Automating Segmentation of Lateral Ventricles in 3.0 Tesla MR Images

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Purpose

The lateral ventricles are major cavities in the top section of the human brain filled with cerebrospinal fluid (CSF). Some brain diseases cause change in shape and size of the lateral ventricles. The advancement of Alzheimer's disease (AD), for instance, is assumed to affect the hippocampus, and thus to indirectly influence the adjacent temporal horns, which are a part of the ventricular system. Manual delineation of regions of interest is time-consuming and error-prone. In this paper we are proposing a semi-automatic procedure for segmenting the lateral ventricles from human brain MR volumes. With the long-term objective of a comprehensive study of AD, particular importance is given to the inclusion of the temporal horns in the segmentation process.

Method

An algorithm was developed for segmenting the lateral ventricles including their temporal horns in MR images. Previous work has addressed this problem using knowledge-based [1] or fuzzy-set [2] approaches, amongst others. Our semi-automatic technique comprises several interdependent processing steps which are designed to eliminate the risk of under- and oversegmentation due to variations in shape and size of the ventricular system (Fig. 1). First, the main bodies of both lateral ventricles are pre-segmented using a constrained 3D region growing (RG) algorithm, starting from user-defined seed points. Second, an additional, less constraining RG step is applied on the ventricles' anterior and posterior ends. This is done to overcome undersegmentation which is likely to occur in this area due to narrowing of the ventricles. The combined result of both RG steps is then further evolved by a level-set method, which propagates the boundaries of the initial, constrained segmentation mask further towards the actual ventricle boundaries. Next, the segmentation of the temporal horns is addressed. A path is traced from user-defined seed points in the anterior end of each horn through the CSF towards the main bodies of the lateral ventricles. The method for tracing the paths is based on the fast-marching algorithm. It is designed in such a way that the shape of the horn is approximated even in areas where there is no visible CSF connection between a horn's end and its corresponding lateral ventricle, due to noise or lack of image resolution, as is the case for a large percentage of datasets. For this purpose, an additional outward force is applied to the tracing process, preventing the path from diverging into adjacent CSF regions while attracting it to the horn's natural course, i.e., the outer boundary of the hippocampus. A region is then grown from the path to fill the CSF of the horns, using a fast-marching approach again. Finally, the masks of the segmented structures (lateral ventricles and temporal horns) are combined to form the final desired segmentation.

The algorithm has been implemented in C++ using the Open Source Library ITK (Insight Segmentation and Registration Toolkit). The region growing methods of ITK have been extended to permit a more precise definition of constraints for preventing leakage. To implement the described path tracing algorithm, a new class has been designed based on existing mechanisms and data structures of ITK.

Results

We applied our method to 35 T1 weighted 3.0 T MR volumes (256x256x96 voxels of 0.86x0.86x2.0 mm³; TR: 12.1 ms, TE: 5 ms). High-field brain MRI has been shown to yield significantly better image data than lower-field acquisitions with regard to resolution and signal/noise-ratio [3–4]. We were able to segment lateral ventricles from the test cases robustly. Fig. 2 shows 3D rendered images of a segmentation result, Fig. 3 shows coronal slices at different locations; the temporal horns are indicated by arrows. Validation of the segmented data is in progress.

Conclusions

We have proposed a method for segmenting the lateral ventricles and their temporal horns focussing on robustness and consistency. It has been successfully tested on a set of 35 datasets. Our future work is to apply the segmentation technique to an age-matched set of Alzheimer patients and normal subjects to carry out studies on shape and volumetrics.

References

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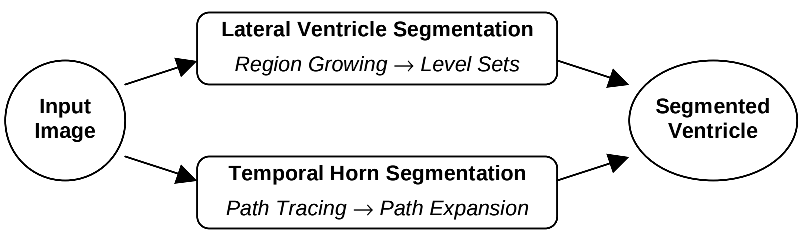

Fig. 1: Simplified flow-chart diagram of the algorithm

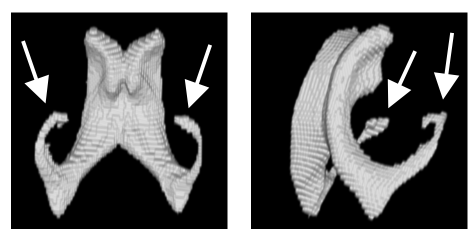

Fig. 2: 3D rendered lateral ventricles

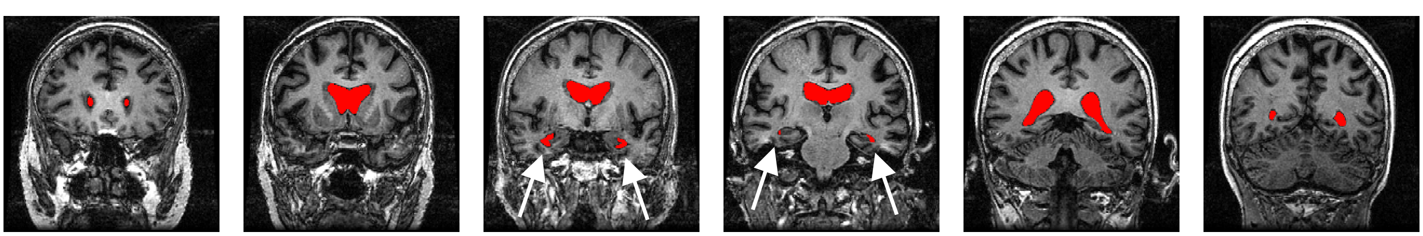

Fig. 3: Segmentation result shown in coronal views