Medical Image Segmentation by Hybridizing Ant Colony Optimization and Fuzzy Clustering Algorithm

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ABSTRACT

Possibilistic c-means (PCM) algorithm was proposed to overcome the noise sensitivity of fuzzy c-means (FCM). However, the performance of PCM depends heavily on the initialization, and often deteriorates due to the coincident clustering problem. To overcome these problems, we propose a new hybrid clustering algorithm that incorporates an ACO-based clustering into PCM, namely ACOPCM for noisy image segmentation. Our ACOPCM solves the coincident clustering problem using pre-classified pixel information and provides the near optimal initialization of the number of clusters and their centroids. Experimental results demonstrate that our proposed approach achieves higher segmentation accuracy than PCM and hybrid fuzzy clustering approaches.

Categories and Subject Descriptors

I.4.6 [**Segmentation**]: Pixel classification, Region growing, Partitioning

General Terms

Algorithms

Keywords

Ant colony optimization, Possibilistic c-means, Medical image segmentation

1. INTRODUCTION

The image segmentation has become an increasingly important pre-processing step in medical image analyses. Since medical images often contain a significant amount of noise caused by the operator and equipment, segmentation in medical imaging is difficult and challenging problem.

In the literature, many approaches have been developed for medical image segmentation. Among them, clustering based approaches perceived a great focus of interest. Especially, possibilistic c-means (PCM) algorithm was proposed to overcome the noise sensitivity of fuzzy c-means (FCM) [4]. PCM relaxes the column sum constraint of the fuzzy membership matrix in FCM and introduces a possibilistic partition matrix, which is used to describe the degree of belonging based on the typicalities of data points to their clusters. However, PCM needs to know the appropriate number of initial cluster and its centroids in advance which directly affect on the cluster compactness and classification accuracy. Also, the possibilistic memberships are very sensitive to the initialization and cluster centers, which often results in the problem of coincident clusters.

Recently, swarm-based heuristic approaches were combined with unsupervised fuzzy clustering to improve the overall clustering accuracy [3, 5]. Those hybrid approaches provide the optimal cluster number and centroids, but they do not resolve the coincident clustering problem of PCM.

In this paper, we propose a hybrid PCM algorithm that incorporates an ACO-based clustering [2], namely ACOPCM for noise-robust medical image segmentation. We adopts ACO-based clustering algorithm which provides the appropriate number of initial cluster and its centroids automatically through its strong capability to converge to global optima. Simultaneously, to overcome the coincident clustering problem of PCM, we use pre-classification pixel information.

2. PROPOSED METHOD

PCM has a strong inherent capability for local searches, but it seems to get trapped into local optima as FCM does due to the initialization of cluster number and centroids. These affect segmentation accuracy and cluster compactness. To overcome the above weakness, we adopt ant colony optimization (ACO) which performs well in discrete optimization and clustering problems thanks to its strong ability for parallel search.

Even though ACO automatically provides the appropriate number of clusters and their centroids, it does not settle the coincident clustering problem of PCM. To deal with this problem, we apply pre-classified ants (pixels) derived from the ACO-based clustering algorithm to PCM. The pre-classified ants which are composed of classified and unclassified ants. The classified ants which are clustered by ACO play the role as base pixels for preventing coincident clusters in PCM. And the remain unclassified ants are classified by PCM using its strong capability of local optimization. The high-level description of the ACOPCM is following:

1. Determine the tentative number of initial clusters and

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their centroids: In order to reduce the time complexity of ACO and provide the optimal number of cluster centers, we roughly choose the tentative number of cluster centers based on pixel intensity statistics as a preprocessing step.

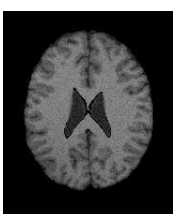
2. Obtain optimal cluster centers and pre-classified ants using ACO-based clustering algorithm: Set the initial cluster number and centroids with the tentative initial cluster centers. Through the ACO-based clustering algorithm, the initial cluster centers could be more compact and optimal.

3. Divide between classified and unclassified ants in pre-classified ants: Assign every cluster centroid to its member of classified ants and remain unclassified ants derived from ACO-based clustering.

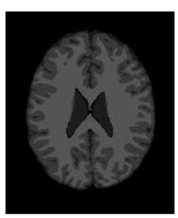
4. Cluster based on PCM with the optimal number of clusters, centroids, and pre-classified ants: Execution PCM with the cluster centers and pre-classified ants. Segment image using possibilistic membership matrix which is based on the majority membership to a cluster.

3. RESULTS & CONCLUSION

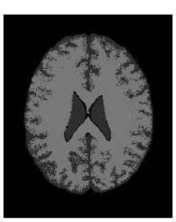
The proposed algorithm was evaluated on simulated brain MR images provided by McConnell Brain Imaging Centre (BIC) of the Montreal Neurological Institute, McGill University [1]. Specifically, we used the 96th brain region slice of the simulated MR image under various noise levels and intensity inhomogeneities (bias-field). Figure 1. shows that the ACOPCM overcomes the coincident clustering problem of PCM.



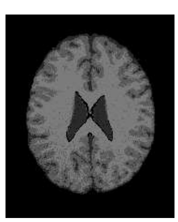
(a)



(b)



(c)



(d)

Figure 1: (a) Original image with 9% noise and 40% bias-field (b) Discrete anatomical model (c) Segmentation result of PCM (d) Segmentation result of ACOPCM

Table 1: Segmentation evaluation of simulated T1-weighted MR images

	Noise Level	7%		9%	
Class	Bias-Field	20%	40%	20%	40%
PCM	CSF	0.839	0.807	0.501	0.482
	GM	0.779	0.741	0.334	0.355
	WM	0.871	0.847	0.409	0.542
ACO [2]	CSF	0.779	0.673	0.664	0.671
	GM	0.746	0.738	0.625	0.69
	WM	0.889	0.847	0.824	0.787
AFHA [5]	CSF	0.827	0.805	0.737	0.736
	GM	0.797	0.767	0.697	0.685
	WM	0.885	0.864	0.817	0.805
PSOPCM [3]	CSF	0.839	0.815	0.519	0.482
	GM	0.779	0.747	0.349	0.335
	WM	0.871	0.847	0.409	0.472
ACOPCM	CSF	0.856	0.831	0.74	0.793
	GM	0.8	0.772	0.684	0.709
	WM	0.889	0.869	0.824	0.823

To compare the accuracy and reliability of the segmentation under different environments, we used the Jaccard similarity index (SI). When the value of SI approaches 1, the segmentation results become closer to the gold standard. We computed the SI for each segmentation method, and its results are presented in Table 1. The table show that the proposed ACOPCM algorithm can obtain the most accurate results among the PCM, ACO-based clustering [2], AFHA [5] and PSOPCM [3] when the noise and bias-field exist in the images. In particular, our algorithm overcomes the coincident clustering problem and get higer segmentation accuracy to high level of noise and bias-field than PCM.

Our ACOPCM automatically provides the appropriate number of clusters and their centroids and solves the coincident clustering problem using pre-classified pixel information. In future works, we will apply ACOPCM algorithm to real-world applications such as object recognition.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] http://www.bic.mni.mcgill.ca/brainweb/.

[2] Y. Han and P. Shi. An improved ant colony algorithm for fuzzy clustering image segmentation. *Neurocomputing*, 70:655–671, 2007.

[3] W. Liu, E. McGrath, C.-C. Hung, and B.-C. Kuo. Hybridization of particle swarm optimization with unsupervised clustering algorithms for image segmentation. *International Journal of Fuzzy Systems*, 10(3):217–230, 2008.

[4] K. R. and K. J. M. A possibilistic approach to clustering. *IEEE Trans Fuzzy Syst.*, 1(2):98–110, 1993.

[5] Y. Z., A. O.Ca, Z. R.b, Y. W.b, and T. J.b. An adaptive unsupervised approach toward pixel clustering and color image segmentation. *Pattern Recognition*, 43(5):1889–1906, 2010.