2D cross entropy method for image segmentation based on artificial bee colony optimization

Xianglan Ye[1, a], Tianhuang Chen[2,b]

[1]Wuhan University of Technology, China, 430063

[2] Wuhan University of Technology, China, 430063

[a]1261800633@qq.com [b] thchen57@126.com

Keywords: image segmentation, two-dimensional cross entropy, artificial bee colony algorithm

Abstract. A kind of image segmentation method with two-dimensional cross entropy was proposed based on the artificial bee colony algorithm to overcome the large amount of calculation and long computing time. Firstly, the principle of two-dimensional cross entropy threshold segmentation was analyzed. Then, the bionic mechanism and searching optimization process of the artificial bee colony algorithm were analyzed, and the threshold segmentation method of two-dimensional cross entropy combined with artificial bee colony algorithm was proposed. Finally, typical image segmentation experiments by using the proposed method were performed and the results were compared with two-dimensional cross entropy exhaustive segmentation method and two-dimensional entropy segmentation method based on Particle Swarm Optimization (PSO). Experimental results show that the speed of the proposed method is ten times faster than the two-dimensional entropy exhaustive segmentation method respectively. Moreover, the threshold selection accuracy and running speed of the proposed method are both better than the threshold segmentation method of two-dimensional cross entropy based on PSO. Therefore, the image segmentation method of two-dimensional cross entropy based on artificial bee colony algorithm can quickly and efficiently resolve image segmentation problems.

Introduction

The threshold segmentation method is a kind of image segmentation method, which is to segment the target and the background from the image by selecting the appropriate threshold [1]. There are many kinds of threshold segmentation methods, such as Otsu, Minimum Error, Cross Entropy [2]. This paper focuses on cross-entropy algorithm.

In 1993, Li has proposed a threshold segmentation method based on cross entropy by using one-dimensional gray-level histogram [3]. In 2005, Rong Mei has extended 1D cross entropy to 2D cross entropy by using gray level and average gray level of the filed [4]. However, as dimension increases, the amount of calculation and computing time has increased. Overcoming the large amount of calculation and long computing time, many people try to use the bionic algorithms, such as Gene Algorithm (GA), Particle Swarm Optimization (PSO).

Artificial Bee Colony (ABC) has many advantages, such as less control parameters, fast convergence, avoiding local optimum, robustness. So, this article will use Artificial Bee Colony to overcome the long computing time of 2D cross entropy image segmentation method.

2D Cross Entropy Method for Image Segmentation

1D Cross Entropy is simple, but can't reflect the local spatial information of the image and is sensitive to noise. 2D Cross Entropy takes gray level and average gray level of the filed into consideration. 2D Cross Entropy Method is more effective and better to express the features of the image than 1D Cross Entropy Method. What is more, 2D Cross Entropy Method for Image Segmentation can prevent the interference of noise.

The 2D Cross Entropy Method for Image Segmentation is as follow.

1. Computing the 2D gray-level histogram by using Eq. 1 and computing the probability of object

by using Eq. 2, background by using Eq. 3.

$$p_{i,j} = \frac{n_{i,j}}{M*N}, \tag{1}$$

$$P_O = \sum_{i=0}^{s} \sum_{j=0}^{t} p_{i,j}, \tag{2}$$

$$P_B = \sum_{i=s+1}^{L-1} \sum_{j=t+1}^{L-1} p_{i,j}, \tag{3}$$

$n_{i,j}$ is the frequency of gray level i and the average gray level of the filed j, $M*N$ is the width and the length of the image and L is the possible number of gray levels.

2. Computing the mean value of object region by using Eq. 4 and background region by using Eq. 5.

$$m_O(s,t) = \frac{1}{P_O} \sum_{i=0}^{s} \sum_{j=0}^{t} ijp_{i,j}, \tag{4}$$

$$m_B(s,t) = \frac{1}{P_B} \sum_{i=s+1}^{L-1} \sum_{j=t+1}^{L-1} ijp_{i,j}. \tag{5}$$

3. Computing 2D Cross Entropy by using Eq. 6.

$$j(s,t) = \sum_{i=0}^{s} \sum_{j=0}^{t} (ijp_{i,j} \ln \frac{ij}{m_O(s,t)} + m_O(s,t)p_{i,j} \ln \frac{m_O(s,t)}{ij}) + \sum_{i=s+1}^{L-1} \sum_{j=t+1}^{L-1} (ijp_{i,j} \ln \frac{ij}{m_B(s,t)} + m_B(s,t)p_{i,j} \ln \frac{m_B(s,t)}{ij}) \tag{6}$$

4. Searching the best threshold (s^*,t^*) by using Eq. 7.

$$j(s^*,t^*) = \max\{\frac{1}{j(s,t)}\} \tag{7}$$

Artificial Bee Colony

Biologists found that after bees come back to the nest, they will dance to convey information about the nectar, which contain the distance between the nectar and the nest, the angle between the nectar and the nest [5]. This communicating form can make the bee swarm complete gathering honey in a synergistic way. In this model, nectar is on behalf of possible solutions within the scope of the solution space. Mining bees will recruit unemployed bees by dancing to share information with other bees and part of unemployed bees will be leading bees. Scouting bees will search new nectar. Following bees will wait information from the leading bees in the nest. When unemployed bees find new nectar, they will be mining bees. After they complete collecting nectar and come back to the nest, they have three choices: becoming unemployed bees by rejecting the nectar, recruiting unemployed bees by dancing, collecting nectar and not recruiting. Artificial bee colony algorithm is to simulate this bionic optimization process of collecting nectar. When artificial bee colony algorithm is finding the optimal solution, leading bees can maintain good solutions, following bees can increase the rate of convergence, and scouting bees can avoid the locally optimal solution.

Artificial bee colony algorithm is as follow.

1. Initialization. Initializing NS feasible solution $(X_1, X_1, \mathbf{L}, X_{NS})$ under the given boundary conditions by using Eq. 8.

$$X_i^j = X_{\min}^j + rand(0,1)*(X_{\max}^j - X_{\min}^j), i \in \{1,2,\mathbf{L},NS\}, j \in \{1,2,\mathbf{L},RD\} \tag{8}$$

NS is bee colony size, $S = RD$ is individual search space.

2. Computing the function of income by using Eq. 9.

$$fit_i = \begin{cases} \frac{1}{1+fit_i}(fit_i \geq 0) \\ |fit_i|(fit_i < 0) \end{cases} \tag{9}$$

fit_i is function value of i feasible solution, ordering the feasible solution by function value and selecting ranking NE feasible solution to be the initializing bee colony $X(0)$, NE is the number of mining bees.

3. To mining bees $X_i(n)$, they will update the position by Eq. 10.

$$V_i^j = X_i^j + j_i^{\ j}(X_i^j - X_k^j) \tag{10}$$

$j_i^{\ j}$ is a random number between -1 and 1, $k \neq i$, k is a random number, j is a random number, $V \in S$.

4. Selecting the bees which have high degree of income as a new generation of mining bees by using greedy strategy from X_i, V_i.

5. Each following bee select a mining bee according to the income of mining bee and search the new position in its domain. Computing individual selection probability of mining bee colony by using Eq. 11.

$$P\{X_i\} = \frac{fit(X_i)}{\sum_{k=1}^{NE} f(X_k)} \tag{11}$$

6. As same as step 3 and step 4, recording the best income and corresponding solution vector.

7. When the number of searching position by a mining bee reaches the upper setting threshold and don't reach a better position, initializing the position of the mining bee.

8 If meeting the convergence criteria, stopping the search and outputting the optimal value and corresponding solution vector, otherwise returns to step 3.

Improving 2D Cross Entropy Method for Image Segmentation

Artificial Bee Colony is a new means to solve the problem of function optimization. Artificial Bee Colony (ABC) has many advantages, such as less control parameters, fast convergence, avoiding local optimum, robustness. We can use Artificial Bee Colony to improve the computational efficiency of 2D cross entropy method for image segmentation.

Let bee to be (s,t). Let the function of income to be $j(s,t)$. Let the distribution of image pixel to be the namespace of solution. Computing the 2D gray-level histogram. Using Artificial Bee Colony to search the best threshold (s^*, t^*). Splitting the image according to the threshold.

Experiments and analyzing results

Lena image segmentation experiments by using the proposed method were performed .The results were compared with two-dimensional cross entropy exhaustive segmentation method and two-dimensional entropy segmentation method based on Particle Swarm Optimization (PSO). The parameters setting of ABC and PSO is shown in Table 1.

Table 1 parameters setting

Algorithm	Parameter
ABC Algorithm(used in this article)	Bee colony size:20;trying times:100;the number of generation:100
PSO Algorithm	Colony size:20;the number of generation:100; constant $C1$:2.49; constant $C2$:2.49;Least rate:-2.5;greatest rate:2.5

The result of splitting image by ABC is shown in Fig. 1. The result of splitting image by exhaustive method is shown in Fig. 2. The result of splitting image by POS is shown in Fig. 3.

Fig. 1 ABC
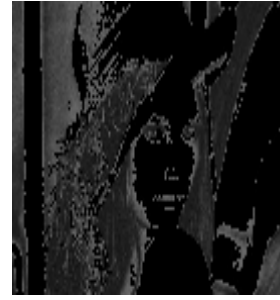

Fig. 2 Exhaustive Method

Fig. 3 POS

The running time and selecting threshold of ABC, POS, exhaustive segmentation method is shown in Table 2.

Table 2 threshold and running time

Algorithm	Threshold (s,t)	Running time
ABC Algorithm	(108,106)	1.72
PSO Algorithm	(115,112)	2.67
Exhaustive Algorithm	(107,106)	19.56

From table 2, we can see that the speed of the proposed method is ten times faster than the two-dimensional entropy exhaustive segmentation method respectively. Moreover, the threshold selection accuracy and running speed of the proposed method are both better than the threshold segmentation method of two-dimensional cross entropy based on PSO.

Conclusions

In this article, the threshold segmentation method of two-dimensional cross entropy combined with artificial bee colony algorithm was proposed and compared with two-dimensional entropy exhaustive segmentation method, two-dimensional cross entropy method based on PSO. Using ABC to process remote sensing image which have high distinguishability is future work.

References

[1] Akanksha Bali, Dr. Shailendra Narayan Singh. A Review on the Strategies and Techniques of image Segmentation. 2015 Fifth International Conference on Advanced Computing & Communication Technologies.

[2] Yiquan Wu, Meng Tianliang, Shihua Wu. 20 years of research on image segmentation threshold value. Journal of Data Acquisition & Processing, 2015, 30(1). In china.

[3] Pun T. A new method for gray-level picture threshold using the entropy of the histogram [J]. Signal Processing, 1998, 2: 223-237.

[4] Rong Mei, Changsheng Jiang, Mou Chen. 2D minimum cross entropy based on genetic algorithm for dynamic image segmentation [J]. Electronics optics & Control, 2005, 12(1): 30-34. In china.

[5] Alim Samat, Peijun Du, Sicong Liu. Maximum 2D Entropy Image Segmentation Based 0n Artificial Bee Colony Optimization[J]. Computer Engineering, 2012, 38(9). In china.