Optik 163 (2018) 81–85

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Short note

New result on maximum entropy threshold image segmentation based on P system

B. Wang[a,b], L.L. Chen[a,*], J. Cheng[c]

[a] School of Electrical and Information Engineering, Xihua University, Chengdu, 610096, PR China
[b] School of Applied Mathematics, University Electronic Science and Technology of China, Chengdu, 610054, PR China
[c] School of Science, Hubei University for Nationalities, Enshi, Hubei, 445000, PR China

ARTICLE INFO

Article history:
Received 22 January 2018
Accepted 20 February 2018

Keywords:
Image segmentation
Maximum entropy
Threshold
Fitness
Optimization

ABSTRACT

In this paper, maximum entropy threshold image segmentation based on P system is studied. A new P system and related interaction rules are designed, and particle swarm optimization (PSO) algorithm with different inertia weights is adopted as the evolution operator of new P system. Some typical experiments are carried out to show the advantage of given algorithm, which finally is successfully applied to the image segmentation of breakdown insulator in power system.

1. Introduction

Image segmentation is an important part of image analysis, and can be used to separate the target from the background and provide technical support for fault identification. Up to now, many algorithms on image segmentation have been presented. Ref. [1] proposed an improved sobel edge detection algorithm to achieve tumor extraction. Ref. [2] proposed a multi-scale local region level set method to complete the segmentation of non-uniform intensity images. Ref. [3] proposed a wavelet analysis method based on the transition region to improve the accuracy of image segmentation. Ref. [4] proposed a semi-supervised clustering method to realize the automatic segmentation of MR images. Ref. [5] proposed an image segmentation method based on improved self-organizing feature mapping. Ref. [6] proposed a multi-layer MET algorithm based on artificial bee colony (ABC) algorithm to realize the multi-threshold image segmentation. However, there still exist large rooms for improvement in speed and accuracy for image segmentation. As a random search algorithm, classic PSO algorithm has rapid propagation in populations, and is very suitable for image segmentation, but is easy to go into the local optimal solution.

Membrane computing, can be called P system, is a type of distributed and parallel computational model that is inspired by the structure and function of cells and organs. It was formally proposed by Păun Gheorghe in 1998 [7] and became a branch of natural calculation. Ref. [8] proposed a PSO algorithm based on membrane computing to solve the 3-order singularity problem. Ref. [9] proposed membrane evolution algorithm to optimize DNA encoding. Ref. [10] proposed a hybrid method based on differential evolution and tissue membrane system to solve the problem of optimization of constrained parameters. However, membrane computing is never combined with PSO to realize maximum entropy threshold image segmentation. All these motive this research.

* Corresponding author.
E-mail address: 3130479005@qq.com (L.L. Chen).

https://doi.org/10.1016/j.ijleo.2018.02.062
0030-4026/

In this paper, a new P system and related interaction rules will be constructed, then PSO algorithm based on the new P system and related interaction rules will be proposed to realize image segmentation of breakdown insulator in power system. Finally experiments will be carried out to show the effectiveness and advantage of given algorithm.

2. Maximum entropy threshold segmentation

Shannon entropy in information theory is used in image segmentation [11,12,16], and the optimal segmentation threshold is determined to obtain the maximum information on the object and background in the image.

2.1. Single threshold segmentation

According to Shannon entropy theory, the image gray level is set as [0 ~ M-1], the entropy of one-dimensional histogram is defined as [13]:

$$H = -\sum_{i=0}^{M-1} p_i \ln p_i$$

where p_i is the probability of a pixel with gray value i.
Let

$$P_t = \sum_{i=0}^{t} p_i$$

$$H_t = -\sum_{i=0}^{t} p_i \ln p_i$$

where t is the threshold.
In the case of a single threshold, the image is divided into background (A) and target (B) by threshold t.
The probability distribution entropies are:

$$H_A(t) = -\sum_{i=0}^{t} \frac{p_i}{P_t} \ln \frac{p_i}{P_t} = \ln p_i + \frac{H_i}{p_i}$$

$$H_B(t) = -\sum_{i=0}^{t-1} \frac{p_i}{1-P_t} \ln \frac{p_i}{1-P_t} = \ln(1-p_t) + \frac{H-H_i}{p_t}$$

where $H_A(t)$ is the probability distribution entropy of background, and $H_B(t)$ is the probability distribution entropy of target.
The total image entropy H(t) of is the sum of $H_A(t)$ and $H_B(t)$ as

$$H(t) = H_o(t) + H_B(t) = \ln p_i(1-p_t) + \frac{H_i}{p_i} + \frac{H-H_i}{p_t}$$

When H(t) takes the maximum value, the target and the background obtain the maximum information entropy, corresponding threshold t is the optimal threshold. The advantage of Single threshold segmentation is algorithm is simple, but the disadvantage is that we can not effectively search the optimal threshold using exhaustive search method in practice.

2.2. Multi-threshold image segmentation

Multi-threshold segmentation can be used for image with multiple objects. The total entropy of image with k thresholds is:

$$H(S_1, S_2, \cdots, S_k) = ln\left(\sum_{i=1}^{S_1} p_i\right) + ln\left(\sum_{i=S_1+1}^{S_2} p_i\right) + \cdots + ln\left(\sum_{i=S_k+1}^{n} p_i\right) - \frac{\sum_{i=1}^{S_1} p_i \ln p_i}{\sum_{i=1}^{S_1} p_i} - \frac{\sum_{i=S_1+1}^{S_2} p_i \ln p_i}{\sum_{i=S_1+1}^{S_2} p_i} - \cdots - \frac{\sum_{i=S_k+1}^{n} p_i \ln p_i}{\sum_{i=S_k+1}^{n} p_i}$$

where $S_1, S_2, \cdots, S_k$ are segmentation thresholds, such that $S_1 < S_2 < \cdots < S_k$.