

Brain Image Segmentation by Multiscale Analysis and Template Matching

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Introduction

The primary goal of brain image segmentation is to partition a given brain image into non-intersecting regions representing true anatomical structures such as grey matter, white matter, etc. Over the last decade, many methods have been proposed to tackle this problem. A partial list includes edge-based methods [1], knowledge or rule-based methods [2], statistical model-based methods [3], neural network methods [4], and deformable model based methods [5]. In spite of this progress, automatic segmentation of brain structures remains a very challenging task. This paper presents a new hybrid method which integrates multiscale analysis, image normalization and elastic template deformation.

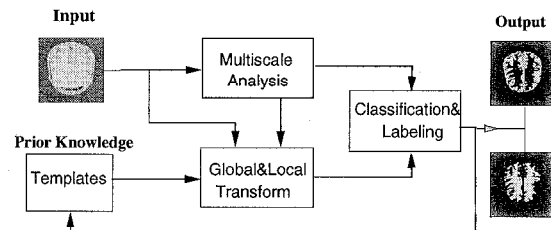


Figure 1: Main components of the proposed method

The Proposed Method

As shown in Fig. 1, the proposed method first decomposes an input image into “homogeneous” regions using multiscale analysis of its intensity variations. An appropriate template is then deformed globally and locally to match the observed image. The desired segmentation is finally generated by grouping the homogeneous regions together using a probabilistic model.

Multiscale Analysis: The objective of this analysis is to decompose an input image $I(x, y)$ into homogeneous regions $\{R(j)\}$. Many algorithms have been proposed for multiscale analysis. We choose the region segmentation algorithm proposed in [6] because the algorithm provides a multi-level decomposition of the whole image with different level corresponding to different homogeneity scales.

Template Deformation: In the proposed method, prior knowledge of brain structures is incorporated in brain templates which is transferred to the input image by a deformation transform. This transform contains two main components: a global affine transform and a local elastic deformation. The global affine transform is based on the algorithm reported in [7] which converts a head image to its normal form, effectively handling the issues of scale, rotation and translation invariance. Starting from the globally registered template, the local deformation further transforms it to match the input image. A fluid transform based on [5] has been implemented. This transform can handle large non-linear deformations while preserving the topological relationships of image features in the template (i.e. the transform is homomorphic).

Classification: The final segmentation is determined based on both the multiscale analysis results and the matched template. In essence, the matched template provides structural constraints for the algorithm to piece the various regions together to form anatomically meaningful structures. In order to do so, we define the probability that pixel m belongs to the k th structure, S_k , in scale j as $P^{(j)}(m, k) = \frac{\text{Area}(R^{(j)}(m) \cap S_k)}{\text{Area}(R^{(j)}(m))}$, where $R^{(j)}(m)$ represents the homogeneous

region in scale j which contains pixel m . Taking into account all the scales, the probability that pixel m belongs to S_k can be defined as $P(m, k) = \sum_j \alpha(j) \{P^{(j)}(m, k), j = 1, 2, \dots, J\}$. The coefficients $\alpha(j)$, can be obtained by training.

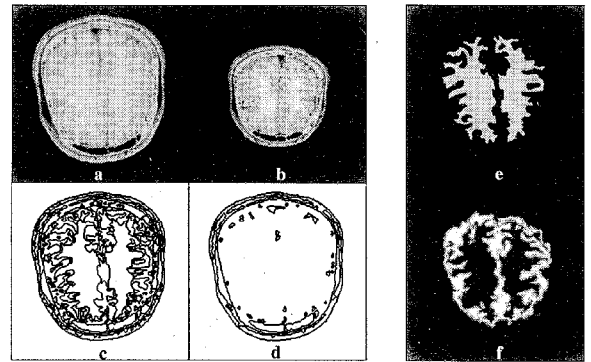


Figure 2: Segmentation results: (a) is the image to be segmented; (b) is the template image; (c-d) are “homogeneous” regions of (a) in two different scales; (e-f) are the final segmented white and grey matter.

Results

The proposed method has been tested using real brain images. A set of representative results is shown in Fig 2. As can be seen, the proposed method can extract the grey matter and white matter accurately. The proposed method has also been tested using brain images from the Visual Human database. In this study, we first manually segmented a few slices to provide necessary brain templates for the proposed method. In the processing stage, a template is used to guide the segmentation of the adjacent slices automatically. We have found that the method is quite effective in segmenting the 3D data set in this fashion.

Conclusion

This paper presents a hybrid method for automatic brain image segmentation. A key contribution of the paper is to combine multiscale segmentation, image normalization, and template deformation for the segmentation task. Preliminary experimental results have shown that this method can produce rather accurate segmentation of brain structure with properly constructed templates.

Acknowledgments

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References

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