Optimizing the Between-Class Variance using the VNS Metaheuristic for Brain MRI Segmentation

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Keywords: Brain MRI Segmentation, Variable Neighborhood Search Algorithm, Multi-level Thresholding, Metaheuristic, Between-Class Variance function.

Abstract— Image segmentation is a very crucial step in medical image analysis which is the first and the most important task in many clinical interventions. Recent works on image segmentation are interested in segmentation of brain Magnetic Resonance Images (MRI), which consists in detecting the three types of tissue: white matter (WM), gray matter (GM) and cerebrospinal fluid (CSF). In (Despotović et al., 2015), several methods for brain MRI segmentation were described such as the intensity-based segmentation methods, thresholding methods, atlas-based methods, surface-based methods and hybrid segmentation methods. All of these segmentation approaches present advantages as well as disadvantages. (Pal et al.,2016) provided a survey on various techniques, used for image segmentation and applied for MRI, that detect the tumor by segmenting the brain images into constituent parts. Also, the advantages and disadvantages of Image segmentation were discussed.

Concerning image thresholding, it includes bi-level and multilevel thresholding. The bi-level thresholding classifies the pixels into two categories; pixels, with gray levels above a determined threshold, belong to the first group; the other pixels belong to the second one. However, the multilevel thresholding divides the pixels into a number of groups or classes. Every class contains pixels having gray levels within a specific range defined by several thresholds. Image thresholding approaches can be parametric or nonparametric. In this current work, we are interested in the nonparametric approaches, in which, we search thresholds that optimize an objective function mainly like the between-class variance function (Otsu, 1979), the Kapur's function (also named the entropy) (Kapur et al., 1985) and the cross entropy (Li and Lee, 1993).

In the literature, many metaheuristic algorithms were applied in image segmentation such as the simulated annealing adapted to continuous problems (Nakib et al., 2007), the ant colony (Tao et al., 2007), the genetic algorithm (Hammouche et al., 2008), the particle swarm optimization (Ye et al., 2008), the honey bee mating (Horng, 2010) and the artificial bee colony (Miledi and Dhouib, 2015). In (Hassanzadeh et al., 2017), authors proposed an improved fuzzy adaptive firefly algorithm in which, a fuzzy system is used to adapt Firefly Algorithm parameters in order to improve its ability in global and local searches. Hence, we propose in this paper to exploit the variable neighborhood search (VNS) metaheuristic to solve the problem of multilevel thresholding for brain Magnetic Resonance Images (MRI) segmentation. In fact, the VNS metaheuristic was first developed by (Mladenovic and Hansen, 1997) where the basic idea is a systematic change of a neighborhood within a local search. In recent years, the VNS has been proven as a very effective metaheuristic, used for solving a wide range of complex optimization problems. The basic strategy of the VNS is to focus on the investigation of solutions which belong to some neighborhoods of the current best one. In order to avoid being trapped in local suboptimal solutions, the VNS changes the neighborhoods, directing the search in the promising and unexplored areas. In this work, the VNS method is exploited to optimize the between-class variance. In fact, the main idea of the between-class variance method is to separate the pixels, of a given image, according to their intensity values into distinct classes in a way that the separation between classes in terms of their intensity values would be the best. Thus, our novel segmentation approach, named the VNS-BCV, is tested on a set of brain MRI to show its robustness and proficiency. Experimental results are interesting and encouraging.

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