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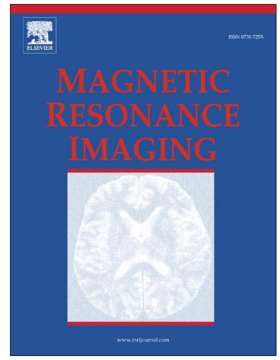

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An accurate and robust skull stripping method for 3-D magnetic resonance brain images

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Abstract

Segmentation of brain region from an MR volume is an essential prerequisite for any automatic medical image processing application as it increases both speed and accuracy of the diagnosis in manifold. Due to material heterogeneity and resolution limitation of imaging devices, the MR image introduces graded intensity of tissues within the brain region. Moreover, it incurs the blurring effect at the brain surface. In spite of these artifacts, all the tissues of brain region of an MR image are perceived to be hanged together within the brain. In this regard, this paper introduces an accurate and robust skull stripping algorithm, termed as ARoSi. It is based on a novel concept, called rough-fuzzy connectedness, introduced in this paper. In the proposed method, the connectedness of a voxel to the brain region is determined by its degree of belongingness to the brain region as well as the degree of adjacency to the brain. Moreover, the proposed ARoSi algorithm considers the local spatial information of the voxel of interest, which reduces the effect of noise, and in turn, helps to improve the performance of the proposed method. Finally, the performance of the proposed ARoSi algorithm, along with a comparison with other state-of-the-art algorithms, is demonstrated on T1-weighted 3-D brain MR volumes obtained from four different data sets. The experiments show that the performance of ARoSi is consistent across all the four data sets, including diseased data sets. The proposed algorithm achieves highest mean Dice coefficient of value 0.951 for all the volumes of four different data sets, among six existing brain extraction methods.

Keywords: Segmentation, rough sets, fuzzy affinity, degree of connectedness, spatial information.

1. Introduction

Magnetic resonance imaging (MRI) is an important and non-invasive medical imaging technique. A significant advantage of MRI is its ability to provide high contrast between different soft tissues, making tissue characterization more feasible [29]. Numerous applications of brain MR images, such as multi-modal brain image registration, brain tissues segmentation, and pathology detection, require brain region extraction as a necessary preliminary stage. The process of brain extraction or skull stripping includes the removal of non-brain areas, like eyes, dura, scalp, skull, etc., from brain MR volumes. The existing skull stripping algorithms, which have been proposed in the literature so far, can be categorized into four broad areas, namely, thresholding with morphology [15, 18], deformable surface models [2, 5, 13, 28], region-based [1, 9, 19], and hybrid approaches [7, 8, 10, 11, 14, 22, 23, 25, 27]. In general, the methods in first category use intensity thresholding for extraction of initial brain region. Then, subsequent applications of various morphological operations generate the final binary brain mask. In these approaches, selection of the threshold value is pivotal in determining the accurate brain mask, which, in turn, ensures the effectiveness of the diagnosis.

The deformable surface model based approaches first define a surface model that is well suited for brain MR applications, and then deform the surface iteratively from its initial position until an optimal solution is found. Smith [28] developed a brain extraction tool (BET), using a deformable model that evolves the initially approximated surface by applying a collection of locally adaptive image forces. Different parameters and initial brain surface are estimated prior to the application of the surface model. The method requires no pre-registration or other pre-processing before being applied. However, one main drawback of BET is that it is prone to smoothing across fine sulci and overestimation of the brain boundary [28]. Another popular method, called 3DSkullStrip, a program provided by the Analysis of Functional NeuroImages (AFNI) package [5], extracts the brain from surrounding tissues of T1-weighted MR images.

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