Automatic regional segmentation of newborn brain MRI using mathematical morphology on dual contrast

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Introduction

Segmentation of newborn brain structures from MRI is still a difficult problem compared to adults for the following reasons: 1) contrast between gray and white matter is inverted and changes during the first weeks of life; 2) strong signal heterogeneity due to myelination process, which affect both cortical structures (central gyri) and white matter regions (corticospinal tracts); 3) the small size of the brain requires high resolution MRI, which leads to low signal-to-noise; and 4) small structures, especially the cortex, are prone to partial volume effects. Automatic methods developed for adults are therefore not suited for infants. Warfield et al. [1] proposes a k-nearest neighbour classification combined with template matching. This approach has the advantage of separating myelinated from non-myelinated white matter, but suffers from partial volume errors. Improvement of this method was proposed by using probabilistic atlas to define priors [2]. However, intensity based segmentation methods are limited due to significant tissue inhomogeneities. We propose a morphological based automatic segmentation of 4 different regions (cerebellum, brain stem, right- and left-cerebrum) of newborn brain MRI. Furthermore, the cerebrum hemispheres were segmented in white and gray matter.

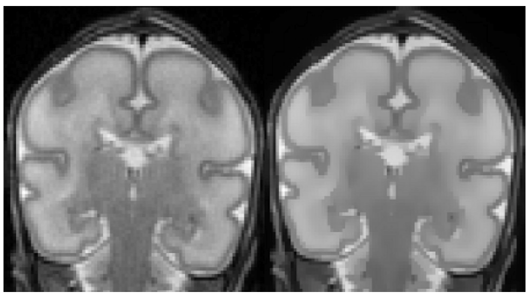

Figure 1: *Raw T2 image (left) and after filtered (right)*

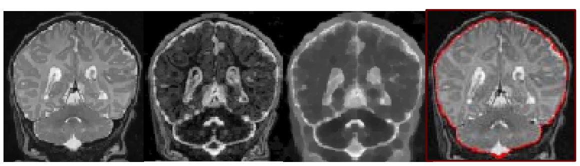

Figure 2: *Original image, gradient image, viscous-closing of the gradient and watershed line superimposed on original image.*

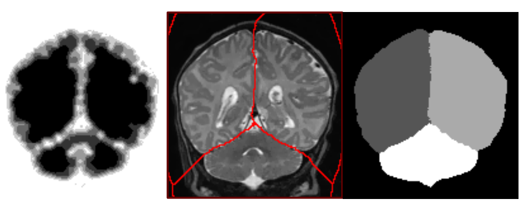

Figure 3: *Distance transform of the union of gray and white matter classes, watershed of the 3 regions, and labelled image of the 3 compartments.*

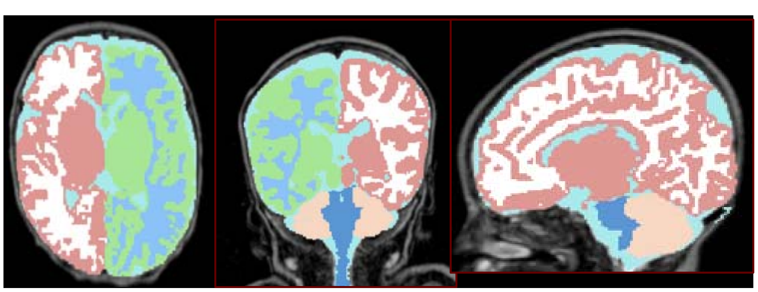

Figure 4: *Example of the results of the segmentation*

Material and Methods

Subjects and MRI acquisition Babies from 30 to 40 weeks of gestational age were included in this study. Coronal T1 and T2 MRI with a resolution of 0.8x0.8x1.2 mm^3 were obtained at 3T (Trio, Siemens) using MPRAGE (TR/TE/TI 2500/2.89/1100 ms) and fast spin echo (TR/TE 4600/150 ms, ETL 15). Acquisition time was 7,0 and 5,5 min respectively. Coregistration of T1- and T2-weighted images was done with SPM2 [3].

Data processing Anisotropic diffusion filter was applied to reduce the amount of noise without altering brain structures contours [4]. The diffusion coefficient κ was estimated automatically based of the standard deviation of homogeneous regions (figure 1). The intracranial cavity was isolated using viscous watershed [5], which appeared to be a robust method for watershed algorithm (figure 2).

The compartmentalization of the brain in left-, right-hemisphere and cerebellum was accomplished using watershed applied to the sum of the viscous gradient and the 3D distance transform of the union of gray and white matter obtained from 3 clusters k-means classification (figure 3).

The final segmentation of cerebrospinal fluid (CSF), gray matter and white matter classes was performed on the separated cerebrum hemispheres. CSF was removed first by selecting the brightest among the simple points belonging to the inner gradient. This point, which corresponds to CSF is removed. The procedure is repeated until the entire CSF is remove, giving rise to cerebrum objects. Gray matter and white matter tissues were obtained by lambda thickening [6]. To do so, seeds located in the white matter have to be detected. Because the histogram of these 2 classes are well separated, the 2 seeds can be obtained simply by k-means classification followed by an erosion to get rid of partial volumes.

Results

Figure 4 represents the coronal, saggital and axial views of the cerebellum, the brain stem, as well as the white and gray matter of the left- and right-hemisphere of a newborn brain.

Discussion and Conclusion

We have presented a new method for automatic newborn brain segmentation using multi-channel MRI. The tools used in this work are: 1) The anisotropic diffusion for the filtering step, 2) the k-means classification in double modality T1 and T2 to determine the seeds, 3) the watershed segmentation based on markers and gradients functions, 4) the homotopic lambda thinning and thickening and 5) the component tree building and pruning. The parameters used in the different functions were determined by image analysis, providing a fully automatic algorithm. This method may provide an attractive alternative methods to segmentation based on voxel's intensity. In fact, intensity-based classification was used only to estimate broad homogeneous regions. These regions were then used as markers for the different segmentation steps.

The major contribution of our method is the automatic separation of the cerebellum, the brain stem and the 2 hemispheres. This regional subdivision will permit to better interpret volume changes observed during brain development under normal and pathological conditions.

Future work will include the segmentation of subcortical gray matter and the distinction of myelinated from non-myelinated white matter regions.

References [1] Warfield SK *et al*, Medical Image Analysis 2000 4:43-55 [2] Prastawa M *et al*, Medical Image Analysis 2005,9:457-466 [3] www.fil.ion.ucl.ac.uk/spm [4] Perona P *et al*, IEEE Trans Patt Anal Mach Intel 1990, 12:no7 [5] Vachier C *et al*, J Math Vis 2005, 22:251-267 [6] Dokladal P *et al*, Pattern Recon 2003, 36.