A Robust Brain Segmentation of Multispectral MRI Using A Supervised Hybrid Classifier

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INTRDOCUTION

Multispectral MRI, providing a stack of high quality images with specific image contrast, is important for clinical studies and researches of brain morphometry. Quantitative assessment of the brain tissues from MR images can be performed by unsupervised methods, which currentlyhave been applied for automated segmentation of brain image and desirable for reproducible in clinical environments for brain morphometry. But, there are some considerations that must be taken into account for the effects of mis-registration, anatomical diversity, specific target volumes, and different populations.

A supervised hybrid classifier, derived from iterative Fisher's linear discriminant analysis (IFLDA) [1] coupled with the volume sphering analysis (VSA) and support vector machine (SVM) [2], has been developed to effectively segment multispectral brain MRI. With no need of a prior knowledge about the tissue intensity or anatomical information, the proposed hybrid classifier utilizes the statistics-based approach for tissue classification of multispectral MRI and takes advantages of significant reduction of operator burden and tremendous saving of computing time [3]. In this experiment, we focused on the brain volume measurement of GM, WM and CSF in different groups of subjects and tested the clinical applicability of the proposed method in brain volume morphometry.

MATERIALS and METHODS

The synthetic data from the BrainWeb Simulated Brain Database included T1-weighted, T2-weighted and proton density images with voxel size of 1x1x1mm and various noise levels. Real brain MRI data were acquired from ten young adult healthy subjects, ten elderly subjects and ten dementia subjects by using in a whole body 1.5T MR system. The protocol included high-resolution 3D acquisition of T1-weighted images (MP-RAGE), T2-weighted and FLAIR images.

The hybrid classifier approach consists of two stage processes. First, the pre-processing stage included motion correction with rigid body approach, intensity inhomogeneity correction with N3 method, and skull striping with FSL-Brain Extraction Tool (BET). Second, the classification stage comprised with VSA, SVM and IFLDA for brain segmentation. The entire volume data of multi-spectral MR images are initially sphered by removing the first two order statistics. Then, a small set of training data, containing a 3x3 matrix (of 9 pixels) of GM, WM, CSF and background (BG), were depicted by operator from any one of 3D images for SVM classification of the sphered multispectral images. The results of SVM classification served as the training samples of FLDA to classify tissue substances. Finally, the classified results from FLDA were used as the training samples of the next FLDA to classify tissue substances iteratively.

For synthetic data experiments, the similarity index was calculated to estimate how close of the classified GM, WM and CSF voxels to the ground truth data, for evaluating the accuracy of the proposed hybrid method in brain tissue segmentation. Brain volume measurement of GM, WM and CSF from real MRI data was repeated three times by one operator at an internal of one week and another two measurements by two other operators. The intra- and inter-operator variability was utilized to evaluate the consistency of the hybrid classifier in brain volume measurements. In addition, the similarity index of the segmented GM, WM and CSF voxels between every pair of three measurements was also calculated to further analyze the reproducibility of the proposed hybrid method.

RESULTS

The supervised hybrid classifier generates accurate brain morphometry of the synthetic image data (Table 1). The means of GM, WM and CSF volume measurements in three groups of study subjects were 626.1±95.5ml, 472.6±82.1ml and 139.2±28.5ml in young adults, 552.6±28.0ml, 486.7±34.9ml and 208.4±48.2ml in aged adults, 485.2±64.3ml, 416.0±46.2ml and 238.2±56.8ml in dementia group. Table 2 showed the low means of coefficients of variance of three measurements by one and three operators. Table 3 illustrated the high similarity indices of the classified GM, WM and CSF voxels between different segmentation experiments by one operator and by different operators.

Table 1. The simularity indexes of GM, WM and CSF quantification in the high-resolution synthetic MRI ($1x1x1mm^3$) at various parameter settings

Simularity index		GM	WM	CSF
0% of intensity nonuniformity	Noise 0%	0.977	0.988	0.957
	Noise 1%	0.970	0.981	0.955
	Noise 3%	0.951	0.963	0.950
	Noise 5%	0.933	0.946	0.946
20% of intensity nonuniformity	Noise 1%	0.963	0.976	0.951
	Noise 3%	0.963	0.976	0.951
	Noise 5%	0.933	0.946	0.945

Table 2. Coefficients of variances of GM, WM and CSF volume quantification in three groups of subjects.

	CV.% of three measurements by one operator			CV.% of three measurements by three operators		
	Young adults	Aged adults	Dementia	Young adults	Aged adults	Dementia
GM	0.07±0.10	0.05±0.04	0.16±0.14	0.12±0.12	0.06±0.04	0.34±0.30
WM	0.04±0.06	0.03±0.03	0.18±0.22	0.07±0.07	0.04±0.02	0.38±0.45
CSF	0.36±0.27	0.07±0.10	0.20±0.21	0.38±0.29	0.12±0.08	0.24±0.24
GM+WM	0.05±0.04	0.01±0.01	0.04±0.04	0.05±0.04	0.02±0.01	0.06±0.05

Table 3. The mean similarity indices of GM, WM and CSFclassification in three groups of subjects between three measurements by one operator and three operators.

	Three measurements by one operator			Three measurements by three operators		
	Young adults	Aged adults	Dementia	Young adults	Aged adults	Dementia
GM	99.90±0.16	99.96±0.07	99.76±0.25	99.85±0.16	99.94±0.03	99.70±0.23
WM	99.92±0.18	99.98±0.03	99.80±0.21	99.87±0.18	99.96±0.02	99.72±0.28
CSF	99.80±0.18	99.95±0.07	99.85±0.17	99.66±0.31	99.92±0.05	99.83±0.17

DISCUSSION

The proposed supervised hybrid classifier has several advantages in quantification of normal GM and WM brain tissues, and particularly CSF volume, which had been difficult to be effectively and correctly quantified by the other techniques in previous studies. First, the segmentation technique was performed in a native coordinate space, without transformation to the standard coordinate space. Second, there was no need of probabilistic atlas for initialization of classification. Third, the supervised segmentation method only required a one small set of training samples, with minimizing operator burden and operator- independent results. Forth, the supervised method could effectively reduce the computational cost in processing a large data set of 3D high spatial-resolution multispectral MRI. Last, the proposed hybrid method provides a high reproducible segmentation for brain morphometry.

CONCLUSION

The proposed supervised hybrid method can perform a high reproducible segmentation in the native coordinate space, avoiding the registration problems in transformation to a standard coordinate space, which would be particularly promising for longitudinal studies of brain morphometry with multispectral MRI.

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