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Subpixel curvature estimation of the corpus callosum via splines and its application to autism

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Abstract
Autism is a neurodevelopmental disorder with abnormal corpus callosum (CC) size [1]. Most previous studies used the area of predefined Witelson partition [5] as a morphometric measure but other shape metrics have not been considered. We present a novel computational technique for curvature estimation via piecewise quintic splines and use it in both CC nonlinear dynamic time warping algorithm [4] and detecting the regions of curvature difference.

Methods
A group of 2D mid sagittal cross section images of the corpus callosum was taken from males of similar age, 15 autistic, and 12 normal controls. The level set method as described by Sethian[2], was used to extract the outline of the corpus callosum automatically. Thus the pixelated CC contour was reconstructed into a rough closed curve in Euclidean space (Figure 1. red). Smoothing of this zigzag contour was necessary to account for the partial volume effect (Figure 1. blue). Two different methods were used to smooth and estimate the curvature function. The first method uses Taubin's smoothing [3], a Gaussian filtering without shrinkage, followed by the least-squares estimation. The second method uses a series of quintic splines to estimate the first and second derivatives to compute the curvature. Afterwards a curve from the control group was chosen as a template and all other curves are registered to the template. First an affine registration was used to normalize the global CC size differences. Second the fast nonlinear dynamic-time warping algorithm was used [4]. The algorithm penalized against large deformation and curvature difference, thereby matching the extrema of curvature while maintaining a smooth and stable deformation. After registering the curves, a local estimation of curvature could be compared across subjects, using Welch's t-test at each point to correct for the somewhat unequal variance in a few areas (Figure 3).

Results
Both methods provided effective estimates of curvature for the entire CC contours. The smoothing splines performed better in terms of ease of fit and more stable results. The results of the comparison of curvatures between the autistic and control subjects are as shown in Figure 2 where the sample mean curvature functions are plotted (blue: autistic, red: control). Figure 4 is the P-value map where the blue areas indicate more significant curvature difference. Most significant curvature difference is detected at the posterior midbody (R1).

Acknowledgements
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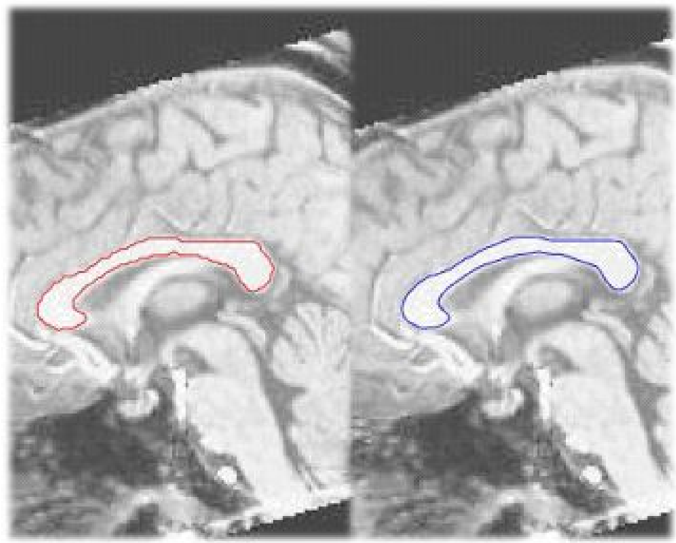

Figure 1. Leveset segmentation and smoothing

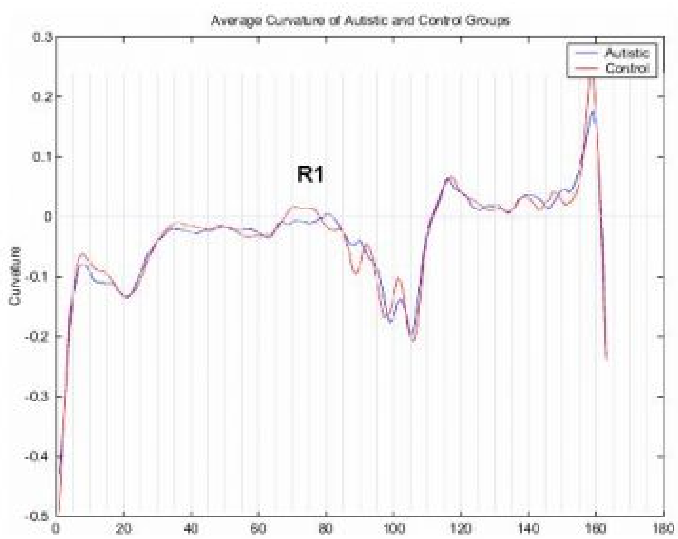

Figure 2. Mean curvatures for autism and control

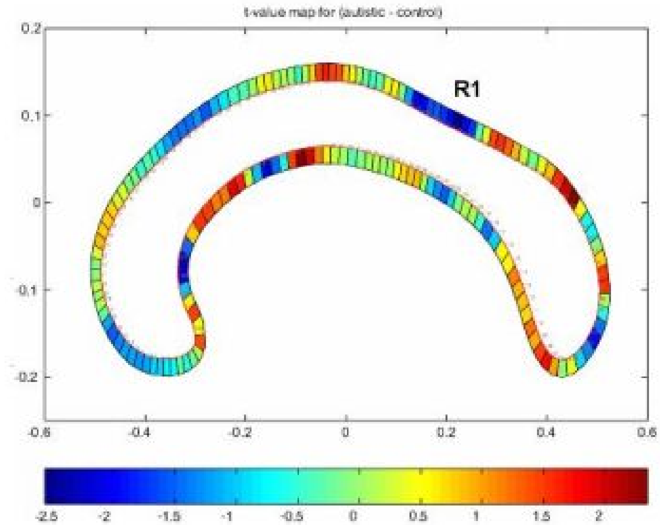

Figure 3. t-map of curvature difference between autism and control

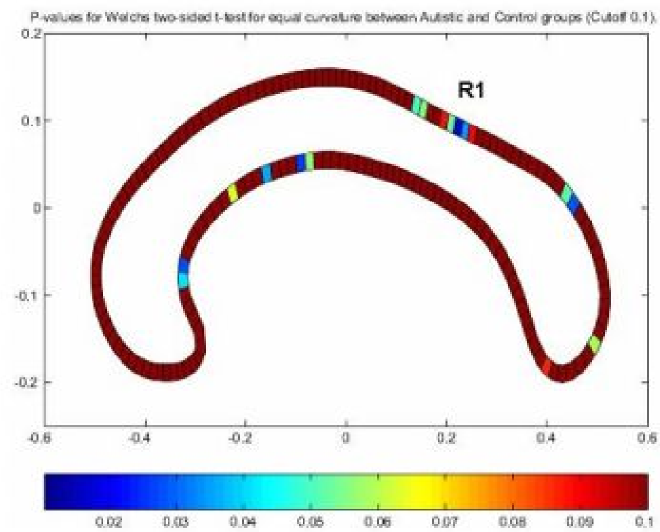

Figure 4. p-map of curvature difference