Chapter 32
Bioinspired Inference System for MR Image Segmentation and Multiple Sclerosis Detection

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ABSTRACT

Multiple sclerosis (MS) is a chronic autoimmune and inflammatory disease affecting the central nervous system (CNS). Magnetic resonance imaging (MRI) provides sufficient imaging contrast to visualize and detect MS lesions, particularly those in the white matter (WM). A robust and precise segmentation of WM lesions from MRI provide essential information about the disease status and evolution. The proposed FPSOPCM segmentation algorithm included an initial segmentation step using fuzzy particle swarm optimization (FPSO). After extraction of WM, atypical data (outliers) is eliminated using possibilistic C-means (PCM) algorithm, and finally, a Mamdani-type fuzzy model was applied to identify MS. The objective of the work presented in this paper is to obtain an improved accuracy in segmentation of MR images for MS detection.

INTRODUCTION

Multiple sclerosis (MS) is an inflammatory, demyelinating and neurodegenerative disease of the central nervous system involving immune-mediated destruction of myelin and axonal damage that affects both white matter (WM) and gray matter (GM). MS is characterized by the formation of focal inflammatory lesions, also called plaques (Villà et al., 2019). It may cause various potential symptoms, including visual problems (Costello., 2016), spasms (Pozzilli., 2014), numbness (Koutsis et al., 2016), fatigue (Sebastião et al., 2017), among others. MS is usually diagnosed by the supporting neuroimaging methods, such as MRI to detect the injured WM (Wang et al., 2018).

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MS lesions are typically measured in-vivo from MRI requiring the aid of automatic or semi-automatic segmentation algorithms. The most frequent modalities to segment WM lesions include proton density-weighted (PD-w), FLAIR and T2-weighted (T2-w), this is because lesions appear hyper-intense on these sequences which makes them easier to detect (Villà et al., 2019). However, WM lesions in MS can be detected with standard MRI acquisition protocols without contrast injection. It has been shown that many features of lesions, such as volume (Kalincik et al., 2012) and location (Sati et al., 2016) are important biomarkers of MS and can be used to detect disease onset or even track its progression. Therefore, accurate segmentation of WM lesions is important to understand the progression and prognosis of the disease. With T2-w MR imaging sequences, most lesions appear as bright regions in MR images, which is useful for automatic segmentation. Although manual delineations are considered as the gold standard, segmenting lesions manually from 3D images is tedious, time consuming, and often not reproducible. Therefore, automated lesion segmentation from MRI is required and constitutes an active area of development in MS research (Roy et al., 2018).

In fact, robust and efficient tissue segmentation of various body structures is of a crucial significance for various medical applications such as identification of brain pathologies and tumor definition from MR images (Hill et al., 2014). Actually, image segmentation is regarded a crucial stage in the image processing system that straights to efficiently guide the clinicians in the process of medical diagnosis. Moreover, related tasks such as position detection, primitive extraction, or pattern recognition are all strongly dependent on the quality of the segmentation. Hence, a precise segmentation of MS lesions in MRI is essential for a precise diagnosis, suitable treatment improvement and patient follow-up of the MS disease.

Due to the importance of image segmentation in the different stages of disease diagnosis, treatment planning and surgical navigation, it has become necessary to design efficient and robust MS segmentation algorithms. Indeed, automated MS detection and segmentation from MRI has to primarily, as the name suggests, use a fully automated MS segmentation approach for lesions extraction, secondly provide a good classification of these lesions and finally, offer early and precise detection of multiple sclerosis. In this paper, we propose a new approach to improve MS detection and segmentation. Our approach builds-up upon three main steps, namely: initial brain tissue segmentation into gray matter (GM), WM, and cerebrospinal fluid (CSF) is performed using the Fuzzy Particle Swarm Optimization (FPSO) algorithm. This is followed by a second step where the lesions are segmented as outliers to the normal apparent WM brain tissue using a Possibilistic C-means (PCM) algorithm and finally, we integrate a decision-making system employing a Mamdani-based inference fuzzy model to identify MS lesions.

The paper is organized as follows: Section 2 reviews related work on MS segmentation by combining MRI information. Section 3 describes proposed method in detail. Results are presented and discussed in Section 4. The conclusion and the future directions are presented in Section 5.

RELATED WORK

Precise segmentation of MS lesions is an important task for understanding and characterizing the progression of the disease (Rolak, 2003). To this aim, both manual and automated methods are used to compute the total number of lesions (Aslani et al., 2019). Although manual methods lead to subjective decisions and diagnosis, which may be misleading, hence post processing of MS is important and preferable. In MRI, it is possible to observe how MS lesion disseminates through space and time. For this reason, MRI