

Automatic Segmentation of Human Brain, Grey and White Matter in MRI: A Robust and Accurate Algorithm Based on the Tissues' Features Analysis

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Introduction

The recognition and segmentation of brain tissues is usually performed with manual or semiautomatic softwares. Semiautomatic softwares have an overall accuracy of about 9% compared with results obtained through manual segmentation, while fully automatic softwares actually provide inferior accuracies [1]. Moreover, we noticed that most of the commercial softwares do not offer built-in evaluations of the precision of the obtained results. All in all, this is very time consuming and implies high subjectivity of the results.

These remarks emphasize the usefulness of an algorithm for automatic analysis of brain tissues, specifically for grey and white matter segmentation from raw images, without the introduction of subjective parameters and able to give informations about the precision of the results.

Method Characteristics

The algorithm we realized works on 3D reconstructed T1 images using balloons, intensity based and geometrical connectivity techniques.

The first part of the algorithm (Fig.1) automatically analyzes the raw data matrices using built-in criteria such as spatial localization, anatomical proportions, geometrical connectivity and intensity values. It then extracts the cerebrum and detects its volume. This is done through experimental analyses of the raw data matrix and identification of the voxels correspondent to the external cerebrum surface. Another important part of our algorithm is constituted by a process we called 'certain spatial localization'. This process uses characteristic features of few substructures to identify them in the raw data. Moreover the introduction of precision values for the obtained results is included in our algorithm.

The second part of the algorithm (Fig.2) automatically analyzes the 3D data obtained for the extracted cerebrum using anatomical, geometric, statistic, and solid experimental analysis criteria. It automatically segments white and grey matter and measures their volumes. The experimental analysis criteria of our algorithm are justified through accurate analyses and anatomical and structural considerations. The most important feature of our algorithm is that, in addition to intensity based criteria, it includes criteria based on geometrical topologic characteristics of grey-white matter interface to identify separation surface. Moreover it includes an autocalibration process to select the separation intensity between white and grey matter with a constant criterion. Also in this case our algorithm does not use approximated approaches, but identifies the voxels most probably belonging to the searched surface.

Results

The algorithm was tried on 160 subjects, and worked in the 100% of the studies.

First Part of the algorithm: the average accuracy results for the cerebral volumes extracted are about +2.5%, while the average precision evaluations obtained are about $\pm 3\%$. The time needed for this process is about 8 minutes with our HP4200 workstations. A comparison of our algorithm results with commercial softwares as FSL and Brains2 was also performed on 50 subjects. The most important difference between our algorithm and the others is that ours identifies the brain surface with the maximum possible resolution through exact determination of the tissue correspondent to the voxel, while the others use approximated approaches such as triangulation or masks. Compared with FSL Bet and Brains2, our algorithm showed inclusion of all parts of cerebrum and more than double accuracy in the comparison with manually extracted cerebra (Tab.1).

Second part of the algorithm: the average accuracy results for grey matter volumes extracted are about +2.5%, while the average precision evaluations obtained are about $\pm 3\%$. The average accuracy errors for the white matter volumes extracted are of 0%, while the average precision evaluations obtained are of the order of $\pm 3\%$. The time needed for this process is of about 10 minutes with our HP4200 workstations. Also in this case was performed a comparison of our algorithm results with a commercial software called FSL Fast on 50 subjects. The most important difference between our algorithm and FSL Fast is that ours includes criteria based on geometrical topologic characteristics of grey-white matter interface to identify separation surface, besides intensity based criterions. So it doesn't include tissues with intensity

equal to the considered one if they're not geometrically connected to it and included in cerebrum. Different tissues are instead usually included with FSL Fast. Moreover our algorithm includes an autocalibration process that applies a constant criterion for selecting the separation intensity between white and grey matter. Another comparison between our algorithm and FSL Fast is done on the σ (full width at half maximum) of the distribution of the grey-white matter separation intensities. The reduction of the subjectivity of the segmentation process is confirmed by the results obtained (Fig.3), that show less dispersion in the separation intensities distribution obtained with our autocalibration algorithm then the dispersion obtained by human being.

Conclusions

We realized an automatic algorithm to extract and segment grey and white matter in T1 weighted MRI 3D reconstructed images.

In comparison to commercial softwares, it shows better total error (3% vs 9%). Also, it is fully automated, utilizes constant criterions to distinguish different tissues, and evaluates the precision of the results. It should also be emphasized the accuracy of our algorithm, since it includes the whole extracted tissues, while usually other softwares do not. Furthermore, our algorithm used the so-called 'spatial certain localization', which is based on the automatic localization of substructures in the encephalon and leads to simple subdivision and study of specific cerebrum geometric areas as left or right hemispheres, frontal and parietal lobes.

References

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- [3] Suri et al., Computer Vision and Pattern Recognition techniques for 2-D and 3-D MR cerebral cortical segmentation: A State of the Art Review, *Pattern Analysis and its Applications*, 1(5):46-76, 2002

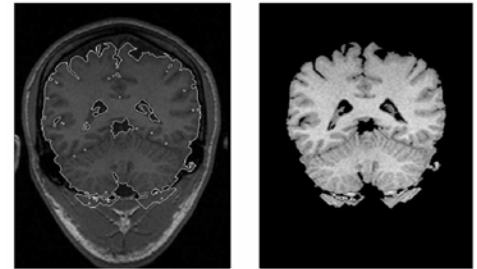


Fig.1: Brain extraction in an intermediate section

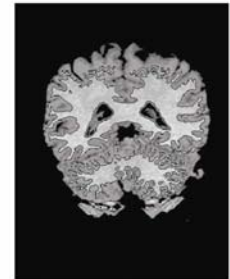


Fig.2: Grey and white matter segmentation in an intermediate section

Algorithm	Relevated Accuracy
FSL Bet	(+9% _o , -9% _o)
Brains2	(+10% _o , -9% _o)
Realized Algorithm	(+3% _o , -1% _o)

Tab.1: Accuracy relevated on segmented cerebrum volume

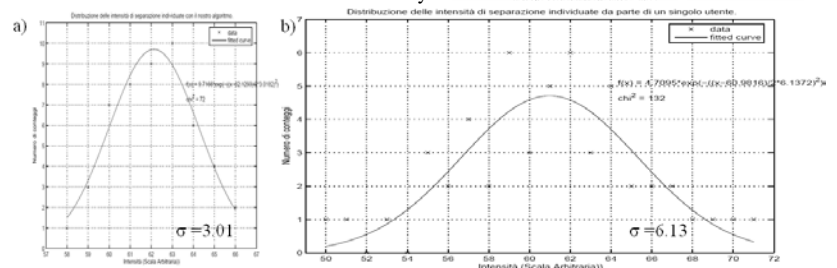


Fig.3: Grey-white matter separation intensities distribution with a) our algorithm b) FSL Fast