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Handcrafted fuzzy rules for tissue classification

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Abstract

This article proposes a handcrafted fuzzy rule-based system for segmentation and identification of different tissue types in magnetic resonance (MR) brain images. The proposed fuzzy system uses a combination of histogram and spatial neighborhood-based features. The intensity variation from one type of tissue to another is gradual at the boundaries due to the inherent nature of the MR signal (MR physics). A fuzzy rule-based approach is expected to better handle these variations and variability in features corresponding to different types of tissues. The proposed segmentation is tested to classify the pixels of the T_2-weighted axial MR images of the brain into three primary tissue types: white matter, gray matter and cerebral–spinal fluid. The results are compared with those from manual segmentation by an expert, demonstrating good agreement between them.

Keywords: Magnetic resonance imaging; MRI; Segmentation; Fuzzy rules; Rule-based system; Pattern analysis; Gray level; Handcrafted rule

1. Introduction

Magnetic resonance imaging (MRI) has been used in a number of clinical investigations of varying complexities. A greater dynamic range of soft-tissue contrast [e.g., gradual transition across boundaries inherent to magnetic resonance (MR) images] poses a special challenge to the segmentation of anatomical boundaries. In addition, other problems encountered are due to potential sources of errors, such as image noise, intensity nonuniformity, factors related to image weightings and so on. Any proposed mechanism in an algorithm should adequately address issues to overcome the problems. Accurate segmentation of anatomical and pathological boundaries in the brain structures is necessary to improve the clinical utility of MRI.

Segmentation in MR images is a widely studied problem, and techniques (supervised and nonsupervised) are discussed in the literature [1–10]. The basic approaches to image segmentation are based upon: (a) boundary representation, (b) regional characteristics and (c) a combination of boundary and region-based features. Each approach basically identifies homogeneous regions or contours of local inhomogeneity. Thresholding provides the simplest way for region-based segmentation. Comprehensive surveys discussing various aspects of thresholding are available in the literature [11,12]. Threshold selection algorithms have been compared with the help of experimental results on a set of real-life images or on a set of histograms [13,14]. The object and background regions have been separated with the help of first-order and second-order statistics, giving good results for a large class of MR images [15].

Soft computing techniques deal with partial truth or decision making with imprecision and uncertainty. These techniques use fuzzy logic, a neural network and genetic algorithms, which play important roles in the development of MR image segmentation techniques. Fuzzy rule-based systems [16,17] are based on models describing the behavior of the system to be constructed by a set of "examples" in the form of if–then rules. Such constructions contain an uncertainty model of the type vagueness rather than

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