Novel MR for Fetal Morphometry

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Motion Estimation and 3D image Formation

Advances in MRI and post processing have revolutionized our ability to quantify early human brain growth in-utero [1]. Motion correction of fast multi-slice imaging permits the formation of true 3D images of the moving fetal head in the majority rather than a fraction of cases, and allows large scale studies of normal human fetal brain growth. The first practical approach to 3D fetal brain imaging [2], proposed a reconstruction based method, by combining ideas from slice to volume matching and image mosaicing. This two step iterative approach involves the formation of a putative 3D image from the scattered slice data to which slice alignment is refined. Newer approaches [3] avoid reconstruction during motion estimation and directly co-align slices so that the anatomy delineated along their collective intersections are consistent. This allows a direct least squares formulation amenable to efficient optimization schemes which can achieve sub-voxel accuracy which permits high resolution 3D reconstruction.

Delineation of Tissue Zones and Boundaries in the human fetal brain

Adult brain MRI tissue segmentation is a well developed field that makes use of a variety of approaches including atlas driven and constrained statistical labeling techniques which can automatically assign image voxels with a tissue classification. Unlike the adult brain, MRI of the early fetal brain reveals a range of tissue zones whose relative contrasts and spatial distributions change dramatically from week to week. These data pose unique challenges to automated analysis that have been overcome by the construction of computational brain atlases which can be used to synthesize age specific tissue priors to drive a conventional EM labeling framework [4,5] to replace careful manual tracing studies [6] with accurate automated measurements.

In-Utero Mapping of Brain Tissue Growth Rates

Regional tissue volumes reveal patterns of growth in the fetal brain [7]. However, in order to quantitatively probe local patterns of volume growth that form a complex folded adult brain, it is necessary to accurately map brains of different ages and containing different tissue zones into a common coordinate frame. Making use of initial automated tissue segmentation we can estimate deformations between only age consistent tissue boundaries of different fetal brains using symmetric groupwise registration. Tensor based morphometry can then be used to construct spatial statistical models of tissue growth rates and detect regions where tissue expansion increases linearly or accelerates over time in regions underlying sulcal formation. In addition, these techniques can map the emergence of subtle asymmetries in local brain size.

In-Utero Mapping of Cortical Folding

The ability to accurately extract boundaries between cortical plate, sub-plate and CSF allow the construction of fine scale surface representations of the early human cortex which are amenable to geometric analyses [8] that can detect the subtle signs of early sulcal formation and allow spatial statistical modeling of the process of gyrification [9] and the detection of abnormal cortical formation [10]. These methods can make use of fine scale groupwise registration to form symmetric group average anatomies and examine local patterns of surface folding asymmetry.

References

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