



An overview of Cuckoo Optimization Algorithm based Image Processing

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Abstract

The Cuckoo Search (CS) algorithm is an effective swarm intelligence optimization algorithm whose important developments were presented by Yang and Deb in 2009. The CS algorithm has been used in many applications to solve optimization problems. This paper describes an overview of the applications of CS in the scope of image processing to solve optimization problems for the image during the years 2015-2021. The main categories reviewed that used CS in the field of image processing are: image segmentation, image optimization, image noise removal, image classification, feature extraction in images, image clustering and edge detection. The aim of this paper is to provide an overview and summarize the literature review of applying CS algorithm in these categories in order to extract which categories that applied this algorithm more than others. From this review we conclude that CS was mostly applied in the image segmentation category to optimize the threshold search.

Keywords:

Cuckoo Search Algorithm; Swarm Intelligence; Image Processing, Image segmentation.

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1. INTRODUCTION

Swarm intelligence optimization algorithms are beneficial instrument that can be practically utilized in all areas of optimization. One such algorithm is the Cuckoo Search algorithm (CS), which was recently proposed by Yang and Deb in 2009. This algorithm is within the category of bio-inspired algorithms [1][2]. The cuckoo is distinguished by a beautiful sound and aggressive breeding method. Where the cuckoo lays its eggs in the nests of birds or other host species. This process is called forced brood parasitism [3][4]. The principle of the CS algorithm is the determined egg laying and breeding of cuckoos itself. When the host bird detects that the eggs do not belong to it, it does one of two things: It either tosses these strange eggs away or plainly leaves its nest and builds a new nest elsewhere. There are three basic rules to describe CS algorithm [5][6]:

- ❖ every cuckoo lays one egg at a time, and dumps it in a randomly selection nest.
- ❖ The best nests, which have high quality eggs, will be passed on to future generations.
- ❖ The number of ready host nests is determined and the egg laid by a cuckoo may be selected by the host bird with a probability $p_a \in (0, 1)$. When the host bird detects that the eggs do not belong to it, it does one of two things: It either tosses these strange eggs away or plainly leaves its nest and builds a new nest elsewhere.

According to the above three rules, the host bird can either disposal of the egg, or plainly leave off the nest and build a new nest in others place.

Like other swarm intelligent algorithms, the CS algorithm begins with a set population of cuckoos randomly. These initial cuckoos have some eggs to lay in some host birds' nests. The host species abandon the nest or discard the cuckoo's egg when it detects in its nest that the egg does not belong to it. This can be done simply in the algorithm by approximating this last assumption by the fraction p_a of the n nests which are randomly replaced by new ones. Each egg corresponds to appropriate solution and its fitness value is computed. By using the idea of Le'vy flight as given in (1); the cuckoo finds new solution [4][5][6]:

$$x_i(t+1) = x_i(t) + \alpha \oplus \text{Le'vy}(\lambda) \quad (1)$$

Where $x_i(t)$ and $x_i(t+1)$ refer to the position of the current and new nest respectively, $i = 1, 2, \dots, n$; n is the number of bird nests, α is the step size ($\alpha > 0$) which utilized to control the

range of random search. In most of the cases consider that $\alpha=1$, The product \oplus means entry-wise multiplications, λ is Lévy distribution coefficient. The Lévy(λ) supplies a random optimization route for Lévy flight while the random step length is drawn from a Lévy distribution by (2) [4][5][7]:

$$\text{Le'vy}(\lambda) = t^{-\lambda}; 1 < \lambda \leq 3 \quad (2)$$

The relationship between Levy flight random optimization route and the time t obeys the Levy probability distribution which has an infinite mean and variance. Here the sequential jumps or steps of a cuckoo principally form a random walk process that obeys a power-law step-length distribution with a heavy tail. Lévy flight makes the CS more active in exploring the search space because the randomization is more efficient as the step length is heavy-tailed and any large step is possible and therefore will make sure that the system will not be trapped in a local optimum [7][8][9].

The Pseudo-code of Cuckoo Search [10] [11]:

```

Begin
Objective Function  $f(X), X = (x_1, x_2, \dots, x_n)^T$ 
Generate initial population of  $n$  host nests  $X_i (i = 1, 2, \dots, n)$ 
While ( $t < \text{Max Generation}$ ) or (stop criterion)
  Get a cuckoo randomly by Lévy Flights
  Evaluate its quality fitness  $F_i$ 
  Choose a nest among  $n$  (say,  $j$ ) randomly
  If ( $F_i > F_j$ )
    Replace  $j$  by the new solution;
  End If
A fraction ( $p_a$ ) of worse nests is abandoned and new ones are built;
Keep the best solutions (or nest with quality solutions)
Rank the solution and find the current best
End while
  Post process results and visualization
End Begin
    
```

The objective of this paper is to give a brief review of CS with the aim of demonstrating its use to solve optimization problems that arise in the scope of image processing during 2015–2021. This paper includes the introduction of CS algorithm, section2 present the preceding studies of using cuckoo search in the scope of image processing, Section3 present a brief of the main uses CS in the scope of image processing and finally the conclusion in section 4.

2. Preceding Studies of Using CS in the Scope of Image Processing

In this section, the CS application in the scope of image processing is reviewed through previous researches. The main uses of Cuckoo Search in this scope are:

- Image segmentation by optimize threshold search [15] [13][18] [17][19] [25][27][28][29][31].
- Image enhancement [12][16][22].
- Image de-noising [21] [26].
- Image Classification [24][30].
- Image clustering [20][32].
- Feature extraction in image [14].
- Edge detection and optimize the edge [23].

During 2015–2021, there are several literatures regarding

contributions made to the use of the cuckoo algorithm in the scope of image processing for solving optimization problems: Ashour et al. [12] in 2015 proposed algorithm for a medical image enhancement using log transform in an optimization framework based on CS. The proposed algorithm applied to enhance the image dataset of low contrast Computed Tomography (CT). The results show that the CS is better than PSO with respect to the convergence rate and the fitness values based on Mean Square Error (MSE), Structural Content (SC), Maximum Difference (MD), Peak Signal to Noise Ratio (PSNR).

In 2016:

Preetha et al. [13] suggested a color image segmentation algorithm. They selected the seeds utilizing histogram analysis then optimized the threshold using CS. The experimental results show that the optimized threshold using CS gives finer segmentation results than not optimized based on these parameters: Normalized Probabilistic Rand Index (NPR), Global Consistency Error (GCE) and Variation of Information (VOI).

Sudha and Selvarajan[14] suggested methods based on Enhanced Cuckoo Search (ECS) with k-Nearest Neighbor (K-NN) Classifier to find the optimal features from mammogram images of breast tumors. A bunch of features have been extracted (texture, intensity histogram, radial distance and shape) using suggested method. For accuracy they used some distance measures such as Euclidean distance, City block distance, Minkowski distance and chi-Square Distance. Experimental results show that the performance of suggested method ECS with K-NN better in accuracy (using Euclidean distance) with the minimum number of features than others methods: CS, Harmony Search (HS), ECS with minimum distance classifier and CS, HS with K-NN.

Suresh and Lal [15] suggested a method named $CS_{McCulloch}$ for image segmentation which was founded on CS. In addition, they scrutinized the effect of combination of Mantegna method with CS algorithm ($CS_{McCulloch}$). Each of these algorithms were used to maximize three fitness functions: Otsu’s between class variance, Kapur’s entropy and Tsallis entropy. Experimental results proved that the $CS_{McCulloch}$ algorithm with all three fitness functions improved the result of segmentation quality with computation time and exceeds these algorithms PSO, Darwinian Particle Swarm Optimization (DPSO), Artificial Bee Colony (ABC), CS and $CS_{McCulloch}$ by measuring PSNR, MSE, FSIM and CPU running time.

In 2017:

Janga and Sharma [16] proposed method based on Adaptive Histogram Equalization (AHE) - Redundant Wavelet Transform (RWT) with SVD and Particle Swarm Optimization – CS (PSO-CS) algorithm to enhance the quality of the low brightness satellite images to get better visualization. Firstly, they used AHE for enhancing the entire image and analyzing it into four sub band by RWT. To Optimize each band of RWT by using CS algorithm and LL threshold sub band of the image is gained by using singular value decomposition (SVD). At the end used Inverse

Redundant Wavelet Transform (IRWT) to reconstruct enhanced the image. The proposed method proved strong when applied on the numerous low quality satellite pictures.

Vennila and Venkatesan [17] suggested method that use Cuckoo search algorithm which propped with Tsallis entropy and Granular computing to enhance the segmentation of the color satellite images powerfully. The use of the cuckoo algorithm made optimum values for the threshold which in turn reduced the execution time and computational cost.

Naidu and Kumar [18] proposed an Adaptive Cuckoo Search algorithm (ACS) to optimize multilevel threshold for image segmentation by maximizing the Shannon and Fuzzy entropy. By using natural and standard images, the result shows that the ACS algorithm achievement is surpasses the firefly algorithm (FA) and cuckoo search (CS) with higher value of Structural Similarity Index (SSIM).

In 2018:

Wang et al. [19] proposed CS with FCM (Fuzzy C-means) method to segment grey images. The experimental results show CS-FCM is better than FCM, GA-FCM, PSO-FCM based on fitness value and CPU time.

Dhal et al. [20] improved CS algorithm based image clustering method for the suitable segmentation of breast histopathology images. The results offer that CS supply better-quality segmented images compare to traditional cluster K-means algorithm in terms of accounting for PSNR, computational time, fitness values and the values of quality parameters.

Ramya et al. [21] proposed methodology that used Adaptive Switching Weighted Median (ASWM) Filter cascaded with CS algorithm to reduce the mean absolute error of mammogram breast image which is highly corrupted by impulse noise density. The experimental result gives the noticeable result with high impulse noise density up to 90% and the visible result offer the improvement in the inner part of the edges and preserve the structural features sharpen.

Narang et al. [22] suggested a new technique which use cuckoo optimization algorithm with fuzzy logic technique to enhance the quality of image. Firstly, transformed the image from domain of RGB to HSV with conservation the color information whole within the image. Based on two threshold values, the image has been classified into three areas: 1. underexposed area, 2. overexposed area, 3. mixed area. To fuzzifier each area, the degree of membership is determined. For underexposed and overexposed area are fuzzified using Gaussian membership whilst mixed area is determined by sigmoid membership. Visual factors and fuzzy contrast are parameters that supply the quantitative analysis of an image. Using cuckoo optimization algorithm to optimize the objective function which is consisted of entropy and visual factor. The results of images enhancement using cuckoo optimization algorithm is more satisfactory with less execution time when compared with Bacterial Foraging algorithm (BFO) and Ant Colony Optimization (ACO).

Barjoei et al. [23] proposed model based on cuckoo algorithm and medical engineering optimization methods to edge detection and reduce noise in order to diagnosis the

heart disease. This model performed well.

In 2019:

Janarthanan et al. [24] proposed system which is combined Neural network (NN) with cuckoo Optimization Algorithm (COA) to classify remote sensing images. Used NN to train these images which is from the Indian Pines dataset. joint COA with NN, assist the mission of classification and to compute the cost function. Integration of the cuckoo algorithm with networks helped in the mission of classification and to compute the cost function. The results shown that the achievement and error rate of the proposed system is better than other classical techniques. Also, the results shown the power of the COA for optimum the cost function with least computational time compared to other technologies. In addition, COA is robust for its ability to resolve the image regions that unclassified with finer performance than classical methods.

Aslam et al. [25] proposed method depending on adaptive thresholding with COA to resolve the problem of disclosure and assessment of surface defects on metal coating surfaces. The result displays that the proposed method is superb when compared with adaptive thresholding with PSO, median based *otsu* and *otsu's* method in terms of sensitivity, accuracy and precision measures.

Thakare and Kale [26] proposed a new method based on the algorithm of the Cuckoo Optimization Algorithm (COA) to remove noise from the scanned document image. The experimental result show that the new method COA surpass others traditional methods (wiener and anisotropic filters) with minimum MSE and maximum PSNR, SSIM values.

In 2020:

Qi et al. [27] utilized the cuckoo algorithm to optimize the classical maximum class variance method to obtain optimal segmentation by optimize threshold search.

Santhos et al. [28] used three algorithms: HS, Electromagnetism Optimization (EMO) and McCulloch's Algorithm inspired Cuckoo Search Optimization algorithm (MACSO) with two fitness functions Otsu and Kapur to segment mammogram image. The result shows MACSO with Otsu outperforms of others methods using measures such as: best fitness, MSE, PSNR, SSIM and TIME.

In 2021:

Duan et al. [29] proposed a new method called (ICS) improved cuckoo search algorithm to search for the optimal multilevel thresholding. The result displays that the proposed method is superb when compared with seven heuristic algorithms using many measures such as objective function value, standard deviation, PSNR, FSIM, and SSIM, Wilcoxon rank sum convergence performance.

Shivakanth and Tanwar [30] used CS to classify the remote sensing image processing. The result of computation using CS is preferable than PSO and GA. Rahaman and Sing [31] used adaptive cuckoo search (ACS) algorithm to optimize threshold value to segment a satellite image. The result of ACS is better than $CS_{McCulloch}$ algorithm based several measurements such as PSNR, MSE, FSIM, SSIM, UIQI, and CPU time.

KHRISSI et al. [32] proposed method which used CSA with FCM. The CSA used to explore optimal centers of clusters then apply FCM on many images selected BSD300 database. The result shows that the performance of proposed method is better than FCM, FCM-GA and FCM-PSO based on these measures: best values of fitness, MSE, PSNR, Correlation Coefficient (CC), RI (Rand Index), Global Coherence Error (GCE), Boundary Displacement Error (BDE) and Information of Variation (VOI).

Scope of Image Processing

This section offers about the main uses of CS in the scope of image processing based on the reviewed through previous researches. Figure 1, shows the result of the reviewed through previous researches. It shows the several and main uses of CS algorithm in the scope of image processing to solve different optimization problems. It is obvious from the Figure 1, that the brief of the main uses of CS in the scope of image processing were Image segmentation by optimize threshold search followed Image enhancement, Image de-noising, Image Classification, Feature extraction, Image clustering and Edge detection.

3. A Brief of the Main Uses CS in the

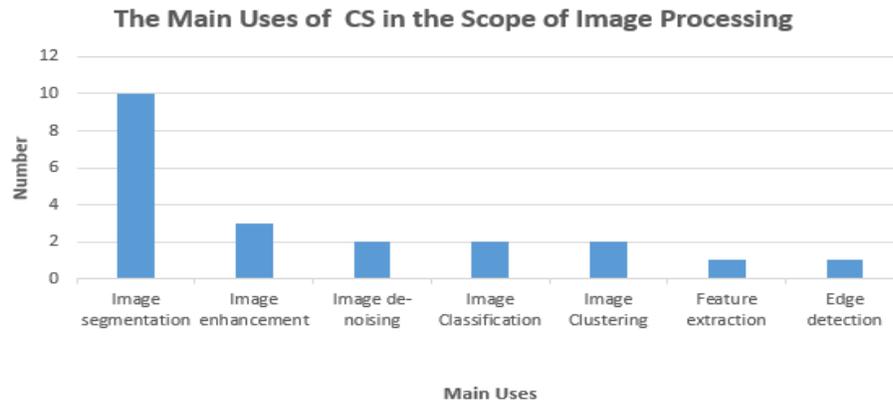


Fig. 1. The Main Uses of Cuckoo Search in the Scope of Image Processing

Table (1) gives the summarize of the literature review of applying CS algorithm in the main categories in the scope

of image processing. As well as the evaluation parameters which are used to compare with other methods:

Table (1): Summarize of applying CS algorithm in the scope of image processing.

Category	Research	Year	The best proposed algorithm	Compared with others algorithms	performance evaluation parameters
Image segmentation by optimize threshold search	[15]	2016	CS _{McCulloch}	PSO, DPSO, ABC, CS, CS _{McCulloch}	PSNR, MSE, FSIM, CPU running time
	[13]	2016	CS	without CS	NPR, GCE and VOI
	[18]	2017	ACS	FA, CS	SSIM
	[17]	2017	Tsallis entropy and Granular computing methods with CS algorithm	Tsallis entropy and Granular computing methods	execution time, computational cost
	[19]	2018	CS-FCM	FCM, GA-FCM, PSO-FCM	fitness value and CPU time
	[25]	2019	Adaptive thresholding with COA	Adaptive thresholding with PSO, Median based Otsu, Otsu's Method	Sensitivity, accuracy, precision
	[27]	2020	Maximum inter-class variance method with CS	Original solution	Fitness value, target value
	[28]	2020	MACSO with fitness functions Otsur	MACSO with fitness functions Kapur HS, EMO with two fitness functions Otsu and Kapur	best fitness, MSE, PSNR, SSIM and TIME.
	[29]	2021	ICS	Several heuristic algorithms	objective function value, standard deviation, PSNR, FSIM, and SSIM, Wilcoxon rank sum convergence performance

	[31]	2021	adaptive cuckoo search (ACS) algorithm	CS _{McCulloch} algorithm	PSNR, MSE, FSIM, SSIM, UIQI, and CPU time
<i>Image enhancement</i>	[12]	2015	CS	PSO	MSE, SC, MD, PSNR, execution time
	[16]	2017	PSO-CS	PSO	execution time
	[22]	2018	CS	BFO, ACO	execution time
<i>Image de-noising</i>	[21]	2018	ASWM with CS	ASWM	Mean Absolute Error (MAE), PSNR
	[26]	2019	COA	wiener filter, anisotropic filter	MSE, PSNR and SSIM
<i>Image Classification</i>	[24]	2019	NN with COA	NN	execution time, computational cost
	[30]	2021	CS	PSO, GA	execution time, computational cost
<i>Image clustering</i>	[20]	2018	CS	K-means algorithm	PSNR, computational time, fitness values, values of quality parameters.
	[32]	2021	CSA with FCM	FCM, FCM-GA, FCM-PSO	MSE, PSNR, CC, RI, GCE, BDE and VOI
<i>Feature extraction</i>	[14]	2016	ECS with K-NN	CS, HS	Euclidean distance, City block distance, Minkowski distance and chi-Square Distance.
<i>Edge detection</i>	[23]	2018	edge detection using CS	canny edge detection algorithm	quick diagnosis before surgery

4. Conclusion

This paper gives a brief literature review of applying CS in the main categories in the scope of image processing to solve optimization problems during 2015–2021. The aim of this paper is to summarize the overview of applying CS in these categories that review.

Through the several studies reviewed in these categories, it is concluded that the Variants CS mostly applied in the image segmentation area by optimize threshold search followed image enhancement then image de-noising, image classification and image clustering as the same level. And finally, the lowest level to apply CS algorithm in two categories: feature extraction and edge detection.

It also concluded that the CS algorithm is superior in accuracy when compared to several algorithms based on all performance evaluations. This is because CS uses Lévy flights to explore the global search space in order to obtain optimal values.

In precis, from the preceding studies CS is very efficacious in all the experiment optimization problems.

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نظرة عامة على خوارزمية تحسين الوقواق اعتمادا على

معالجة الصور

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الخلاصة:

تعد خوارزمية بحث الوقواق احد خوارزميات تحسين ذكاء السرب الفعالة والتي تم عرض تطوراتها المهمة بواسطة Yang and Deb في عام 2009. تم استخدام خوارزمية CS في العديد من التطبيقات لحل مشكلات التحسين. تصف هذه الورقة نظرة عامة على تطبيقات CS في نطاق معالجة الصور لحل مشاكل التحسين للصور خلال الأعوام 2015-2021. ان الفئات الرئيسية التي تمت مراجعتها والتي استخدمت CS في مجال معالجة الصور هي: تجزئة الصور، تحسين الصور ، إزالة ضوضاء الصور، تصنيف الصور، استخراج الميزات في الصور، تجميع الصور واكتشاف الحواف. ان الهدف من هذه الورقة هو تقديم نظرة عامة وتلخيص المراجعة الأدبية لتطبيق خوارزمية CS في هذه الفئات من أجل استخراج اي الفئات طبقت هذه الخوارزمية أكثر من غيرها. من هذه المراجعة نستنتج ان CS تم تطبيقه في الغالب في فئة تجزئة الصور لتحسين البحث عن العتبة.

الكلمات المفتاحية: خوارزمية بحث الوقواق، ذكاء السرب، معالجة الصور، تجزئة الصور.

