Analyzing the Developing Brain by Quantifying Curvature Measures

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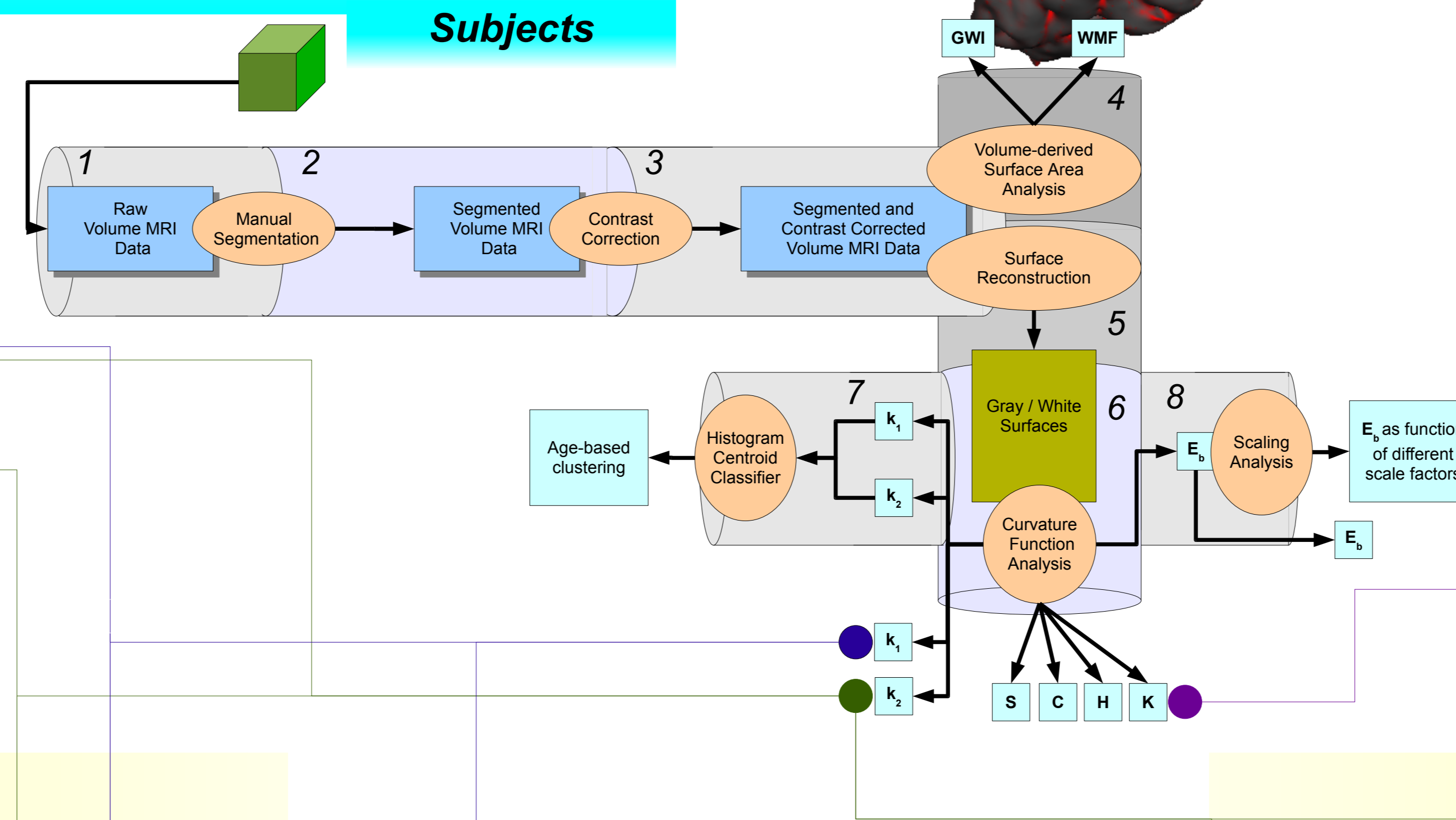
introduction

• Analyzing functions of curvature on brain surfaces can be a more sensitive marker for developmental disorders than volume/surface measurements;
• study considers functions of principal curvature across :
  • cohort of normal neonate, pediatric, and adult subjects
  • normal and abnormal (polymicrogyria) pediatric subjects
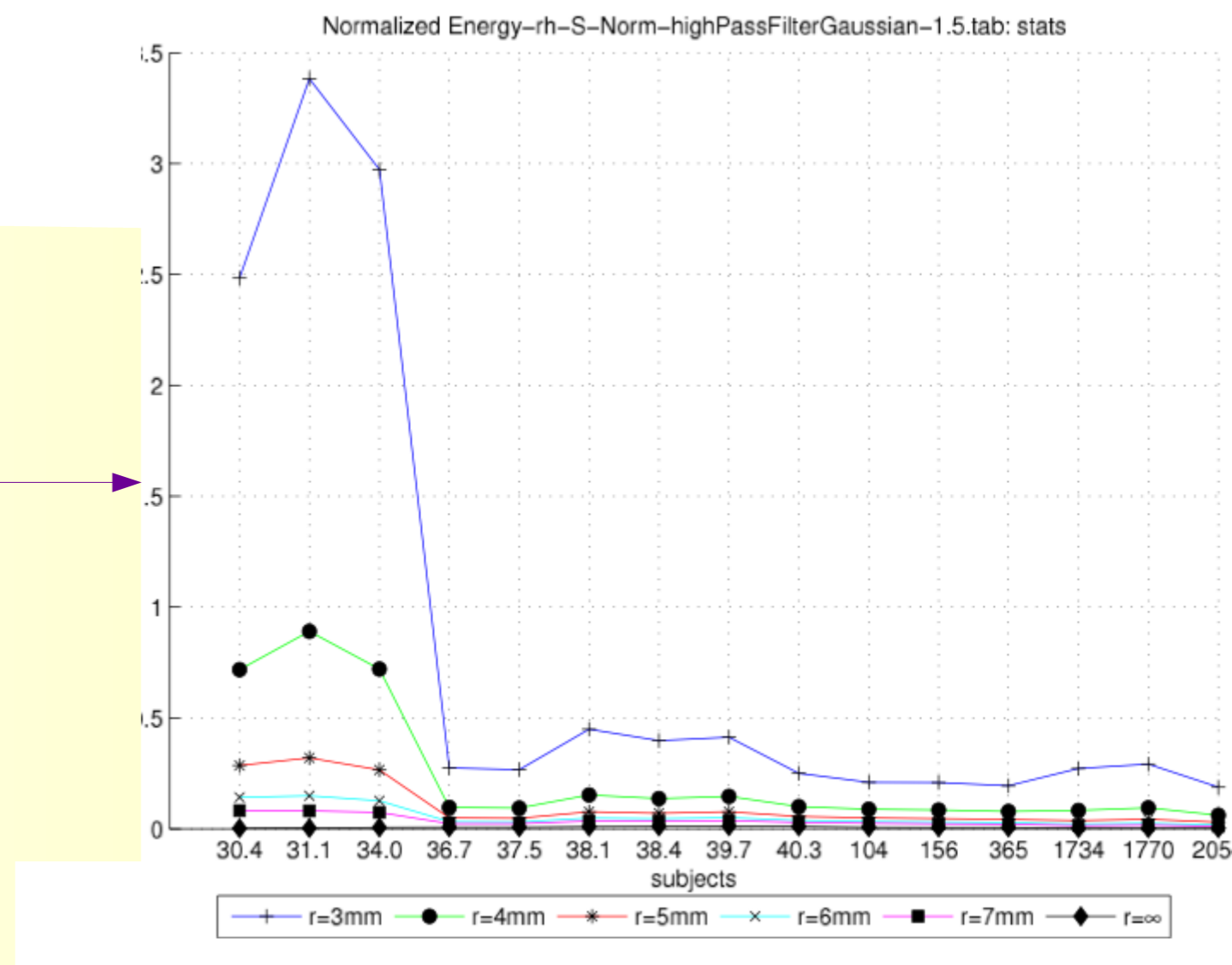• principal Gaussian curvature is used to flag areas of interest on cortical surface.

• T1 weighted axial 3D SPGR images were collected on a 1.5T (GE, Milwaukee), a 1.5T Siemens and 3.0T Siemens (Siemens, Erlangen, Germany) scanners:
  • TR/TE   = 30/8
  • flip angle   = 25 to 30°
  • Matrix size = 256x192
  • FOV   = 220x165mm
                   200x150mm
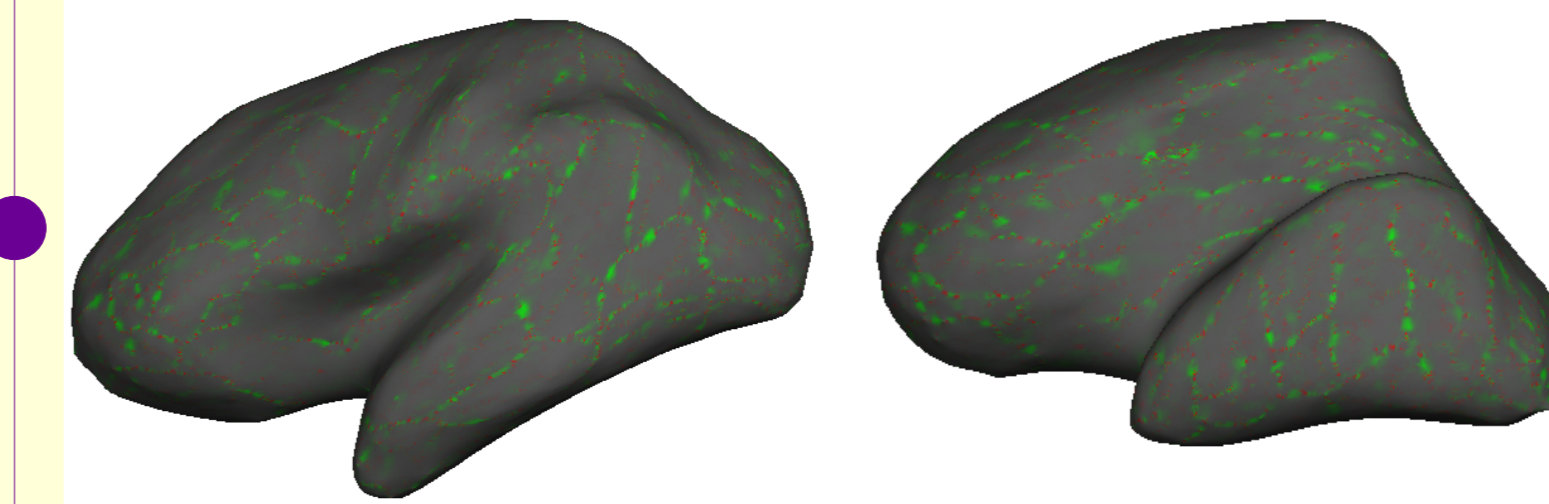 • slice thickness = 1.2 to 1.4mm

Subjects

Curvature functions

• in this paper we analyzed the gray-white junction for:
  • Maximum curvature, k_1
  • Minimum curvature, k_2
  • Gaussian curvature, $K = k_1 k_2$
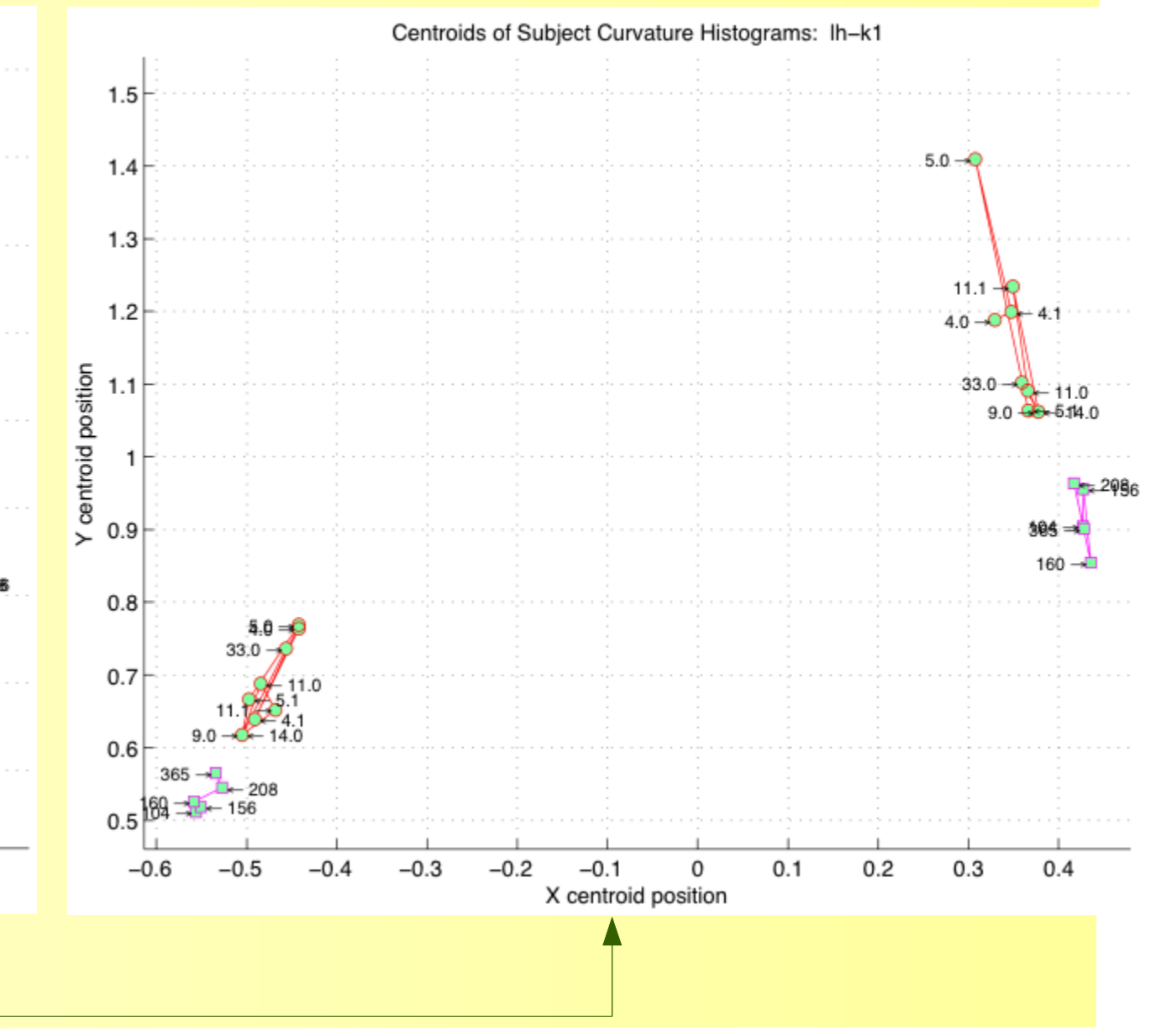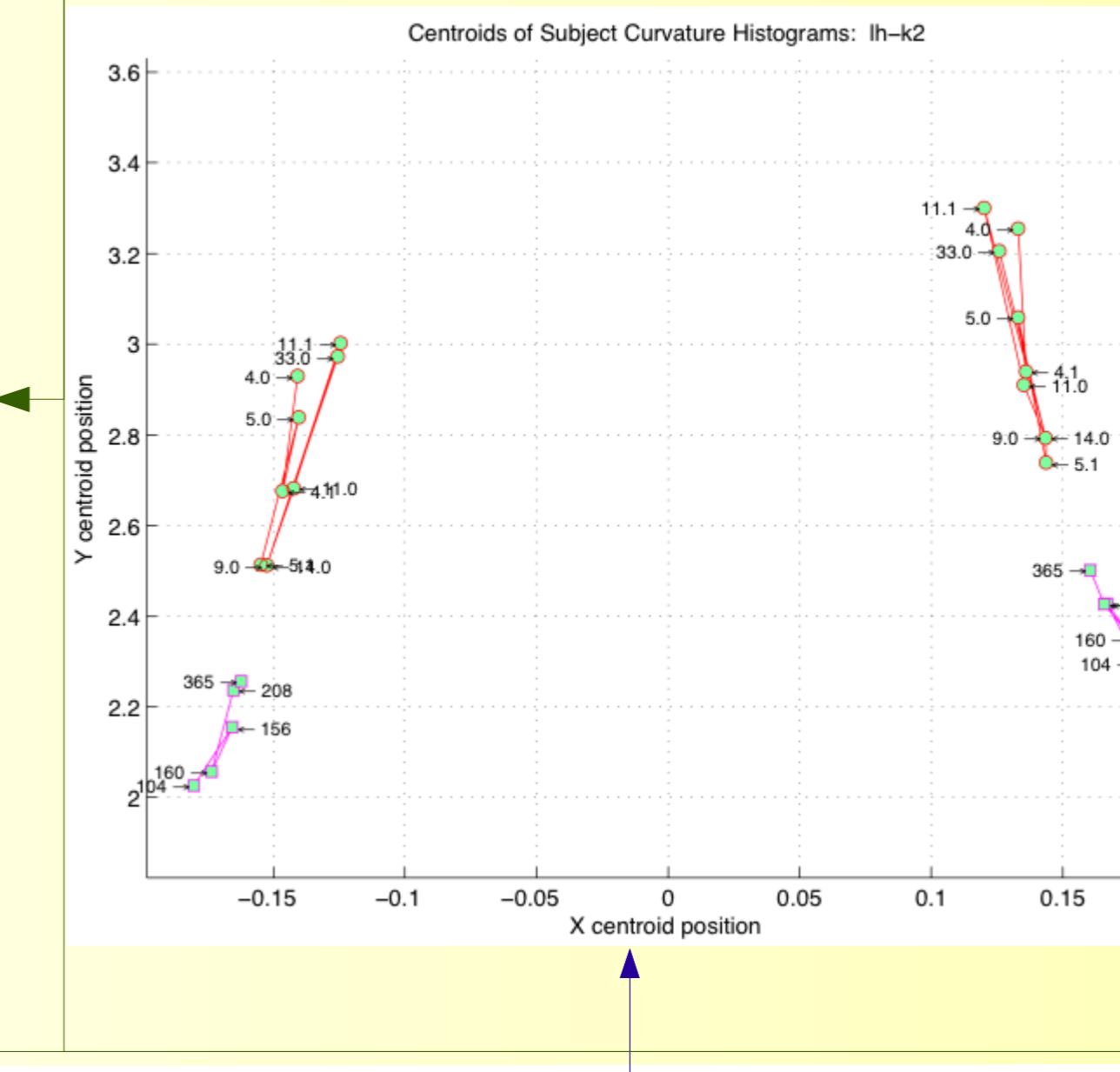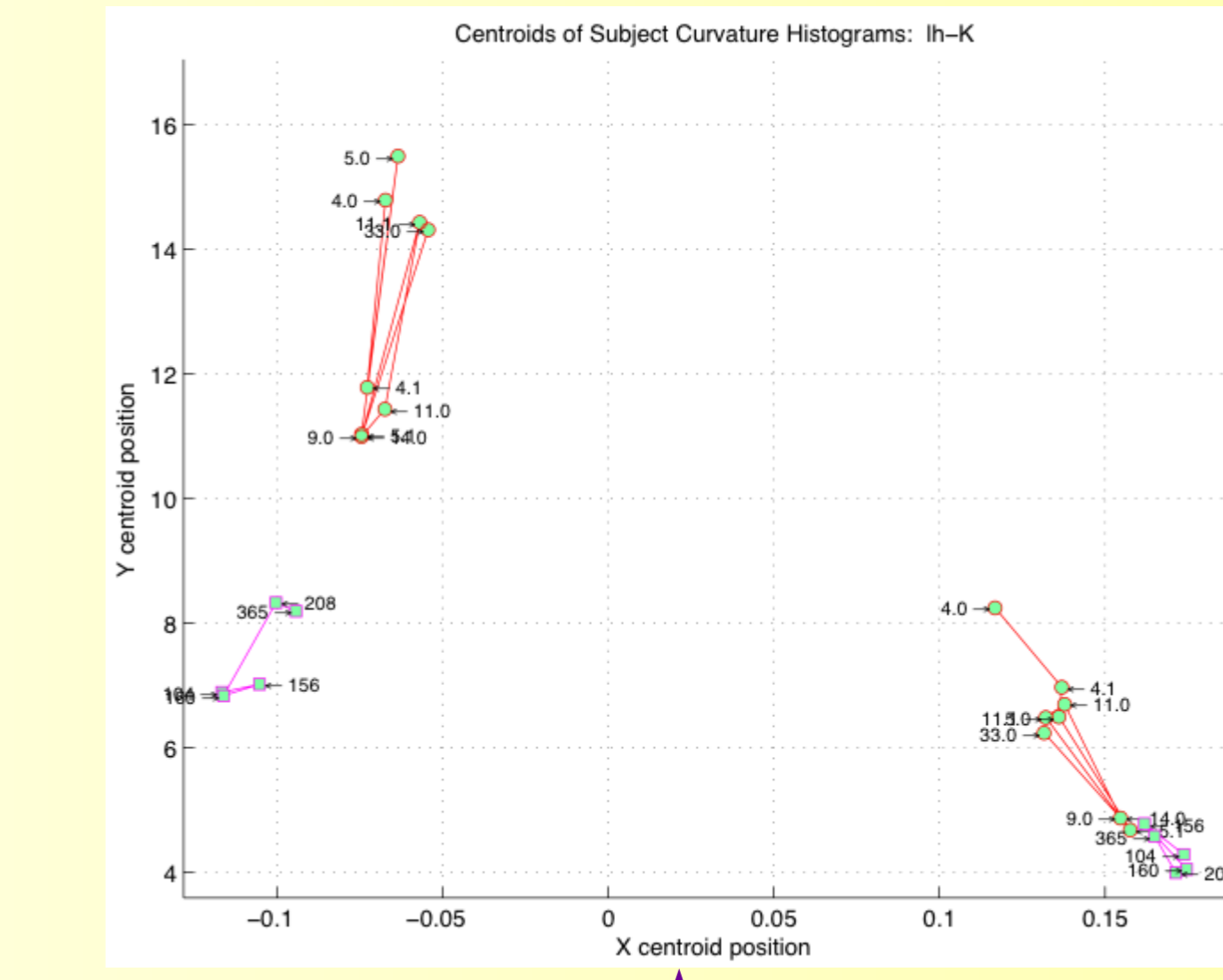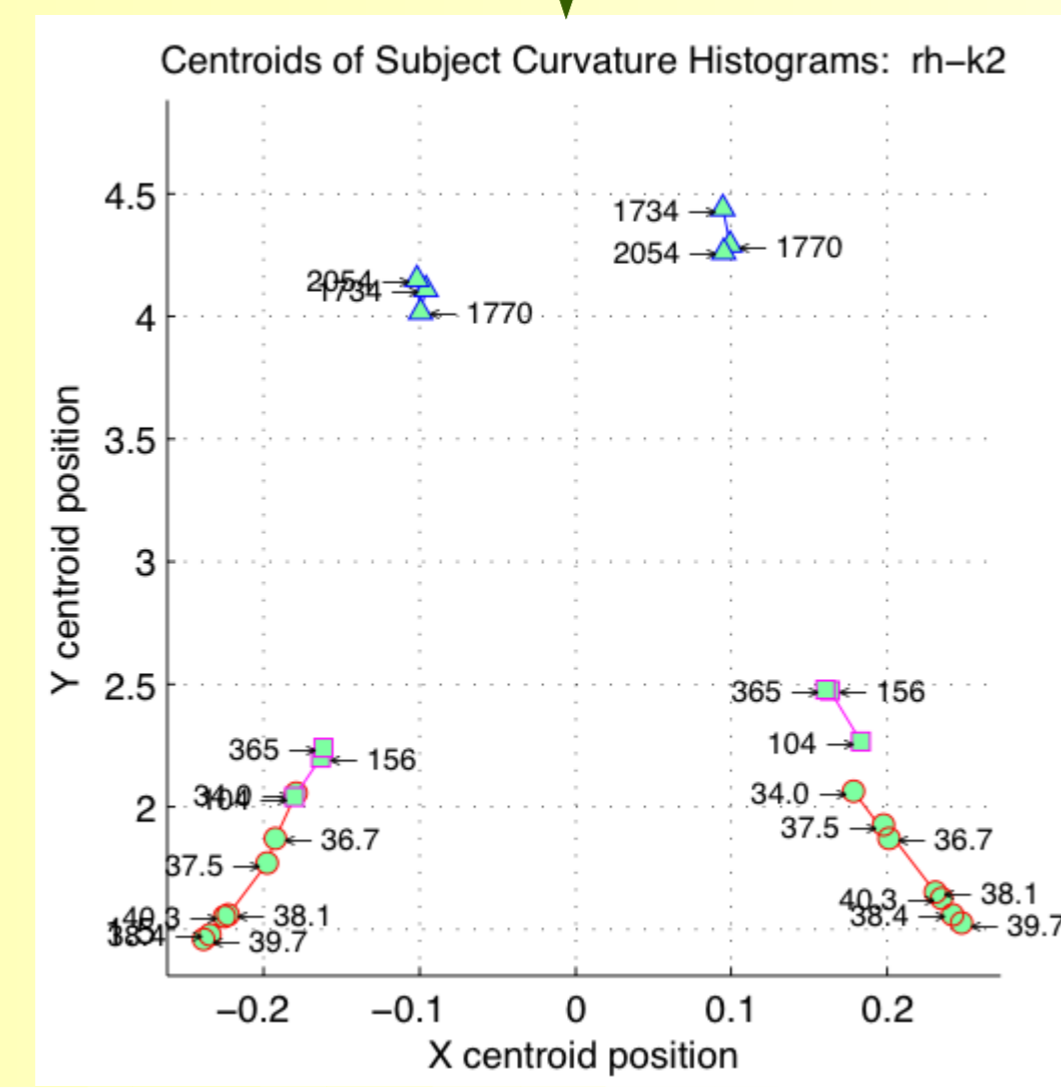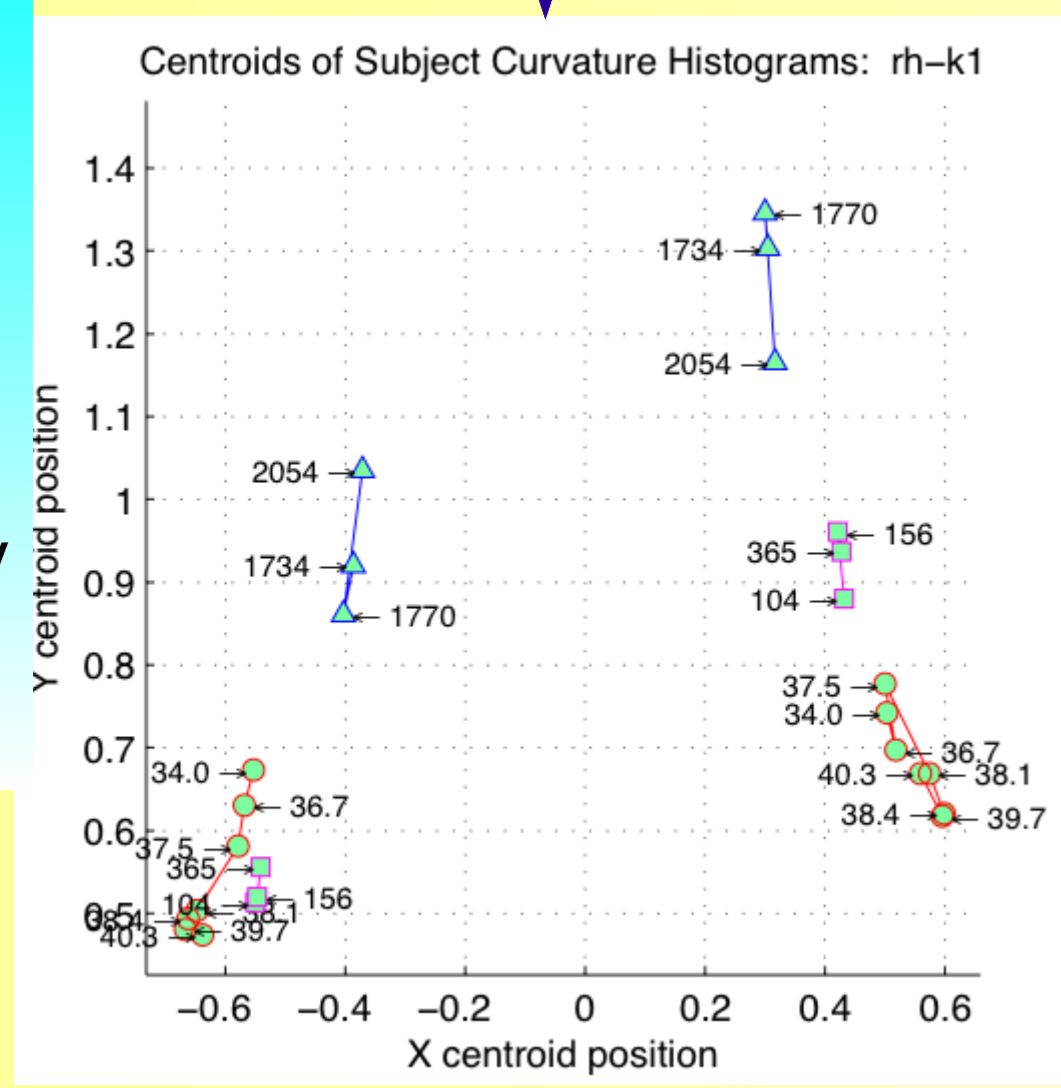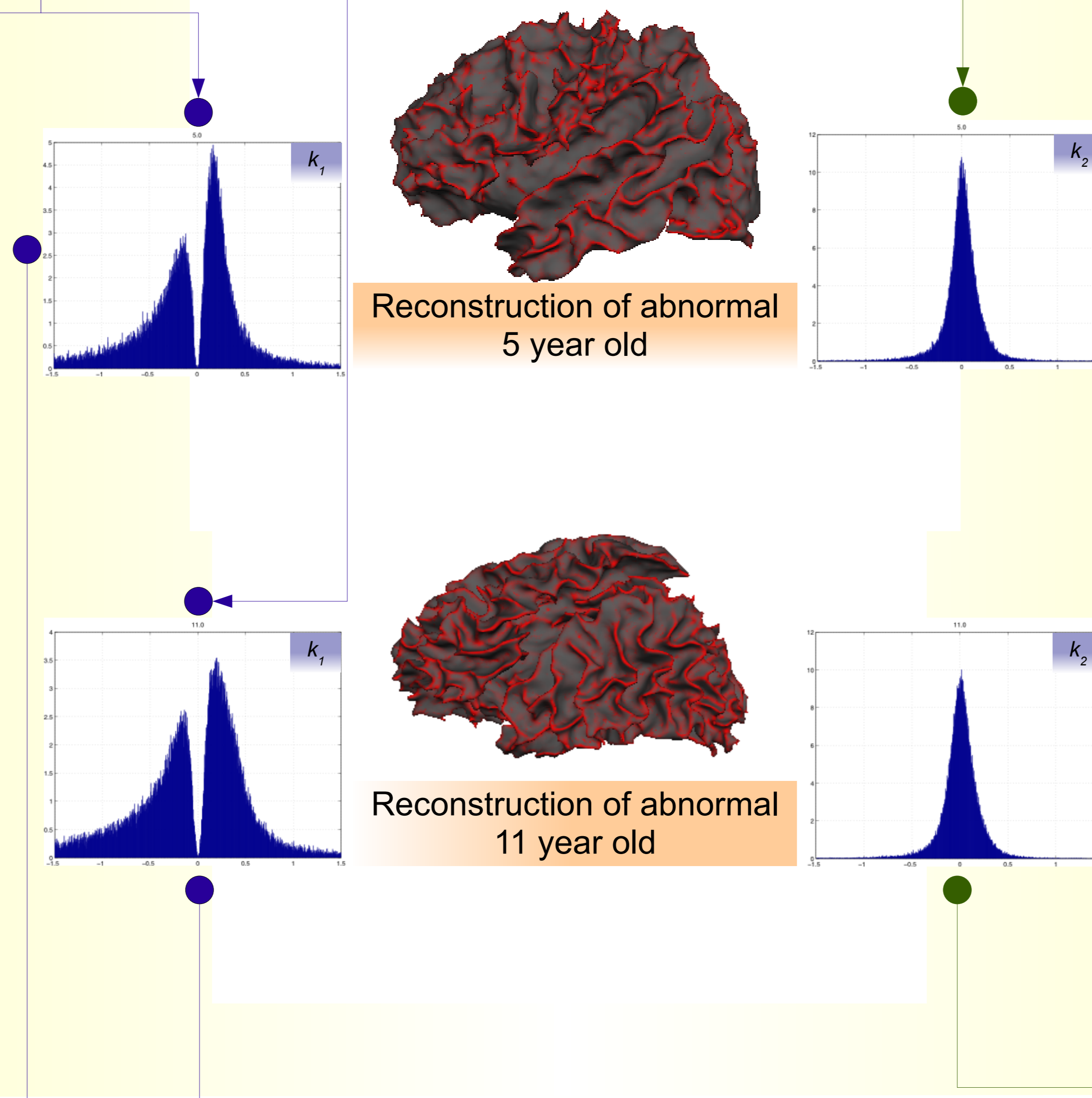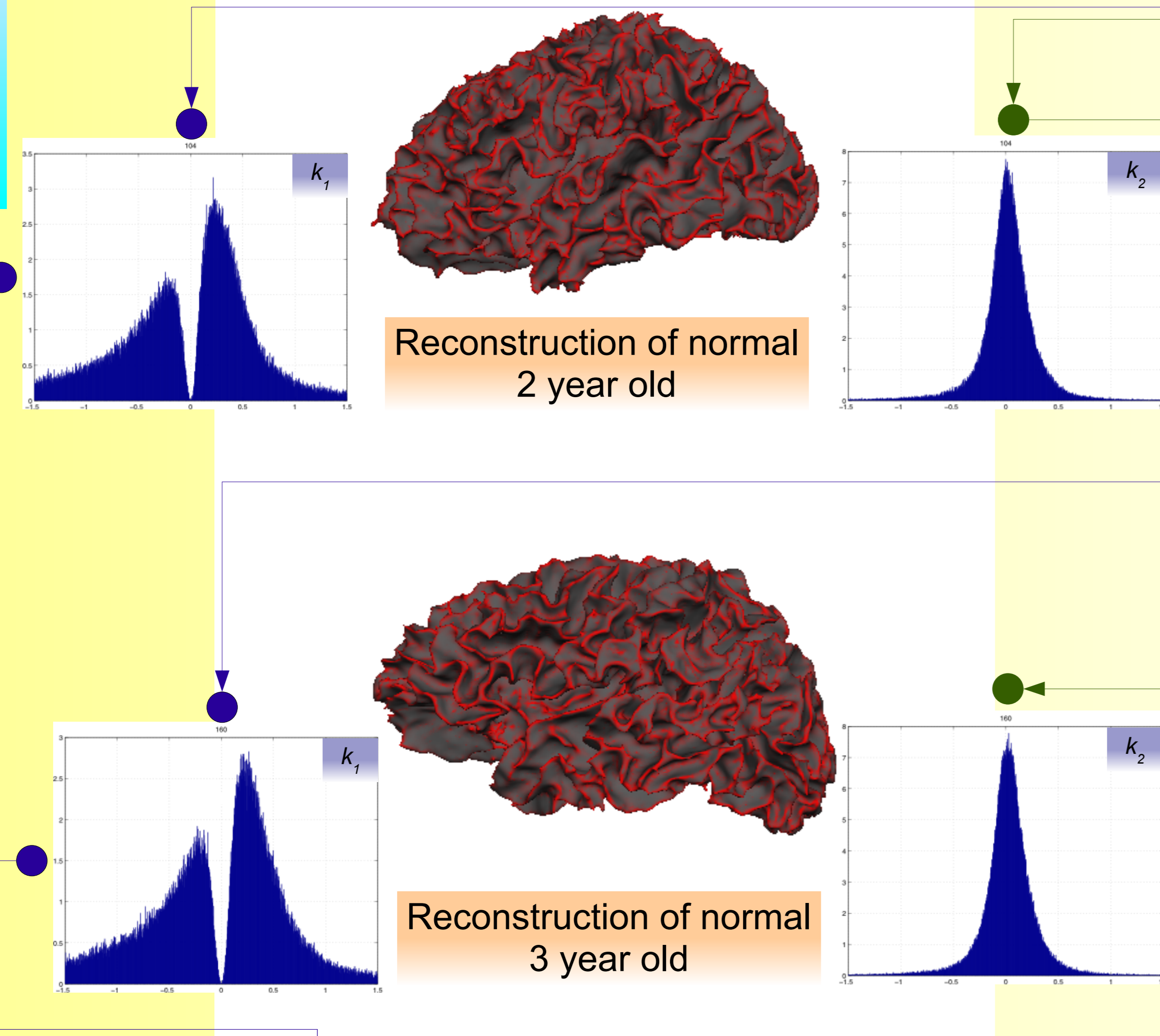 • Sharpness curvature, $S = (k_1 - k_2)^2$

• Adaptive filtering based on Gaussian curvature:
  • Gaussian curvatures thresholded at curvature values between different sulcal scales between $3mm^{-1}$ and $7mm^{-1}$
  • Sharpness of curvature (Willmore Bending) normalized per area at each threshold.

Spatial and Frequency Analysis

• Spatial analysis:
  • Histogram function summarized curvature distribution across surface.

Reconstruction of normal 2 year old

Reconstruction of normal 3 year old

• Frequency analysis
  • Positive and negative lobes of histogram function considered separately and geometric centroids of each determined
  • Centroids plotted on coordinate axes and any clustering properties examined.

Reconstruction of abnormal 5 year old

Reconstruction of abnormal 11 year old

Centroids of Subject Curvature Histograms: rh–k1

Centroids of Subject Curvature Histograms: rh–k2

Centroids of Subject Curvature Histograms: lh–K

Centroids of Subject Curvature Histograms: lh–k2

Centroids of Subject Curvature Histograms: lh–k1

results

Data Acquisition

• volumetric MRI data was collected from:
  • 7 normal newborn subjects with corrected gestational ages (cGA) 31 - 40 weeks;
  • 4 normal pediatric subjects with ages between 2 yrs and 7 yrs;
  • 8 abnormal pediatric subjects with ages between 4 yrs and 14 yrs
  • 3 normal adult subjects with ages of 30, 33, and 40 yrs;
  • 1 abnormal 33 yr old adult.

• A curvature analysis showed age-related clustering in normals across several functions.
• For abnormal cases, the curavture analysis demonstrated marked differentiation between matched control and experiment cohorts.
• Normalized Bending Energy as function of surface Gaussian showed measurably higher energy in early neonate folding surfaces.

conclusion