Improved fuzzy c-mean algorithm for Medical Image segmentation

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Abstract

Image segmentation is a very important part of image processing. This paper presents an image segmentation approach using improved fuzzy c-mean (FCM) algorithm. The improved fuzzy c-mean algorithm is formulated by modifying the distance measurement of the standard fuzzy c-mean algorithm. The original Euclidean distance in the fuzzy c-mean algorithm is replaced by correlation distance, and thus the corresponding algorithm is derived and called as the improved fuzzy c-mean algorithm, which is shown to be more robust than original fuzzy c-mean algorithm. Experimental results on both synthetic and real MR-images show that the proposed algorithms have better performance when noise and other artifacts are present than the standard algorithms.

1. Introduction

Image segmentation is a challenging task in image analysis. A large variety of methods of have been proposed in several years. The fuzzy c-mean technique that has been successfully applied to analysis, clustering designs in the field of astronomy, geology, medical image, target recognition, image segmentation. An image can be acted in different feature spaces, and fuzzy c-mean method classifies by grouping the similar data points in the feature space into clusters.

Image segmentation plays important role in medical image. In the field of medical diagnosis an extensive diversity of imaging techniques is presently available, such as radiography, computed tomography (CT) and magnetic resonance imaging (MRI) [1],[2]. In the recent times, magnetic resonance image is the most effectively used for diagnostic image examination for brain diagnostic image examination for brain diseases such as tumor. Even through original fuzzy c-mean algorithm yields good results for segmenting noise free images, it fail to segment image corrupted by noise, outliers and other imaging artifacts.

Medical image segmentation is an essential step for most successive image analysis task. This paper presents an image segmentation approach using improved fuzzy c-mean algorithm [3], [4].

2. Clustering

The process of grouping a set of physical or abstract objects into classes of similar objects is called clustering. A cluster is a collection of data objects that are similar to one another within the same cluster and are dissimilar to the objects in other clusters.

There are two properties in clustering:

• Homogeneity inside clusters: the data, which belongs to one cluster, should be as similar as possible.

• Heterogeneity between the clusters: the data, which belongs to different clusters, should be as different as possible.

By definition,

"cluster analysis is the art of finding groups in data", or "clustering is the classification of similar objects into different groups, or more precisely, the partitioning of a data into subsets (clusters), so that the data in each subset (ideally) share some common trait-often proximity according to some defined distance measure"[5]. Clustering is an important task of research. Clustering is the unsupervised data mining technique, which partitions the input space into K regions depending on some similarity/dissimilarity metric where the value of K may or may not be known a priori. The main objective of any clustering technique is to produce a $K \times n$ partition matrix U(X) of the given data set X, consisting of n patterns, $X = x_1, x_2 \ldots, x_n$.

3. Improved fuzzy c-mean algorithm

Fuzzy c-mean (FCM) algorithm, also known as fuzzy ISODATA, was introduced by Bezdek [6] as an extension to Dunn's algorithm [7]. The fuzzy c-mean based algorithms are the most commonly used fuzzy clustering algorithms in practice.

Let $X = x_1, x_2, \ldots, x_N$, where $x_i \in \Re^n$ present a given set of feature data. the objective of fuzzy c-mean algorithm is to minimize the fuzzy c-mean cost function formulated as

$$J(U,V) = \sum_{j=1}^{C}\sum_{i=1}^{N} \mu_{ij}^{m} \left\| x_i - v_j \right\|^2 \qquad 1$$

$V = v_1, v_2, \ldots, v_C$ are the cluster centers. $U = \mu_{ij}{}_{N\times C}$ is a fuzzy partition matrix, in which each member μ_{ij} indicates the degree of membership between the data vector x_i and the cluster J. the values of matrix U should satisfy the following conditions

$$\mu_{ij} \in [0,1], \forall i = 1,\ldots,N, \forall j = 1,\ldots,C \qquad 2$$

$$\sum_{j=1}^{C} \mu_{ij} = 1, \forall i = 1,\ldots,N \qquad 3$$

The exponent $m \in [1,\infty)$ is the weighting exponent, which determines the fuzziness of the clusters. The most commonly used distance norm is the Euclidean distance $d_{ij} = \left\| x_i - v_j \right\|$, although Babuska suggests that other distance norm could produce better results [8]. The Euclidean distance in improved fuzzy c-mean algorithm is replaced by the correlation distance. And this improved fuzzy c-mean algorithm is to be more robust than the original fuzzy c-mean algorithm.

Minimization of the cost function J(U,V) is a nonlinear optimization problem, which can be minimized with the following iterative algorithm:

Step 1: Initialize the membership matrix ***U*** with random values so that the conditions (2) and (3) are satisfied. Choose appropriate exponent m and the termination criteria.

Step 2: Calculate the cluster centers ***V*** according to the equation:

$$v_j = \frac{\sum_{i=1}^{N} \mu_{ij}^{m} x_i}{\sum_{i=1}^{N} \mu_{ij}^{m}}, \forall j = 1,\ldots,C \qquad 4$$

Step 3: Calculate the new distance by correlation:

$$d_{ij} = \rho_{x,y} = corr(x,y) = \frac{\mathrm{cov}(x,y)}{\sigma_x \sigma_y} \qquad 5$$

Step 4: Update the fuzzy partition matrix **U**:

If $d_{ij} > 0$ (indicating that $x_i \neq v_j$)

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{C} \left(\frac{d_{ij}}{d_{jk}} \right)^{\frac{2}{m-1}}} \qquad 6$$

Else

$$\mu_{ij} = 1$$

Step 5:

If the termination criteria have been met, stop

Else go to **Step 2**

A suitable termination criterion could be to calculate the cost function (Eq. 1) and to see whether it is below a certain tolerance value or if its improvement compared to the previous iteration is below a certain threshold [9]. Also the maximum number of iteration cycles can be used as a termination criterion.

Experiments are conducted on real images to examine the performance of the proposed improved fuzzy c-mean technique in segmenting the MR-images.

4. Experimental results

The proposed improved fuzzy c-mean algorithm is implemented using MATLAB and tested on real images to explore the segmentation accuracy of the proposed approach.

The proposed approach of image segmentation using improved fuzzy c-means algorithm eliminates the effect of noise greatly. This in turn increased the segmentation accuracy of the proposed image segmentation technique.

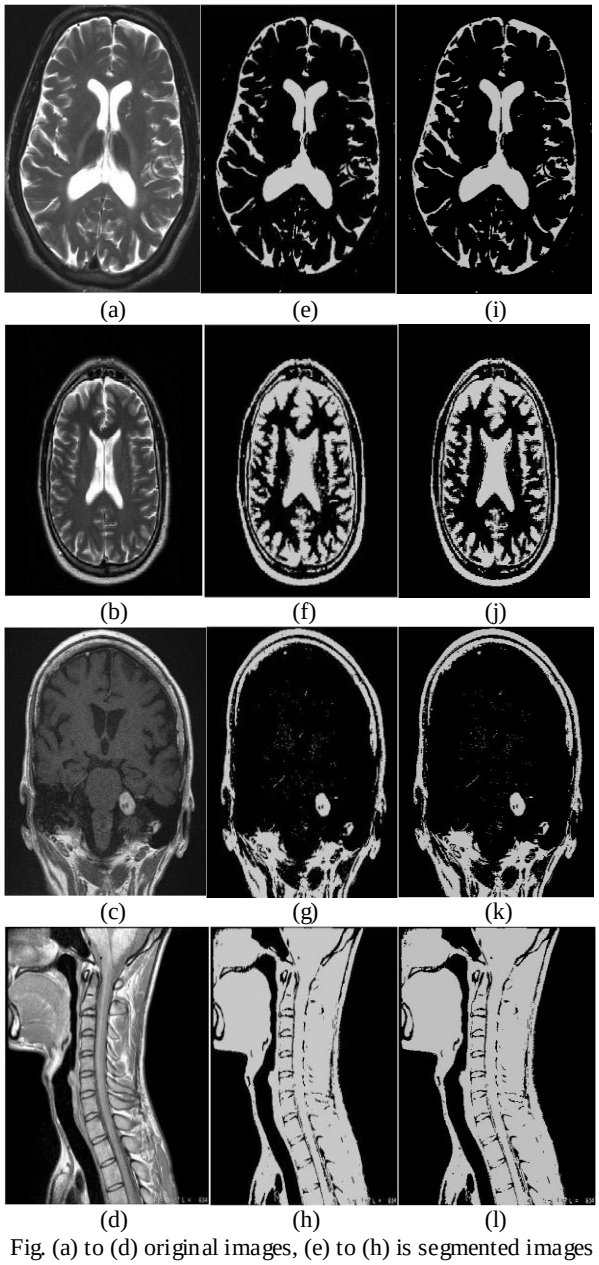

Fig. (a) to (d) original images, (e) to (h) is segmented images using fuzzy c-mean algorithm of original images (a) to (d) respectively, (i) to (l) is segmented images using improved fuzzy c-mean algorithm of original images (a) to (d) respectively

5. Conclusion

Fuzzy c-mean algorithm is one of a traditional clustering method and has been generally useful for medical image segmentation. On the other hand, conventional fuzzy c-mean algorithm at all times suffers from noise in the images. Even through the original fuzzy c-mean algorithm yields good results for segmenting noise free images, it fails to segment images corrupted by noise, outliers and other imaging artifact. in the proposed improved fuzzy c-mean algorithm, are incorporated to control the trade-off between them. The algorithm is formulated by modifying the distance measurements of the standard fuzzy c-mean algorithm to allow the labeling of a pixel to be influenced by other pixels and to control the noise effect during segmentation. The experimental results suggested that the proposed algorithm performed well than other fuzzy c-mean extension, segmentation algorithm.

6. References

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