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A hybrid approach for the delineation of brain lesion from CT images

Anjali Gautam [a,*], Balasubramanian Raman [a], Shailendra Raghuvanshi [b]

[a] Department of Computer Science and Engineering, Indian Institute of Technology, Roorkee, India
[b] Department of Radiology, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, India

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ABSTRACT

Brain lesion segmentation from radiological images is the most important task in accurate diagnosis of patients. This paper presents a hybrid approach for the segmentation of brain lesion from computed tomography (CT) images based on the combination of fuzzy clustering using hyper tangent function as the robust kernel and distance regularized level set evolution (DRLSE) function as the edge based active contour method. Kernel based fuzzy clustering method divides the image into different regions. These regions can be used to find region of interest by using DRLSE algorithm to generate the optimal region boundary. The proposed method results in smooth boundary of the required regions with high accuracy of segmentation. In this paper, results are compared with standard fuzzy c-means (FCM) clustering, spatial FCM, robust kernel based fuzzy clustering (RFCM) and DRLSE algorithms. The performance of the proposed method is evaluated on CT scan images of hemorrhagic lesion, which shows that our method can segment brain lesion more accurately than the other conventional methods.

1. Introduction

Image segmentation is the process of partitioning an image into separate regions. It is considered as the most challenging issue in image processing [1]. Segmentation has been widely used in the analysis of medical images in which it is typically used to locate the region of interest. Radiology images obtained from different imaging modality like computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), positron emission tomography (PET), X-ray, etc., are used for the medical diagnosis [1,2]. However, for the internal examination of human head, CT scan is widely used by physicians because it is cheaper, and has the ability to investigate most of the neurological problems like stroke, tumor, head injuries etc. An accurate segmentation of meaningful regions from CT images is still considered as a challenging problem therefore, there is a great need of a proper boundary detection algorithm that can easily delineate the region of interest from the brain. Many semi-automatic [3–9] and automatic [10–13] segmentation methods have been widely used by researchers to detect meaningful regions from

* *Corresponding author at*: Indian Institute of Technology, Roorkee, India.
E-mail addresses: anga3.dcs2015@iitr.ac.in (A. Gautam), balarfma@iitr.ac.in (B. Raman), sraghuvanshi1@gmail.com (S. Raghuvanshi).
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the medical images using level set and fuzzy c-means (FCM) clustering.

Previous methods based on level set and clustering techniques were having drawbacks like irregular detection of object shape and less noise removal due to which incorrect segmentation of input image was obtained. In this paper, to facilitate and enhance the segmentation results we have developed a new hybrid method for lesion delineation from CT images by combining the modified version of RFCM proposed by Kannan et al. [14] and distance regularization level set evolution proposed by Li et al. [4].

The main contributions in this article are:

1. Collection of head CT scan images of hemorrhagic stroke patients from hospital.
2. Proposed a new variant of fuzzy clustering which is termed as modified robust fuzzy c-means clustering (MRFCM).
3. Proposed a new algorithm for stroke lesion detection from CT scan images by using the combination of MRFCM and DRLSE method which is termed as hybrid clustering and distance regularized level set (HCDRLS) method.

The organization of this article is as follows: Section 2 discusses about the related work, and the background of robust FCM and DRLSE method is given in Section 3. Section 4 illustrates the materials and methods used. In Section 5 experiments and analysis of results are discussed and finally conclusions are presented in Section 6.

2. Related work

Segmentation of medical images is a difficult task and several algorithms have been proposed by many researches in order to facilitate the diagnosis of patients. In image clustering, FCM is an unsupervised clustering technique for image segmentation [15]. It was introduced by Dunn in 1973 and further improved by Bezdek in 1984, where fuzzy c-partition of sample points in all the clusters is characterized by a membership function which lies between 0 and 1 [16,17]. Moreover, for all clusters, the sum of memberships for each sample point must be unity. FCM can preserve more information from the image in comparison with hard c-means algorithm. However, it does not take into account spatial information which makes it sensitive to noise and other artifacts [18]. To deal with this inhomogeneity, many algorithms were proposed based on new clustering methods.

Ahmed et al. [19] proposed bias-corrected FCM (BCFCM) by adding regularization term in the objective function which biases the solution towards piecewise-homogeneous labeling. Their method works efficiently in removing salt and pepper noise. Chen and Zhang [20] proposed two variants of BCFCM where they used mean and median filtered images which were named as FCM_S1 and FCM_S2 respectively. In their other method [21], they used kernel-induced distance and which was named as kernelized fuzzy c-means (KFCM) algorithm where they replaced Euclidean distance with Gaussian radial basis function (GRBF). In their other variant, spatially constrained was added to KFCM as the penalty term to the objective function which is the kernel to indemnify intensity inhomogeneity of MR images and termed as SKFCM. GRBF was also used by Elazab et al. in order to calculate the objective function. They also include the contextual information of neighboring pixels which was controlled by assigning the weights to pixels using average grayscale of the local window. They named the method as adaptively regularized kernel-based fuzzy c-means clustering (ARKFCM) [22]. Chuang et al. [23] have also introduced the membership function with spatial information which was the summation of membership function in the neighborhood of each pixel under consideration. The method was able to remove noisy spots and spurious blobs which was named as SFCM. Kannan et al. [14] replaced Euclidean distance with a new hyper tangent function to construct effective objective function and termed it as RFCM. Other variant of fuzzy clustering was proposed by Dubey et al. [11] where centroid of clusters are initialized by intuitionistic fuzzy roughness measure which was based on upper approximation of rough set, and fuzzy histogram as lower approximation of rough set. Wang et al. [24] proposed a method that includes both local and non-local spatial information. Along with these methods, multiobjective techniques have also been used for the segmentation of images which are based on optimization problems of Genetic Algorithms (GA) [25,26]. Multiobjective genetic algorithm (MOGA) proposed by Bandyopadhyay et al. [25] was based on two cluster validity indices i.e. *Jm* measure and *XB* index. *Jm* calculates the global variance of cluster and its lower value indicates better clustering result. Besides it, *XB* index is a combination of global and local situations. MOGA uses these indices as the objective functions which are simultaneously optimized. Some recent works on multi-objective based clustering techniques were proposed by Alok et al. and Prakash in [27–29]. However, due to high time complexity of GA based algorithms, they cannot be used preferably in medical practice to segment large image dataset. Hence, in order to get good segmentation results, many variants of FCM have come into existence [30,31]. Still, they fail to achieve high segmentation accuracy on medical image dataset.

The level set method is also widely used in medicine for image segmentation which was proposed by Osher and Sethian [32] in 1988 for a variety of surface motion problems. It is based on two central embeddings where firstly, interface is embedded as the zero level set of a higher dimensional function. Next, interface's velocity is embedded to that higher dimensional level set function (LSF). Their method is based on partial differential equations and can naturally handle the topological merging, breaking and dependence on curvature. Another variant of the level set is ''fast marching methods'' based on Dijkstra algorithm developed by Sethian [3]. Adalsteinsson and Sethian introduced the narrow-band level set method [33]. In the standard level set method, ϕ is the distance function ($\phi = 0$ at the boundary) which needs to be reinitialized after some steps due to inaccurate numerical approximations, so that ϕ can be close to the signed distance function. To remove this drawback of reinitialization many researchers have proposed different methods. Li et al. [4] derived a unique forward-and-backward (FAB) diffusion effect that can maintain the desired shape of the LSF such that the signed distance function is in a proximity of zero level set (boundary). Their method is termed as distance regularization level set evolution (DRLSE). Modified version of DRLSE

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