Fetal cortex extraction using subject specific priors

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Introduction: There is growing research interest in study of the human cerebral cortex and tools such as BrainVoyager and FreeSurfer allow the adult cortex to be extracted from MR images. Xue et al.[1] developed an accurate extraction framework for the neonatal cortex using T2w data. Volumetric T2w image data are now available for fetuses using the slice to volume reconstruction (SVR) method[2,3]. Cortical extraction from these images would be valuable to facilitate both fetal growth studies and provide normative data for premature babies.

Xue et al. used an expectation maximisation approach incorporating a correction step for mislabelled partial volume voxels. The method was initialised using k-means clustering to estimate tissue class distributions because there is no available atlas of priors for this age group. This initialisation proved to be insufficiently reliable for routine use with SVR fetal images, so we have developed a method of creating subject specific priors for the cortex.

Method: The approach uses classifier fusion[4] to provide prior probability maps for the tissue classes in a target SVR fetal brain image. Xue's algorithm[1] was used to create a set of 24 atlases of tissue type density (grey matter, white matter, CSF) in the cortical region of images from neonates with ages ranging from 26-32 weeks. The grey scale neonatal images were registered to each fetal SVR image using a non-rigid registration algorithm[5] to create 24 classifiers of tissue type for each candidate cortical voxel. Fusion through averaging was used to generate a consensus density value for each tissue at each pixel, producing a customised spatial prior to initialise the EM tissue classification process and to subsequently extract the inner cortical boundary with white matter.

The method was tested on 12 fetal subjects (gestational ages 20-30 wks). Data were acquired on a Philips 1.5T Achieva system with a 5 channel cardiac coil using single shot Fast Spin Echo acquisitions (TR=1046ms, TE=120 ms, 1.18x1.18mm^2, 2.5mm slice) and were reconstructed using the method of Jiang[3] as modified by Bertelsen[6]. The segmentations were assessed visually and compared to manual delineations of the cortex in sets of four transverse and three coronal slices spanning the brain for each dataset. Segmentation consistency was assessed by calculating the nearest distances between manually identified points and the automatically generated cortex. Intra-observer consistency for manual segmentation was tested in the same way using independent delineations done in separate sessions

Results: Visually accurate cortical labelling was achieved in all subjects – see figure for examples. The mean intra-rater error was 0.3±0.43mm; mean manual - automatic segmentation error across all slices for all subjects was 1.15±1.03mm.

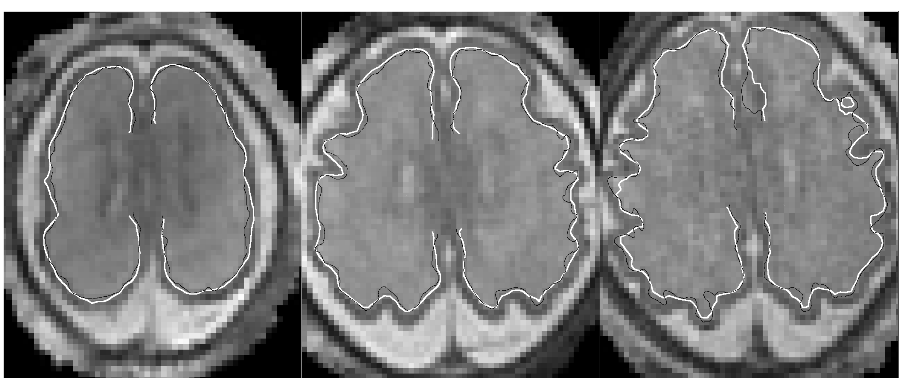

Figure: Inner cortex boundary overlaid on corresponding anatomy for 3 fetal subjects aged 25, 28 and 29 weeks (left to right). Black line = manual delineation, white line = automatic delineation

Discussion: Customized spatial priors for the cortex can be produced by atlas fusion and this allows accurate cortical segmentation of the fetal brain to be achieved for a wide range of gestational ages. These results suggest that production of spatial priors by atlas fusion has promise for a wide range of segmentation applications.

References: 1) Xue et al Neuroimage, 2007, 38p461; 2) Rousseau et al Academic Radiol, 2006, 13p1072; 3) Jiang et al TMI, 2007 26p967; 4) Heckemann et al NeuroImage, 2006, 33p115; 5) Rueckert et al TMI, 1999, 18p712; 6) Bertelsen et al Proc ISMRM, 2008, p3437