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Oturum Başkanı		Oturum Başkan Yrd.
Prof.Dr. Uğur Yüzgeç		
Sıra	Yazar Bilgisi	Bildiri Bilgileri
15:00	Yüksek Lisans Öğrenci Cihat Doğan - Prof.Dr. Uğur Yüzgeç	Hızlandırılmış Karşıt Öğrenme Tabanlı Tek Aday Optimizasyon Algoritması
15:15	Yüksek Lisans Öğrenci Cihat Doğan - Prof.Dr. Uğur Yüzgeç	Kümeleme Problemleri İçin Karşıt Öğrenme Tabanlı Tek Aday Optimizasyon Algoritması
15:30	Dr. Öğretim Üyesi Yasemin Samav	Sustainability in Polymeric Wastes
15:45	Dr. Öğretim Üyesi Feridun Karakoç - Fatih Enes Alp - Arş.Gör.Dr. Melih Canlıdınç - Arş.Gör. Ahmet Dayanç	Sıvı Yakıtlı Roket Motorlarının Hesaplamalı Analizi: CH_4+O_2 ve Flp Yakıt Karışımları Üzerine Bir Çalışma
16:00	Araştırmacı Ali Kocaman	Farklı Zemin Sınıflarında Düşey Elastik Tasarım Spektrumlarının Kirişlere Etkisi ve K.Maraş Deprem ile Karşılaştırılması
16:15	Soru, cevap ve tartışma	

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Accelerated Opposition Learning based Single Candidate Optimization Algorithm

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Abstract

In order to address optimization problems effectively, the development of efficient optimization algorithms holds paramount importance. This study focuses on developing the search capability of the Single Candidate Optimization (SCO) algorithm, introduced by Shami et al. in 2022. Distinguishing itself from other population-based heuristic algorithms, the SCO algorithm aims to expedite the solution-finding process by employing a single candidate solution. In this study, the improvement of the SCO algorithm incorporates an accelerated opposition-based learning mechanism (AccOppSCO). To assess the performance of the proposed AccOppSCO algorithm, it was tested for various optimization problems from the literature. The evaluation revealed that the AccOppSCO algorithm can generate more accurate solutions compared to the original SCO algorithm.

Keywords: Opposition Learning, Heuristic Algorithm, Single Candidate Optimization Algorithm.

INTRODUCTION

Optimization problems are of great importance in various fields, including science, engineering, economics and other disciplines. The primary objective of such problems is to achieve the best possible outcome while satisfying a set of constraints, or to optimize a specific objective. For example, optimization encompasses various objectives such as cost minimization, activity maximization and resource optimization. Solving optimization problems, which are characterized by complex structures in their models and requirements, poses considerable challenges. Numerous optimization techniques are used to find the optimal solution through different approaches. However, for certain optimization problems, existing methods may prove insufficient, leading to a continuous search for more effective solutions.

Heuristic algorithms play a fundamental role in tackling intricate problems by offering efficient and adaptable approaches. These algorithms draw inspiration from natural phenomena or social behaviors to optimize the objective function and seek the most favorable solutions. Their application domains encompass a broad spectrum of fields, including engineering, business, artificial intelligence, and computer science. Some well-known examples of heuristic algorithms are Genetic Algorithm (GA) (Lambora, 2019), Particle Swarm Optimization (PSO) Algorithm (Kennedy, 1995; Eberhart, 1995), Ant Colony Optimization (ACO) Algorithm (Dorigo, 2019), Simulated Annealing (SA) Algorithm (Rutenbar, 1989), Differential Evolution (DE) Algorithm (Lampinen, 2005), and Artificial Bee Colony



(ABC) Algorithm (Karaboga, 2014). Population-based heuristic algorithms, like Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) algorithms, may suffer from certain drawbacks. One key issue is the high computational cost, as these algorithms require maintaining and updating a large set of candidate solutions. Additionally, the effectiveness of these algorithms heavily relies on appropriately setting their parameters, which can be a challenging task. Furthermore, population-based algorithms may struggle to escape local optima and may not guarantee finding the global optimum in complex search spaces.

The Single Candidate Optimization (SCO) algorithm is a novel strategy that differs from traditional heuristic search algorithms, especially those based on swarm-based methods (Shami, 2022). Unlike swarm-based heuristics, SCO focuses exclusively on a single candidate solution throughout the optimization process, with the goal of achieving improved solutions. The optimization process consists of two phases, each of which uses different approaches to update the position of the candidate solution. While single-solution based algorithms and two-phase approaches have historically been considered as separate heuristic optimization methods, SCO merges these concepts into a unified, robust algorithm. A notable aspect of this algorithm is the implementation of a unique set of equations that update the position of the candidate solution based solely on its own information, such as its current position. By integrating these elements, SCO provides a fresh and effective approach to solving optimization problems.

While the Single Candidate Optimization (SCO) algorithm offers certain advantages, it is essential to carefully consider its potential limitations. The exclusive reliance on a single candidate solution may hinder its ability to explore the solution space thoroughly. The absence of diverse candidate solutions could lead to difficulties in escaping local optima, possibly limiting the algorithm's capability to find the global optimum. Furthermore, the performance of SCO is sensitive to the position of the initial candidate solution, which may affect the quality of the final solution obtained. Another drawback is that the exploration mechanism employed by SCO could cause the candidate solution's position to converge to a zero point rapidly, potentially delaying convergence in cases where the optimal solution lies in non-zero solution points.

Opposition-based learning is a powerful technique that has revolutionized the field of optimization algorithms. Introduced by Tizhoosh in 2005, it is based on the concept of opposition, which involves evaluating candidate solutions not only based on their original values but also their opposite counterparts (Tizhoosh, 2005). The opposite of a solution is obtained by negating the values of its components or by applying a specific transformation. This unique approach aims to enhance the exploration capability and convergence speed of optimization algorithms. By considering opposite solutions, opposition-based learning introduces additional diversity into the search process. This diversity allows the algorithm to explore different regions of the search space simultaneously, which can lead to a more comprehensive exploration and increase the likelihood of finding better solutions. The integration of opposition-based learning has been proven to be effective in improving the performance of various optimization algorithms across diverse problem domains.

In this study, an accelerated opposition learning based mechanism is integrated into the structure of SCO algorithm to improve its search performance and to overcome the aforementioned handicaps of

the algorithm. To test the performance of the novel proposed accelerated opposition learning based SCO (AccOppSCO) algorithm, 23 well-known minimization problems are taken from the literature. The obtained results show that the AccOppSCO algorithm is more successful than the original SCO algorithm.

MATERIAL & METHODS

Single Candidate Optimization (SCO) Algorithm

The Single Candidate Optimization (SCO) algorithm represents a breakthrough approach that differs from conventional search algorithms by using only a single candidate solution throughout the entire optimization process. Unlike swarm-based algorithms that rely on multiple particles, SCO focuses solely on a single solution with the primary goal of achieving better optimization results. By dividing the optimization process into two distinct phases, SCO employs different strategies and mechanisms that synergistically contribute to both exploration and exploitation capabilities. This unique combination of the single-candidate approach and the two-phase strategy enables SCO to effectively exploit the strengths of each methodology, resulting in a powerful and versatile optimization algorithm. In the first stage of SCO, the position of the candidate solution is updated according to the following formula:

$$x(j) = \begin{cases} S(j) + (w|S(j)|), & \text{if } r_1 < 0.5 \\ S(j) - (w|S(j)|), & \text{otherwise} \end{cases} \quad (1)$$

$$w(i) = e^{-\left(\frac{b \cdot i}{i_{max}}\right)^b} \quad (2)$$

where $x(j)$ is the candidate solution's position, j stands for the dimension, w represents the weight parameter, $S(j)$ denotes the best candidate for each iteration, b is the constant parameter, i is the iteration, i_{max} is the maximum iteration, and r_1 is the random number in range 0 and 1. In the second stage of the SCO algorithm, a systematic search is conducted, initially exploring the surrounding vicinity of the best position obtained in the first phase. This comprehensive exploration aims to cover a broad range of the search space. Subsequently, as the second phase progresses, the search narrows down, allowing for a more focused examination of the most promising regions. The diagram below illustrates the step-by-step process by which the candidate solution updates its position during the second phase.

$$x(j) = \begin{cases} S(j) + (wr_2(ub(j) - lb(j))), & \text{if } r_2 < 0.5 \\ S(j) - (wr_2(ub(j) - lb(j))), & \text{otherwise} \end{cases} \quad (3)$$

where ub , lb represent the upper boundary and lower boundary, and r_2 represents the random number. A crucial aspect of the SCO pertains to the adaptive behavior of its parameter w , which exhibits an exponential decrease as the number of function evaluations increases. This dynamic characteristic serves a vital role in striking a balance between exploration and exploitation during the optimization process. By initially setting w to a relatively high value, SCO effectively explores the search space. As the optimization progresses, the gradual decrease of w facilitates a shift towards exploitation, focusing on refining the solution in later stages. Moreover, SCO effectively addresses the challenge of potential entrapment in local optima by introducing a modification to the position update during the second stage.

In cases where a consecutive set of m function evaluations fails to yield fitness improvement, the candidate solution's position undergoes an adjustment procedure, as detailed below:

$$x(j) = \begin{cases} S(j) + (r_3(ub(j) - lb(j))), & \text{if } r_3 < 0.5 \\ S(j) - (r_3(ub(j) - lb(j))), & \text{otherwise} \end{cases} \quad (4)$$

where r_3 is the random number. The position update equation (4) serves a critical role in facilitating a transition from exploitation to exploration for the candidate solution within the SCO algorithm. This transition is instrumental in aiding the algorithm's ability to escape from local optima, a phenomenon where the candidate solution becomes confined to suboptimal regions of the search space. By incorporating this shift in the position update mechanism, the SCO algorithm gains the capability to explore alternative regions of the search space more effectively, mitigating the risk of being trapped in suboptimal solutions and promoting the pursuit of better optimization outcomes.

Accelerated Opposition Learning based Single Candidate Optimization (AccOppSCO) Algorithm

In this subsection, the accelerated opposition based learning mechanism, which is integrated into the algorithm structure to improve the search performance of the original SCO algorithm and overcome some of its handicaps (limited exploration ability, sensitivity to the first candidate solution selection, etc.), is described. Opposition-Based Learning (OBL) is a mechanism that incorporates the concept of opposition into optimization algorithms, evaluating solutions based on their original values as well as their opposite counterparts. By considering opposite solutions, it introduces additional diversity and facilitates exploration of the search space, potentially leading to improved optimization outcomes (Tizhoosh, 2005). This OBL mechanism is augmented with an acceleration coefficient (ac) to expedite the convergence speed of the optimization process (Dinkar, 2019).

In the opposition-based initialization phase, the candidate is utilized to derive opposition candidate. This process generates an individual that is deemed more advantageous compared to that obtained through random initialization. By incorporating opposition-based techniques, this initialization step enhances the suitability of the assigned individual for subsequent optimization procedures. The procedure is outlined below:

$$\tilde{x} = (ub + lb) - x \quad (5)$$

where \tilde{x} represents the opposite position of initial candidate generated randomly. After each iteration in the optimization process, an opponent candidate is determined using a predefined jump probability value. Subsequently, superior candidates are selected for the next iteration from a combination of the current and the opponent candidates. The implementation of the opposition-based generation jump relies on comparing the jump rate (Jr) with a random number within the range $[0, 1]$, as depicted in the following expression:

$$\tilde{x}(i+1) = \begin{cases} ub + lb - x(i), & \text{if } r_4 < Jr \\ x(i), & \text{otherwise} \end{cases} \quad (6)$$

While adopting the OBL strategy ensures convergence acceleration, the generated opposite candidate may exhibit unexpected exploration behaviour. While increased exploration is beneficial in the early stages of generation, the algorithm must gradually shift towards exploitation as the number of generations increases. Consequently, we have employed a second strategy here, which involves making OBL adaptive with an acceleration coefficient (C_a) to strike a balance between exploration and exploitation. To achieve this, the acceleration coefficient C_a is used to approximate the equilibrium between exploration and exploitation and is adaptively reduced as the number of iterations increases (Dinkar, 2019). The calculation of this parameter (C_a) can be derived as given below:

$$C_a = C_{max} - i \cdot \frac{C_{max} - C_{min}}{i_{max}} \quad (7)$$

where C_{max} is the maximum value (1), and C_{min} is the minimum value ($1e-5$), i represents the current iteration, and i_{max} denotes the maximum iteration. The Eq. (5) is updated by this procedure as follows:

$$\tilde{x} = (ub + lb - x) \cdot C_a \quad (8)$$

EXPERIMENTAL RESULTS

In this study, 23 well-known minimization problems from the literature are considered to compare the performance of the proposed AccOppSCO algorithm with the original SCO algorithm. In Fig. 1, these benchmark problems are shown for two dimensions. Firstly, 2D analyses of some of these functions are performed for both algorithms. We have chosen four different minimization problems, namely test problems 7, 14, 17 and 21.

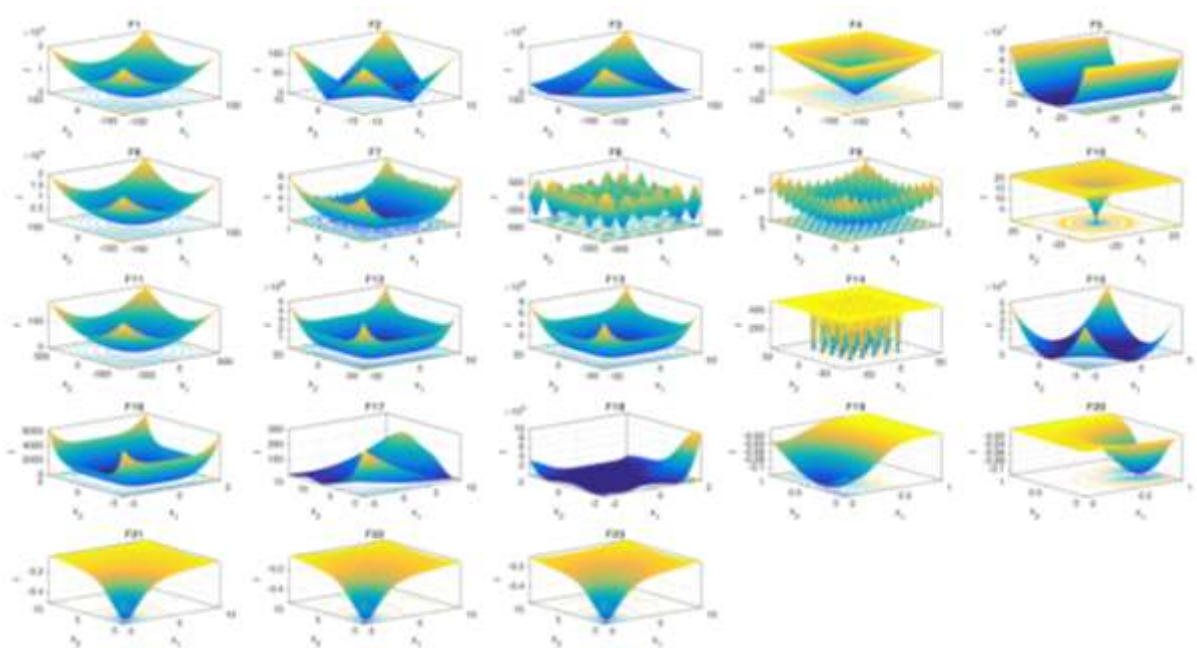


Figure 1. Benchmarks used in this study.

The analyses include search history analysis, which shows the movement of the candidate in the search space throughout the optimization process, trajectory analysis, which shows the change of the first dimension of the candidate's position, search agent fitness analysis, which shows the change of the candidate's cost value throughout the optimization, and convergence analysis, which shows the convergence of candidate solutions. Fig. 2 shows the analyses results of the selected benchmarks.

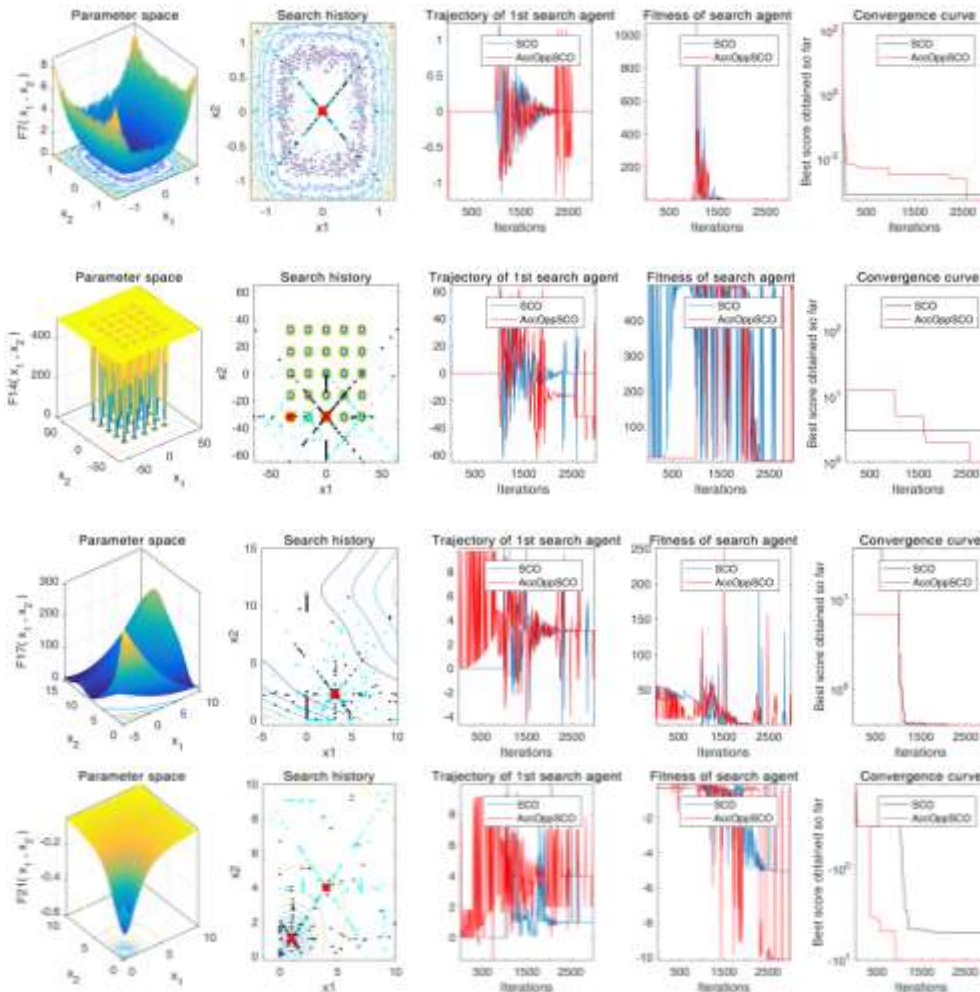


Figure 2. Convergence Curves of SCO and OppSCO

Looking at the convergence curves of the four selected functions, it is clearly seen that the AccOppSCO structure proposed in the optimization process has a better convergence. In Table 1, the statistical results are summarized for 30 runs of SCO and AccOppSCO algorithms. According to the comparison results of 30 runs of the SCO and AccOppSCO algorithms on 23 test functions, it is evident that AccOppSCO has outperformed SCO algorithm. AccOppSCO has exhibited superior performance based on the following metrics: in terms of the best and worst metric values, the AccOppSCO algorithm outperforms the SCO algorithm by 82.61% with a success rate of 19/23 in all test functions. Also from the results, AccOppSCO is more successful (69.57%) than SCO in Median and Mean metrics in 16 out of 23 functions. Furthermore, AccOppSCO showed a more consistent and stable performance across

test functions, with a lower standard deviation (86.96%) compared to SCO. Based on these findings, it can be concluded that AccOppSCO outperforms SCO in optimizing test functions.

Table 1. *Statistical results of SCO and AccOppSCO algorithms for 30 runs.*

No	SCO					AccOppSCO				
	Best	Worst	Median	Mean	Std	Best	Worst	Median	Mean	Std
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	1.89E-304	2.02E-247	9.74E-272	1.27E-247	0.00E+00	1.39E-293	4.97E-260	1.03E-270	3.42E-261	0.00E+00
3	0.00E+00	3.53E-239	0.00E+00	1.18E-239	0.00E+00	0.00E+00	5.32E-166	0.00E+00	1.77E-167	0.00E+00
4	5.53E-181	1.45E-32	9.37E-133	4.85E-33	2.65E-32	1.33E-191	1.71E-10	4.07E-126	5.70E-12	3.12E-11
5	2.85E+01	2.90E+01	2.89E+01	2.88E+04	1.14E-01	2.87E+01	2.89E+01	2.89E+01	2.89E+01	5.70E-02
6	1.46E-01	6.50E-01	2.10E-01	2.50E-01	1.13E-01	1.46E-01	4.32E-01	3.10E-01	3.08E-01	6.97E-02
7	1.98E-02	2.95E-03	3.13E-04	4.57E-04	5.38E-04	7.36E-06	5.16E-04	1.82E-04	2.18E-04	1.46E-04
8	-9.98E+03	-7.30E+03	-8.23E+03	-8.28E+03	6.97E+02	-1.01E+04	-7.14E+03	-8.37E+03	-8.29E+03	7.36E+02
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	8.88E-13	8.88E-13	8.88E-13	8.88E-13	4.01E-27	8.88E-16	8.88E-16	8.88E-16	8.88E-16	4.01E-31
11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	1.96E-02	2.58E-01	5.43E-02	7.27E-02	5.14E-02	1.18E-02	2.11E-01	8.80E-02	8.44E-02	4.82E-02
13	3.33E-01	2.99E+03	1.51E+03	1.52E+04	7.05E-01	7.29E-01	2.45E+00	1.84E+00	1.69E+00	4.50E-01
14	9.98E-01	1.99E+03	9.98E-01	1.20E+04	4.04E-01	9.98E-01	1.99E+00	9.98E-01	1.06E+00	2.52E-01
15	3.52E-04	1.23E-01	1.35E-03	7.05E-03	2.27E-02	3.26E-04	2.70E-02	8.30E-04	3.49E-03	5.72E-03
16	-1.03E+03	-1.03E+03	-1.03E+03	-1.03E+03	0.00E+00	-1.03E+00	-1.03E+00	-1.03E+00	-1.03E+00	0.00E+00
17	3.98E-01	3.98E-01	3.98E-01	3.98E-01	0.00E+00	3.98E-01	3.98E-01	3.98E-01	3.98E-01	0.00E+00
18	3.00E+00	3.00E+00	3.00E+00	3.00E+00	0.00E+00	3.00E+00	3.00E+00	3.00E+00	3.00E+00	0.00E+00
19	-3.86E+03	-3.86E+03	-3.86E+03	-3.86E+03	0.00E+00	-3.86E+00	-3.86E+00	-3.86E+00	-3.86E+00	0.00E+00
20	-3.32E+03	-3.13E+03	-3.32E+03	-3.27E+04	7.67E-02	-3.32E+00	-3.10E+00	-3.20E+00	-3.23E+00	9.22E-02
21	-1.02E+01	-2.63E+00	-1.02E+01	-8.64E+04	2.61E+04	-1.02E+01	-5.10E+00	-1.02E+01	-9.81E+00	1.28E+00
22	-1.04E+01	-2.77E+03	-1.04E+01	-8.30E+04	2.86E+04	-1.04E+01	-1.04E+01	-1.04E+01	-1.04E+01	1.81E-15
23	-1.05E+01	-5.13E+03	-1.05E+01	-9.28E+04	2.32E+04	-1.05E+01	-5.18E+00	-1.05E+01	-9.82E+00	1.85E+00

RESULTS

In this study, the Single Candidate Optimization (SCO) algorithm is considered and an accelerated opposition learning based mechanism is integrated into the algorithm structure to improve its search performance. For the performance comparison of AccOppSCO algorithm with the original SCO, 23 benchmark problems were taken from the literature.

In conclusion, the AccOppSCO algorithm has proven to be a highly effective and promising optimization technique based on the extensive comparison results with the traditional SCO algorithm. Through the incorporation of opposition-based learning and the adaptive acceleration coefficient, AccOppSCO successfully achieves a better balance between exploration and exploitation, leading to improved optimization outcomes. The obtained results indicate that AccOppSCO consistently outperforms SCO in terms of various metrics, such as the Best, Median, Mean, and standard deviation. Moreover, AccOppSCO demonstrates enhanced stability and consistency in solving the test functions, showcasing its capability to handle complex optimization challenges. With its ability to efficiently explore the search space while avoiding premature convergence, AccOppSCO holds great potential for a wide range of real-world applications and complex optimization problems. As further research and improvements are made, AccOppSCO is expected to emerge as a valuable and reliable optimization algorithm in various domains.

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