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Mutated Butterfly Optimization Algorithm

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Abstract**: *Butterfly optimization algorithm is a nature inspired metaheuristic algorithm which adapts food foraging behavior of butterflies. Butterfly optimization algorithm was introduced to solve benchmark functions and engineering design optimization problems. Mutated butterfly optimization algorithm, a new variant of butterfly optimization algorithm is proposed in this work for solving global optimization problems. It is an approach which combines butterfly optimization algorithm with Cauchy mutation to achieve global optimal solution by avoiding entrapment in local optima. The validation of proposed algorithm is carried out on low dimensional and high dimensional test functions. The experimental results are compared with basic butterfly optimization algorithm and other variants of it reported in the literature. The Wilcoxon signed rank test is also performed to identify the significance of proposed algorithm with other methods. The proposed method has achieved better results than basic butterfly optimization algorithm and its variants on various test functions.***

Index Terms**: *Butterfly Optimization Algorithm, Nature Inspired Metaheuristic Algorithm, Mutated Butterfly Optimization Algorithm, Cauchy Mutation, Wilcoxon Signed Rank Test***

I. INTRODUCTION

Butterflies are the most beautiful insects in nature. The primary food source of butterflies is nectar from flowers. Butterflies emit fragrance which makes them follow each other to find out nectar. The nectar searching property of butterflies inspired Arora and Singh to devise Butterfly Optimization Algorithm(BOA) [1]. Nature inspired methods based on other behaviours of butterflies also exist. Monarch Butterfly Optimization Algorithm mimics the migration behaviour of monarch butterflies and Artificial Butterfly Optimization Algorithm simulates the mating behaviour of speckled wood butterflies [2]- [5].

To improve the performance of nature inspired metaheuristic methods, various mechanisms are being adopted by the researchers. The incorporation of Cauchy mutation operator with them is one of those mechanisms. The nature inspired methods like Artificial Bee Colony Algorithm, Bat Algorithm, Differential Evolution Algorithm, Firefly Algorithm, Flower Pollination Algorithm, Genetic Algorithm, Imperialist Competitive Algorithm and Particle Swarm Optimization algorithm have clubbed Cauchy mutation operator with them [6]- [15].

Since the introduction of BOA, several variants of it have been developed like Modified Butterfly Optimization Algorithm (MBOA), Chaotic BOA-based methods (CBOA), Improved Butterfly Optimization Algorithm (IBOA), Hybrid BOA with Artificial Bee Colony algorithm (BOA/ABC) and Hybrid BOA with Differential Evolution algorithm (BOA/DE) [16]- [20].

A new variant of BOA, Mutated Butterfly Optimization Algorithm(BOA-C) is proposed in this work with the intention of achieving global optimal solution for optimization problems. BOA-C utilizes Cauchy mutation operator to avoid entrapment in local optima. In BOA-C, worst butterfly is not considered at the time of determining new position of butterflies by random selection. The performance of proposed Mutated Butterfly Optimization algorithm is validated on low dimensional and high dimensional test functions [21]. The experimental results are compared with results of basic BOA and other variants of BOA found in the literature for better analysis. Wilcoxon signed rank test, a pairwise statistical comparison is also carried out to identify significant difference between proposed algorithm and other studied algorithms individually [22]- [25].

II. PROPOSED ALGORITHM

The proposed algorithm, BOA-C is an enhanced version of BOA with Cauchy mutation operator. BOA-C considers a swarm of butterflies in which butterflies are positioned in random locations. The fragrance of butterflies is determined based on its sensory modality, stimulus intensity and power exponent of modality as in BOA [1]. The best and worst butterflies are identified depending on the amount of fragrance emitted by them. Butterflies always fly towards new location in search of better quality of nectar. The two phases, local search and global search in BOA are utilized for updating position of butterflies. But, in local search phase of BOA-C, butterflies other than worst butterfly are only randomly selected from the same swarm. The switch probability is its main deciding factor of those phases. The fitness at new position is evaluated. Then, fitness is updated with better one. After that, Cauchy mutation is applied on the best butterfly. Cauchy mutation is based on Cauchy distribution which generates large random numbers capable of performing longer jumps [12]. An additional scale parameter is also used with standard Cauchy distribution employed for mutation of best butterfly. The Cauchy mutation helps best butterfly to extend it search in the search space. The best butterfly updates its fitness if it has achieved better fitness after mutation. The process continues until stopping criteria is met and best butterfly thus obtained is considered as the optimal solution. The pseudocode of proposed Cauchy mutated BOA is presented below.

<u>Pseudocode: Mutated Butterfly Optimization Algorithm</u>

a. Initialize butterfly population randomly
b. Initialize sensory modality, power exponent and
   switch probability

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c. Determine stimulus intensity
d. while maximum iteration not met do
  i. for each butterfly do
    1. Determine fragrance of the butterfly
  ii. end for
  iii. Find the best and worst butterflies
  iv. for each butterfly do
    1. Generate rand from uniform numbers [0,1]
    2. if (rand < switch probability) then
      Fly towards best butterfly
    3. else
      Fly towards randomly chosen butterflies other than worst butterfly
    4. end if
    5. Determine new fitness of the butterfly
    6. if (new fitness better) then
      Update fitness of the butterfly
    7. end if
    8. Mutate the best butterfly
    9. if (fitness of mutated one better) then
      Update fitness of the best butterfly
    10. end if
  v. end for
  vi. Update value of power exponent of modality
e. end while
f. Output best solution

To summarize, main characteristics of BOA-C and some other variants of BOA are presented in Table 1.

Table 1: Characteristics of BOA and its Variants

Alg	Global Search	Local Search	Improvement Mechanism	Remarks
BOA	Fly towards best butterfly	Fly towards randomly selected butterflies	NA	Solved benchmark functions and classical engineering design problems
MBOA	BOA Global Search	BOA Local Search	Intensive Exploitation of best butterfly	Avoided local optima and premature convergence of BOA
BOA/DE	BOA Global Search	Mutation of DE	Hybridization of BOA and DE	Achieved faster convergence than BOA
IBOA	BOA Global Search	BOA Local Search	Dynamic and adaptive adjustment strategy of sensory modality	Improved searching capability of butterflies
BOA-C	BOA Global Search	BOA Local Search in which random selection of butterflies other than worst one	Cauchy mutation applied to best butterfly. An additional scale parameter used with standard Cauchy distribution	Improves search capability of best butterfly Avoids local optima entrapment

III. EXPERIMENT AND RESULT ANALYSIS

The experiment was conducted to assess the performance of BOA-C on well-known test functions. The test functions considered were categorized into low dimensional and high dimensional test functions. The details of test functions obtained from literature are given in Table 2[21].

BOA-C was executed 25 times on each test function. For each run of BOA-C, 100 iterations and 30 butterflies were considered.

Table 2: Details of Test Functions

Fn	Formula	*n*	Limits	Category
f_{bky}	$f_{bky}(x) = x_1^2 + 2x_2^2 - 0.3\cos(3\pi x_1) - 0.4\cos(4\pi x_2) + 0.7$	2	[-100,100]	Low Dim
f_{bth}	$f_{bth}(x) = (x_1 + 2x_2 - 7)^2 + (2x_1 + x_2 - 5)^2$	2	[-10,10]	Low Dim
f_{lvy}	$f_{lvy}(x) = \sin^2(3\pi x_1) + (x_1-1)^2(1+\sin^2(3\pi x_2)) + (x_2-1)^2(1+\sin^2(2\pi x_2))$	2	[-10,10]	Low Dim
f_{mas}	$f_{mas}(x) = 0.26(x_1^2 + x_2^2) - 0.48x_1x_2$	2	[-10,10]	Low Dim
f_{qne}	$f_{qne}(x) = \sum_{i=1}^{n} ix_i^4 + rand(0,1)$	30	[-1.28,1.28]	High Dim
f_{rck}	$f_{rck}(x) = \sum_{i=1}^{n-1}[100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	30	[-10,10]	High Dim
f_{sel}	$f_{sel}(x) = \max 1 \le i \le n \|x_i\|$	30	[-10,10]	High Dim
f_{sre}	$f_{sre}(x) = \sum_{i=1}^{n} x_i^2$	30	[-100,100]	High Dim

The values assigned to sensory modality and switch probability were 0.01 and 0.8 respectively. The power exponent of modality has been assigned values in the range [0.1,0.3]. The scale parameter of standard Cauchy distribution was taken as 1.0 and that of additional scale parameter as 0.1.

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To get a clear picture on the efficiency of BOA-C, best solution obtained, number of fitness evaluations carried out to achieve it and computing time of the algorithm were noted. The simulation results obtained by BOA and BOA-C on eight test functions are given in Table 3.

Table 3: Simulation Results of BOA and BOA-C on Test Functions

No.	Fn	Alg	NFE	Best	Time
1	f_{bky}	BOA	2292	9.58E-01	0.00004
		BOA-C	703	0.00E+00	0.0002
2	f_{bth}	BOA	2196	1.98E-05	0.00008
		BOA-C	2795	4.92E-09	0.00008
3	f_{lvy}	BOA	673	1.14E-01	0.00004
		BOA-C	1700	7.71E-05	0.0002
4	f_{mas}	BOA	2800	2.16E-04	0.00008
		BOA-C	390	0.00E+00	0.00016
5	f_{qne}	BOA	1100	2.25E+00	0.00004
		BOA-C	743	5.26E-10	0.00052
6	f_{rck}	BOA	2900	5.27E+01	0.00044
		BOA-C	1197	2.88E+01	0.00096
7	f_{sel}	BOA	2900	2.80E+00	0.00036
		BOA-C	99	7.38E-196	0.0002
8	f_{sre}	BOA	1500	4.72E+01	0.00028
		BOA-C	263	0.00E+00	0.00036

BOA-C has achieved solutions similar to that of best known solutions on test functions, f_{bky}, f_{mas} and f_{sre}. The solutions obtained by BOA-C for test functions considered are better than BOA. It has also taken a minimum number of fitness evaluations to achieve the best solution than BOA on every high dimensional test functions and some of the low dimensional test functions. It can be inferred that incorporation of Cauchy mutation has improved the performance of BOA. However, computing time of BOA-C was more than BOA on most of the test functions. The increase in execution time was due to the improvement mechanism added to it. The variable values of low and high dimensional test functions for best fitness value obtained by BOA-C on the corresponding test function are tabulated separately in Tables 4 and 5.

Table 4: Low Dimensional Test Functions Variable Values for BOA-C Best Solution

Variable	f_{bky}	f_{bth}	f_{lvy}	f_{mas}
Best	0.00E+00	4.92E-09	7.71E-05	0.00E+00
x_1	-2.09E-09	1.000049	0.999745	2.99E-162
x_2	-1.00E-09	2.999972	0.991572	3.52E-162

Table 5: High Dimensional Test Functions Variable Values for BOA-C Best Solution

Variable	f_{qne}	f_{rck}	f_{sel}	f_{sre}
Best	5.26E-10	2.88E+01	7.38E-196	0.00E+00
x_1	0.001377	0.012556	1.54E-196	-1.51E-163
x_2	-0.00026	0.007068	-6.63E-196	-9.92E-164
x_3	-0.00172	0.002865	7.03E-196	-6.17E-163
x_4	8.33E-05	0.009172	-4.06E-196	-1.23E-163
x_5	-0.00108	0.005374	-5.05E-197	-1.33E-163
x_6	-3.91E-05	0.008924	5.31E-196	-5.25E-163
x_7	0.001165	0.009831	-3.58E-197	-6.23E-163
x_8	-0.00124	0.000988	-6.43E-196	-4.28E-163
x_9	1.57E-05	0.006902	-1.41E-196	2.08E-163
x_{10}	-0.0015	0.005565	-7.11E-196	2.37E-163
x_{11}	0.000423	0.007186	-1.80E-196	6.40E-164
x_{12}	-0.00068	-0.01209	-3.61E-196	3.05E-163
x_{13}	0.001101	0.013881	-3.16E-196	-3.17E-163
x_{14}	0.001358	0.002821	5.55E-196	2.00E-163
x_{15}	-0.00073	0.00261	-7.11E-196	-4.15E-163
x_{16}	-0.00077	0.006652	-5.76E-196	-2.34E-163
x_{17}	0.000412	0.009082	2.33E-196	4.87E-163
x_{18}	-0.00103	0.007775	-2.14E-197	-3.12E-163
x_{19}	-0.00092	0.00768	7.07E-196	-5.95E-163
x_{20}	-4.53E-06	0.009518	7.38E-196	5.02E-163
x_{21}	-0.00104	-0.00098	-5.79E-196	-3.92E-163
x_{22}	-0.0002	-0.00504	5.73E-196	-1.54E-163
x_{23}	-0.00109	0.004069	-1.85E-196	-4.36E-164
x_{24}	0.000911	0.002005	2.22E-196	7.09E-163
x_{25}	0.001481	0.008297	-4.40E-196	4.42E-163
x_{26}	0.001078	0.015596	3.65E-196	-3.05E-163
x_{27}	-0.00034	0.000953	-1.85E-197	2.91E-163
x_{28}	-0.00072	0.008833	-1.74E-196	-5.30E-164
x_{29}	0.001186	0.004684	3.65E-196	-4.65E-164
x_{30}	0.000144	-0.00167	2.67E-196	2.22E-164

The convergence of BOA and BOA-C on test functions are also depicted in figures 1 to 8. It clearly illustrates convergence of best butterfly obtained by the algorithms.

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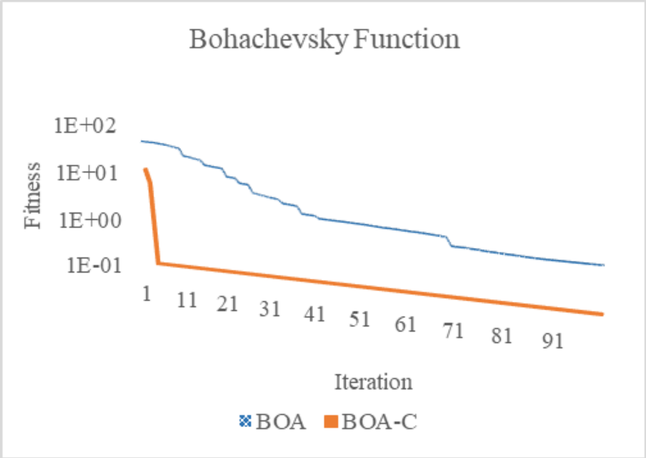

Fig 1: Convergence of BOA and BOA-C on fbky

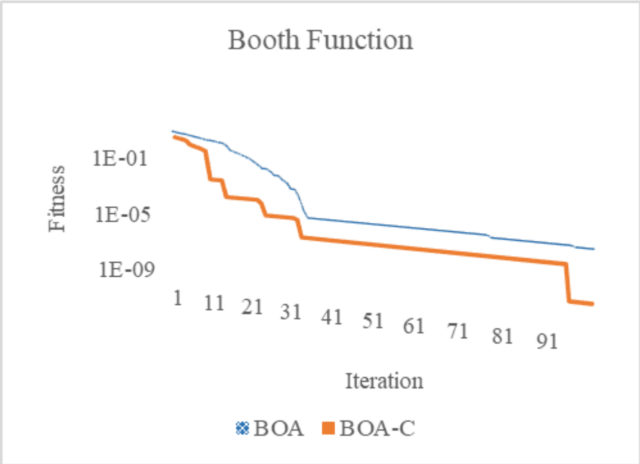

Fig 2: Convergence of BOA and BOA-C on fbth

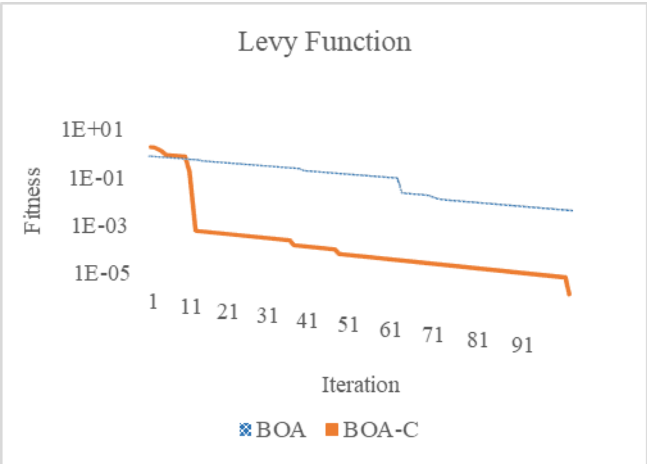

Fig 3: Convergence of BOA and BOA-C on flvy

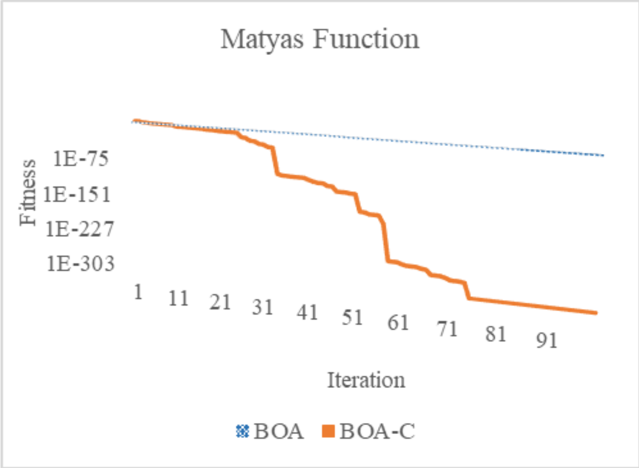

Fig 4: Convergence of BOA and BOA-C on fmas

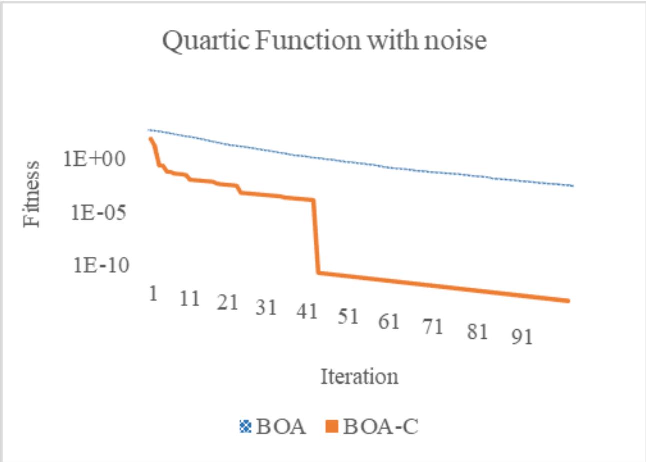

Fig 5: Convergence of BOA and BOA-C on fqne

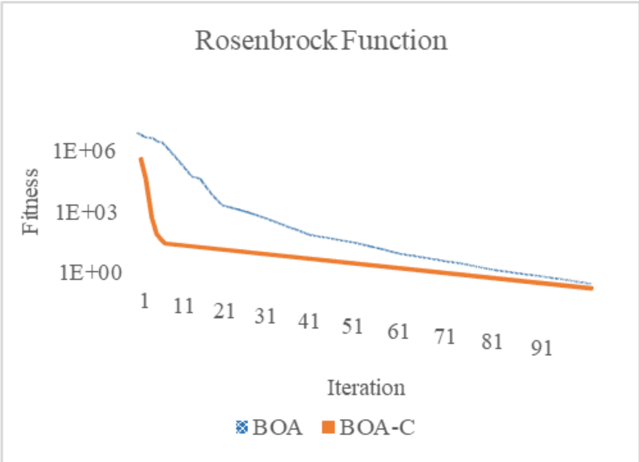

Fig 6: Convergence of BOA and BOA-C on f_{rck}

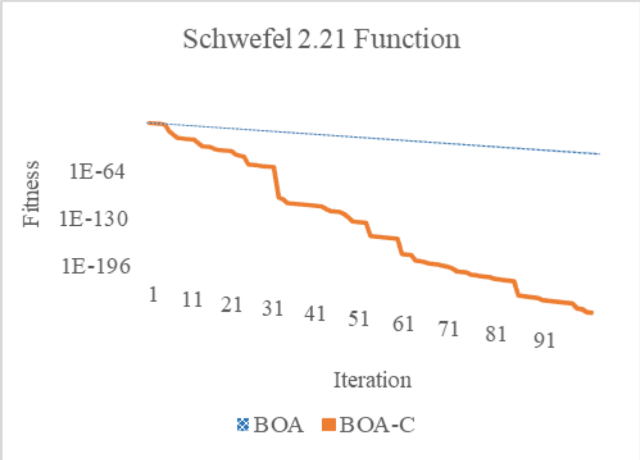

Fig 7: Convergence of BOA and BOA-C on fsel

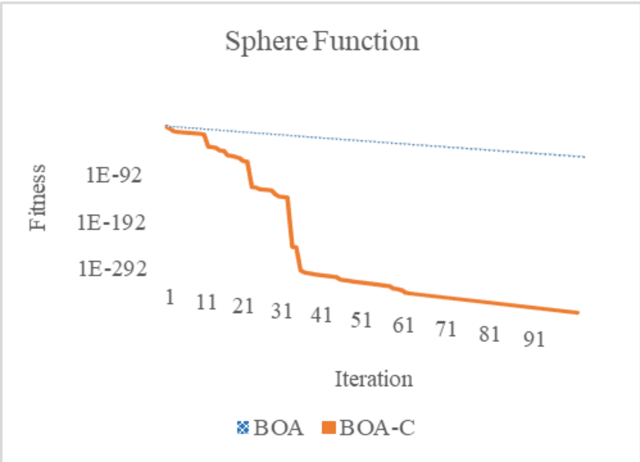

Fig 8: Convergence of BOA and BOA-C on fsre

BOA-C converges to solutions better than BOA on all the test functions. Cauchy mutation operator has enabled best butterfly in BOA-C to increase its search capability and attain global optimal solutions. In other words, BOA-C has improved quality of solutions by avoiding local optima.

The performance of BOA-C on test functions was further analyzed with that of basic BOA, MBOA, BOA/DE and IBOA. For comparison, performance mean and standard deviation values obtained by BOA and BOA-C are noted in Tables 6 and 7 along with values of BOA variants which are taken from the literature [16], [20].

Table 6: Performance Mean of BOA and its Variants on Test Functions

Fn	Algorithm				
	BOA	**MBOA***	**BOA/DE***	**IBOA***	**BOA-C**
f_{bky}	4.52E+00	0.00E+00	4.30E-08	9.10E+00	0.00E+00
f_{bth}	2.41E-01	0.00E+00	5.21E-03	1.99E-03	1.92E-01
f_{lvy}	4.58E+00	1.31E+00	2.21E+00	4.51E+01	5.06E-01
f_{mas}	1.01E-01	8.03E-152	1.88E-06	5.95E-09	6.83E-153
f_{qne}	2.52E+00	9.42E-03	3.59E-02	3.42E+05	1.76E-03
f_{rck}	5.66E+01	2.88E+01	2.89E+01	3.38E+03	2.88E+01
f_{sel}	2.93E+00	2.81E-03	3.89E-03	1.56E+00	7.38E-71
f_{sre}	5.18E+01	2.00E-12	9.76E-05	5.26E+10	5.77E-130

Table 7: Standard Deviation of BOA and its Variants on Test Functions

Fn	Algorithm				
	BOA	**MBOA***	**BOA/DE***	**IBOA***	**BOA-C**
f_{bky}	2.87E+00	0.00E+00	8.63E-08	1.01E+00	0.00E+00
f_{bth}	2.41E-01	0.00E+00	9.47E-03	2.37E-03	3.72E-01
f_{lvy}	3.97E+00	1.95E-01	2.72E-01	1.60E+00	4.74E-01
f_{mas}	9.03E-02	2.54E-151	3.26E-06	4.76E-09	3.41E-136
f_{qne}	1.31E-01	5.64E-03	3.17E-02	2.26E+05	1.88E-03
f_{rck}	1.92E+00	9.66E-02	7.12E-02	1.91E+03	3.46E-02
f_{sel}	4.86E-02	4.72E-03	3.54E-05	4.86E-01	2.32E-70
f_{sre}	2.36E+00	2.13E-09	4.05E-05	3.34E+09	2.59E-129

* Results obtained from literature

It is observed that BOA-C has obtained better performance mean and standard deviation values than basic BOA on every test functions. It has also produced competitive results with other BOA variants.

The statistical analysis based on Wilcoxon signed rank test at a significance level of 0.05 was also carried out and the results are shown in Table 8. The analysis determined whether BOA-C and other compared algorithms have shown any significant difference in their performances on test function.

Table 8: Wilcoxon Signed Rank Test Result on BOA and its Variants

Fn	**BOA vs BOA-C**	**MBOA vs BOA-C**	**BOA/DE vs BOA-C**	**IBOA vs BOA-C**
f_{bky}	+	=	+	+
f_{bth}	+	-	-	-
f_{lvy}	+	+	+	+
f_{mas}	+	+	+	+
f_{qne}	+	+	+	+
f_{rck}	+	=	+	+
f_{sel}	+	+	+	+
f_{sre}	+	+	+	+
Better	**8**	**5**	**7**	**7**
Worse	0	1	1	1
Equal		2		

The statistical analysis resulted in twenty-seven better results, three worst results and two equal results for BOA-C out of thirty-two comparisons carried out. It is noted that BOA-C has obtained worse solutions than compared algorithms only on f_{bth}. The analysis demonstrates that BOA-C is significantly better than basic BOA and IBOA on low dimensional and high dimensional test functions. However, there is no enough evidence to show its significant difference from MBOA and BOA\DE on test functions.

The ranks were also assigned to BOA and its variants considering their performances. The rank summary of the algorithms is specified in Table 9.

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Table 9: Rank Summary of BOA and its Variants

Fn	Algorithm				
	BOA	MBOA	BOA/DE	IBOA	BOA-C
f_{bky}	4	1.5	3	5	1.5
f_{bth}	5	1	3	2	4
f_{lvy}	5	2	3	4	1
f_{mas}	5	2	4	3	1
f_{qne}	4	2	3	5	1
f_{rck}	4	1.5	3	5	1.5
f_{sel}	5	2	3	4	1
f_{sre}	4	2	3	5	1
Total	36	14	25	33	**12**

BOA-C scored lowest value among the algorithms for solving most of the test functions considered. The rank summary shows that BOA-C has secured first rank followed by MBOA, BOA/DE, IBOA and BOA. It is worthwhile to note that Cauchy mutation in BOA-C has improved its performance on low dimensional and high dimensional test functions.

IV. CONCLUSION

BOA-C is an improved version of BOA in which Cauchy mutation operator is applied on best butterfly to enhance its global search capability. The performance of BOA-C is tested on both low dimensional and high dimensional test functions. The study is remarkable since BOA-C has resulted in higher quality solutions than basic BOA and its variants on test functions considered. It is also worth mentioning that BOA-C has avoided local optima entrapment on test functions. In future, various mechanisms for intensive exploitation and extensive exploration for BOA can be investigated and then integrated with it for achieving optimal solutions. BOA-C can also be utilized to solve classical engineering design optimization problems and combinatorial optimization problems.

NOMENCLATURE

Alg	Algorithm
Fn	Test Function
f_{bky}	Bohachevsky Function
f_{bth}	Booth Function
f_{lvy}	Levy Function
f_{mas}	Matyas Function
f_{qne}	Quartic Function with noise
f_{rck}	Rosenbrock Function
f_{sel}	Schwefel 2.21 Function
f_{sre}	Sphere Function
x_i	i^{th} Variable of Test Functions
n	Dimension of Test Functions
Low Dim	Low Dimensional Test Function
High Dim	High Dimensional Test Function
NFE	Number of Fitness Evaluations done by algorithm
Time	Computing Time of the algorithm in seconds
+	BOA-C is better than compared algorithm
-	BOA-C is worse than compared algorithm
=	BOA-C is equal to compared algorithm

REFERENCES

1. Arora, S. and Singh, S.," Butterfly optimization algorithm: a novel approach for global optimization", Soft Computing, 2018, pp.1-20.
2. Wang, G.G., Deb, S. and Cui, Z.," Monarch butterfly optimization ", Neural Computing & Applications, 2015.
3. Faris, H., Aljarah, I. and Mirjalili, S.," Improved monarch butterfly optimization for unconstrained global search and neural network training", Applied Intelligence, 48(2), 2018, pp.445-464.
4. Wang, G.G., Deb, S., Zhao, X. and Cui, Z.," A new monarch butterfly optimization with an improved crossover operator", Operational Research, 2016, pp.1-25.
5. Qi, X., Zhu, Y. and Zhang, H.," A new meta-heuristic butterfly-inspired algorithm", Journal of Computational Science, 23, 2017, pp.226-239.
6. Zheng, J.G., Zhang, C.Q. and Zhou, Y.Q.," Artificial bee colony algorithm combined with grenade explosion method and Cauchy operator for global optimization", Mathematical Problems in Engineering, 2015.
7. Paiva, F.A., Silva, C.R., Leite, I.V., Marcone, M.H. and Costa, J.A.," Modified bat algorithm with cauchy mutation and elite opposition-based learning", 2017, November, In Computational Intelligence (LA-CCI), 2017 IEEE Latin American Conference on (pp. 1-6). IEEE.
8. Ali, M. and Pant, M.," Improving the performance of differential evolution algorithm using Cauchy mutation", Soft Computing, 15(5), 2011, pp.991-1007.
9. Wang, H., Wang, W., Sun, H. and Rahnamayan, S.," Firefly algorithm with random attraction", International Journal of Bio-Inspired Computation, 8(1), 2016, pp.33-41.
10. Salgotra, R. and Singh, U., "Application of mutation operators to flower pollination algorithm",Expert Systems with Applications, 79, 2017,pp.112-129.
11. Iqbal, M.A,Khan,N.K., Jaffar, M.A.,Ramzan, M.and Baig, A.R," Opposition based genetic algorithm with Cauchy mutation for function optimization", 2010, April In Information Science and Applications (ICISA), 2010 International Conference on (pp. 1-7). IEEE.
12. Xu, S., Wang, Y. and Lu, P.," Improved imperialist competitive algorithm with mutation operator for continuous optimization problems", Neural Computing and Applications, 28(7), 2017, pp.1667-1682.
13. Wang, H., Li, H., Liu, Y., Li, C. and Zeng, S.," Opposition-based particle swarm algorithm with Cauchy mutation", 2007, September, In Evolutionary Computation, 2007. CEC 2007. IEEE Congress on (pp. 4750-4756). IEEE.
14. Wu, Q. and Law, R.," Cauchy mutation based on objective variable of Gaussian particle swarm optimization for parameters selection of SVM", Expert Systems with Applications, 38(6), 2011, pp.6405-6411.
15. Wang, H., Li, C., Liu, Y. and Zeng, S.," A hybrid particle swarm algorithm with Cauchy mutation", 2007, April, In Swarm Intelligence Symposium, 2007. SIS 2007. IEEE (pp. 356-360). IEEE.
16. Arora, S., Singh, S. and Yetilmezsoy, K.," A modified butterfly optimization algorithm for mechanical design optimization problems", Journal of the Brazilian Society of Mechanical Sciences and Engineering, 40(1), 2018, p.21.
17. Arora, S. and Singh, S.," An improved butterfly optimization algorithm with chaos. Journal of Intelligent & Fuzzy Systems", 32(1), 2017, pp.1079-1088.
18. Arora, S. and Singh, S.," An Improved Butterfly Optimization Algorithm for Global Optimization", Advanced Science, Engineering and Medicine, 8(9), 2016, pp.711-717.
19. Arora, S. and Singh, S.," An Effective Hybrid Butterfly Optimization Algorithm with Artificial Bee Colony for Numerical Optimization", International Journal of Interactive Multimedia & Artificial Intelligence, 4(4), 2017.
20. Arora, S. and Singh, S.," A hybrid optimisation algorithm based on butterfly optimisation algorithm and differential evolution", International Journal of Swarm Intelligence, 3(2-3), 2017, pp.152-169.
21. Jamil, M. and Yang, X.S.," A literature survey of benchmark functions for global optimization problems", 2013, arXiv preprint arXiv:1308.4008.
22. McCrum-Gardner, E.," Which is the correct statistical test to use?", British Journal of Oral and Maxillofacial Surgery, 46(1), 2008, pp.38-41.

23. Derrac, J., García, S., Molina, D. and Herrera, F.," A practical tutorial on the use of nonparametric statistical tests as a methodology for comparing evolutionary and swarm intelligence algorithms", Swarm and Evolutionary Computation, 1(1), 2011, pp.3-18.
24. Wilcoxon, F.," Individual comparisons by ranking methods", Biometrics bulletin, 1(6), 1945, pp.80-83.
25. Wilcoxon, F.," Probability tables for individual comparisons by ranking methods", Biometrics, (3), 1947, pp.119-122.

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