Expert Systems with Applications 41 (2014) 3538–3560

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Cuckoo search algorithm and wind driven optimization based study of satellite image segmentation for multilevel thresholding using Kapur's entropy

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A R T I C L E I N F O

Keywords:
Image segmentation
Multilevel thresholding
Kapur's entropy
Cuckoo search algorithm
Wind driven optimization
Particle swarm optimization
Swarm intelligence

A B S T R A C T

The objective of image segmentation is to extract meaningful objects. A meaningful segmentation selects the proper threshold values to optimize a criterion using entropy. The conventional multilevel thresholding methods are efficient for bi-level thresholding. However, they are computationally expensive when extended to multilevel thresholding since they exhaustively search the optimal thresholds to optimize the objective functions. To overcome this problem, two successful swarm-intelligence-based global optimization algorithms, cuckoo search (CS) algorithm and wind driven optimization (WDO) for multilevel thresholding using Kapur's entropy has been employed. For this purpose, best solution as fitness function is achieved through CS and WDO algorithm using Kapur's entropy for optimal multilevel thresholding. A new approach of CS and WDO algorithm is used for selection of optimal threshold value. This algorithm is used to obtain the best solution or best fitness value from the initial random threshold values, and to evaluate the quality of a solution, correlation function is used. Experimental results have been examined on standard set of satellite images using various numbers of thresholds. The results based on Kapur's entropy reveal that CS, ELR-CS and WDO method can be accurately and efficiently used in multilevel thresholding problem.

1. Introduction

Image segmentation is a critical and challenging task using multilevel thresholding technique. Now a day's multilevel thresholding is a powerful and famous tool, and it is extensively used in the field of image processing. Basically, it is a technique of partitioning the original image into some distinct classes for meaningful information. Segmentation is having major importance and elementary place in image processing for interpretation of any image. Segmentation is in fact the method of subdividing an image into its constituent regions or objects, based on shape, size, color, position or texture of image regions.

There are various methods for image segmentation. Over the years numerous schemes for image segmentation have been exploited and anticipated in the literature. It was found that the thresholding technique is the most popular technique out of all the existing approaches used for segmentation of various types of images (Akay, 2013)

Motivation behind the extensive use of thresholding technique is due to its easy implementation and computationally efficient performance. Basically, thresholding is used to identify and extract a target from its background on the basis of distribution of gray levels or texture in image objects (Liao, Chen, & Chung, 2001). Understanding or analysis of any image requires the image to be accurately segmented into significant regions. Therefore, multilevel thresholding plays a very important role. It is well known that the image segmentation deals with subdividing the image into objects of meaningful information, which is useful in various applications such as satellite image processing, medical imaging, pattern recognition, biomedical imaging, and remote sensing, etc.

If the images are segmented into two regions, such as the background and object of interest or foreground, it is known as bi-level thresholding. To achieve more than two classes, it is extended into multilevel thresholding. Bi-level or multilevel thresholding is a simple and effective technique. However, it requires an optimum threshold value to classify foreground from their background because each objects have their own distinct gray-level distributions (Huang & Wang, 2009). The foremost objective of using bi-level thresholding or multilevel thresholding for image segmentation

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http://dx.doi.org/10.1016/j.eswa.2013.10.059

is to determine a best threshold value. In which, bi-level thresholding selects only one threshold to separate the pixel values into two distinct classes where multilevel thresholding used to perform multiple thresholds through which pixels can be divided into several groups (Horng, 2011). Over the years there are several image thresholding examines in the literature. In favor of multilevel thresholding techniques, various studies have been reported in the literature for segmentation of images to classify the significant patterns of interest (Ghamisi, Couceiro, Benediktsson, & Ferreira, 2012; Ghamisi, Couceiro, Martins, & Benediktsson, 2013; Hammouche, Diaf, & Siarry, 2010; Melo-Pinto et al., 2013; Penga, Zhang, & Zhang, 2013). Many techniques for multilevel thresholding have been developed over the years to recognize the patterns (Dirami, Hammouchea, Diaf, & Siarry, 2013; Manikandan, Ramar, Iruthayarajan, & Srinivasagan, 2014; Xue & Titterington, 2011).

The reason behind using global thresholding is that background and object of interest areas in an image can be interpreted by taking its histogram with probabilities for each gray level. However, in case of remote sensing images or real life images, bi-level thresholding does not give appropriate performance. As a result, there is strong requirement of multilevel thresholding, which splits histogram of the image into the number of classes of homogenous gray levels such that some criterion is optimized (Agrawal, Panda, Bhuyan, & Panigrahi, 2013). Hence, various criteria in literature have been presented to achieve multi-level thresholding.

Over the years, many thresholding techniques have been developed. Otsu (1979) and Liao, Chung, and Chen (2001) technique is used to maximize the sum of between-class variances to get segmented regions in an image. Tsai (1985) has used the moment-preserving principle to select thresholds of input gray-level image called Tsallis entropy technique widely used for image thresholding operation. Kittler and Illingworth (1986) assume that the gray levels of each object in an image are normally distributed. The above nonparametric approaches are simple and effective in bilevel thresholding.

Kapur, Sahoo, and Wong (1985) proposed a method for gray-level picture thresholding using entropy of the histogram. Since, Kapur's criterian is used to maximize the entropy of each distinctive class or the sum of entropies based on information theory. The threshold values are determined in such a way that the gray-level moments of an input image are preserved in the output image. Amongst all the remarkable image thresholding methods, entropy-based approaches have drawn the attentions of many researchers. Superior performance of Kapur's method was recognized by the researchers (Akay, 2013; Hammouche et al., 2010) as compared to other thresholding techniques.

Kapur's entropy measures always lead to positive probabilities and a global maximum for the entropy. The researcher Sezgin and Sankur (2004) have reported that the results using Kapur's entropy gives improved performance, and it produces better average scores than the other entropy-based calculations on nondestructive sample images. Therefore, in this paper, Kapur's entropy is selected as the entropy computation due to its achievability and better performance for segmentation purpose. Now a day's evolutionary computational algorithms are most extensively used due to optimum solution properties for finding the best threshold values, and it has drawn the attention of researchers because of computational inefficiency of the conventional comprehensive techniques (Akay, 2013).

Over the years, in the literature, numerous works on the topic has been presented based on swarm algorithms, including genetic algorithm (GA) (Hammouche, Diaf, & Siarry, 2008; Tao, Tian, & Liu, 2003; Yin, 1999), PSO (Akay, 2013; Maitra & Chatterjee, 2008; Yin, 2007), artificial bee colony (ABC) (Akay, 2013; Cuevas, Sencion, Zaldivar, Perez-Cisneros, & Sossa, 2012; Horng, 2011; Horng & Jiang, 2010; Zhang & Wu, 2011), ant colony optimization (ACO) (Tao, Jin, & Liu, 2007; Ye et al., 2005), bacterial foraging (BF) (Sathya & Kayalvizhi, 2010; Sathya & Kayalvizhi, 2011; Sathya & Kayalvizhi, 2011; Sathya & Kayalvizhi, 2011), and honey bee mating optimization (HBMO) (Horng, 2010). Yin (1999) has presented an efficient and fast scheme using genetic algorithm to obtain optimal threshold values for multilevel thresholding. After that Yin (2007) has proposed a PSO based multilevel minimum cross entropy threshold selection method to achieve near-optimal thresholds. The researchers Zhang and Wu (2011) used ABC algorithm for optimizing the Tsallis entropy. Thereafter, Akay (2013) proposed a study for multilevel thresholding using PSO and ABC algorithm for optimizing the Kapur's entropy. PSO was formulated by Kennedy and Eberhart (1995) and Eberhart and Shi (2001), which is a swarm-based stochastic optimization technique that is based on the social behavior of bird flocking or fish schooling. These techniques successfully give optimum performance using distinct versions of the basic algorithms and different objective functions, such as maximum entropy, Tsallis entropy, between-class variance and Kapur's entropy. In 2009, Yang and Deb (2009) and Yang and Deb (2010) formulated a new metaheuristic algorithm, called cuckoo search algorithm which is based on the interesting breeding behavior such as brood parasitism of certain species of Cuckoos, and the preliminary studies show that it is very promising and could outperform the existing algorithms such as GA, PSO, ABC, ACO, BF and HBMO (Cuevas et al., 2012; Eberhart and Shi, 2001; Hammouche et al., 2008; Horng, 2010; Horng & Jiang, 2010; Kennedy and Eberhart, 1995; Maitra & Chatterjee, 2008; Sathya & Kayalvizhi, 2010; Sathya & Kayalvizhi, 2011; Tao et al., 2007; Ye et al., 2005; Yin, 2007; Zhang & Wu, 2011; Sathya & Kayalvizhi, 2011; Sathya & Kayalvizhi, 2011).

Metaheuristic algorithms are very popular and well-known global optimization schemes. These techniques attempt to reproduce social behavior or natural phenomena. In order to solve different optimization problems, numerous novel metaheuristic algorithms are proposed which is useful in various applications. Such algorithms can increase the computational efficiency, solve larger problems, and implement robust optimization codes. Recently, Gandomi et al. have proposed a metaheuristic approach to solve structural optimization problems using cuckoo search algorithm in combination with Lévy flights (Gandomi, Yang, & Alavi, 2013a). In addition to solve unconstrained and constrained global optimization, a new coupled eagle strategy in combination with the efficient differential evolution has been introduced (Gandomi, Yang, Talatahari, & Deb, 2012). Furthermore, to increase the global search mobility in case of robust global optimization, a novel technique named Firefly algorithm in combination with chaos has been developed (Gandomi, Yang, Talatahari, & Alavi, 2013b). The aim of developing modern metaheuristic algorithms is to expand the carrying out global search ability in terms of three major reasons: solving problems faster, solving large problems, and obtaining robust algorithms (Gandomi et al., 2012, 2013a,b; Panda, Agrawal, & Bhuyan, 2013).

The working nature of CS algorithm is inspired by the life of cuckoo bird in combination with Lévy flight behavior of some birds and fruits flies. On the other hand, ABC algorithm may also be considered as a typical swarm-based approach for optimization, in which the search algorithm is inspired by the foraging behavior of bee colonies (Cuevas, Sención-Echauri, Zaldivar, & Pérez, 2013; Horng, 2013; Kumar, Kumar, Sharma, & Pant, 2013). The studies show that the CS algorithm is remarkably promising and could outperform the other known algorithms, such as WDO. In this paper, CS algorithm is used for finding a global optimal solution using Kapur's entropy. Aim of this paper is to examine the search abilities of CS, ELR-CS and WDO algorithms for segmentation using multi-level thresholding. In addition, study of the fitness functions are gained for better comprehensive comparative investigation of both