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ORIGINAL ARTICLE

Evaluation of k-Means and fuzzy C-means segmentation on MR images of brain

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Abstract This paper does the qualitative comparison of Fuzzy C-means (FCM) and k-Means segmentation, with histogram guided initialization, on tumor edema complex MR images. The accuracy of any segmentation scheme depends on its ability to distinguish different tissue classes, separately. Hence, there is a serious pre-requisite to evaluate this ability before employing the segmentation scheme on medical images. This paper evaluates the ability of FCM and k-Means to segment Gray Matter (GM), White Matter (WM), Cerebro-Spinal Fluid (CSF), Necrotic Focus of Glioblastoma Multiforme (GBM) and the perifocal vasogenic edema from pre-processed T1 contrast axial plane MR images of tumor edema complex. The experiment reveals that FCM identifies the vasogenic edema and the white matter as a single tissue class and similarly gray matter and necrotic focus, also. k-Means is able to characterize these regions comparatively better than FCM. FCM identifies only three tissue classes whereas; k-Means identifies all the six classes. The experimental evaluation of k-Means and FCM, with histogram guided initialization is performed in Matlab®.

1. Introduction

Image segmentation is one of the most interesting and challenging problems in computer vision generally and medical imaging applications specifically. Segmentation partitions an image area or volume into nonoverlapping, connected regions, being homogeneous with respect to some signal characteristics (1). Segmentation approaches are subject to multiple challenges stemming from image noise, image inhomogeneities, image artifacts such as partial volume effect, and discontinuities of boundaries due to similar visual appearance of adjacent brain structures. A variety of segmentation techniques have been developed to address these challenges. Brain MR segmentation methods can be classified into three main categories: probabilistic and statistical-based, atlas-based, and deformable model-based techniques (2). Hence, there is a mandatory prerequisite to investigate the ability of the segmentation scheme to characterize the complete tissue classes, present in the image, separately, before employing any statistical segmentation frame work. MR images of tumor edema complexes exhibit homogenous intensity features

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between WM and edema and similarly between necrotic focus and GM, as evident in Fig. 1. This is an investigation of the ability of FCM and k-Means to characterize the GM, WM, CSF, necrotic focus, vasogenic edema and background present in pre-processed axial plane T1 contrast MR images of GBM-edema complex.

Wen and Celebi (3) compared hard C-means and FCM clustering for color quantization. The results demonstrate that FCM is significantly slower than hard C-means, and that with respect to output quality, the former algorithm is neither objectively nor subjectively, superior to the latter.

Panda et al. (4) tested the performances FCM and k-Means. Two distance measures such as Manhattan (MH) and Euclidean (ED) are used to note how these distance measures influence the overall clustering performance. The performance has been compared based on seven parameters, sensitivity, specificity, precision, accuracy, run time, average intra cluster distance and inter cluster distance. Based on the experimental results, the paper concluded that both k-Means and FCM performed well.

However, k-Means outperformed FCM in terms of computational efficiency. FCM-MH combination produced most compact clusters, while k-Means-ED yielded most distinct clusters.

In Etehadtavakol et al. (5), two color segmentation techniques, k-Means and FCM for color segmentation of infrared (IR) breast images are modeled and compared. k-Means algorithm generated empty clusters. The fuzzy nature of IR breast images helps the FCM segmentation to provide more accurate results with no empty cluster.

Yin et al. (6) is a comparison of k-Means and FCM performance for automated determination of the Arterial Input Function (AIF). The results demonstrate that k-Means analysis can yield more accurate and robust AIF results, although it takes longer to execute than the FCM. Authors consider that this longer execution time is trivial relative to the total time required for image manipulation in a PACS setting, and is acceptable if an ideal AIF is obtained. Therefore, the literature suggested, the k-Means method is preferable to FCM in AIF detection.

Sueli et al. (7) presented a comparison among non-hierarchical and hierarchical clustering algorithms including SOM (Self-Organization Map) neural network and FCM. Data were simulated, considering correlated and uncorrelated variables, non-overlapping and overlapping clusters with and without outliers. A total of 2530 data sets were simulated. The results showed that FCM had a very good performance in all cases being very stable even in the presence of outliers and overlapping. All other clustering algorithms were very affected by the amount of overlapping and outliers. SOM neural network did not perform well in almost all cases being much affected by the number of variables and clusters. The traditional hierarchical clustering and k-Means methods presented similar performance.

In Ghosh and Dubey (8), centroid based k-Means and representative object based FCM clustering algorithms are compared. These algorithms are applied and performance is evaluated on the basis of the efficiency of clustering output. The numbers of data points as well as the number of clusters are the factors upon which the behavior patterns of both the algorithms are analyzed. Literature observed FCM produces close results to k-Means clustering but it still requires more computational time than k-Means.

Wang and Garibaldi (9) applied k-Means and FCM to cluster a lymph node tissue section which had been diagnosed with metastatic infiltration. Each cluster algorithm was run 10 times as different initialization states may lead to different clustering results. The performance of the two algorithms was compared by subjectively altering the number of clusters from 2 to 9 and analyzed the results using false-color images which are produced as a function of the spatial coordinates on the tissue section. In the initial stages of this experiment, it was observed that the ranges of the first three principal components were too small and may lead to small objective function values in FCM. Therefore, the minimal amount of improvement must be set to a small enough value to allow the cluster center positions to improve; otherwise the iteration will stop prematurely. After adjusting this setting, the performance of FCM was significantly better. The results show that FCM can separate the major different tissue types using just a small number of clusters, whereas k-Means is only able to separate them if a larger cluster number is used.

It seems the segmentation accuracy of FCM and k-Means is image dependent. The literatures are not unanimous regarding their opinion about the performance of k-Means and FCM. This paper proceeds through the specification of test images, preprocessing, mathematical formulation of k-Means and FCM. Eventually, qualitative evaluation of segmentation results of both the algorithm, in terms of number of tissue classes identified and the accuracy of clustering are furnished.

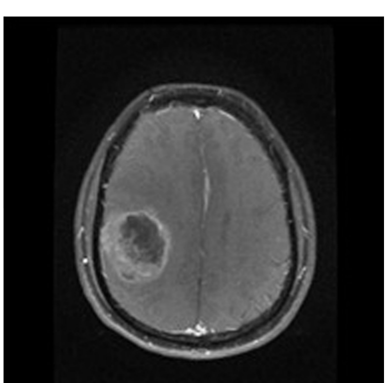

Fig. 1 Axial plane T1 contrast MRI of GBM-edema complex. (Image Courtesy: Hind Labs, Kottayam Medical College Kerala).

2. Materials and methods

Axial Plane T1 contrast enhanced (Series: AX T1 SE FS + C, Spin Echo Sequence (SE)) MR images (courtesy: Hind Labs, Govt. Medical College Kottayam, Kerala) were selected for the experimental evaluation of k-Means and FCM. The specification of MR equipment is; Manufacturer: GE Medical Systems, Model Name: Signa HDxt, Acquisition Type: 2D and 1.5T field strength. Experimental evaluation of FCM and k-Means was performed on Matlab®, (Version: 7.12.0.635 (R2011a)) Image Processing Tool Box. The preprocessing includes elimination of noisy background, restoration with bilateral filter (10) contrast enhancement with Contrast Limited Adaptive Histogram Equalization (CLAHE) (11)