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Enhanced Cuckoo Intelligence Search Algorithm

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Abstract

Cuckoo Search (CS) algorithm is a meta-heuristic technique that displays several merits. For example, it is easier to apply and less tuning parameters also, it is suitable for solving optimization problems. However, easily fall into local optimum has been established and has a slow convergence rate as a result of the cuckoo search parameters being kept constant. Therefore to handle this issue, an Enhanced Cuckoo Intelligence Search (ECIS) algorithm was developed which is an upgraded CS algorithm. The efficiency of ECIS was tested by some benchmark constrained optimization test functions and it was shown that ECIS gives a better optimal value than CS.

Keywords: Cuckoo search algorithm, enhanced cuckoo intelligence search algorithm and levy flight.

1. INTRODUCTION

CS is built on the life of a bird named ‘cuckoo’ [1]. The rudimentary of this unique optimization technique is the laying of egg and breeding of this bird. In this modeling we use the egg of adult cuckoos and the cuckoos. The adult cuckoos eggs are being laid in other birds territory. Then the development of the egg occur and the become a mature cuckoo if they are not detected and detached by the owner of the nest(host birds). The migration of collections of cuckoos and environmental conditions expectantly lead them to congregate and reach the optimum place for breeding and reproduction.

CS was designed by Yang and Deb [1]. The CS algorithm was stirred by the parasitic reproductive behavior of some cuckoo class by egg laying their host nest. This decreases the likelihood of the eggs being ignored so re-productivity rises. It is significant to indicate that several host birds involve in direct conflict with interfering cuckoos. In general, hatching of cuckoo egg is a bit earlier than that of their host. When the first egg of the cuckoo is hatched which brings the first cuckoo chick, his first disposition action is to eject the egg of its host by sightlessly forcing the eggs of the host outside the nest. This deed leads to growing the cuckoo chick's share of food that the host bird provide. The breeding conduct of cuckoo can be well implemented in several optimization problems. Lévy Flights tool is used instead of ordinary random walk to improve the efficiency [2].

[3], proposed a modified cuckoo search algorithm by introducing random inertia weight C algorithm parameter in order to improve the peed of convergence and accuracy of the CS algorithm. [4], proposed a multimodal CS algorithm which is a modification of the standard CS algorithm. This was done by introducing the memory mechanism, new selection strategy and depuration procedure. Other works on modified cuckoo search and some other metaheuritic algorithms can be found in [5],[6],[7],[8],[9].

To the best of our knowledge, we have identified that no work has been done on cuckoo search by updating the cuckoo search parameter (p_a, ϕ and α) at each iteration. We therefore complement and extend previous works by considering p_{ai}, ϕ_i and α_i which is the value of p_a of the iteration, value of ϕ of the current iteration and value of α of the current iteration respectively. The aim of this work is to reduce the possibility of the CS algorithm being trapped by local optimal solution by modifying the fixed cuckoo search algorithm parameters. The motivation behind this work is the premature convergence of CS algorithm.

The rest of the paper is arranged as follows: Chapter two deals with experiment and discussion, chapter three deals with computational consideration, chapter four deals with discussion on numerical results and chapter five deals with the conclusion.

2. EXPERIMENT AND DISCUSSION

The parameter switching(p_a) and step size(α) used in CS help the technique to generate an improved solution.

These parameters are major in fine-tuning of solution and are used in the modification of speed of convergence of the algorithm.

2.1 Pseudo code of CS Algorithm

Data: Objective function $f(x)$

Result: Best or optimal solution

Step 1: Initialization of parameters (n, p_a, ϕ and α)

Step 2: Generate initial population of n host nest x_i

Step 3: While (t<MaximumGeneration) or (stop criterion) do $t = t + 1$

Step 4: Randomly get a cuckoo search

Step 5: Generate solution by Levy flights

Step 6: Evaluate its objective f_i

Step 7: Choose randomly a nest among n(say, j)

Step 8: If ($f_i > f_j$) then replace j by the new solution i

Step 9: End

Step 10: A fraction (p_a) of worse nests are abandoned

Step 11: Now nests/solution are generated

Step 12: Keep best solution(or nests with quality solutions)

Step 13: Rank the solutions and find the current best solution

Step 14: Go to step 3

Step 15: End.

2.2 Parameter CS Algorithm

The below are the parameters used in the above Cuckoo Search(CS) Algorithm
Levy flight:

$$L(s, \phi) = \frac{\phi \Gamma(\phi) sin(\pi\phi/2)}{\pi s^1 + \phi}, \qquad 0 \leq \phi \leq 2 \tag{1}$$

ϕ is always chosen to be 1.5
Step size:

$$\alpha = 0.01(x_i - x_{best})s \tag{2}$$

where

$$s = \frac{u}{|v|^{1/beta}}, \qquad u = (0, \sigma^2), v = (0, 1) \tag{3}$$

where u and v are random number drawn from normal distribution

$$\sigma = [\frac{\Gamma(1+\phi) sin(\pi\phi/2)}{\phi\Gamma[(1+\phi)/2]2^{(\phi-1)/2}}]^{1/\phi} \tag{4}$$

where Γ is the standard gamma function. In practice its easier to choose $\sigma = 0.01$ update of nest(global search):

$$x_i^{t+1} = x_i^t + \alpha * L(s, \phi) \tag{5}$$

update of nest(local search):

$$x_i^{t+1} = x_i^t + \alpha s * H(p_a - \epsilon)(x_j^t - x_k^t) \tag{6}$$

where $*$ is an entry-wise multiplication and x_j^t and x_k^t denotes two different solutions randomly selected by random permutation.
$H(u)$ is a heaviside function define as a unit step discontinuous function in which its value is zero and one for non negative number selected from a uniform distribution.

2.3 Enhanced Cuckoo Intelligence Search (ECIS) Algorithm

The parameter p_a, ϕ and α introduce in the CS algorithm enhance the global and local solution of the algorithm. The parameters are significant in fine-tuning of solution vectors, and in adjusting the rate of convergence of the algorithm, it can be potentially used.

For p_a, ϕ and α fixed value are used in CS algorithm. These values are set at the initial step of the algorithm and cannot be changed during new generations. This main weakness of this techniques appears in the number of iteration to find an optimum.

In this paper a new method is proposed, this method is an enhanced CS called enhanced Cuckoo Intelligence Search (ECIS) Algorithm which implement calculating or generating a new value of p_a, ϕ and α at each iteration or at every generation.

In this algorithm we introduce and implement the following:
We replace p_a, ϕ and α by p_{ai}, ϕ_i and α_i respectively in the cuckoo search algorithm, where

$$p_{a_i} = p_{a_{max}} - \frac{i}{it_{max}}(p_{a_{max}} - p_{a_{min}}) \tag{7}$$

$$\phi_i = \phi_{max} - \frac{iter}{it_{max}}(\phi_{max} - \phi_{min}) \tag{8}$$

$$\alpha_i = \alpha_{max} - \frac{1}{it_{min}} ln(\frac{\alpha_{min}}{\alpha_{max}}) \tag{9}$$

Tab 1:Parameter of Enhanced Cuckoo Intelligence Search (ECIS) Algorithm and meaning

Parameter	Meaning
$iter$	number of current iteration
it_{max}	maximum number of iteration
p_{a_i}	value of p_a of current iteration
$p_{a_{min}}$	minimum value of p_a
$p_{a_{max}}$	maximum value of p_a
ϕ_i	value of ϕ of current iteration
ϕ_{min}	minimum value of ϕ
ϕ_{max}	maximum value of ϕ
α_i	value of α of current iteration
α_{min}	minimum value of α
α_{max}	maximum value of α

Various test show that suitable algorithm parameter leading to good result can approximately be values in table 2.2

Tab 2:Value for Parameter of enhanced Cuckoo Intelligence Search (ECIS) Algorithm

Parameter	Value
$p_{a_{min}}$	0.005
$p_{a_{max}}$	1.0
ϕ_{min}	2.0
ϕ_{max}	1.0
α_{min}	0.5
α_{max}	0.05

2.4 Pseudo Code of Enhanced Cuckoo Intelligence Search (ECIS) Algorithm

Data: Objective function $f(x)$

Result: Best or optimal solution

Step 1: Initialization of parameters $(n, p_{a_{max}}, p_{a_{min}}, \phi_{max}, \phi_{min}, \alpha_{max}, \alpha_{min})$

Step 2: Generate initial population of n host nest x_i

Step 3: While (t<MaximumGeneration) or (stop criterion) do

$t = t + 1$

Step 4: Calculate $p_{a_{iter}}, \phi_{iter}, \alpha_{iter}$
Step 5: Get a cuckoo randomly
Step 6: Generate solution by Levy flights
Step 7: Calculate its solution quality or objective f_i
Step 8: Select a nest among n(say, j) randomly
Step 9: If $(f_i > f_j)$ then replace j by the new solution i
Step 10: End
Step 11: A fraction (p_a) of worse nests are abandoned
Step 12: New nests/solution are built/generated
Step 13: Keep best solution(or nests with quality solutions)
Step 14: Rank the solutions and find the current best solution
Step 15: Go to step 3
Step 16: End.

3. COMPUTATIONAL CONSIDERATION

The numerical results are presented in table 4.1 and it was obtained from the solution of some test problems presented in this section using MATLAB R2010a (7.10.499) run on the PC Intel(R) samsung, a 32 bit Os Laptop windows 7 operating system.
The following conventional benchmark problems from [10], were used to test the performance of the new (ECIS) algorithm:

$F1$=$5h_1 + 5h_2 + 5h_3 + 5h_4 - \sum_{c=1}^{4} - \sum_{c=5}^{4} h_c^{13} h_c$
subject to
$q(1) = 2h(1) + 2h(2) + h(10) + h(1) \leq 10$
$q(2) = 2h(1) + 2h(3) + h(10) + h(12) \leq 10$
$q(3) = 2h(2) + 2h(3) + h(11) + h(12) \leq 10$
$q(4) = -8h(1) + h(10)$
$q(5) = -8h(2) + h(11)$
$q(6) = -8h(3) + h(12)$
$q(7) = -2h(4) - h(5) + h(10)$
$q(8) = -2h(6) - (7) + h(11)$
$q(9) = -2h(8) - h(9) + h(12)$

$h(c) = [0, 1], \quad c = 1, .., 9$
$h(c) = [0, 100], \quad c = 10, 11, 12$
$h(13) = [0, 1]$

$F2$= $5.35785472h(3)^2 + 0.8356891h(1)h(5) + 37.293239h(1) - 40792.141$

subject to
$q(1) = 0 \leq 85.334407{+}0.0056858h(1)h(4){+}0.0006262h(1)h(4){-}0.0022053h(3)h(5) \leq 92$

$q(2) = 90 \leq 80.51249 + 0.0071317h(2)h(5) + 0.0029955h(1)h(2) + 0.0021813h^2(3) \leq 110$

$q(3) = 20 \leq 9.300961{+}0.0047026h(3)h(5){+}0.0012547h(1)h(3){+}0.0019085h(3)h(4) \leq 25$

$h(1) = [78, 102]$
$h(2) = [33, 45]$
$h(c) = [13, 100] \quad c = 3, 4, 5$

$F3$=$3h(1) + 0.000001h(1)^3 + 2h(2) + 0.000002/(3h(2)^3)$;
subject to
$q(1) = h(4) - h(3) + 0.550$
$q(2) = h(3) - h(4) + 0.550$
$q(3) = 1000scn(-h(3) - 0.25) + 1000scn(-h(4) - 0.25) + 894.8 - h(1)$
$q(4) = 1000scn(h(3) - 0.25) + 1000scn(h(3) - h(4) - 0.25) + 894.8 - h(2)$
$q(5) = 1000scn(h(4) - 0.25) + 1000scn(h(4) - h(3) - 0.25) + 1294.8$

$h(c) = [0, 1200] \quad c = 1, 2$
$h(c) = [-0.55, 0.55] \quad c = 3, 4$

$F4$=$(h(1) - 10)^3 + (h(2) - (20))^3$
subject to
$q(1) = (h(1) - 5)^2 + (h(2) - 5)^2 - 100 \leq 0$
$q(2) = -(h(1) - 6)^2 - (h(2) - 5)^2 + 82.81 \leq 0$

$h(1) = [13, 100]$
$h(2) = [0, 100]$

$F5$=$h(1)^2 + h(2)^2 + h(1)h(2) - 14 * h(1) - 16h(2) + (h(3) - 10)^2 + 4(h(4) - 5) + (h(5) - 3)^2 + 2(h(6) - 1)^2 + 5h(7)^2 + 7(h(8) - 11)^2 + 2(h(9) - 10)^2 + (h(10) - 7)^2 + 45$
subject to
$q(1) = 105 - 4h(1) - 5h(2) + 3h(7) - 9h(8) \geq 0$

$q(2) = -3(h(1)-2)^2 - 4(h(2)-3)^2 - 2h(3)^2 + 7h(4) + 120 \geq 0$
$q(3) = -10h(1) + 8h(2) + 17h(7) - 2h(8) \leq 0$
$q(4) = -h(1)^1 - 2(h(2)-2)^2 + 2h(1)h(2) - 14h(5) + 6h(6) \geq 0$
$q(5) = 8h(1) - 2h(2) - 5h(9) + 2h(10) + 12 \geq 0$
$q(6) = -5h(1)^2 - 8h(2) - (h(3)-6)^2 + 2h(4) + 40 \geq 0$
$q(7) = 3h(1) - 6h(2) - 12(h(9)-8)^2 + 7h(10) \geq 0$
$q(8) = -0.5(h(1)-8)^2 - 2(h(2)-4)^2 - 3h(5)^2 + h(6) + 30 \geq 0$

$h(c) = [-10, 10] \quad c = 1, .., 10$

$F6$=$scn(2h(1))^3(2h(2))/(h(1)(h(1)-h(2)))$
subject to
$q(1) = h(1) + h(2) + 1 \leq$
$q(2) = 1 - h(1) + (h(2)-4)^2 \leq 0$

$h(1) = [0, 10]$
$h(2) = [0, 10]$

$F7$=$(h(1)-10)^2 + 5(h(2)-12)^2 + h(3)^4 + 3(h(4)-11)^2 + 10h(5)^6 + 7h(6)^2 + h(7)^4 - 4h(6)h(7) - 10h(6) - 8h(7)$
subject to
$q(1) = 127 - 2h(1)^2 - 3h(2)^4 - h(3) - 4h(4)^2 - 5h(5) \geq 0$
$q(2) = 282 - 7h(1) - 3h(2) - 10h(3)^2 - h(4) + h(5) \geq 0$
$q(3) = 196 - 23h(1) - h(2)^2 + 6h(6)^2 + 8h(7) \geq 0$
$q(4) = -4h(1)^2 - h(2)^2 - 2h(3)^2 - 5h(6) + 11h(7) \geq 0$

$h(c) = [-10, 10] \quad c = 1, .., 7$

$F8$=$h(1) + h(2) + h(3)$
subject to
$q(1) = 1 - 0.0025(h(4) + h(6)) \geq 0$
$q(2) = 1 - 0.0025(h(7) + h(7) - h(4)) \geq 0$
$q(3) = 1 - 0.01(h(8) + h(5)) \geq 0$
$q(4) = h(1)h(6) - 833.33252h(4) - 100h(1) + 83333.333 \geq 0$
$q(5) = h(2)h(7) - 120h(5) - h(2)h(4) + 1250h(4) \geq 0$
$q(6) = h(3)h(8) - 125000 - h(3)h(5) + 2500h(5) \geq 0$

$h(1) = [100, 10000]$
$h(c) = [1000, 10000] \quad c = 2, 3$
$h(c) = [10, 1000] \quad c = 4, .., 8$

$F9$=$h(1)^2 + (h(1) - 1)^2$
subject to
$q(1)$=$h(2) - h(1)^2$

$h(c) = [-1, 1] \quad c = 1, 2$

3.1 Computational Results

The computational result is given in table Tab 3

Tab 3: Result obtained with CS and ECIS

No	CS	ECIS
F1	-46.00000	-46.000008
F2	-40792.14100	-49744.1214
F3	300.47455	210.11130
F4	-7973.0000	-8881.24000
F5	-84.00000	-92.94429
F6	-inf	-inf
F7	6.90268	2.14460
F8	4434.86940	4221.91242
F9	1.98010	5.00000

4. DISCUSSION ON NUMERICAL RESULTS

From the result tabulated in table 3.1, it can be seen that ECIS proposed in this paper performs better than CS in terms of value of the objective function in seven test functions out of nine test functions in table 3.1 .

5. CONCLUSION

To improve the performance of CS algorithm, an enhanced CS algorithm ECIS algorithm based on calculating the CS parameters at each iteration is introduced in this paper. In conclusion, **the ECIS algorithm outperforms standard CS algorithms in term of reaching optimum solution, speed and robustness.** Therefore ECIS algorithm is recommended for solving optimization problems.

Conflit of Interest
The authors declare no conflict of interest

Data Avaliability
Not applicable

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