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The two-dimensional double-entropy threshold based on the parallel genetic simulated annealing algorithms

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ABSTRACT

In this paper, aiming at solving the problem arising from the application of the two-dimensional entropy method in double threshold segmentation, which is time-consuming and highly complex, the author introduces the parallel genetic simulated annealing algorithm to optimize it. Besides, the author structures parallel genetic simulated annealing algorithm to search for a two-dimensional maximum entropy value of the optimal threshold. This optimized algorithm shortens the calculation time, accelerates the speed of obtaining the optimal threshold and improves the efficiency of image segmentation.

1. Introduction

Image segmentation is a basic image analysis technology; it is the precondition of image recognition and image understanding. It has always been the hot spot of the image researchers.

In the process of image segmentation research, threshold method because of its simple, stable performance and become the core technology in image segmentation. Its principle as follows: divide the image into several parts through one or more thresholds the grayscale, the same gray value of pixels to belong to the same target. Threshold segmentation methods have been widely applied both in domestic and abroad such as the between-cluster variance method [1]. The two-dimensional maximum entropy values method [2] and the minimum error method [3]. *D* maximum entropy threshold method is widely used because it does not require prior knowledge, and the non-ideal bimodal or multimodal image histogram can be better segment, but in the process of the realization of dual-threshold segmentation method using full search method to find the global optimal threshold, the algorithm complexity increases, the computation time overhead shows geometric growth compared to single threshold algorithm, it is difficult for real-time processing, limiting its application and promotion.

To solve the problem arising from the application of the two-dimensional entropy method in double threshold segmentation, which is time-consuming and highly complex, domestic and foreign scholar began to introduce the genetic algorithm into a two-dimensional entropy threshold method to optimize the segmentation, using its robustness for global parallel search and looking for the best individual of the optimization of the group; Guo and some other scholars proposed a two-dimensional maximum entropy image segmentation based on particle swarm optimization method [4,5], which regards point gray and regional gray average as a threshold and use particle swarm algorithm for image's two-dimensional threshold space to global search. Chang proposed a two-dimensional entropy dual threshold's adaptive image segmentation method [6] based on the principle of two-dimensional entropy threshold segmentation, using the genetic algorithm of variable code for threshold segmentation. This adaptive method has optimization and optimal classification number advantages at the same time. As a result, image segmentation can achieve good results, and threshold value speeds up search optimization. Ou proposed that combining genetic algorithm grains [7] and two-dimensional entropy method to select a threshold. This method chooses an appropriate gray value of the two-dimensional histogram information to initialize, by the way, of operating selection, crossover and mutation to search for the optimal threshold, which greatly improves image segmentation accuracy.

Introducing genetic algorithm and using a global parallel optimization technique is aimed at finding the best individual in the individual optimization in order to reduce the computational complexity and increase application value of 2D entropy method. Foreign scholars also used the idea of the combination of genetic algorithms and threshold method to research. In the reference [8], authors use genetic algorithm to optimize the minimum cross-entropy threshold method (MCET), and propose that using multilevel MCET to select multiple thresholds and using

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the recursive method to reduce calculation complexity in the multistage MCET objective function to achieve rapid segmentation purposes. Quantum genetic algorithm (called IQGA) was first proposed in the reference [9,10] in which authors introduce a strategy of adaptive adjustment, by dividing dimensional vector space into several one-dimensional low-dimensional solution spaces to speed up rate of convergence, search ability and stability.

The introduction of genetic algorithms greatly improves the efficiency of segmentation. However, because of premature convergence, precision and stability of two-dimensional entropy method is limited. In order to further improve this shortcoming, this method combines simulated annealing algorithm with parallel genetic algorithm to optimize the two-dimensional maximum entropy algorithm. Optimal group mechanism [11,12] of parallel genetic algorithm combines the computer's high-speed parallelism and natural parallelism of genetic algorithm to optimize the two-dimensional maximum entropy algorithm, greatly enhancing the solving speed of genetic algorithm and segmentation quality in which the climbing ability of the simulated annealing algorithm is used to improve algorithm convergence speed. In this algorithm, two-dimensional maximum entropy [13] as the fitness function's evolution of the individual conducts in a number of different subgroups of in parallel, and the two-dimensional entropy discriminant function is used as a fitness function of parallel genetic algorithms, using simulated annealing parallel genetic algorithms for global optimization, reaching the purpose of threshold search purposes.

2. Two-dimensional maximum entropy

The core of the two-dimensional maximum entropy image segmentation method is to use point gray and region gray to structure two-dimensional histogram, forming the spatial distribution of information, which works as the basis to select the optimal threshold. In this paper, two-dimensional entropy dual-threshold segmentation based on parallel simulated annealing algorithms is an improved method for gray image target segmentation. Assuming that the original image is f, $f = I_{m\times n}$, of which I shows an image corresponding to the digital matrix, m and n means the number of rows and columns of the matrix and the corresponding image's height and width respectively, the gray level of the original image is L. Two-dimensional histogram is constructed as follows:

First, put the image pixel gray $f(i, j)$ as the first dimension's parameter $x_1(i, j) = f(i, j)$;
Then, select a neighborhood $\delta(m, n)$ of pixel $f(i, j)$, choosing a fixed size of the template expression in the image's neighborhood, which usually is 3×3, that is to say, choosing eight pixels adjacent to pixel $f(i, j)$, and calculating that point's all pixels average in the neighborhood as the second dimension of the two-dimensional histogram. Computation formula is as follows:

$$x_2(i,j) = \frac{1}{9} * \sum_{m=-1}^{1}\sum_{n=-1}^{1} f(i+m, j+n) \tag{1}$$

Thus obtain the two-dimensional histogram of the image in which each pixel in the image corresponds to a point gray – region gray average pairs (x_1, x_2).

Set the size of the original image of $m \times n$, and $N_{i,j}$ for the pixel points which the neutral gray image for i and its regional grayscale average pixel points for j, $p(i, j)$ as the incidence of the point of gray – regional grayscale average probability of happening, then formula as the following

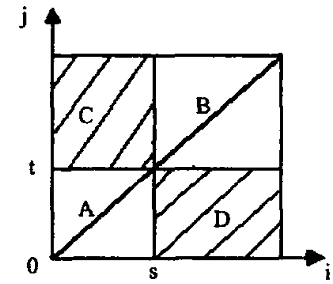

Fig. 1. XOY plan – double threshold.

$$p(i,j) = \frac{N_{i,j}}{m \times n} \quad i, j = 1, 2, 3, \ldots, L \tag{2}$$

$p(i, j)$ represents the image's two-dimensional histogram about point grayscale to gray region, In which point target and background are mostly concentrated in the diagonal area of the *XOY* surface, Noise of deviation on the diagonal distribution and the information of edge contained are negligible in order to reduce the amount of calculations. According to the distribution of different parameters on the diagonal area, an optimal threshold can be determined, making representative target and the background's information entropy the largest and getting best treatment effect (Fig. 1).

Each point gray scale in the image and its neighborhood average gray level has the same changing range. Each pixel gray level and its average gray level form a neighborhood gray-scale binary group. Based on the method of reference [2], structure two-dimensional histogram and use two-dimensional histogram threshold vector $V = (s, t)$ for image segmentation. In the divided figure, there are two kinds: O and B, on behalf of the target and background respectively.

$$s \in [0, K), \quad t \in [0, K),$$

So the probability of target and background can get respectively.

$$P(O) = \sum_{i=0}^{s}\sum_{j=0}^{t} P(i,j) \qquad P(B) = \sum_{i=s}^{K}\sum_{j=t}^{K} P(i,j)$$

$$L(O) = -\sum_{i=0}^{s}\sum_{j=0}^{t}\left(\frac{P(i,j)}{P(O)}\right)\ln\left(\frac{P(i,j)}{P(O)}\right) = \ln P(O) + \frac{L(s,t)}{P(O)} \tag{3}$$

In the formulas, $L(s, t)$ represents objective entropy:

$$L(s,t) = -\sum_{i=0}^{s}\sum_{j=0}^{t} P(i,j)\ln P(i,j) \tag{4}$$

$$L(B) = \ln(1 - P(O)) + \frac{L_{K,K} - L_{S,T}}{1 - P(O)} \tag{5}$$

$$L_{K,K} = -\sum_{i=0}^{K}\sum_{j=0}^{K} P(i,j)\ln(P(i,j)) \tag{6}$$

$$L_A = L(O) + L(B) \tag{7}$$

In the formulas, $L(A)$, $L(B)$ represent image's total entropy. The optimal threshold of image segmentation should make $L(A)$ the biggest, is

$$V^* = (s,t)^* = \arg\left\{\begin{array}{c}\max(L(A)) \\ 0 \prec s, t \prec K\end{array}\right\} \tag{8}$$