Symbiotic Organisms Search Optimization for Multilevel Image Thresholding

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Abstract
Determination of optimum thresholds is the prime concern of any multilevel image thresholding technique. The traditional methods for multilevel thresholding are computationally expensive, time-consuming, and also suffer from lack of accuracy and stability. To address this issue, the authors propose a new methodology for multilevel image thresholding based on a recently developed meta-heuristic algorithm, Symbiotic Organisms Search (SOS). The SOS algorithm has been inspired by the symbiotic relationship among the organism in nature. This article has utilized the concept of the symbiotic relationship among the organisms to optimize three objective functions: Otsu’s between class variance and Kapur’s and Tsallis entropy for image segmentation. The performance of the SOS based image segmentation algorithm has been evaluated using a set of benchmark images and has been compared with four recent meta-heuristic algorithms. The algorithms are compared in terms of effectiveness and consistency. The quality of the algorithms has been estimated by some well-defined quality metrics such as peak signal-to-noise ratio (PSNR), structure similarity index (SSIM), and, feature similarity index (FSIM). The experimental results of the algorithms reveal that the balance of intensification and diversification of the SOS algorithm to achieve the global optima is better than others.

Keywords
Entropy, Image Segmentation, Multi-Level Thresholding, Nature Inspired Optimization, Symbiotic Organisms Search

1. Introduction
Image segmentation is a process of separating an image into the meaningful region of the interesting object. Nowadays it has wide application in medical diagnosis, pattern recognition, and remote sensing. This technique used as a pre-processing step of analysis of images, therefore accuracy in segmentation plays a vital role in the decision-taking system. Over the year, various method for thresholding are proposed in the literature, among them Otsu’s between class variance (Otsu, 1979), Kapur’s (Kapur et al., 1985) and Tsallis entropy (Tsai, 1985) method has been widely used as the image segmentation

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technique because of their simplicity and relatively easy to implements. In Otsu’s method, optimum thresholds are calculated by maximizing the between the class variance of the region whereas Kapur’s and Tsallis entropy used moment-preserving principle and entropy of the histogram to find optimum thresholds. The main goal of thresholding-based segmentation is to search optimized thresholds which maximized the objective function.

The classical optimization techniques are generally based on the derivative of the objective function and therefore, they are unable to provide the global optima, specially, in case of non-differentiable objective functions. Meta-heuristic optimization techniques are better in this case and so they have been widely used in various applications in various fields of science and technology (Garg, 2018, 2016) (Reddy et al., 2016), (Reddy et al., 2017), (Gadekallu et al., 2017). During the last few years, many nature-inspired meta-heuristic algorithms and their improved versions are used for image segmentation. Aziz et al. (Aziz et al., 2017) compared the performance of some recent optimization algorithms used for image segmentation. He et al. (He et al., 2017) developed an improved version of the firefly algorithm for segmentation of the color image. Grey wolf algorithm (Kayom, 2017) proposed by Kayom was used to optimize Otsu’s between class variance and Kapur’s entropy for multilevel image segmentation, Yunzhi et al. (Yunzhi et al., 2017) used Bayesian Honey Bee Mating algorithm for image segmentation supported by Bayesian theorem. Elephant Herding Optimization (EHO) (Wang et al., 2016, Tuba et al., 2017), Social Spider Optimization (SSO), Flower Pollination (Ouadfel et al., 2016), Cuckoo Search (CS) (Agrawal et al., 2013), Artificial Bee Colony (ABC) (Zhang et al., 2011; Akay, 2013) are also used for image segmentation. However, most of them have some control parameters which are used to regulate the results. In image segmentation problem, we have to handle the images of different nature (i.e. the different statistical distribution of pixels). Hence, there is a need for tuning the control parameters for each image. Moreover, the convergence rate and segmentation quality are the other criteria of the image segmentation problem.

Recently, a new nature-inspired meta-heuristic optimization algorithm, SOS (Cheng et al., 2014) algorithm has been introduced to search for global optima in solving optimization problems. This algorithm is based on the mathematical formulation of the symbiotic relationship of the organism in the ecosystem. This algorithm has been successfully applied in several complex real-life optimization problems (Eki et al., 2017, Cheng et al., 2016, Tran et al., 2016, Prasad et al., 2016, Dosoglu et al., 2016, Panda et al., 2016, Abdullahi et al., 2016) which proves its exploitation power and the ability to solve the problems. In view of the above, the present work aims to verify the efficiency of the proposed SOS algorithm and compare its performance with other recent meta-heuristic algorithms in multilevel thresholding for image segmentation in terms of solution quality, convergence speed, and time complexity.

The remaining part of the paper is prepared as follows: Section 2 provides the problem formulation and the description of the objective function; The SOS algorithm is discussed in Section 3; Section 4 describes the application procedure of SOS in multilevel thresholding for image segmentation. Experiment setup and analysis of results are discussed in Section 5; and finally, we draw the conclusions in Section 6.

2. FORMULATION OF IMAGE SEGMENTATION PROBLEM

The mathematical formulation of multilevel image segmentation is represented by:

\[
R_{region \_1} \gets P \quad \text{if} \quad 0 \leq P < T_{threshold \_1}
\]

\[
R_{region \_2} \gets P \quad \text{if} \quad T_{threshold \_1} \leq P < T_{threshold \_2}
\]

\[
R_{region \_n} \gets P \quad \text{if} \quad T_{threshold \_n-1} \leq P < T_{threshold \_n}
\]
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E. Parsopoulos Konstantinos and N. Vrahatis Michael (2010). *Particle Swarm Optimization and Intelligence: Advances and Applications* (pp. 88-132).
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