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Biological lateral inhibition and Electimize approach to template matching

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ABSTRACT

Template matching is an important topic in the field of image processing and it is widely used in image fusion and image registration. In this paper, a hybrid biological method of Electimize and lateral inhibition (LI) is proposed to complete the task of template matching. The proposed biological image processing technique is named LI-Electimize. Electimize is an innovative multi-level evolutionary algorithm that mimics the phenomenon of flow of electrons and the electric current and has been successfully used to solve NP-hard optimization problems, such as cash flow optimization problem. Electimize demonstrates higher capabilities in searching the solution space extensively and identifying global optimal alternatives. Furthermore, lateral inhibition mechanism, which is verified to have good effects on image edge extraction and image enhancement, is employed for image pre-processing. In this work, the proposed biological LI-Electimize incorporates both advantages of Electimize and lateral inhibition which could make better performance. The detailed process of biological LI-Electimize is also given. Series of comparative experimental results of particle swarm optimization (PSO), PSO based on lateral inhibition (LIPSO), Electimize and LI-Electimize demonstrate the better feasibility and effectiveness of the proposed LI-Electimize in solving the template matching problems.

1. Introduction

As an important issue in image processing, template matching, which has a wide application in object detection and object tracking, is a strategy to find the existence of a pattern within a given image [1]. Template matching strategy involves the translation of the template to every possible position in the original image and the evaluation of the match between the template and the source image at the position [2].

The classical template matching method is based on gray cross-correlation measurement by comparing the template with the captured image pixel by pixel. Many template matching algorithms have been developed and can be classified as statistics-based strategy and features-based strategy [3]. The former strategy can be considered as an optimization process of finding the maximum correlation between the original image and the template. The latter makes use of image features such as border, unique points, texture, entropy, and energy. The performance of feature-based strategy largely depends on the quality and stability of selected feature, which varies in different situations. Compared with the feature-based strategy, the statistic-based strategy does not require extensive feature extractions and has strong ability of noise suppression. Moreover, it is easy to program and implement on hardware. Therefore, the statistics-based strategy is widely used in practice of matching complex images [3]. In the matching process, similarity values between the template and all possible positions in the original image have to be computed. Hence, a huge computational cost will be unacceptable in real-time application. Recently, many global optimization algorithms have been applied as searching strategy in the statistics-based template matching, e.g., ant colony optimization (ACO) [4,5], artificial bee colony (ABC) [6,7], PSO [8], biogeography-based optimization (BBO) [9,10], and so on. In this paper, Electimize is introduced to solve the template matching problem.

Electimize is a new multi-level evolutionary algorithm proposed by Mohamed Abdel-Raheem and Ahmed Khalafallah [11–13]. The algorithm is based on simulating the phenomenon of electrical conductivity in which the intensity of the flowing electric current depends on the resistance of the circuit branches. In Electimize, every wire in the multiple circuit represents a feasible solution. The object is to find the best conductor in the solution space. Compared

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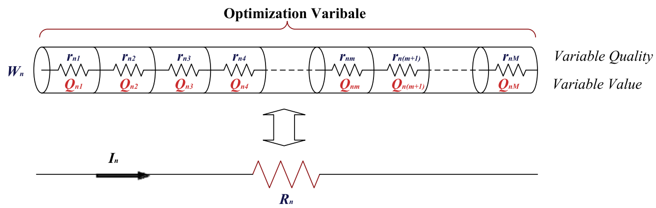

Fig. 1. Variable representation in Electimize

with other evolutionary algorithms, Electimize pays consideration to the performance of the values of variables in the solution string independently instead of merely evaluating each string as a whole. Recently, this algorithm exhibited high efficiency in solving different types of NP-hard static and dynamic optimization problems.

In this paper, lateral inhibition is utilized to pre-process the original image and the template before using Electimize for matching. The hybrid biological method is named Electimize algorithm based on lateral inhibition (LI-Electimize). The lateral inhibition mechanism is firstly discovered and proposed by Hartline and his research team when they carried out an electrophysiology experiment on the limulus' vision. By widespread research, lateral inhibition mechanism, which can increase the accuracy and the stability of template matching, has been certified to be effective in image enhancement and edge extraction [14,15]. The proposed method LI-Electimize, which combines the advantages of both Electimize and lateral inhibition, demonstrates better performance compared to other evolutionary algorithms.

This paper introduces the biological lateral inhibition mechanism and Electimize for solving the problem of template matching. The rest of this paper is organized as follows. Section 2 introduces the basic principle of Electimize. Section 3 describes the mechanism of lateral inhibition, while in Section 4, the detailed implementation procedures of the proposed biological LI-Electimize algorithm for template matching are specified. In Section 5, a series of comparative experimental results are shown to elucidate the feasibility and effectiveness of the proposed method. The final section contains our concluding remarks.

2. The basic principle of Electimize

Electimize is a very recently proposed intelligent optimization method that was inspired by the natural phenomenon of the flow of electrons through electric conductors. This flow induces an electric current with a variable intensity that changes with the resistance of the conductor to the flow of electrons through it [13]. Any change in the conductor's resistance will result in a change in the intensity of the current immediately. The electric current will response quickly according to the change in the conductor's resistance. Unlike current evolutionary algorithms that utilize some hypothetical assumptions to qualify solutions, Electimize utilizes Ohm's law and Kirchhoff's rule to qualify solutions.

In Electimize, every conductor (wire) consists of several segments of different resistances connected in series. The values of all the segments in one circuit branch collectively represent a candidate solution for the optimization problem, as shown in Fig. 1. Electimize identifies the variable quality by calculating the resistance. In each wire, there is a global resistance for the wire as a whole (wire resistance) and a local resistance for each of its segments (values comprising the solution).

In Fig. 1, W_n is the nth wire representing values for the string of variables to optimize; I_n denotes the intensity of current in this conductor, which is equivalent to the value of fitness function; R_n represents resistance of wire, which indicates the global quality of the solution; Q is defined as a variable value in every segment; r_{nm} is the internal resistance of the mth segment in the nth wire, which represents the quality of the segment; n denotes the wire number $(1, 2, \ldots, N)$ in the network; and m denotes the segment number $(1, 2, \ldots, M)$ in every wire.

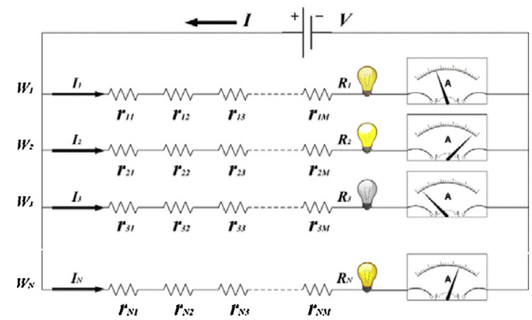

Fig. 2. Solution population represented as an electric circuit

In the resistor network, the wires that represent the individuals of the population of solutions are connected to the source in parallel, as shown in Fig. 2. The current intensity is the evaluation criteria to measure the quality of the solution. Electimize is designed to evaluate the global resistance of each wire and the local resistance of each segment in every wire. Then, the best wires are recognized in each iteration and the chance to be chosen of the most potential value will be increased. The process is iterative until the wire with the best conductivity is created.

3. Lateral inhibition mechanism

The lateral inhibition mechanism was first discovered and confirmed by Hartline and his group when conducting electrophysiology experiments on limulus' vision in 1932 [16]. The results showed that each microphthalmia of limulus' ommateum is regarded as a receptor, which is restricted by its neighboring receptors. The inhibition is reciprocal and spatially summed [3]. And the level of inhibited effect is damping when the distance is increasing.

In retinal images, intensively excited receptors in illuminatingly light area inhibit those in dark area more strongly than the latter to the former [17]. Thus, distortion and contrast of sensory information are enhanced. This mechanism can be applied to image pre-processing. On the basis of classical lateral inhibition model by Hartline, lateral inhibition mechanism was introduced to pre-process both the original image and the template, which stress the spatial resolution and increases the efficiency and accuracy of template matching.

In this work, we choose the following matrix as the lateral inhibition modulus:

$$L = \begin{bmatrix} 0.025 & 0.025 & 0.025 & 0.025 & 0.025 \\ 0.025 & 0.075 & 0.075 & 0.075 & 0.025 \\ 0.025 & 0.075 & 0 & 0.075 & 0.025 \\ 0.025 & 0.075 & 0.075 & 0.075 & 0.025 \\ 0.025 & 0.025 & 0.025 & 0.025 & 0.025 \end{bmatrix} \tag{1}$$

The matrix to process the template and the original image can be described as [18]:

$$Ima = Ima - Ima \otimes L \tag{2}$$

where $\otimes$ denotes the convolution operator and Ima is the gray value of images.

Finally, the image's edge is extracted:

$$I(m, n) = \begin{cases} 255 & \text{if} \quad Ima(m, n) \geq T \\ 0 & \text{if} \quad Ima(m, n) \leq T \end{cases} \tag{3}$$