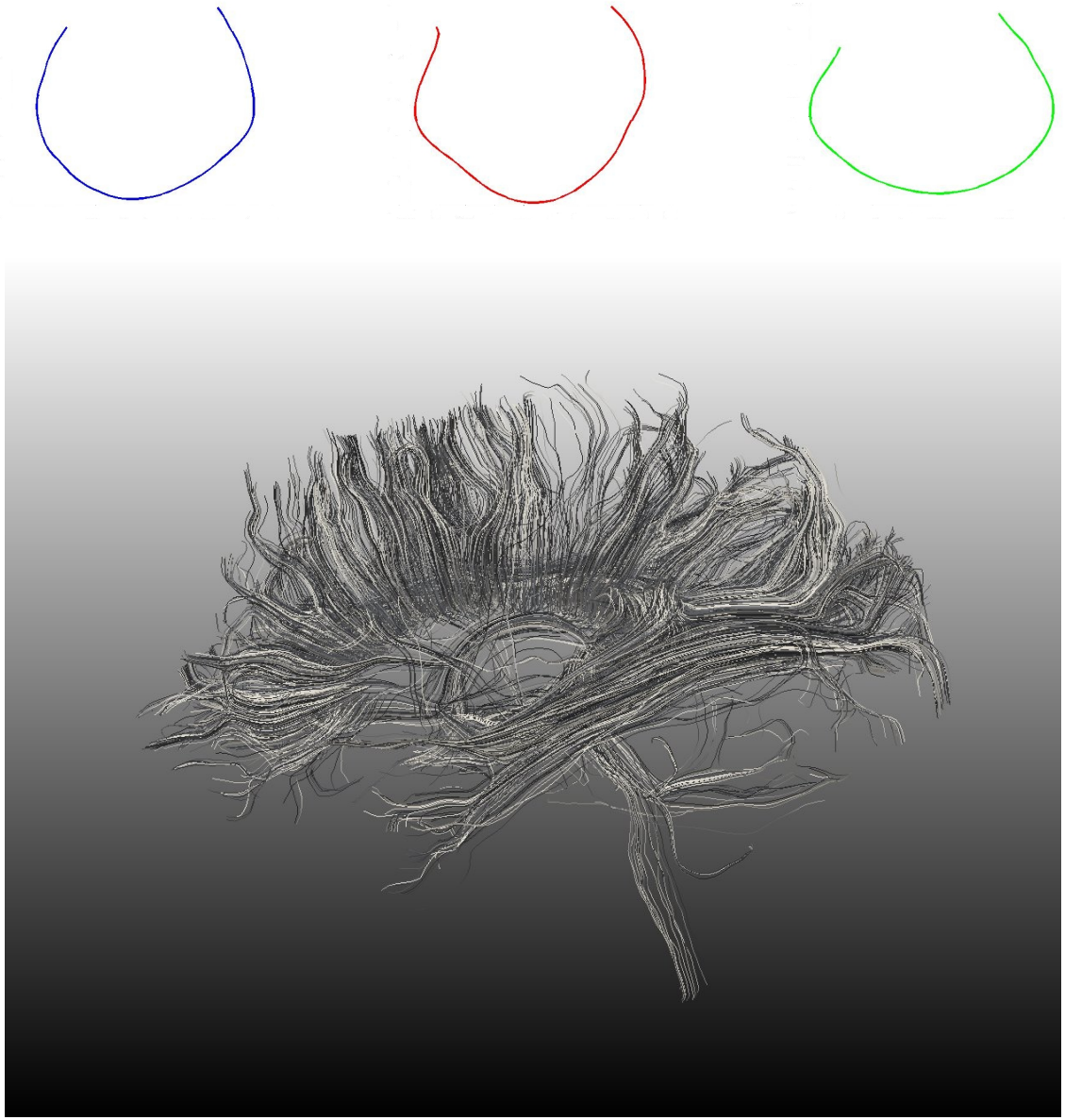

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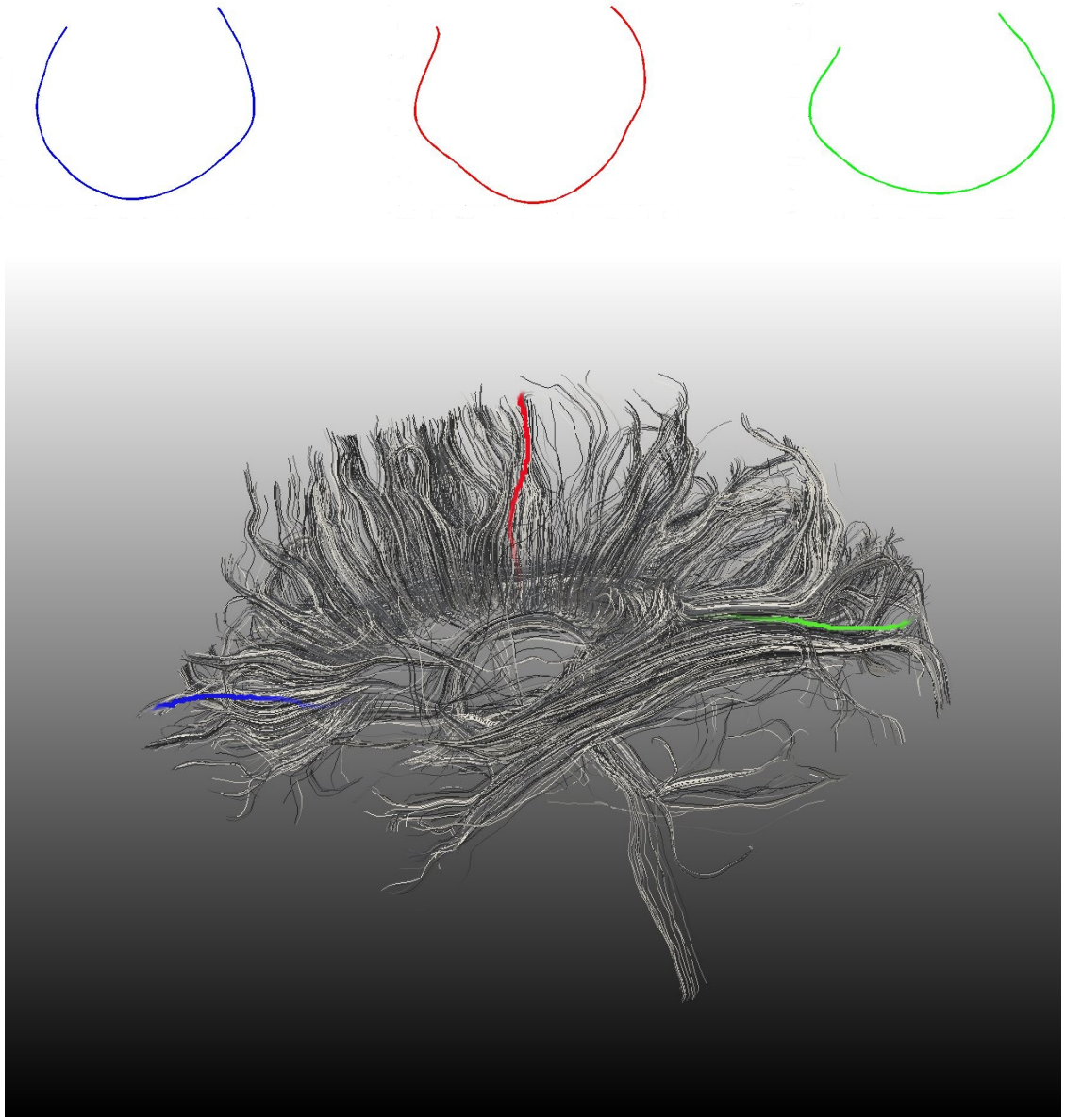

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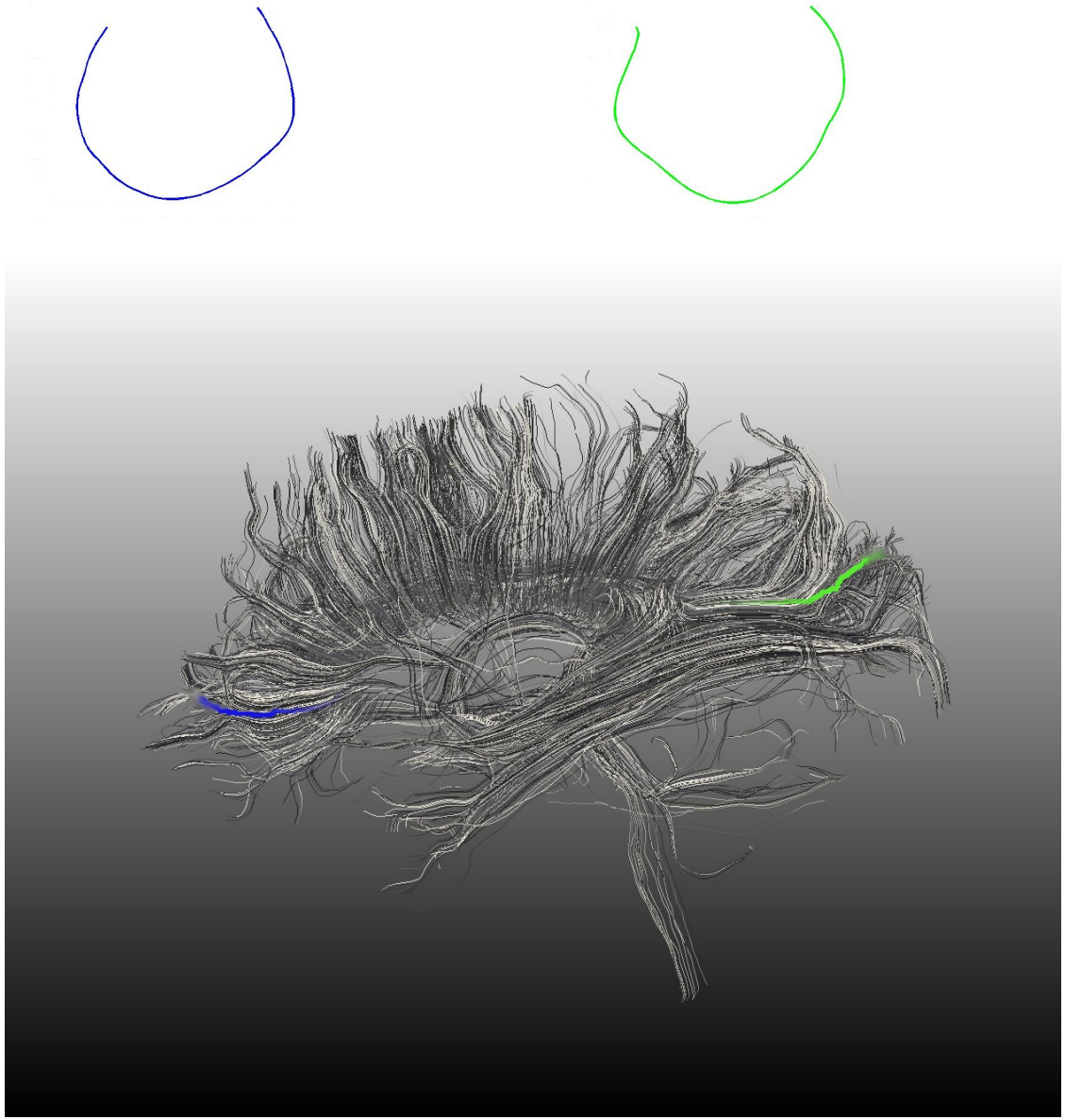

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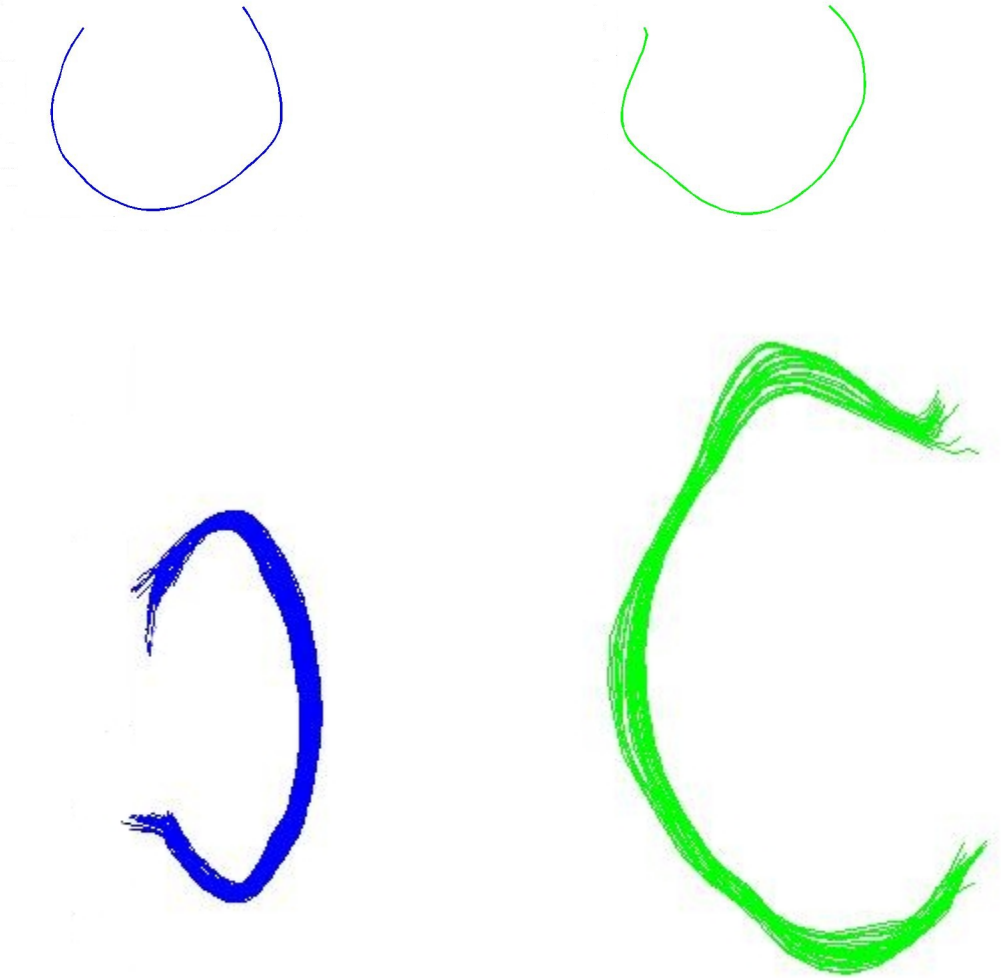

Fiber Tracts: Physical Features

position

orientation

scale

shape

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

Joint Manifolds

- $\mathcal{S}_1$: Shape + scale + orientation + translation
- $\mathcal{S}_2$: Shape + scale + orientation
- $\mathcal{S}_3$: Shape + scale
- $\mathcal{S}_4$: Shape + orientation
- $\mathcal{S}_5$: Shape

† M. Mani, S Kurtek, C. Barillot, A. Srivastava. *A Comprehensive Riemannian Framework for the Analysis of White Matter Fiber Tracts,* In ISBI '2010.

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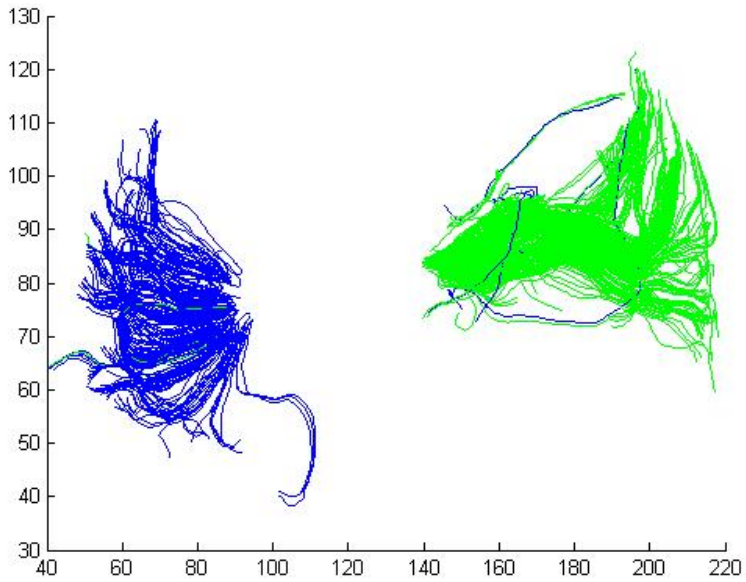
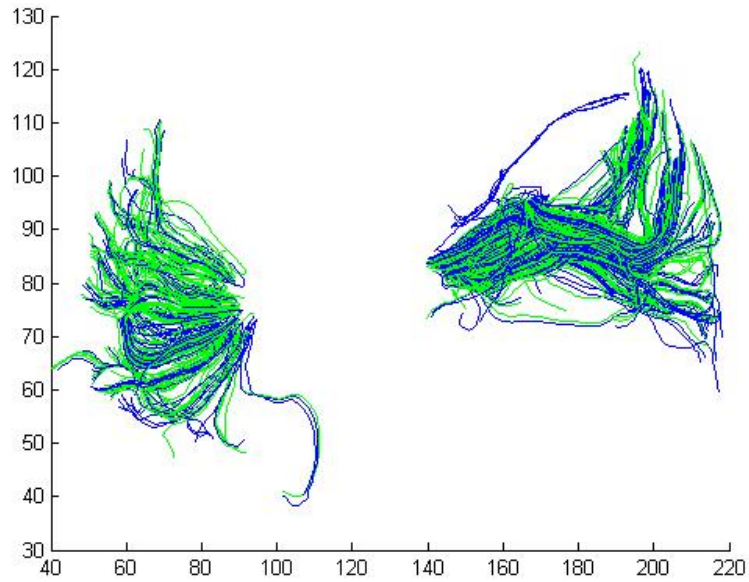
Manifold	distance metric
shape + scale + orientation + translation	$d(\beta_1, \beta_2) = \|h_1 - (h_2, \gamma^*)\|$
shape + scale + orientation	$d(\beta_1, \beta_2) = \|q_1 - (q_2, \gamma^*)\|$
shape + scale	$d(\beta_1, \beta_2) = \|q_1 - O^*(q_2, \gamma^*)\|$
shape + orientation	$\mathrm{d}(\beta_1, \beta_2) = \min_{\gamma \in \Gamma} \left(\cos^{-1}(\int_0^1 \langle (q_1, \gamma)(t), (q_2, \gamma)(t) \rangle \, dt) \right)$
shape	$d(\beta_1, \beta_2) = \min \left(\cos^{-1}(\int_0^1 \langle (q_1, \gamma)(t), O^*(q_2, \gamma)(t) \rangle \, dt) \right)$

Illustration: Clustering Fibers in the Corpus Callosum



(a) shape+scale+orientation



(b) shape

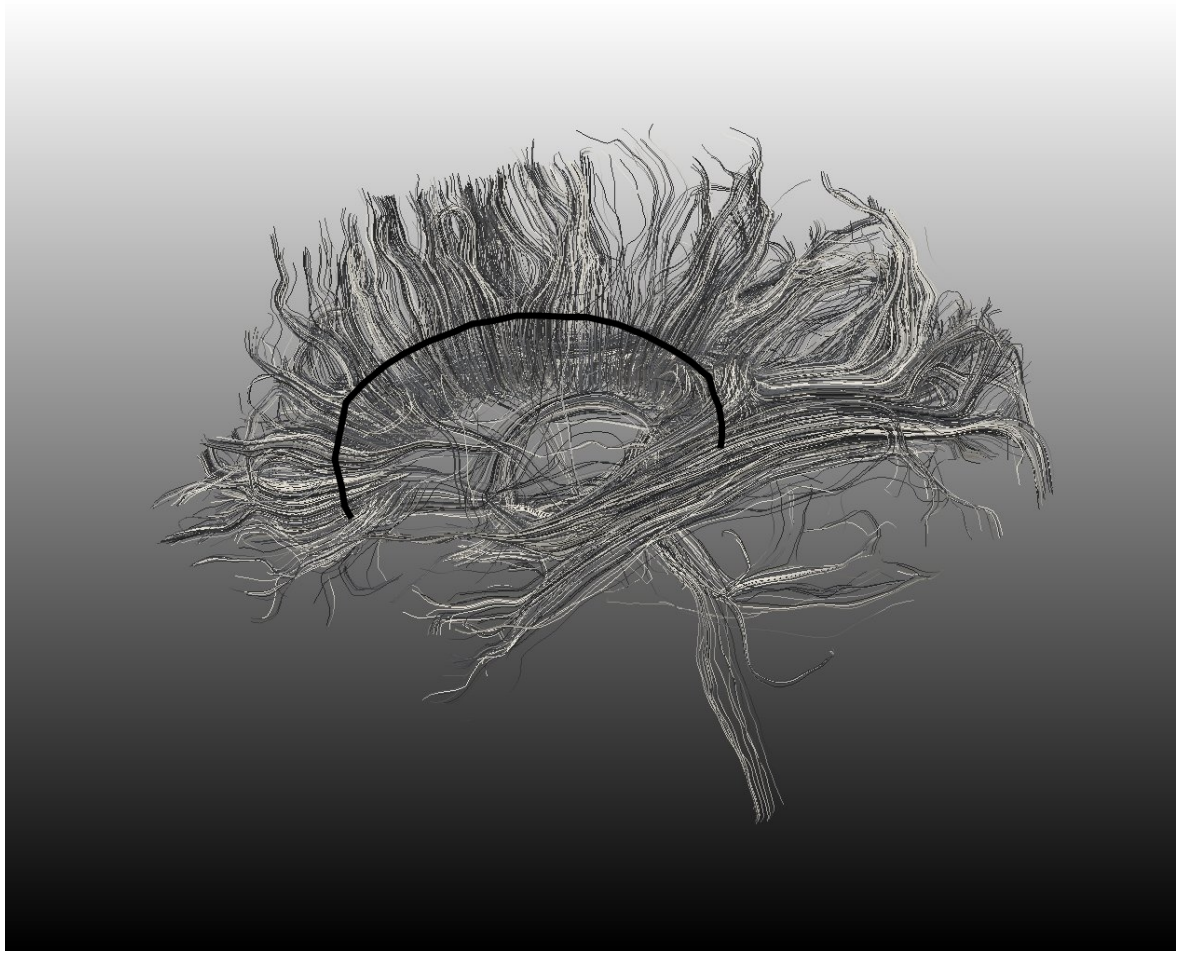
Study: Morphological Changes in the Corpus Callosum

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



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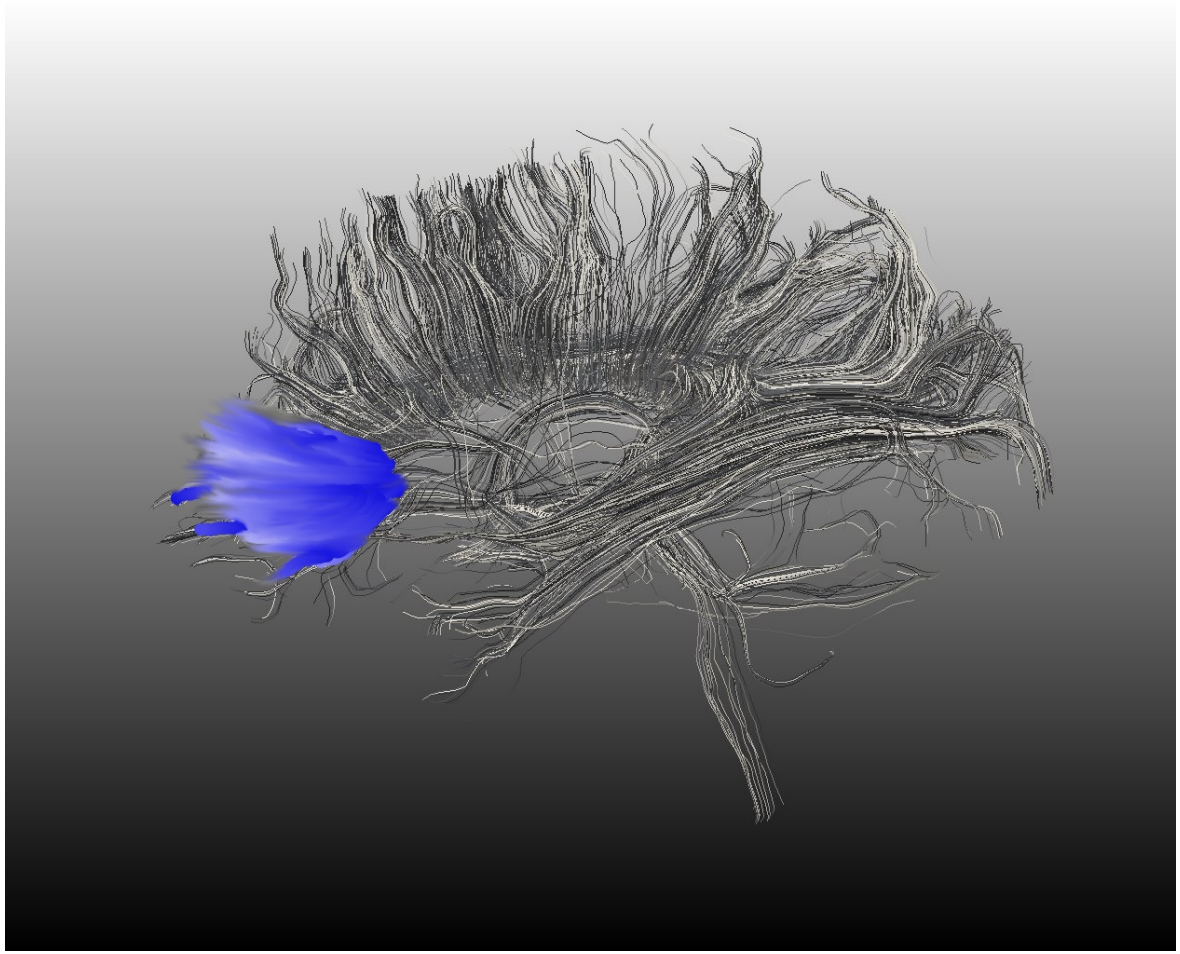

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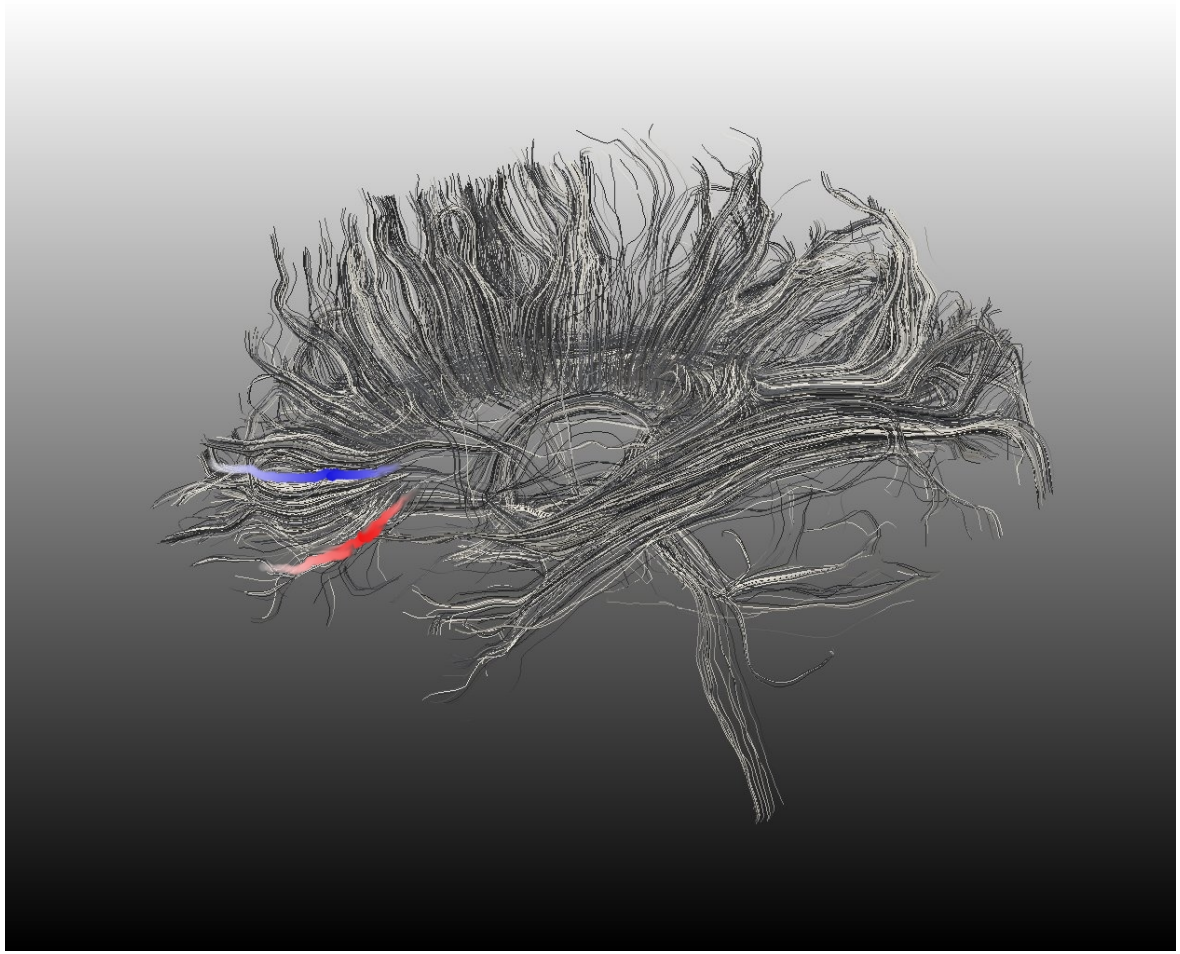
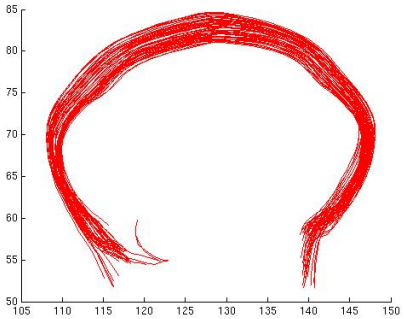


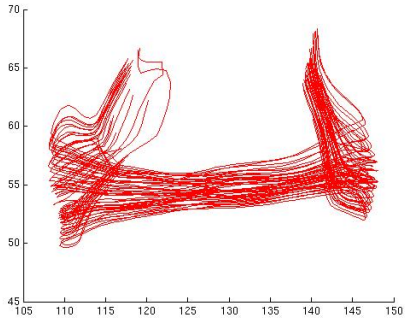
Data Set

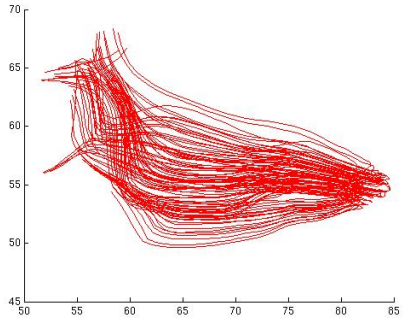
- 2 curves
  - LC: section of the rostrum
  - UC: section of the genu
- 10 control subjects
  - 22 - 42 years
  - male
  - right handed
- 10 MS subjects
  - on average, 10 years since onset of disease
  - age-matched
  - primarily female

Mean Curves of a DTI Fiber Bundle: Genu

fiber bundle







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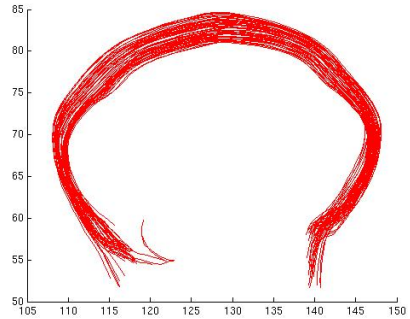
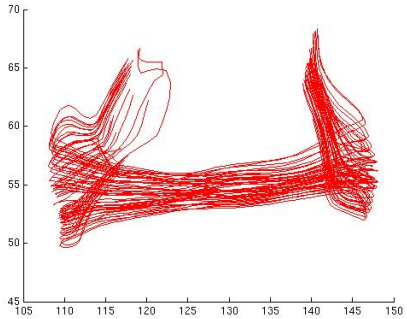
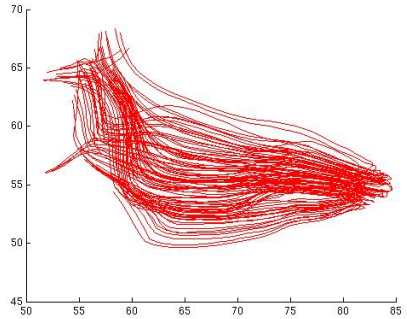
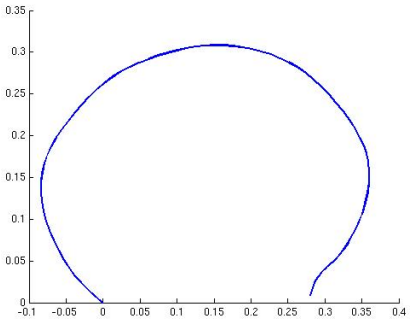
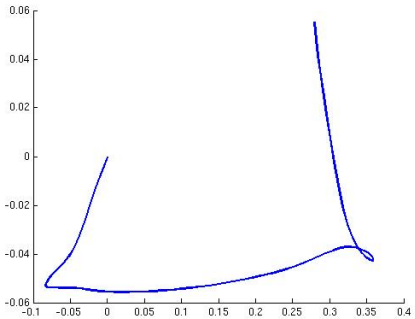


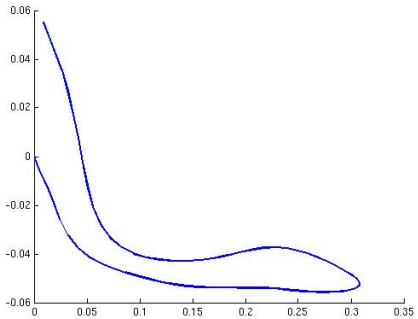




shape







Mean Curves of a DTI Fiber Bundle: Genu

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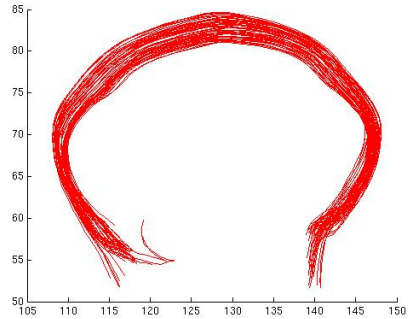
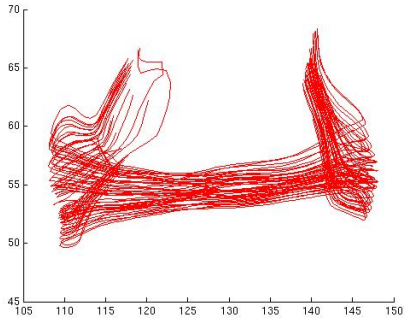
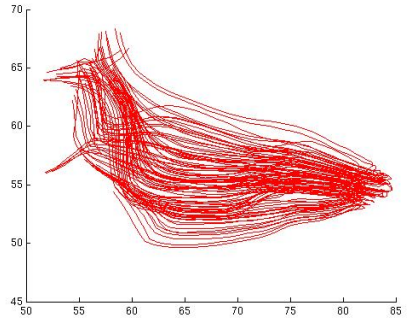
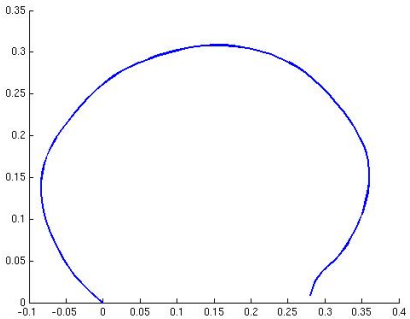
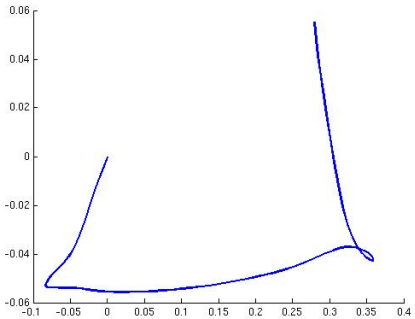
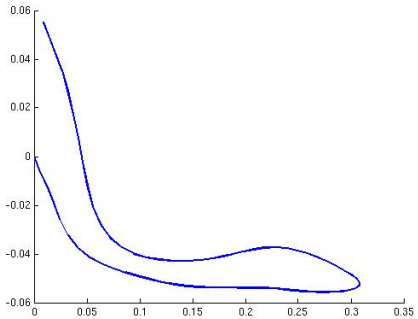
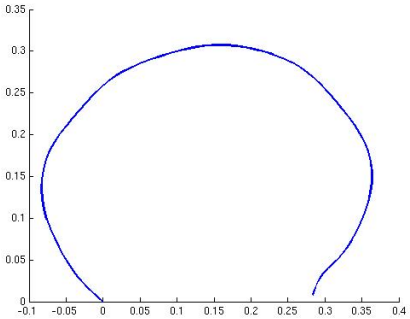
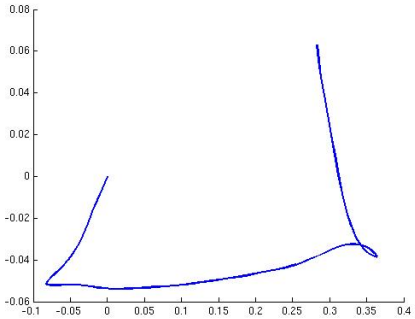
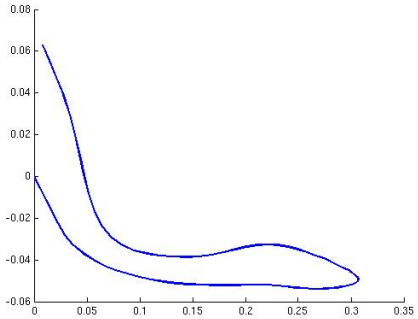




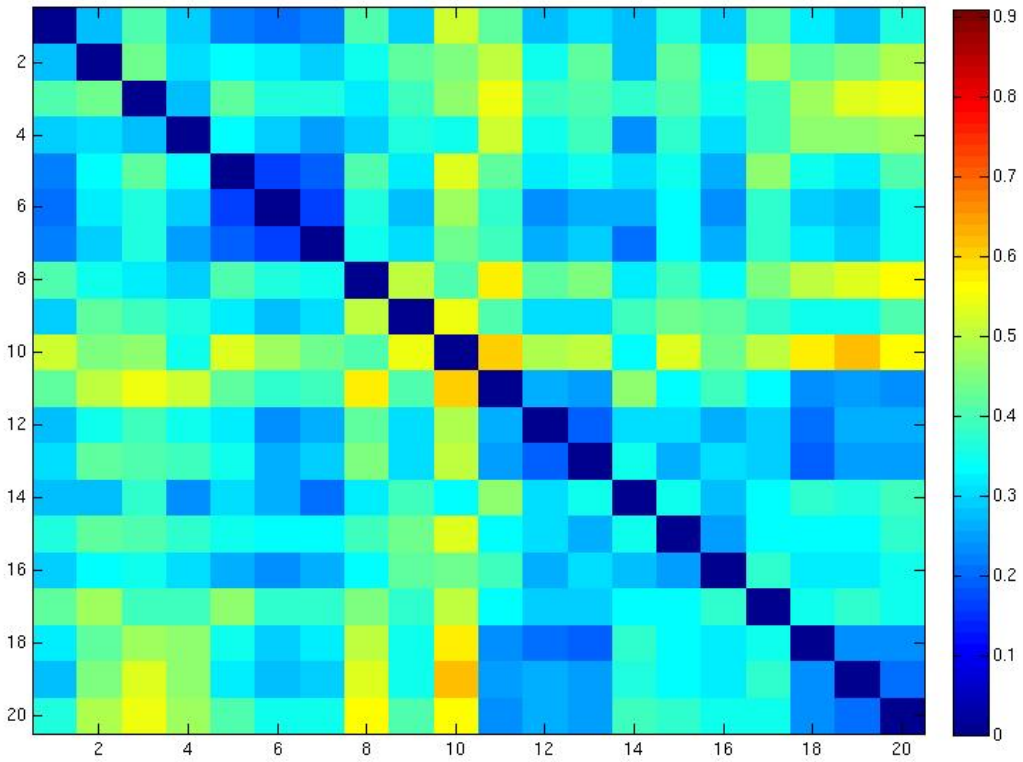
shape

shape+ orientation

Distance Maps



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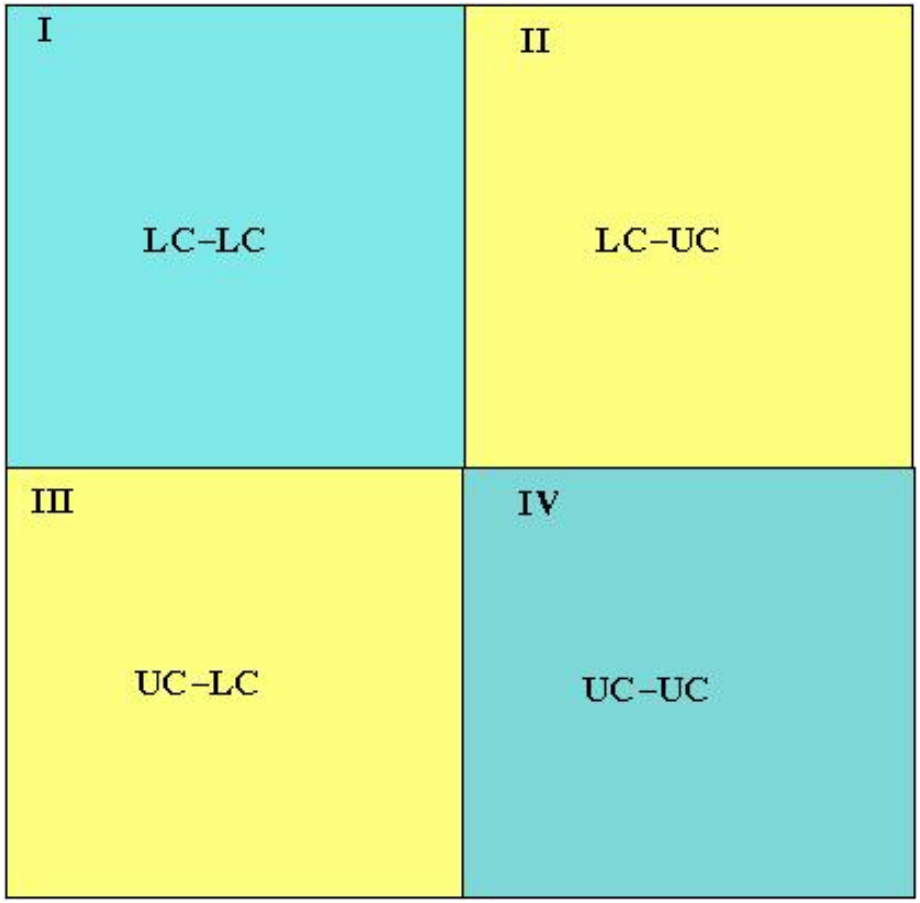
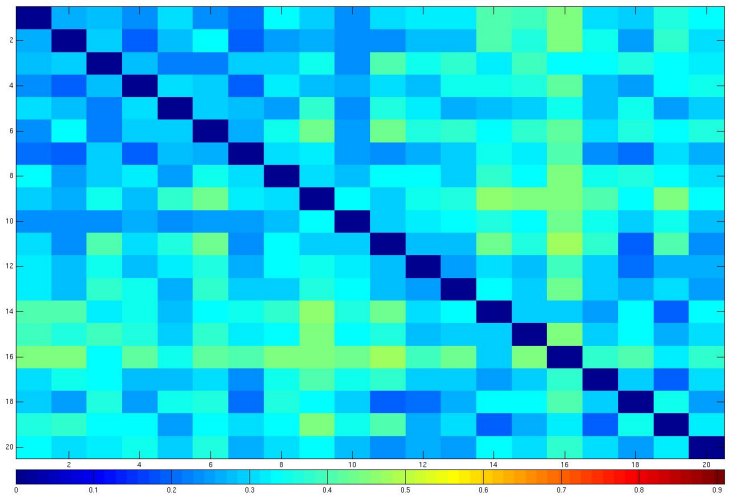
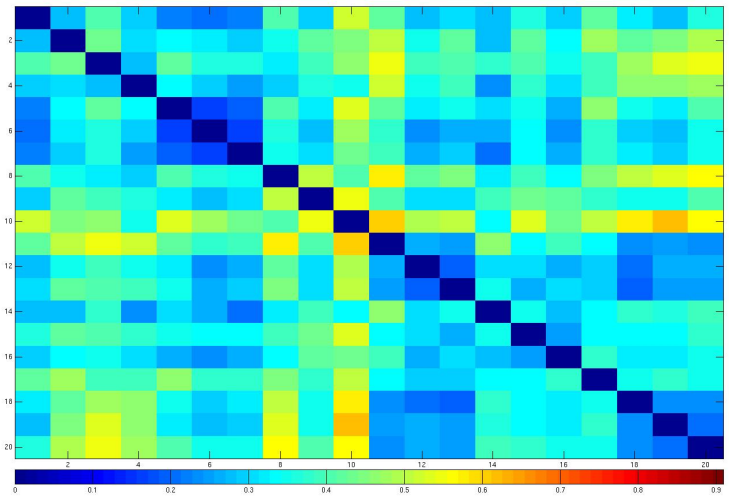


Distance Maps

Shape Manifold



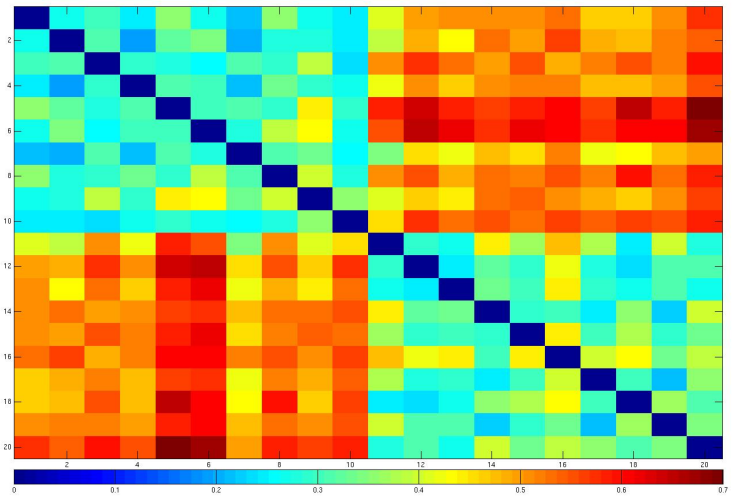
control



MS

Distance Maps

Shape+Orientation Manifold



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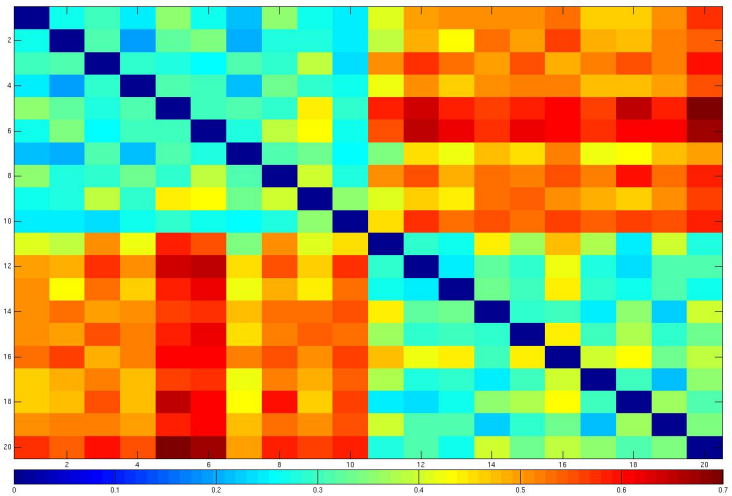

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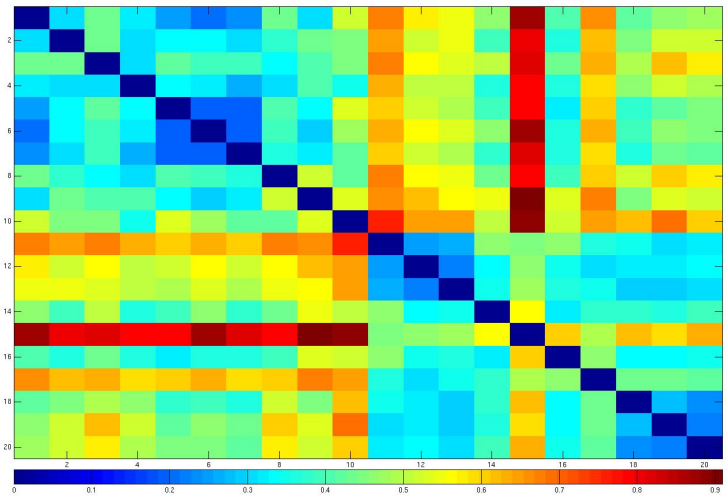

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Distance Maps

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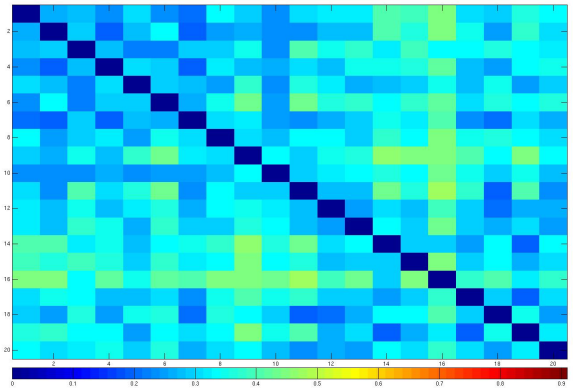
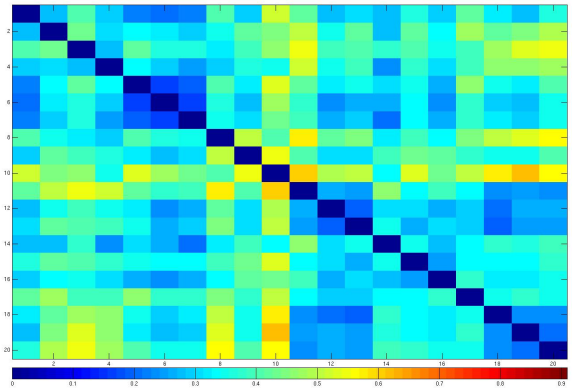
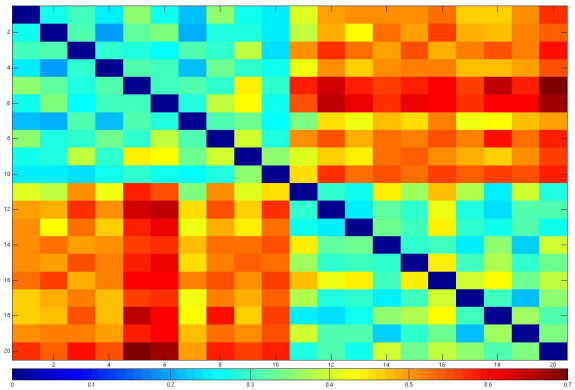
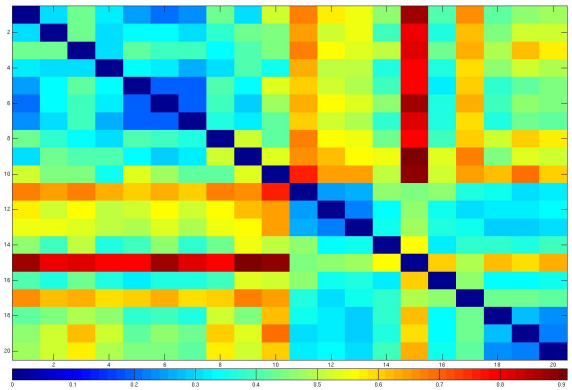




shape+ orientation





control

MS

Within-group variance for distance distributions

		LC-LC	**UC-UC**	**LC-UC**
shape	NC	0.0026	0.0048	0.0030
	MS	0.0089	0.0039	0.0089
shape+orientation	NC	0.0032	0.0043	0.0040
	MS	0.0080	0.0108	0.0176

† Distances between the same curve (d = 0) were not included

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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