Automated Partial Volume Tissue Classification in Preterm Neonates

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Introduction: Automated tissue classification is an important step in the analysis of MRI data. Well-established approaches exist for adult brain images, but very preterm neonates present additional challenges. Much smaller heads result in lower resolution and greater noise. The grey matter (GM) and white matter (WM) contrasts are also reversed in neonates on T1 and T2 images. As a result, partial volume (PV) voxels which contain both GM and cerebral spinal fluid (CSF) end up appearing as WM. A handful of approaches, mostly based on the classic expectation-maximization algorithm (EM), have focused on this problem [1]. We present an alternative automated multispectral segmentation algorithm, based on the trimmed minimum covariance determinant method of Tokha et al [2], originally designed to solve the PV problem in adults using a more computationally efficient algorithm that the EM-approach.

Algorithm: Following [2], our approach models three tissue classes (CSF, GM, WM) as multispectral Gaussians, and two PV classes (CSF/GM, GM/WM) as weighted sums of the above. Manually selected training data is first used to produce an initial hard classification. This initial classification is pruned to remove likely PV voxels, and the parameters for the three tissue classes are then calculated using the minimum covariance determinant estimator [2]. The likelihood of each voxel belonging to each class is then calculated, with the likelihood of belonging to a PV class computed from the marginal distribution for the mixture of two classes with relative proportions unknown. These likelihoods are then refined by an iterative process of maximum a posteriori (MAP) labeling using a Markov random field (MRF) model for the adjacent 26 voxel neighbourhood [2]. In order to deal with the particular PV problems found in preterm neonates, we have modified the neighbourhood function of the MRF, as described in Table 1. In addition, after each iteration, two simple morphological operations are performed – one to erode small patches of CSF/GM partial volumes surrounded by WM, and the second to erode small patches of WM or GM/WM surrounded by CSF or CSF/GM.

Evaluation: This algorithm was tested on 44 preterm neonates born at less than 32 weeks GA, scanned within two weeks of birth on a 1.5T MRI system (Signa EXCITE HD, GE Medical) with a neonatal head coil and MR-compatible incubator (AIR Inc., Cleveland). Scans included T1 SPGR (1 x 1 x 1mm, TR=23ms, TE=4ms), T2 FRFSE (1 x 1 x 1mm, TR=4000, TE=145), and proton density (1 x 1 x 1.5mm, TR=27ms, TE=4ms), all using an axial orientation and a 128 x 128 mm FOV. These three volumes were used as the inputs to the segmentation algorithm. Training data were selected for all subjects, and the results of the segmentation were evaluated visually. In addition, a second user independently selected training data for 12 of the subjects, and the final results were compared using a Dice overlap measure. Finally, all 44 segmentations were registered to a common space using affine registration and the results combined.

Results and Conclusions: Sample results are seen in Figure 1 and show clear GM/WM/CSF differentiation. Our results also successfully identified the CSF/GM partial volumes in most cases. In addition, the inter-rater comparison produced highly favourable results, with all mean Dice coefficients > 0.8 (Table 2). Thus, this algorithm represents a fast and reliable alternative approach to automated tissue classification in preterm neonates, with visually satisfactory results and excellent repeatability.

k \ j	CSF	C/G	GM	G/W	WM
CSF	2.0	1.0	-1.0	-1.0	-1.0
C/G	1.0	1.0	1.0	-1.0	-2.0
GM	-1.5	0.5	2.0	0.5	-1.5
G/W	-2.0	-1.0	1.0	1.0	1.0
WM	-1.0	-1.0	-1.0	1.0	2.0

Table 1: Neighbourhood function for MRF at voxel k, surrounded by 26 neighbour voxels j.

	CSF	C/G	GM	G/W	WM
Mean	0.95	0.93	0.96	0.83	0.98
SD	0.05	0.05	0.02	0.09	0.01

Table 2: Mean inter-rater Dice coefficients

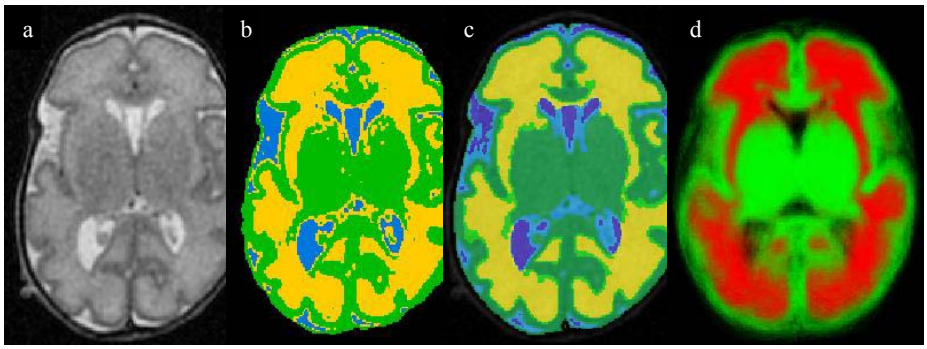

Figure 1: T2 image from a preterm neonate scanned at 32 weeks GA (a); Initial hard classification – note stray WM voxels outside cortex and in ventricles (b); Final result of PV classification (c); Average of WM and GM from PV classification of 44 preterms.

References: [1] Weisenfeld and Warfield. *NeuroImage* 47 (2009), pp. 564-572; [2] Tokha et al. *NeuroImage* 23 (2004), pp. 84-97