Study on Remote Sensing Image Segmentation Based on ACA–FCM

Qian Wang\textsuperscript{a}, Qi-peng Zhang\textsuperscript{a,}\textsuperscript{*}, Wei Zhou\textsuperscript{b}

\textsuperscript{a}Department of History and Culture, Gansu Normal University for Nationalities, Hezuo, China
e-mail: wangq306@163.com, \textsuperscript{*}(contact) e-mail: qp0720aaa@163.com

\textsuperscript{b}College of Geography and Environment Science, Northwest Normal University, Lanzhou, China
e-mail: zhouw866@163.com

Abstract

Image segmentation refers to certain provisions in accordance with the characteristics of the image into different regions, and it is the key of remote sensing image recognition and information extraction. Remote sensing image based on the complexity of the background features, has a wealth of spatial information, how to extract huge amounts of data in the region of interest is a serious problem. The traditional segmentation methods have obtained good results, but there are defects such as noise-sensitive, over-smoothing and loss of image information. Ant colony optimization algorithm is a fast heuristic optimization algorithm, easily integrates with other methods, and it is robust. ACA–FCM can greatly enhance the speed of image segmentation, while reducing the noise on the image. The image segmentation based on ACA–FCM is carried out and compared with traditional methods. Experimental results show that ACA–FCM can quickly and accurately segment target and it is an effective method of image segmentation.

1. Introduction

Image segmentation is base of the image recognition and image understanding, and the results of segmentation directly impact on the follow-up image processing. Image segmentation has been one of the difficulties of image processing technology, because of the influences, such as the complexity of image background, the diversity of target characteristics, noise and so on. ATR (Automatic target recognition) often uses segmentation to separate the target from background. The traditional segmentation methods have obtained good results, but there are defects such as noise-sensitive, over-smoothing and loss of image information.
Ant colony algorithm is a population-based biomimetic evolutionary heuristic algorithm and presented by Italy Colonic et al in early 1990’s [1]. Since proposed, the algorithm has been successfully applied to the TSP, the issue of network routing, job-shop scheduling problem, vehicle routing problem. Ant colony algorithm is ideally suited for cluster analysis because of its characteristics of parallelism and discreteness. Image segmentation can be seen as the process of clustering among different pixel characteristics, so the algorithm will be improved and applied to remote sensing image segmentation in this paper. Experimental results show that the targets can be quickly and accurately segmented by ACA–FCM

2. Theory of ACA

ACA [2-4] (ant colony algorithm), known as ant algorithm, is inspired by the collective behavior of ant colony. The study shows that the ants are always able to find the optimal path in the foraging process, with the effect by pheromone. And individual ants use pheromones to exchange and cooperate with other ants in order to find the optimal path. If the path is blocked, the ants will soon go around the obstacle once again to find the most excellent path. The stronger the pheromone of the path is, the greater the probability of the path is selected by individual ants. Hence, there will be more ants choose this path; the pheromone on the path will be getting stronger and stronger, and the ants choosing the path is also more and more. Finally, almost all the ants choose the best path. Through analysis, we found that ants foraging can be seen as a process of pheromone communication and continuous clustering among the individual ants.

3. Image segmentation application of ACA–FCM

Image segmentation is the process of searching food among the ants with different characteristics. Image data will be regarded as different attributes of the ants, and the cluster center will be regarded as the "food source". Given the original image X, each pixel xi (i = 1,2,3,4,...,N) as each ant. It is assumed that the initial amount of information on a path with the same initial value. In a certain scope, the pheromones secreted by ants will affect the thickness of amount of information on the path. The process of clustering can be described as follows [5-6]:

- The N data samples are initially distributed into a class of all (X1, X2, X3, ••• Xn);
- Calculate the Euclidean distance between the data samples Xi and the cluster center Cj

\[ d_{ij} = \sqrt{\sum_{k=1}^{m} (X_{ik} - C_{jk})^2} \]  

(1)

Where p is the weighted factor, determined by the contribution rate of various components in clustering;
- Calculate the pheromone concentration phij on each path. Set cluster radius r, the amount of information on the path (i, j) is defined as

\[ ph_{ij} = \begin{cases} 1 & d_{ij} \leq r \\ 0 & d_{ij} > r \end{cases} \]  

(2)

- Calculation of integrated into the cluster center Xi probability Cj:

\[ P_{ij} = \begin{cases} \frac{ph_{ij}^a(t)ao_{ij}^a(t)}{\sum_{j \in S} ph_{ij}^a(t)ao_{ij}^a(t)} & j \in S \\ \text{otherwise} \end{cases} \]  

(3)

Where a, \( \beta \) are the contribution rates of the accumulation of pheromone concentration and enlightening information for the ants to choose the path during the pixels clustering process. Xi
embody the similarity between the sample $X_i$ and the cluster center $C_j$.

- Compare the probability $p_{ij}$ with the probability threshold $p_0$ and merger, pheromone concentration will be updated and the cluster centers will be re-calculated. The pheromone concentration is updated as follows:

$$p_{ij}(t + 1) = (1 - \rho) p_{ij}(t) + \Delta p_{ij}$$

(4)

Where $\rho$ is volatile factor of pheromone concentration over the time, $\rho \in [0, 1]$.

- Determine whether there is a merge, if no merge, then stop the cycle.

### 4. Improved aca in image segmentation

An image includes the target, background, border and noise and so on. Gray is an important characteristics factor to distinguish the target from background. Edge gradient values usually are higher than that of the target and background, in addition to the pixel difference in the image field can be well used to distinguish the pixels within the different regions. In an image, the gray, gradient and the mean reflect the characteristics of target, background, border and noise; so that image segmentation can be seen as that each ant is a three-dimensional vector of above three characteristics.

#### 4.1. Clustering Center

Each pixel of the image can be seen as an ant, ant carries out the traversal analysis with the rest of each pixel. The random city of ant’s action makes the overall calculation larger and longer computing time. So the paper analyzes the image feature, sets the initial cluster center for ant, makes ant carry out cluster computing and the probability of selection directly with cluster center, thereby reducing the blindness of ant’s action and speeding up the clustering process.

The extraction of first Eigen values gray-scale of cluster center usually obtains by the peak of gray histogram. Because gray histogram reflects in visual the pixel frequency of each gray level. You can choose a peak point of the histogram as gray-scale features of the cluster center. Background and objectives occupy a large number of pixels, the number of border pixels is much larger than the number of noise pixels, and therefore it can determine the mean of gradients as the gradient cluster centers based on the gray histogram of original image and the gradient of the image.

Furthermore, we can calculate the peak value of the division of the gray area as the cluster center mean gray.

#### 4.2. Pheromone

In the foraging process of ants, the information hormone continuity volatile over time. On the other hand, the concentration of pheromone is increased with the choice of the path. After the completion of a cluster, the pheromone on the each path will be updated.

There are two ways to update pheromone, one is update pheromone on all the paths after a cycle; another is to update only the pheromones through the path of ant goes across, and the rest paths take the same pheromone or reduce. The latter is closer to the real ant colony search. If there are more ants to choose the path, the path is enhanced pheromone. In order to avoid local optimal, the concentration of pheromone can be adjusted through the following means[7].

$$p_{ij}(t + 1) = (1 - \rho) p_{ij}(t) + \Delta p_{ij}$$

(5)
Where $\rho \in [0,1]$ is the evaporation coefficient of pheromone concentration with time. Formula (5) can give attention to initial concentration value of information at all times $t$, when it updates the information at time $t+1$ on the path.

5. Test and conclusions

In this paper, taking Remote Sensing image in summer as an example. The size of the Remote Sensing image is 329×329; and the selected characteristics including vegetation, roads, built-up areas, bare land, water and agricultural land (Fig.1). Test is run on Windows XP operating system, Matlab9.0 software. The specific parameters are as follow: the cluster radius is 90, the information concentration is 0.95, the value of the choice probability is 0.4, alpha is 0.4, and beta is 3.

Test results were get on environment of Windows XP, Matlab9.0a. It can be seen from Fig.2 that Log operator could well segment the road from the image, but for other types of land, the segmentation effect is not so obvious because of the influence by the texture feature. Fig.3 is the segmentation result combining a LoG operator with Canny operator. The types of surface features in the image can hardly be segmented, the effect is bad. It can be seen that Fig. 4 achieved better result by ACA–FCM, and the types of surface features in the image have been well segmented, and the effect is obvious. The effect of the segmentation is run based on setting the cycle number 550 and the operation lasted for 307s. Running time is proportional to the cycle number, the larger the number is, and the longer it runs. From the comparison among Fig.2 to Fig.4, it can be seen that the ACA–FCM is an effective method for remote sensing image segmentation. For the character of multi-band, huge remote sensing images, the parallelism, robustness and autonomy of ant colony algorithm can be applied very well[8]. Application of ACA–FCM to remote sensing image segmentation has obvious effects, comparing with the commonly used edge detection operator.

Figure 1. Original Remote sensing image
Figure 2. Result of LoG edge detector

Figure 3. Result of LoG and Canny detectors
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References

[1] A. Colorni, M. Dorigo, V. Maniezzo, et al. Distributed optimization by ant colonies. Proc. of Europea Conf on Artificial Life. Paris, 1991. 134-142.

[2] Y.F Han, P.F Shi., An improved ant colony algorithm for fuzzy clustering in image segmentation. Neurocomputing 70 (2007) 665-671.

[3] P.Y.Yin, Ant colony search algorithms for optimal polygonal approximation of plane curves. Pattern Recognition 36 (2003) 1783 – 1797.

[4] R.J. Mullen, D. Monekosso, S. Barman, P. Remagnino, A review of ant algorithms. Expert Systems with Applications 36 (2009) 9608-9617.

[5] W.B. Tao, H. Jin, L.M. Liu, Object segmentation using ant colony optimization algorithm and fuzzy entropy. Pattern Recognition Letters 28 (2007) 788-796.

[6] Y.F Han, P.F Shi., Image Segmentation Based on Improved Ant Colony Algorithm. Computer Engineering and Applications 2004.18. 5-7.

[7] K.Z. Tang X.L. Jiang, S. Gao, Image segmentation based on ant colony fuzzy clustering. Computer Engineering and Design. 2008.4. 1770-1772.

[8] X. Mei, Q. Wang, et al, Research on Remote Sensing Image Segmentation Based on Ant colony algorithm- Take the Land Cover Classification of middle Qinling Mountains for Example. MIPPR 2009: Multispectral Image Acquisition and Processing, edited by Jayaram K. Udupa, Nong Sang, Laszlo G. Nyul, Hengqing Tong, Proc. of SPIE Vol. 7494.