Single threshold segmentation for noisy image based on fuzzy ant colony algorithm

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Received 1 July 2014, www.cmnt.lv

Abstract

Firstly, this paper pre-processes the image to be segmented through grey-scale morphological method. Then, based on the in-depth analysis of basic ant colony algorithm, it explains the shortcomings of this algorithm; proposes the improved strategy of ant colony algorithm, namely fuzzy ant colony algorithm, which designs the fitness function of artificial ant colony algorithm with minimum cross entropy and applies the improved fuzzy ant colony algorithm in the spatial-domain noisy image single segmentation. Finally, starting from the segmentation results and convergence, it compares the performances of the improved ant colony algorithm and the basic ant colony algorithm, GA algorithm and AFS algorithm.

Keywords: Noisy Image, Ant Colony Algorithm, Histogram Feature, Threshold Segmentation, Cross Entropy

1 Introduction

This paper is aimed to study the swarm intelligent optimization algorithm based on ant foraging behaviour, namely the artificial ant colony algorithm. The early ant colony algorithm is mostly used in solving function optimization problems. For example, some scholars see the honey of the artificial ant colony algorithm as the possible solution of the function and achieve satisfactory results in optimizing function with ant colony algorithm. Other scholars consider the objective function in the engineering as virtual food and settle the optimization problems of two-dimensional functions with virtual ant colony algorithm. Later, starting from the optimization problems of high-dimensional functions, some scholars demonstrate the excellent performances of artificial ant colony algorithm by comparing particle swarm optimization and other algorithms before they use ant colony algorithm to solve the data clustering problems.

As a new swarm intelligent model, ant colony algorithm still encounters the following problems used in image segmentation. 1)The initialized population is randomly generated in the solution space without considering the characteristics of the image to be segmented; 2)In the threshold search of the basic ant colony algorithm, the individual movement in the population can be seen as a random process in a certain range; however, the actual individual movement has certain fuzziness[1].

Based on the above analysis, this paper improves the optimization efficiency of the intelligent model by integrating the histogram information of image to be segmented, the fuzzy theory and the artificial ant colony algorithm. On the basis of the improved ant colony algorithm, the design of noisy image segmentation is intended to analyse the characteristics of the image to be segmented and suppress the image noise through open operation and closed operation in the grey-scale morphology. Then design the fitness function of the artificial ant colony algorithm with the minimum cross entropy and narrow down the threshold search range of the ant colony by using the histogram information of the image in order to guarantee the image segmentation speed; consider the ant movement process as the fuzziness process and conduct fuzzy control with fuzzy theory. Finally, quickly find the optimal threshold with the improved artificial ant colony algorithm [2].

2 The proposed algorithm

With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely. In the meantime, piracy becomes increasingly rampant as the customers can easily duplicate and redistribute the received multimedia content to a large audience.

2.1 THE IMAGE PRE-PROCESSING OF THE HISTOGRAM ANALYSIS BASED ON GREY-SCALE MORPHOLOGY

It is indicated in the documents that the grey-scale morphological pre-processing can effectively suppress the speckle noise in the noisy images. Therefore, in the noisy image segmentation, we first pre-process the image to be segmented with grey-scale morphology to reduce the noise in the image and then narrow down the

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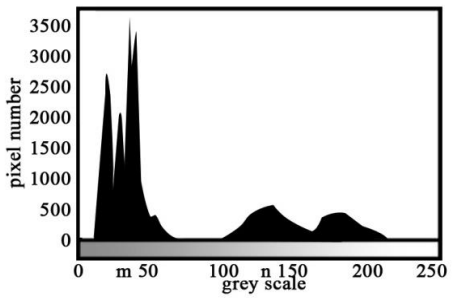
threshold distribution range according to the grey-scale histogram of the pre-processed image.

Take Fig.1 as example. Fig. 1(a) is the original noisy image and Fig.1(b) is the grey-scale histogram after pre-processing (a) with grey-scale morphology. Assume the possible threshold of the image is T, there are obvious differences in the grey scale between the segmentation target and the background, namely that there are two obvious twin peaks in the histogram of the pre-processing image. The threshold is located in the bottom of the twin peaks and its distribution range is between the twin peaks, namely $T \in [m,n]$ in Fig. 1(b).

The solving method of m and n is to calculate the average grey scale of the image in the histogram. Missing the grey scale among [0, c] with the biggest possibility and n is the grey scale among [c+1, 255] with the biggest possibility.

(a) Noisy image



(b) Histogram of noisy image

FIGURE 1 Histogram of noisy image

3 The fuzzy ant colony algorithm

3.1 THE PROBLEMS IN ANT COLONY ALGORITHM

There are still some problems when ant colony algorithm, a new swarm intelligent model is used in image segmentation, including:

1) The initialized population is generated in the solution space without considering the characteristics of the image to be segmented;

2) In the threshold search process of the basic ant colony algorithm, the individual movement in the colony can be seen as a random process in a certain range while the actual movement has certain fuzziness [3].

3.2 FUZZY CONTROL THEORY AND FUZZY MEMBERSHIP FUNCTION

Fuzzy control theory has been used increasingly extensive because no precise mathematical model of the controlled object is needed to be built when designing system. The existing Methods determine fuzzy membership function include:

1) Fuzzy statistical method: make a clear judgment whether a determined element belongs to a variable clear collection in the domain of discourse;

2) Exemplification: estimate the membership function of the fuzzy subset according to membership frequency of limited fuzzy subsets;

3) Expert experience method: determine the membership function according to the processing equation or the corresponding weight coefficient of the fuzzy information given by the actual expert experience;

4) Binary comparison ordering method: determine the general shape and order under certain characteristics through the paired comparisons of multiply objects so as to determine the membership function of the characteristics and these objects [4].

The reconnaissance ant in the basic ant colony algorithm generates a new position randomly in the search space to improve food source. Such new position is so uncertain that it can be seen as a fuzzy process.

In the below text, we determine the fuzzy membership function by using the exemplification in the fuzzy control so as to control the search range of the reconnaissance ant in the artificial ant colony algorithm. After repeated experimental observation, the ant colony has better optimization effects to fulfil this process according to Formula (1) and Formula (2) is the fuzzy control factor.

$$v_{ij} = x_{ij} + \varphi \times (\omega, \theta, t) \times x_{ij}, \quad (1)$$

$$\mu(\omega, \theta, t) = 1/[1 + \exp(-\omega t - \theta)]. \quad (2)$$

In the above formula, v_{ij} is a new possible solution generated by the ant; x_{ij} is the ant which needs improvements; i is the i^{th} ant; j is the number of dimension of the solution space; φ is a random number among [-1,1]; $\mu(\omega, \theta, t)$ is the fuzzy membership function and ω and θ are a set of values from the experiments. In this paper, $\omega = -0.2$, $\theta = 2$ and t is the current iterations [5, 6].

According to Formula (1), with the increase of iterations, the search range of the ant is self-adaptive to the changes. To be specific, in the initial search, the ant is far from the optimal solution and the search range is big, guaranteeing the diversity of the individuals in the colony ad in the later search, the ant is closed to the optimal solution and its search range is small, avoiding oversized step size and skipping the optimal solution [7].

4 The spatial-domain noisy image single threshold segmentation based on fuzzy colony algorithm

The general noisy image has some speckle noise due to other interferences. Therefore, effectively suppress the noise interference before segmenting the image and get the precise segmentation image. This paper pre-processes the image to be segmented with grey-scale morphology and reduce the noise interference. Then, it narrows down the search range of the threshold with the pre-processed image histogram and enhances the optimization speed. On this basis, it takes the two-dimensional cross entropy as the fitness function of the ant colony algorithm and finds the optimal segmentation threshold of the image through fuzzy ant colony algorithm.

In conclusion, the spatial-domain noisy image segmentation process based on fuzzy ant colony algorithm is classified as follows.

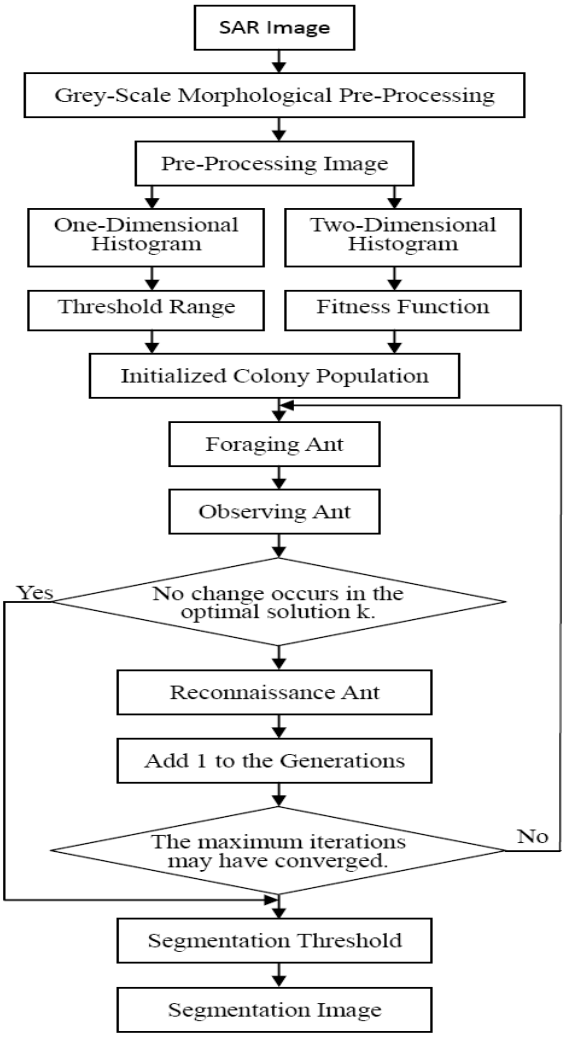


FIGURE 2 The spatial-domain noisy image segmentation based on fuzzy ant colony algorithm

The main steps are as follows:

(1) Pre-process the image to be segmented with appropriate grey-scale morphological factor and get the enhanced image;

(2) According to the histogram feature of the denoised image, narrow down the search range of the threshold to $[m,n]$, namely min and max in the artificial ant colony algorithm are m and n respectively;

(3) According to the grey scale and neighbourhood grey-scale information of the denoised image, get the grey-scale-neighbourhood-grey-scale histogram and calculate the minimum cross entropy in the image:

$$D(s,t)=\sum_{i=m}^{s}\sum_{j=m}^{t}\left[ijp_{ij}\ln\frac{ij}{\mu_1(s,t)}+\mu_1(s,t)p_{ij}\ln\frac{\mu_1(s,t)}{ij}\right]+\sum_{i=s+1}^{n}\sum_{j=t+1}^{n}\left[ijp_{ij}\ln\frac{ij}{\mu_2(s,t)}+\mu_2(s,t)p_{ij}\ln\frac{\mu_2(s,t)}{ij}\right] \quad (3)$$

In the formula, $P_1=\sum_{i=m}^{s}\sum_{j=m}^{t}p_{ij}$, $P_2=\sum_{i=s+1}^{n}\sum_{j=t+1}^{n}p_{ij}$, $\mu_1(s,t)=\frac{1}{P_1}\sum_{i=m}^{s}\sum_{j=m}^{t}ijp_{ij}$, $\mu_2(s,t)=\frac{1}{P_2}\sum_{i=s+1}^{n}\sum_{j=t+1}^{n}ijp_{ij}$, s is the grey-scale value; t is the average neighbourhood grey-scale value and p_{ij} is the grey-scale-neighbourhood-grey-scale joint probability;

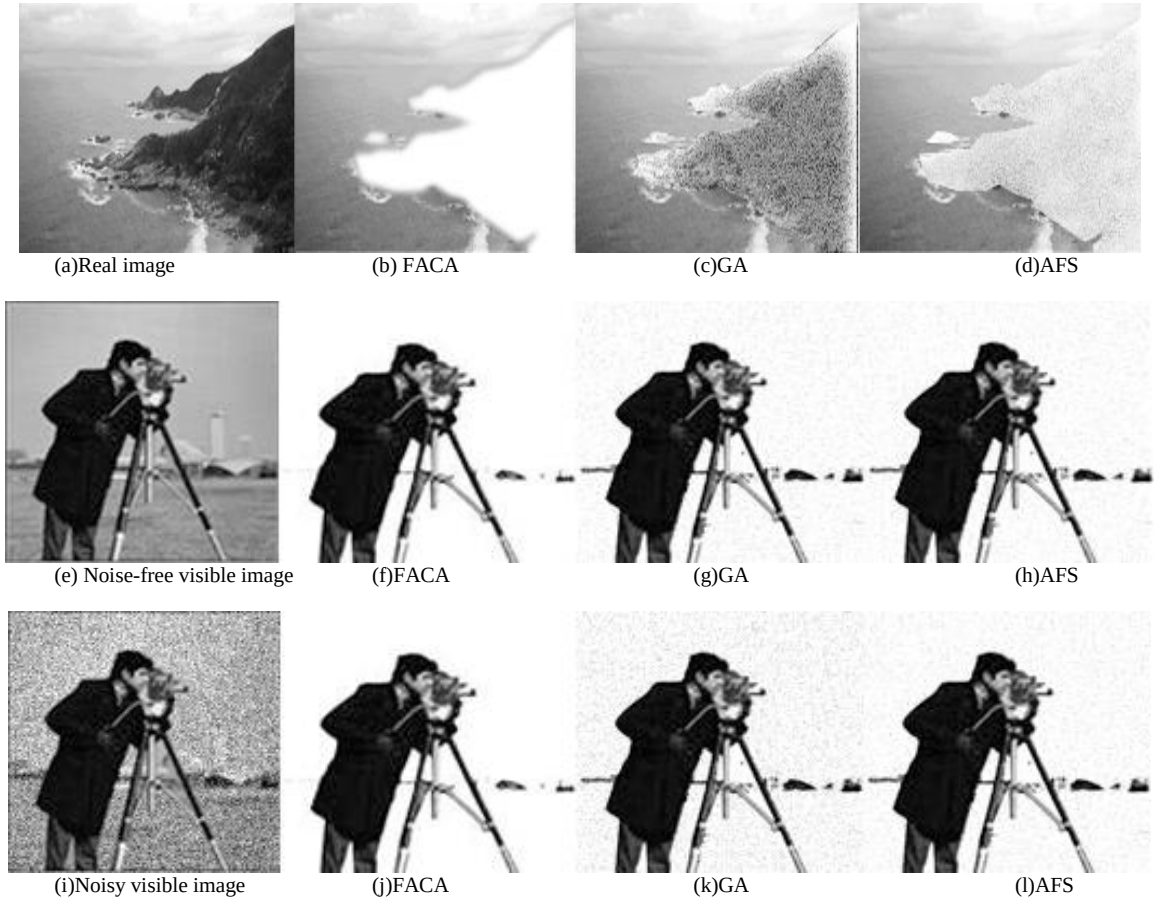
(4) Choose the reciprocal of Formula (3) as the fitness function of the artificial ant colony algorithm and then the corresponding (s,t) is the optimal threshold when the value of $\frac{1}{D(s,t)}$ is maximum;

(5) Segment the image according to the threshold (s,t) and the specific operation is as follows. If the sum of the grey scale of the pixel point (x,y) and the average neighbourhood grey scale is among $[0,s+t]$, then this point is the target pixel with a grey-scale value of 0; otherwise, this point is a background pixel with a grey-scale value of 1 [8].

5 Experimental results and analysis

5.1 THE COMPARISON OF SEGMENTATION RESULTS

The following are a group of image segmentation results by fuzzy ant colony algorithm, GA algorithm and AFS algorithm with visible image, noisy visible image and real image. Results are indicated as Fig. 3.



(a)Real image (b) FACA (c)GA (d)AFS

(e) Noise-free visible image (f)FACA (g)GA (h)AFS

(i)Noisy visible image (j)FACA (k)GA (l)AFS

FIGURE 3. The comparison of the image segmentation results by different optimization algorithms

From Fig.3, it is clear that no target regions has been split when segmenting the real noisy image; the noise has been split completely and there is a hole in the target when segmenting the noise-free visible image and the target has been split precisely when segmenting the noisy visible image since it is sensitive to the noise. Only part of target region has been split when segmenting the real noisy image; a hole appears in the target when segmenting the visible image and the noise and the target haven't been split well when segmenting the noisy visible image. The segmentation method based on fuzzy ant colony algorithm has strong noise immunity and get an intact and clear segmentation image target on the real noisy image with serious speckle noise, the visible image and the visible image with speckle noise.

5.2 THE COMPARISON OF ALGORITHM CONVERGENCE

In order to verify the quick optimization of fuzzy ant colony algorithm, the paper compares its convergence with the basic ant colony algorithm, the genetic algorithm and the artificial fish swarm algorithm with fixed experimental parameters. Make the individuals of the population in the fuzzy ant colony algorithm, the basic ant colony algorithm, GA algorithm and AFS algorithm as 20 and the population search times as 30. Compare the convergence of the fitness function curve when comparing the above algorithms in segmenting Fig. 3(a), as indicated in Fig. 4.

From Fig. 4, it can be seen that the fuzzy ant colony algorithm has converged in the 5th generation and it can search the optimal segmentation threshold; the basic artificial ant colony algorithm has converged in the 13th generation; the genetic algorithm hasn't converged in the 30th generation, so it can't find the optimal threshold and the artificial fish swarm algorithm has converged in the 19th generation, but it hasn't excellent stability. Therefore, the fuzzy ant colony algorithm can converge stably and quickly with small population and search times.

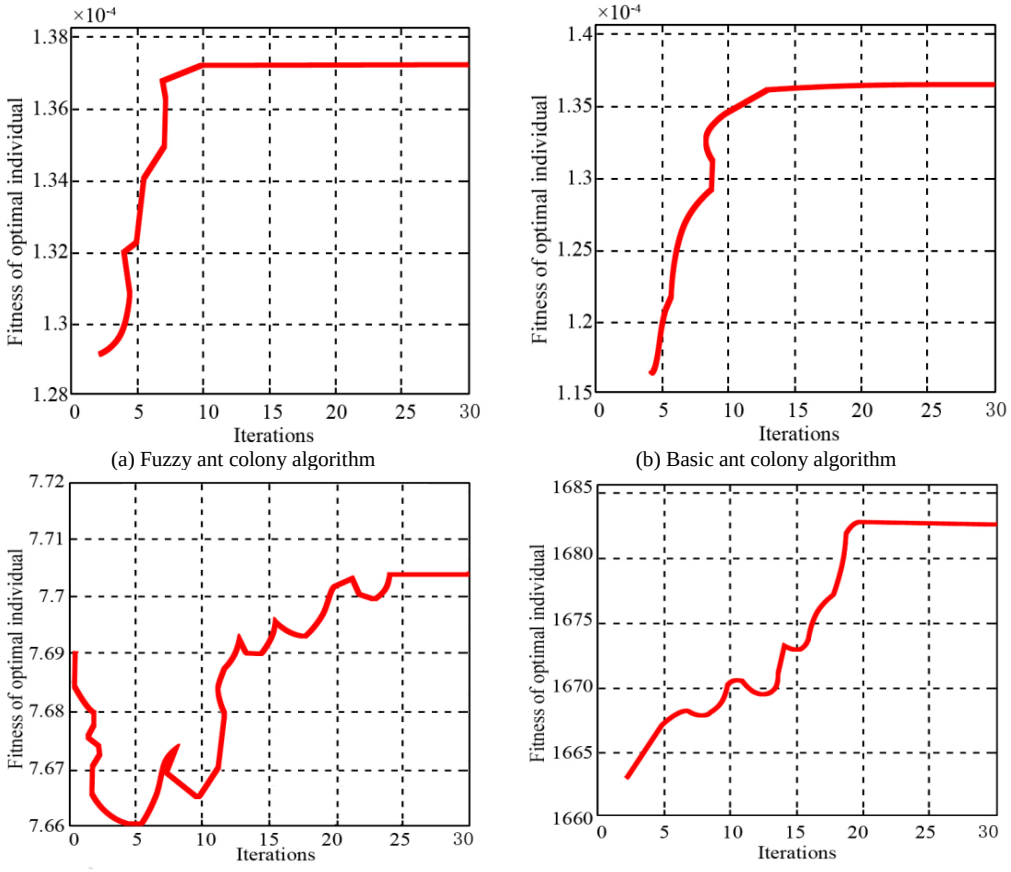


FIGURE 4 The convergence curve of the optimal

6 Conclusion

This paper has come up with a new spatial-domain noisy image segmentation method based on fuzzy ant colony algorithm. The main characteristic of this method is to make full use of the grey-scale features of the image to be segmented. It reduces the noise interference in the noise image segmentation through the grey-scale morphological pre-processing and effectively narrows down the threshold search range by pre-processing the histogram information of the image, which is good for the swarm intelligent algorithm to converge in a shorter time and guarantees the quickness of the segmentation speed. In improving the basic ant colony algorithm, it determines the search range of the reconnaissance ant via the fuzzy control dynamics and accelerates the convergence speed of the ant colony algorithm. The experimental results show that the method in this paper is better than the image segmentation methods based on the genetic algorithm and the artificial fish swarm algorithm in the noise immunity, precision, quickness and stability. The thing to note here is that this method is applicable for the image presenting twin-peak shape after grey-scale morphological processing and further exploration is needed to the images with mixed target and background noise.

Acknowledgments

This work was supported by Ministry of Education, Humanities and Social Sciences Research Projects (Grant No 12YJAZH216).

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