Computerized Medical Imaging and Graphics 38 (2014) 725–734

Contents lists available at ScienceDirect

Computerized Medical Imaging and Graphics

journal homepage: www.elsevier.com/locate/compmedimag

Multi-region labeling and segmentation using a graph topology prior and atlas information in brain images

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ARTICLE INFO

Article history:
Received 30 September 2013
Received in revised form 12 April 2014
Accepted 13 June 2014

Keywords:
Segmentation
Labeling
Multi-region
Atlas information
Topological graph
Multi-level set
Medical image

ABSTRACT

Medical image segmentation and anatomical structure labeling according to the types of the tissues are important for accurate diagnosis and therapy. In this paper, we propose a novel approach for multi-region labeling and segmentation, which is based on a topological graph prior and the topological information of an atlas, using a modified multi-level set energy minimization method in brain images. We consider a topological graph prior and atlas information to evolve the contour based on a topological relationship presented via a graph relation. This novel method is capable of segmenting adjacent objects with very close gray level in low resolution brain image that would be difficult to segment correctly using standard methods. The topological information of an atlas are transformed to the topological graph of a low resolution (noisy) brain image to obtain region labeling. We explain our algorithm and show the topological graph prior and label transformation techniques to explain how it gives precise multi-region segmentation and labeling. The proposed algorithm is capable of segmenting and labeling different regions in noisy or low resolution MRI brain images of different modalities. We compare our approaches with other state-of-the-art approaches for multi-region labeling and segmentation.

1. Introduction

Multi-region image segmentation is a major task in medical imaging and it is important in diagnosis and therapy [1]. Due to poor resolution and weak contrast, image segmentation is difficult in the presence of noise and artifacts [2]. Many existing methods for segmentation are based on image intensity information, shape properties or shape priors [2–5]. Many researches addressed that the medical imaging systems like MRI, although it relatively provides high-resolution anatomical details but the identification of tissue information is limited by several factors like noise and image non-uniformity due to magnetic field inhomogeneities [1]. This gives difficulties of the brain tissue labeling [1,6]. Manual labeling of brain structures is achieved using a lot of information including image intensities, anatomical landmarks, position relative to neighboring brain structures and global position within the brain [7], which need long processing time.

Therefore, the automatic labeling is necessary and to maintain it for brain tissue we consider a topological graph information and tissue labeling for the segmentation that give a precise knowledge about position, size and type of the brain tissue [8]. The topological graph prior gives an information about the organs in the brain images and the atlas gives useful information about the label of the brain regions. The labels transfer from the atlas to the target image after warping the atlas with the target image.

Okada et al. [9] proposed multi-organ segmentation of the upper abdomen by finding the interrelations between the organs based on canonical correlation analysis. Suzuki et al. [10] proposed an atlas based multi-organ segmentation and detection of missing organ in abdominal CT images. Shimizu et al. [11] proposed simultaneous extraction of multiple organs from abdominal CT using abdominal cavity standardization process with feature database and atlas guided segmentation incorporating parameter estimation for organ segmentation. Linguraru et al. [12] proposed multi-region segmentation using graph cut method for four abdominal organ segmentation. Kohlberger et al. [13] proposed multi-organ segmentation from CT medical images using learning-based segmentation and shape representation. Bazin and Pham [14] proposed multi-region segmentation algorithm of brain image using topological and statistical atlases of brain as prior to the segmentation framework. Nocera and Gee [7] proposed tissue classification of cerebral magnetic resonance images using Bayesian estimation method. Fischl et al. [15] proposed an automatic labeling of Neuroanatomical structures in the human brain by estimating the probability information from manual labeled training data. Soni [16] proposed brain tissue classification of only three types of tissue (gray matter, white

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http://dx.doi.org/10.1016/j.compmedimag.2014.06.008
0895-6111/

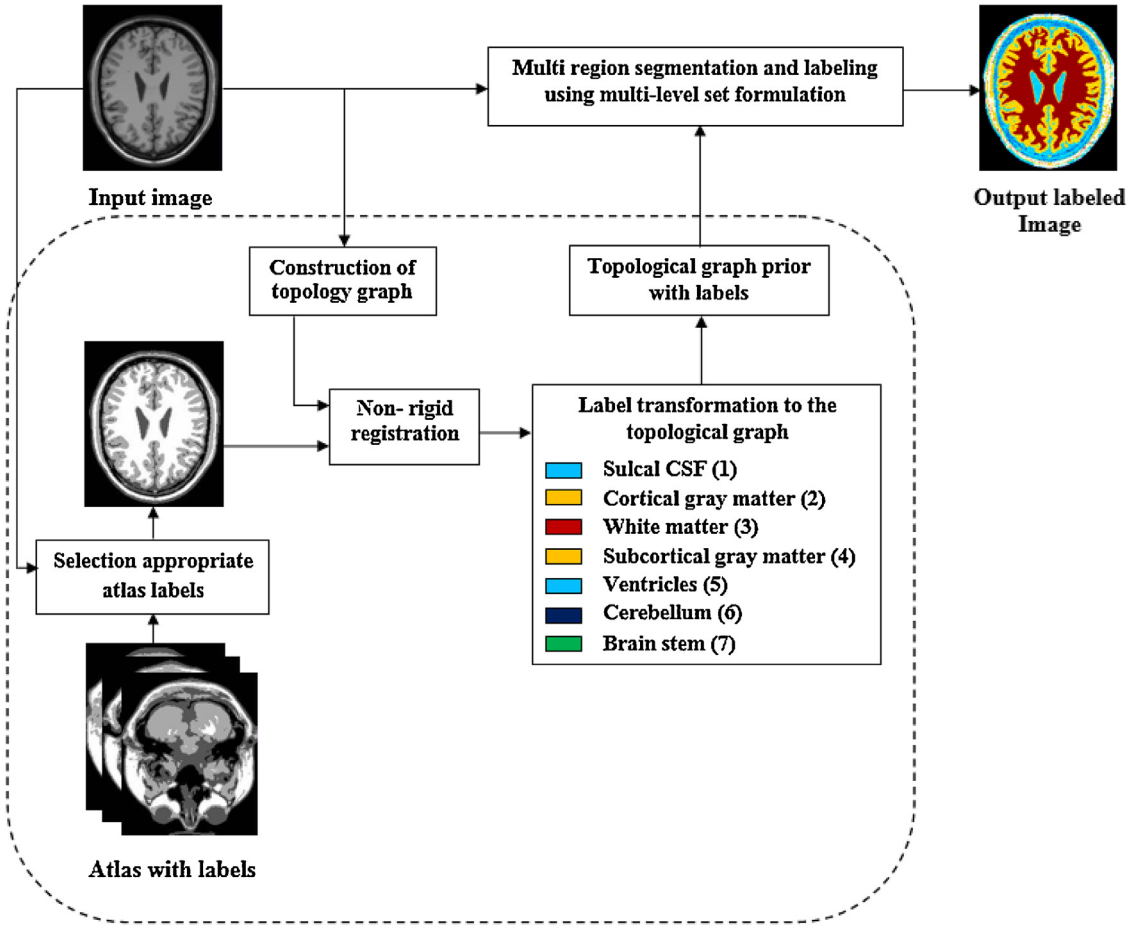

Fig. 1. Block diagram explain the proposed algorithm for multi-region labeling and segmentation.

matter and CSF) using conditional random field for magnetic resonance images. Cocosco et al. [17] proposed a full automatic brain tissue classification method for three types of brain tissue in magnetic resonance images by measuring a tissue probability map. Liu et al. [18] proposed a method for image segmentation using multi-context label tree structure. Sabuncu et al. [19] proposed a nonparametric image segmentation and label fusion approach using image registration. Aljabar et al. [20] proposed a framework for brain tissues multi-atlas segmentation but the accuracy of this approach degrades in the presence of strong noise and by using single atlas information. Mansouri et al. [21] proposed multi-region competition algorithm for intensity-based image segmentation. Vazquez et al. [22] proposed image segmentation algorithm from the viewpoint of image data regularized clustering.

Aforementioned work of multi-region segmentation and labeling focused on either image region intensity with atlas topology [14] or region priors [21] or multi-atlas information for segmentation [20], however the shape of the region of brain tissues may vary from person to person and the intensity differs according to the image modality. Also a multi-atlas methods need more training data and more computational time. Furthermore, the performance of these works degrade in the presence of high level of noise. In contrast to the aforementioned works, our **contribution** of this paper is multi-region segmentation and labeling using a multi-level set formulation which includes a topological graph prior and atlas information in brain images. We propose a new topological representation of brain regions based on object-oriented graph to define an image and use this topological representation to constrain the level set functional energy. Also the proposed object-oriented graph representation is used to compute the similarity between target and atlas template images to map the topological information from an atlas to a target image. The topological graph prior is embedded in the multi-level set energy equation and acts as an additional prior term to identify both the overlapped regions and weak boundaries between adjacent regions in the image, as shown in Fig. 1. The topological graph prior allow us to handle the huge variability of different modalities of the brain images. Consequently, our algorithm is less sensitive to noise and gives accurate segmentation of ambiguous regions of the brain. For brain segmentation and labeling, we propose seven labels of brain tissue as shown in Fig. 3 and Table 3. The outcome of our algorithm is conjoint of multi-class image segmentation and labeling. In all of our experiments, we concentrate on brain segmentation, however, it is worth noting that the method is general and can be applied to other scenarios, for example abdominal organ segmentation by computing the topological relationship of the abdominal organs using abdominal atlas. The organization of this paper is as follows: Section 2 explains the proposed approach. The discussion of the experimental results is presented in Section 3. Finally, the conclusion of the paper is presented in Section 4.

2. Method

In this section we will explain our proposed method for multi-region segmentation and labeling based on a multi-level set formulation with an atlas information and a topological graph prior. The proposed method is based on three steps; Topological graph prior step, label transformation step, and level set energy minimization step.