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A Review on Applications of Metaheuristic Algorithms in Multilevel Thresholding Image Segmentation

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Abstract: In the field of image analysis, segmentation is one of the most important pre-processing steps. One way to achieve segmentation is the use of threshold selection. In particular, multilevel image thresholding is a very important image processing technique that is used as a basis for image segmentation and further higher level processing. However, the required computational time for exhaustive search grows exponentially with the number of desired thresholds. Metaheuristics Algorithms are well known as successful and efficient optimization methods for intractable problems. With the focus on multilevel thresholding, a significant amount of research was globally carried out to explore the best optimal thresholds for segmenting the different application of images. In this article, a review has been reported on the applications of metaheuristic algorithms in multilevel thresholding of image segmentation problems on various output performance measures.

Keywords: Gray images, Metaheuristics, Segmentation, Thresholding.

I. Introduction

Image segmentation is a low-level image processing task that aims at partitioning an image into well-separated regions such that each one contains pixels with similar properties like gray level, color, texture, etc.[1]. It is one of the most important and difficult image analysis tasks and has attracted many researchers across the globe. In recent years, many researchers have conducted massive research on image segmentation. However, there has been no theory of segmentation so far which is universally applicable. Now image segmentation methods have been widely used in various fields of applications. Nowadays there are several methods and algorithms for image segmentation. Image segmentation methods can be divided into four types: histogram-thresholding-based methods; clustering-based methods; texture analysis-based methods and region based split and merging methods, and thresholding is most widely used method for image segmentation [2]. Thresholding is a very simple form of segmentation and it converts gray level image into binary image. A threshold will be determined and then every pixel in an image is compared with the selected threshold. If the pixel lies above the threshold it will be marked as foreground, and if it lies below the threshold marked as background. Again thresholding techniques can further be divided into two types: optimal thresholding methods and property-based thresholding methods. The optimal thresholding methods search for the optimal thresholds by optimizing an objective function. Generally this objective function for optimization is built around histogram of an image. However the number of optimal thresholds is hard to determine and needs to be specified in advance. Thresholding techniques can be classified into two different types: bi-level and multilevel thresholding. If the objects are clearly distinguished from the background of an image by a single threshold value, it is termed as bi-level thresholding; while dividing an image into several different segments by multiple threshold values is known as multilevel thresholding. Over the years, multilevel thresholding techniques play an important role in image analysis and many scholars and researchers have done a lot of work on it.For efficient image segmentation, a multilevel thresholding is used, where multiple thresholds need be provided in advance. Thus the selection of optimum thresholds has remained a challenge over decades. The optimal thresholds are found by either minimizing or maximizing an objective function with respect to the values of the thresholds. The objective function for optimization is developed using histogram information of an image. The classical thresholding methods include: P-tile method, Maximum entropy method, Otsu's method, Moment-preserving thresholding. The classical segmentation methods often fail to give good result for images whose histograms have multiple peaks. In the case of segmenting several objects from background, thresholding technique needs to be extended to multilevel thresholding. However, large amount of calculation and long computation time

occur when exhaustively searching multilevel thresholds. Alternative to the classical segmentation methods are Swarm algorithms. There are several Swarm algorithms applied for image segmentation. The Swarm algorithms found to be superior than classical optimization algorithms when the function to be optimized is discontinuous, non-differentiable and multimodal.

In recent years, researchers have been attracted to bio-inspired metaheuristics for solving the multilevel thresholding problem. In this context, various thresholding algorithms are proposed, which use different metaheuristics. In this field, genetic algorithm (GA)[3], particle swarm optimization (PSO) [4], differential evolution (DE) [5], artificial bee colony (ABC)[6], firefly algorithm (FA)[7] ; bacterial foraging (BF) algorithm[8]; cuckoo search (CS) algorithm[9] and bat algorithm[10]. These methods give satisfactory performance when used to solve multilevel thresholding problem and use different objective functions. Besides, in the recent years, many researchers have been proposed newly proposed metaheuristic algorithms towards on multilevel thresholding image segmentation problems. The whale optimization algorithm [11] , grey wolf algorithm [12], moth swarm algorithm [13] , animal migration optimization algorithm [14], spider monkey optimization algorithm [15], krill herd optimization [16], electromagnetism optimization [17], gravitational search algorithm [18], flower pollination algorithm [19], teaching–learning based optimization [20], and elephant herding [21] optimization algorithms are implemented successfully to evolve the best optimal thresholds with less computational time. The aim of this review deals with applications of metaheuristic algorithms in multilevel thresholding of the different images for the segmentation of the images.

II. Application of Metaheuristic Algorithms in Multilevel Image Thresholding of Digital Images

The various standard benchmark natural images are tested and evaluated the efficiency of metaheuristic algorithms. Farshi[14] determined multiple threshold values by animal migration optimization algorithm for multilevel thresholding. For evaluating the efficiency of proposed method, various benchmark images are used for carrying out the experiments, and obtained results via animal migration optimization algorithm compared with most popular optimization technique such as Particle Swarm Optimization, Genetic and bacterial foraging algorithm. Experimental results figure out that the proposed method provides better result than the other tested algorithms.. Resma and nair [16]novel multilevel thresholding algorithm using a meta-heuristic Krill Herd Optimization (KHO) algorithm has been proposed for solving the image segmentation problem. The performance of the KHO based multilevel thresholding for image segmentation have been tested with standard images and computed the processing time to determine the optimal thresholding, and results are also compared with the other bio-inspired multilevel thresholding methods. KHO based multilevel thresholding observed to be faster than the existing bio-inspired techniques for image segmentation. The segmentation results of KHO algorithm for multilevel thresholding are promising and hence the proposed method can be effectively used for multilevel image segmentation problem.

Oliva et al.[17] introduced a Multilevel Thresholding (MT) algorithm based on the Electromagnetism-like Algorithm(EMO). The approach combines the good search capabilities of EMO algorithm with objective functions proposed by the popular MT methods of Otsu and Kapur. The algorithm takes random samples from a feasible search space inside the image histogram. The approach generates a multilevel segmentation algorithm which can effectively identify the threshold values of a digital image in a reduced number of iterations. Experimental results show performance evidence of the implementation of EMO for digital image segmentation. Gill et al. [20] proposed an application of the cross entropy based Teaching- Learning-based Optimization (TLBO) for gray-scale digital image segmentation. The optimization problem is used to minimize the cross entropy between the segmented image and the original image. The proposed approach is examined with five different standard digital test images have been segmented through selected threshold values at 2^{nd}, 3^{rd}, 4^{th} and 5^{th} levels by the proposed approach. For evaluating the effectiveness of the proposed algorithm, two measures, namely PSNR, uniformity, are used. From the experimental results on various types of images, it is observed that the proposed method produces the better quality thresholded images than the compared methods. Ouadfel and Ahmed [22] implemented a harmony search (HS) algorithm by maximizing three criteria: Between-class variance, Kapur and Tsallis entropy. The HS algorithm is an evolutionary algorithm inspired from the individual improvisation process of the musicians in order to get a better harmony in jazz music. The proposed algorithm has been tested on a standard set of images from the Berkeley Segmentation Dataset. The results are then compared with that of genetic algorithm (GA), particle swarm optimization (PSO), bacterial foraging optimization (BFO), and artificial bee colony algorithm (ABC). Results have been analyzed both qualitatively and quantitatively using the fitness value and the two popular performance measures: SSIM and FSIM indices. Experimental results have validated the efficiency of the HS algorithm and its robustness against GA, PSO, and BFO algorithms. Comparison with the well-known metaheuristic ABC algorithm indicates the equal performance for all images when the number of thresholds is equal to two, three, four, and five. Furthermore, ABC has shown to be the most stable when the dimension of the problem is too high.

Raja et al. [23] proposed using Brownian distribution (BD) guided firefly algorithm (FA). A bounded search technique is also presented to improve the optimization accuracy with lesser search iterations. Otsu's between class variance function is maximized to obtain optimal threshold level for gray scale images. The performances of the proposed algorithm are demonstrated by considering twelve benchmark images and are compared with the existing FA algorithms such as Levy flight (LF) guided FA and random operator guided FA. Alihodzic and Tuba [24] adopted the bat algorithm, for the multilevel image thresholding problem. The results of testing on standard benchmark images show that the bat algorithm is comparable with other state-of-the-art algorithms. The bat algorithm was proved to be superior to all other tested algorithms considering the quality of the solutions (it actually achieved the best result for both mean value and variance, for all tested cases), especially it significantly improved convergence speed (more than two times better than the next algorithm). This shows that our proposed algorithm is excellent. Kotte et al.[25] presented a new objective approach for multilevel thresholding for image segmentation using novel optimization algorithm improved differential search algorithm(IDSA). Three types of objective approaches are discussed for multilevel thresholding image segmentation using IDSA, in which PSNR based objective approach is successful in achieving the target. From the obtained results it is concluded that PSNR based objective approach is better than Otsu's and Kapur's objective approach. Zhou et al.[26] propose a multi-threshold image segmentation method based on the moth swarm algorithm. The meta-heuristic algorithm uses Kapur's entropy method to optimize the thresholds for eight standard test images. When compared with other state-of-the-art evolutionary algorithms, the proposed method proved to be robust and effective according to numerical experimental results and image segmentation results. This indicates the high performance of the method for the segmentation of digital images.

Li et al.[27] put effort on modified discrete grey wolf optimizer algorithm (MDGWO), which improves on the optimal solution updating mechanism of the search agent by the weights. Taking Kapur's entropy as the optimized function and based on the discreteness of threshold in image segmentation, the paper firstly discretizes the grey wolf optimizer (GWO) and then proposes a new attack strategy by using the weight coefficient to replace the search formula for optimal solution used in the original algorithm. The experimental results show that MDGWO can search out the optimal thresholds efficiently and precisely, which are very close to the result examined by exhaustive searches. In comparison with the electromagnetism optimization (EMO), the differential evolution (DE), the Artifical Bee Colony (ABC), and the classical GWO, it is concluded that MDGWO has advantages over the latter four in terms of image segmentation quality and objective function values and their stability. Shen et al[35] applied modified flower pollination algorithm (MFPA) for multi-level thresholding . Two modifications are proposed to improve the original flower pollination algorithm (FPA). Firstly, a fitness Euclidean-distance ratio strategy is employed to modify the local-pollination of the original flower pollination algorithm (FPA). Secondly, the global-pollination in the original FPA is also biologically modified to improve exploration. Experiments are conducted between seven state-of-the-art metaheuristic algorithms and the proposed one. Both real-life images and remote sensing images are used in the experiments to test the performance of the involved algorithms. The experimental results significantly demonstrate the superiority of our method in terms of the objective function value, image quality measures and convergence performance.

Conclusion

The review paper has successfully presented the use of metaheuristic algorithms in multilevel thresholding image segmentation problems.Based on the above discussion the following conclusions are made from the present work and as follows:

- Extensive research was done in GA, PSO algorithms for solving multilevel thresholding of image segmentation.
- Significant efforts have been devoted to segment the Natural, satellite and medical images.
- In the recent literature, different views of the research work were presented in implementing the newly developed Metaheutrics algorithms and such algorithms outperformed well than the other algorithms commonly GA and PSO on various metrics(SSIM,FSIM, Uniformity measures etc).
- Most of the nature inspired algorithms faces the problem of getting trapped in local optimum points other than converging to its global optima. Random sequences used in its initialization phase and along its run have high impact on this premature convergence.
- According to mathematical theorem of no free lunch theorem it is understood that no algorithms is performed better than others.
- Therefore, the different views of the importance of new algorithms, it is understood that the success of segmented image depends heavily upon the accurate implementation of proposed image segmentation algorithms with many control parameters.

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