Improving Quantitative Analysis of Gray and White Matters in Brain Magnetic Resonance Imaging Based on Coupling Independent Component Analysis with Support Vector Machines

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ABSTRACT

Independent component analysis (ICA) is a linear technique for performing blind source separation, can be useful for preprocessing transformation before clustering and segmenting the structures of brain MR images. Support Vector Machine (SVM), a supervised voxel classification method, has been designed using a small set of training data and subsequently refined by actively learning for operating satisfactorily with data outside. In this study, we tried to implement a semi-automated segmentation method by incorporating ICA and a supervised SVM for quantitative volumetric analysis of brain gray and white matter.

INTRDOCUTION

Quantification of brain volume is important for understanding brain structure and diagnosis of subtle anatomical changes in variant brain diseases. Magnetic resonance imaging (MRI) provides a stack of high quality images with different tissue contrast, based on the local tissue parameters of T1, T2 relaxation times and proton density, makes more reliably characterization of each voxel than single-contrast techniques [1]. In recent years, there has been growing interesting in utilization of MR data for segmentation of brain structure. The success of quantitative volumetric measurement of brain depends on the accuracy and reproducibility of the segmentation methods. Recently, a new application of independent component analysis (ICA) in brain MR image analysis was also investigated to perform image evaluation for separating tissues with different relaxation characteristics and generating new contrast images of gray and white matter [2]. This method is a linear technique for performing blind source separation, can be useful for preprocessing transformation before clustering and segmenting the structures of brain MR images. In this study, we tried to develop a semi-automated segmentation method by incorporating ICA and a supervised voxel classification method (support vector machine; SVM) for quantitative volumetric analysis of human brain. The validation of the segmentation method has been tested with simulated image studies.

MATERIALS AND METHODS

Synthetic MR brain images available on website [3] were used to demonstrate the proposed new segmentation method. The simulated images include T1, T2, and PD weighted images with the following parameters: 5 mm slice thickness, 0%, 1% and 3% noise level, and 0% and 20% intensity non-uniformity. At first, we utilized ICA to generate three new statistically independent component (IC) images. Support Vector Machine (SVM), with active learning form a small set of training data, was used for classification of three IC images and quantification of gray matter (GM) and white matter (WM) volumes [4]. Subsequently, GM and WM voxels were extracted before and after removal of the extrameningeal structures in the classified images by a watershed transform, called “stripped-skull method”. Secondly, the stripped-skull method was used to remove the extrameningeal structures in three simulated images. Then, three extracted images underwent the processes of ICA and SVM segmentation for quantification of GM and WM volumes. Reproducibility test was also performed by using different operator-selected training data. The Tanimoto index was measured to statically compare the results of the GM and WM voxels with the ground truth data of the simulated brain images.

RESULTS

The proposed ICA coupled with a feature extraction-based SVM classification technique could effectively segment brain MRI, as shown in Table 1. The results showed that the higher sensitivity of GM voxel classifications, the higher specificity, accuracy and Tanimoto index of WM voxel classifications, independent of segmentation methods. There was a significant difference of specificity, accuracy and Tanimoto index of GM and WM voxel classifications between the “ICA and SVM” segmentation before and after the stripped-skull process due to much decrease in false positive tissue voxels from the extrameningeal structures. There was no significant change of sensitivity of GM and WM voxel classifications because no difference of true positive and false negative voxels was noted before or after removal of the extrameningeal structures. Our results also revealed that no improvement of the brain classification validity by removal of the extrameningeal structures before the processing of “ICA and SVM” segmentation.

Table 1. The results of GM and WM voxel classifications with three different methods by processing the three simulated MR images with 0% of noise and intensity non-uniformity. “ICA +SVM” is the method of coupling ICA with SVM segmentation technique. “Tripped-skull” is the method to remove the extrameningeal structures by a water-shed transform before or after the process of “ICA +SVM”.

		Sensitivity (%)	Specificity (%)	Accuracy (%)	Tanimoto Index
“ICA+SVM” without tripped-skull”	GM	97.60	85.93	88.02	0.57
	WM	87.63	95.20	94.71	0.65
“ICA+SVM” with “tripped-skull”	GM	97.57	95.66	96.04	0.79
	WM	87.45	99.47	98.37	0.84
“Stripped-skull” and “ICA+SVM”	GM	95.22	95.56	95.42	0.75

DISCUSSION and CONCLUSIONS

The unsupervised segmentation methods have many limitations, such as unknown number of clusters which resulting in region merging/splitting. The aforesaid difficulties do not arise in the supervised methods, but the supervised methods necessitate appropriate training, suffer from intra-/interoperator variability, and time-consuming. Our experiment suggested the effective brain MRI segmentation of the proposed two stage technique. The ICA in the first stage was to automatedly separate distinct objects into ICs in the sense of statistical independency, and generated new contrast images of gray and white matter. Then, a supervised voxel classification method (SVM) was in the second stage to segment the desired WM and GM voxels from other brain tissue substances, using a small set of training data and subsequently refined by actively learning for operating satisfactorily with data outside.. This semi-automated segmentation method does not only obviate the limitations, but also performs better than those of other reported in the literatures.

References

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