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A Novel Improved Whale Optimization Algorithm for Global Optimization and Engineering Applications

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Abstract: The Whale Optimization Algorithm (WOA) is a swarm intelligence algorithm based on natural heuristics, which has gained considerable attention from researchers and engineers. However, WOA still has some limitations, including limited global search efficiency and a slow convergence rate. To address these issues, this paper presents an improved whale optimization algorithm with multiple strategies, called Dynamic Gain-Sharing Whale Optimization Algorithm (DGSWOA). Specifically, a Sine–Tent–Cosine map is first adopted to more effectively initialize the population, ensuring a more uniform distribution of individuals across the search space. Then, a gaining–sharing knowledge based algorithm is used to enhance global search capability and avoid falling into a local optimum. Finally, to increase the diversity of solutions, Dynamic Opposition-Based Learning is incorporated for population updating. The effectiveness of our approach is evaluated through comparative experiments on blackbox optimization benchmarking and two engineering application problems. The experimental results suggest that the proposed method is competitive in terms of solution quality and convergence speed in most cases.

Keywords: whale optimization algorithm; swarm intelligence; opposition-based learning; meta-heuristic; gaining–sharing knowledge-based optimization algorithm

MSC: 65K10; 68T01



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1. Introduction

Optimization problems are defined as finding the best solution under a given set of constraints. With the rapid development of technology, it has become especially important to deal with increasingly complex optimization problems. These problems not only are subject to multiple constraints but also often involve higher dimensions. Therefore, various optimization algorithms have been proposed to overcome these challenges. Among these, swarm intelligence algorithms have gained significant attention due to their excellent performance in solving complex problems [1,2]. The core of such algorithms lies in mimicking the collective intelligence of organisms in nature and guiding the group to achieve the overall optimization goal through information sharing among individuals. Well-known swarm intelligence algorithms include Ant Colony Optimization (ACO) [3], Particle Swarm Optimization (PSO) [4], Ant Lion Optimizer (ALO) [5], Bat Algorithm (BA) [6], Firefly Algorithm (FA) [7], and Artificial Bee Colony (ABC) [8]. In particular, the Whale Optimization Algorithm (WOA) [9] has become especially attractive to researchers because of its simple structure, powerful adaptation, and few control parameters. It has been successfully applied to a variety of complex optimization scenarios such as engineering design [10], neural network training [11], image segmentation [12], and path planning [13].

Nonetheless, the Whale Optimization Algorithm shows some limitations, such as susceptibility to local optimum traps and slow convergence. To overcome these challenges, researchers have successively proposed various algorithm variants that focus on four aspects: initialization population optimization, parameter optimization, mechanism formula

optimization, and iterative update optimization. The effectiveness of an optimization algorithm is often closely related to the distribution of the initial population. Li et al. [14] introduced opposition-based learning to improve the initial distribution of the population. Elmogy et al. [15] used two types of discrete chaotic mappings to select the optimal initial population. The algorithm parameters are also crucial to the optimization performance. Sanjoy et al. [16] introduced a unique stage selection parameter and modified two coefficient vectors to balance global and local searches. Sun et al. [17] used a controlling parameter to balance developing and exploring. The core mechanism of the optimization algorithm is an important aspect of improvement. Seyyedabbasi [18] merged WOA with the sine cosine algorithm. Sanjoy et al. [19] implemented a novel cooperative hunting strategy in the exploitation phase and modified the random selection mechanism for solutions in the search phase. The updating mechanism during the iterative process likewise has a significant impact on the final performance of the algorithm. Hemasian-Etefagh and Safi-Esfahani [20] improved performance by grouping populations for iterative update optimization. Additionally, Shen et al. [21] performed an iterative optimization of the population by grouping individuals according to their fitness and giving them different migration strategies. Although the variants mentioned above have increased the performance of WOA from different perspectives, there is still room for further enhancement in global search capability and convergence speed.

To address the above issues, this paper proposes an improved WOA algorithm, named DGSWOA, based on multiple strategies. Specifically, the Sine–Tent–Cosine map (STC) is incorporated to make distribution of the initial population more uniform. In this way, it could expand the search scope in the initial phase of the algorithm, increasing the likelihood of finding a globally optimal solution. Secondly, the DGSWOA adopts a gaining–sharing knowledge based algorithm (GSK) to achieve more efficient exploration by considering the neighborhood of individuals. This strategy avoids complete randomness in the exploration phase and effectively improves the quality of the solution. Finally, Dynamic Opposition-Based learning (DOBL) is introduced to perform population updating according to the fitness ranking of individuals in the population. Based on this, the improved algorithm can further increase the diversity of the solutions obtained, thereby searching the space more efficiently. To verify the effectiveness of the DGSWOA, comparative experiments are conducted on a set of blackbox optimization benchmarking (BBOB) and two engineering application problems. The experimental results show that the performance of the WOA algorithm is significantly enhanced by using these innovative strategies.

The remainder of this paper is structured as follows. A brief description of the Whale Optimization Algorithm is presented in Section 2. Delving into the DGSWOA algorithm, Section 3 provides a detailed explanation of its methodology. Detailed comparative experiments are given in Section 4. Following this, Section 5 applies the DGSWOA algorithm to two specific engineering design problems, with an in-depth analysis of the results. Concluding the paper, Section 6 discusses the main findings and outlines potential directions for future research.

2. Whale Optimization Algorithm

Mirjalili and Lewis [9] introduced the Whale Optimization Algorithm in 2016, which drew inspiration from the hunting behavior of humpback whales. The main hunting behaviors include encircling prey, bubble-net attacking, and searching for prey. In the WOA, the mathematical model corresponding to these three predatory behaviors is described as follows.

2.1. Encircling Prey

In this phase, the Whale Optimization Algorithm simulates humpback whales' behavior in identifying and surrounding prey. The target prey is assumed to be the optimal solution for the current population. The focus of this phase is to efficiently narrow down

the search and focus around the potential optimal solution. The following mathematical formula can be used to describe this behavior:

$$X(t + 1) = X^* - A \cdot D_1 \tag{1}$$

$$D_1 = |C \cdot X^* - X(t)| \tag{2}$$

where t represents the current iteration number, $X(t + 1)$ denotes the next search position, $X(t)$ represents the current iteration position, and X^* signifies the optimal position of the prey in this iteration. The distance between the prey and the whale at $X(t)$ in the current iteration is denoted by D_1 . The mathematical formulas used for computing A and C are as follows:

$$A = 2a \cdot r - a \tag{3}$$

$$C = 2 \cdot r \tag{4}$$

$$a = 2 - \frac{2t}{MaxIter} \tag{5}$$

where r represents random numbers within the interval $[0, 1]$ and a denotes the convergence factor, decreasing from 2 to 0 as the number of iterations increases. Additionally, $MaxIter$ defines the maximum number of iterations permitted and is the maximum value of t .

2.2. Bubble-Net Attacking

The bubble-net attack phase mimics the behavior of the humpback whale as it spirals upwards during feeding. During this phase, the whale approaches the predicted prey location in a spiral path. The following mathematical formula can be used to describe this behavior:

$$X(t + 1) = D_2 \cdot e^{bl} \cdot \cos(2\pi l) + X^* \tag{6}$$

$$D_2 = |X^* - X(t)| \tag{7}$$

where D_2 represents the current distance between the whale and its prey, which is defined as the optimal solution. The mathematical model of the spiral path is formed by e^{bl} and $\cos(2\pi l)$, with b serving as a constant that shapes the spiral and l being a random number in $[-1, 1]$.

Both the encircling and spiral attack mechanisms are in the developmental stage. In this phase, humpback whales are constantly reducing their range of motion while engaging in spiral hunting. p is a random number in $[0, 1]$. It is assumed that the probability p of selecting both mechanisms is the same, 50 percent each. To model both scenarios, we used the following equation:

$$X(t + 1) = \begin{cases} X^* - A \cdot D_1, & \text{if } p < 0.5 \\ D_2 \cdot e^{bl} \cdot \cos(2\pi l) + X^*, & \text{if } p \geq 0.5 \end{cases} \tag{8}$$

2.3. Search for Prey

The explore prey phase is a global search strategy in WOA to recognize new potential target areas in the solution space. In this phase, whales randomly select a search target and update their current position based on the target. The following formula can be used to describe this behavior:

$$X(t + 1) = X_{rand}(t) - A \cdot D_3 \tag{9}$$

$$D_3 = |C \cdot X_{rand}(t) - X(t)| \tag{10}$$

where $X_{rand}(t)$ represents the position of a randomly selected whale in the current iteration and acts as a random target, and D_3 denotes the distance between the current individual and this random target. A and C will be calculated using Equations (3) and (4). This phase is intended to prevent premature convergence to a local optimum while maintaining search diversity.

The selection of the three behaviors is contingent on A and p , as illustrated in Figure 1. The spiral bubble-net attack is chosen when $p \geq 0.5$, whereas encircling prey is opted for when $p < 0.5$ and $|A| < 1$. If $|A| \geq 1$ and $p < 0.5$, global exploration is conducted.

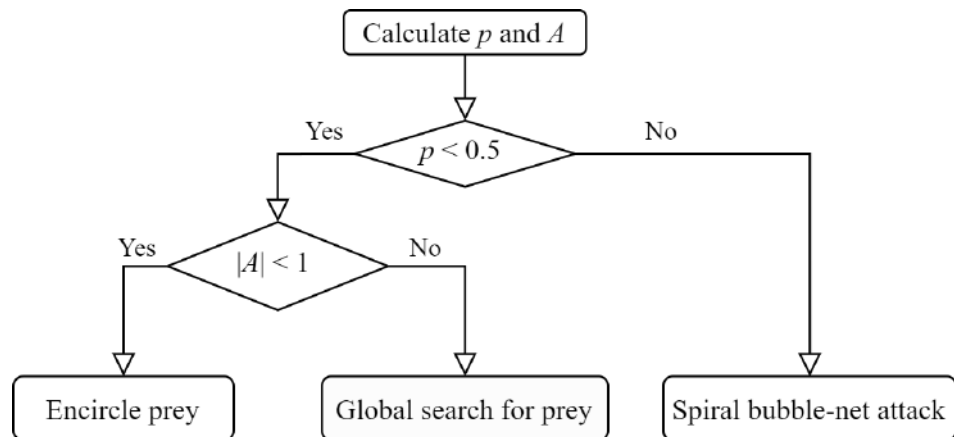


Figure 1. Three selection stages in WOA.

3. Improved Whale Optimization Algorithm

In this section, we first describe in detail the three strategies utilized in the DGSWOA. Then, the overall process and pseudo-code for the DGSWOA are presented. Finally, an analysis of the algorithm’s complexity is provided.

3.1. Sine–Tent–Cosine Map

The initial population distribution has a direct impact on the accuracy and convergence speed of the swarm intelligence optimization algorithm. The original WOA generates the initial population randomly, which may result in a non-uniform spread of individuals throughout the potential solution space. This approach can potentially limit the algorithm’s ability to explore the search space, impacting its overall effectiveness in locating optimal solutions. Chaotic behavior is distinguished by a great degree of unpredictability and randomness [22,23]. This property assists the algorithm in exploring a broader search area and circumventing premature convergence.

In [24], Hua et al. proposed a cosine transform-based chaotic system (CTBCS) that can generate chaotic mappings with complex behaviors using any two chaotic mappings. The chaotic mappings generated by CTBCS are applied to image encryption algorithms, which improve the randomness and security of the algorithms. Both image encryption algorithms and population initialization rely on core properties in chaos theory, such as unpredictability, sensitivity to initial conditions, and the iterative nature. Considering this common property, we choose to use the Sine–Tent–Cosine map generated by CTBCS for the population initialization in the DGSWOA. This strategy ensures a more evenly distributed initial population, enhancing the algorithm’s efficiency in searching for optimal solutions in the search space. The formula for the Sine–Tent–Cosine map is as follows:

$$X_{i+1} = \begin{cases} \cos(\pi(r \sin(\pi X_i) + 2(1 - r)X_i - 0.5)) & \text{if } X_i < 0.5, \\ \cos(\pi(r \sin(\pi X_i) + 2(1 - r)(1 - X_i) - 0.5)) & \text{otherwise.} \end{cases} \quad (11)$$

where r is a control parameter for Logistic, Sine, and Tent mappings within the range $[0, 1]$. Figure 2 presents the bifurcation diagrams of the STC. The figure shows that the output of the STC is randomly distributed throughout the plane. It shows that the output of the STC is more random and unpredictable, which helps to ensure a uniform distribution of individuals.

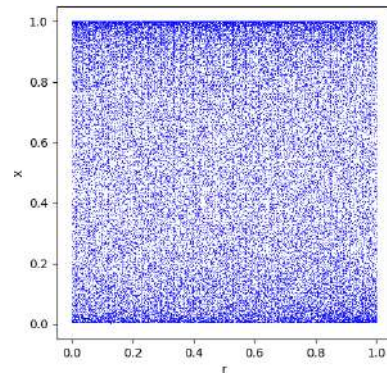


Figure 2. Bifurcation diagram of the Sine–Tent–Cosine map.

3.2. Gaining–Sharing Knowledge Based Algorithm

The gaining–sharing knowledge based algorithm (GSK) [25] is a new natural heuristic algorithm proposed by Mohamed et al. in 2019. The design of this algorithm is inspired by the process of knowledge acquisition and sharing in human society. It has excellent performance in solving optimization problems, especially high-dimensional problems. The GSK algorithm is mainly divided into a junior gaining–sharing knowledge phase and a senior gaining–sharing knowledge phase. The first phase is used to simulate individuals gaining knowledge through small social networks. The second phase is used to simulate individuals gaining knowledge through large social networks.

The junior gaining–sharing knowledge phase is similar to the exploration phase of the optimization process, where the core purpose is to explore and find possible optimization directions in a wide solution space. In this process, individuals place more emphasis on gaining and sharing knowledge, and try to find better solutions through continuous learning and communication. Unlike the random method, the exploration process in this stage has a clear purpose, making the exploration process more efficient and helping to identify potential optimization directions more quickly. The junior gaining–sharing knowledge phase is able to find an effective balance between exploration and exploitation. This means that new solutions are explored while existing knowledge is exploited to maximize the efficiency of the search. By balancing exploration and exploitation, it ensures that new optimization directions can be found while quickly exploiting existing results, thus increasing the convergence speed and the quality of the solutions. Therefore, we introduce the junior gaining–sharing knowledge phase of the GSK algorithm to improve the global search in the original WOA algorithm. The formula is as follows:

$$X_{i,j} = \begin{cases} X_{i,j} + k_f((X_{i,j-1} - X_{i,j+1}) + (X_{\text{rand}} - X_{i,j})) & \text{if } \text{fun}(X_i) > \text{fun}(X_{\text{rand}}) \\ X_{i,j} + k_f((X_{i,j-1} - X_{i,j+1}) + (X_{i,j} - X_{\text{rand}})) & \text{if } \text{fun}(X_i) \leq \text{fun}(X_{\text{rand}}) \end{cases} \quad (12)$$

where k_f denotes the knowledge factor, a number greater than 0, which we set to 0.5. X_{rand} denotes a randomly selected individual and $\text{fun}(X_i)$ denotes the fitness value of individual X_i .

3.3. Dynamic Opposition-Based Learning

Opposition-Based Learning (OBL) [26] is a heuristic learning strategy. The core idea is to simultaneously consider the opposites of the current solution during the search process with the aim of finding the globally optimal solution faster. Li et al. [14] used OBL to initialize the population. Shekhawat et al. [27] used OBL to optimize the Crow Search Algorithm. The OBL strategy and its related variants have been widely used to improve a variety of algorithms, significantly improving their global search capability and convergence speed.

In [28], an innovative variant of the OBL strategy is proposed that introduces dynamic factors and incorporates them into the NSGA-II algorithm. This resulted in a multi-objective

optimization algorithm, ONDX-NSGA-II, which was applied to optimize the structural parameters of a permanent magnet eddy current coupler (PMECC). Inspired by this research, we innovatively introduce a dynamic factor δ into the OBL strategy, enhancing its adaptability. This dynamic factor is designed to gradually decrease as the number of iterations increases, effectively modulating the impact of DOBL. At the same time, the lower the rank of the individual in the population, the greater the impact of DOBL. This can effectively ensure the speed of convergence of the algorithm. It takes into account individual differences and increases the diversity of solutions. The formulas for DOBL are as follows:

$$X'_i = ub_i + lb_i - \delta \cdot X_i \quad (13)$$

$$\delta = \delta_{MAX} - \frac{t}{MaxIter} \times (\delta_{MAX} - \delta_{MIN}) \quad (14)$$

$$\delta_{MIN} = \frac{rank_i}{pop} \times \delta_{MAX} \quad (15)$$

where X'_i represents the inverse solution for the current individual, ub and lb represent the upper and lower limits of the population, δ denotes the dynamic factor, δ_{MAX} is the maximum value of the dynamic factor, set to 1, δ_{MIN} is the minimum value of the dynamic factor, t denotes the current number of iterations, and $MaxIter$ defines the maximum number of iterations permitted. $rank_i$ denotes the current ranking of the individual's fitness value in the population and pop denotes the number of individuals in the population. In order to present the overall process of the DOBL strategy more clearly, the pseudo-code of the DOBL strategy is given in Algorithm 1.

Algorithm 1 Function DOBL

```

function DOBL( $X, t, fun, MaxIter$ )
  Initialize  $\delta_{MAX}$  to 1
  Initialize  $X_{opposite}$  and  $X_{D_{opposite}}$  as zero matrices of the same size as  $X$ 
  Compute fitness for each individual in  $X$  using  $fun$ 
  Sort  $X$  based on fitness to obtain a ranked population
  for each individual  $X_i$  in  $X$  do
    for each dimension  $j$  do
      Determine the rank of  $X_i$ 
      Calculate  $\delta_{MIN}$  and  $\delta$  for  $X_i$  based on its rank and  $t$  //using
      Equations (14) and (15)
      Compute opposite and dynamically opposite solutions for  $X_i$  //using
      Equation (13)
    end for
  end for
  Combine  $X, X_{opposite},$  and  $X_{D_{opposite}}$  into a single population
  Compute fitness for the combined population using  $fun$ 
  Sort the combined population based on fitness
  return the top third of the sorted combined population
end function

```

3.4. DGSWOA Algorithm Description

The flowchart of the proposed algorithm is shown in Figure 3. DGSWOA consists of four main phases: population initialization, parameter calculation, behavior selection, and individual updating. In population initialization, the STC strategy is employed to initialize the population by Equation (11). Based on this, a more uniformly distributed initial population can be obtained. Then, the parameters p and A are calculated in the parameter calculation phase. For behavior selection, an improved global search prey strategy, GSK, is introduced for directing the exploration. This strategy effectively improves the quality of the solution. One of the behaviors of encircling prey, searching for prey, and bubble-net

attacking is chosen to update the individual depending on the values of p and A . Next, DOBL is used to update population individuals to further expand the search area of the population in the individual updation phase. DOBL dynamically calculates the reverse individual based on the individual's fitness ranking by Equation (13). Finally, a boundary check is performed on each individual to ensure that they fall within the specified bounds of lb and ub . Any individual that exceeds these bounds will be adjusted accordingly. Once the maximum number of iterations is reached, the algorithm terminates and returns the best solution so far. The pseudo-code of DGSWOA is shown in Algorithm 2. pop is the population size; dim denotes the dimensionality variable. lb and ub are the upper and lower bounds, respectively. $MaxIter$ is the maximum number of iterations and fun is the defined fitness function.

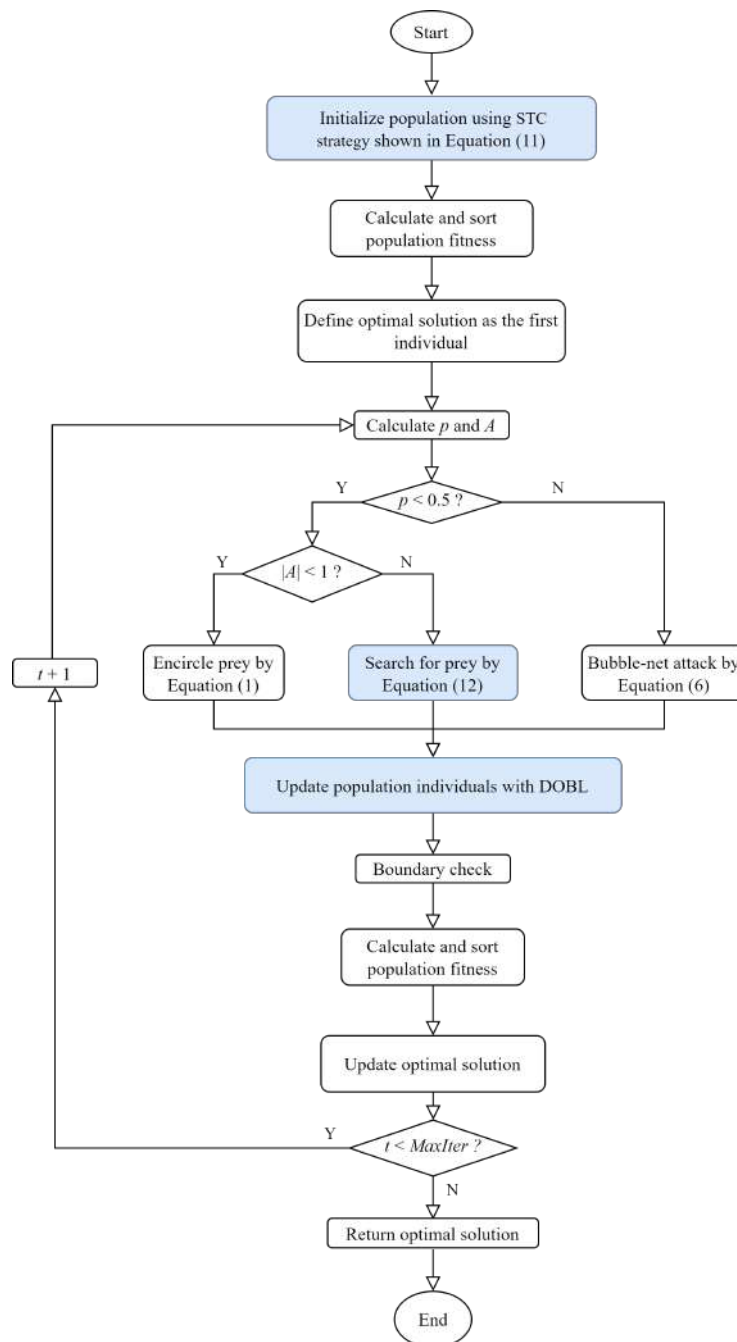


Figure 3. Flowchart of the DGSWOA.

Algorithm 2 DGSWOA Algorithm

Input: $pop, dim, lb, ub, MaxIter, fun$
Output: Global best score, position
Initialize the population X using STC strategy //using Equation (11)
Compute fitness for each individual in X
Sort X based on fitness and determine the global best
for each iteration t up to $MaxIter$ **do**
 Update linearly weight a
 for each individual X_i in the population **do**
 for each dimension j **do**
 Update the position of whale X_i based on the three behaviors //using Equations (1), (6) and (12) for encircling prey, bubble-net attacking and searching prey, respectively
 end for
 end for
 Apply boundary check to the population
 Update the population individuals using DOBL, which is described in Algorithm 1
 Recalculate fitness and update the global best if found
end for
return the global best score, position

3.5. Complexity Analysis

Algorithm complexity is a fundamental concept in computer science. It is used to evaluate the efficiency of an algorithm's execution and the resources it requires. This concept is divided into two main dimensions: the complexity of time and the complexity of space. Time complexity measures the time required to execute an algorithm, while space complexity measures the amount of memory or storage space occupied by the algorithm during execution.

We assume that the number of populations is N , the dimension is D , and the number of iterations is T . Since the algorithm does not add variables, it does not increase the space complexity of the algorithm, which remains $O(N * D)$. We assume that the time complexity of the fitness value function is $O(F)$. In each iteration of the algorithm, the position of each individual is initially updated, an operation that manifests a time complexity of $O(N * D)$. This is followed by a boundary check, ensuring each individual's position remains within the predefined limits with a time complexity of $O(N * D)$. Subsequently, the fitness value for each individual is computed, incurring a computational cost of $O(N * F)$. Upon the completion of the fitness evaluation, the population is sorted in accordance with these fitness values, a procedure that entails a time complexity of $O(N * \log(N))$. The final step in each iteration is DOBL, which similarly possesses a time complexity of $O(N * D)$. Aggregating the computational demands of these steps, the total time complexity per iteration can be approximately delineated as $O(N * D + N * F + N \log(N))$. Consequently, when considering the maximum number of iterations of the algorithm, the total time complexity of the entire algorithm can be approximated as $O(T * (N * D + N * F + N \log(N)))$.

4. Experimental Design and Results Analysis

In this section we present detailed information about the experiments and analysis of the results. This includes a comparison of the effects of different strategies on the algorithms and a comparison between different optimization algorithms.

4.1. Parameter Settings

All experiments in this paper were conducted on a Windows 10 system with 16 G memory and a Python 3.9 environment. The size of the population was set to 30 and the maximum number of iterations was set to 500. For each test function, all algorithms of the same dimension were run independently 30 times. They are compared with the particle swarm optimization (PSO) [4], the genetic algorithm (GA) [29], the gray wolf optimizer

(GWO) [30], the butterfly optimization algorithm (BOA) [31], the seagull optimization algorithm (SOA) [32], the Whale Optimization Algorithm (WOA) [9], LWOA [33], and MSWOA [34]. The parameter settings for each algorithm are shown in Table 1.

Table 1. Parameter settings of optimization algorithms.

Algorithms	Iteration	Population	Details
WOA	500	30	$b = 1, c = 2 \cdot rand, a = 2 - \frac{2t}{MaxIter}, A = 2 \cdot a \cdot r - a$
PSO	500	30	$C1 = C2 = 1.494, \omega = [0.4, 0.9]$
GA	500	30	Roulette wheel selection, a mutation probability of 0.1, and uniform crossover with a crossover probability of 1
GWO	500	30	$a = 2 - \frac{2t}{MaxIter}$
BOA	500	30	$p = 0.8$, power exponent = 0.1, sensory modality = 0.1
SOA	500	30	$fc = 2, u = v = 1$
LWOA	500	30	$\beta = 1.5, b = 1, c = 2 \cdot rand, a = 2 - \frac{2t}{MaxIter}, A = 2 \cdot a \cdot r - a$
MSWOA	500	30	$\beta = 1.5, b = 1, c = 2 \cdot rand, a = 2 - \frac{2t}{MaxIter}, A = 2 \cdot a \cdot r - a$
DGSWOA	500	30	$kf = 0.5, \delta_{MAX} = 1, b = 1, c = 2 \cdot rand, a = 2 - \frac{2t}{MaxIter}, A = 2 \cdot a \cdot r - a$

4.2. Benchmark Functions

The Blackbox Optimization Benchmarking (BBOB) test suite [35] is selected to evaluate the performance of our algorithm, which is listed in Table 2. The suite features 24 noise-free, single-objective, and expandable test functions available in multiple dimensions (2, 3, 5, 10, 20, 40). The difficulty of the problems increases with the number of dimensions. Among them, F₁–F₅ are separable functions focusing on the algorithm’s ability to identify the global optimal solution. F₆–F₉ are functions with low or moderate conditioning. F₁₀–F₁₄ are functions with high conditioning and unimodal. F₁₅–F₁₉ are multimodal functions with adequate global structure, focusing on the algorithm’s ability to balance between exploration and exploitation. F₂₀–F₂₄ are multimodal functions with weak global structure testing the algorithm’s robustness and ability to avoid falling into local optima. The analysis of DGSWOA is based on the mean, standard deviation, optimal and worst solutions obtained for each iteration, and the rank based on the mean. This approach not only measures its average performance and stability, but also identifies its highest and lowest performance benchmarks. Furthermore, ranking by average outcomes facilitates a direct comparison with competing algorithms, highlighting DGSWOA’s relative strengths.

Table 2. Benchmark functions.

F	Functions	Dimension	Search Range
F ₁	Sphere Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂	Separable Ellipsoidal Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₃	Rastrigin Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₄	Büche–Rastrigin Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₅	Linear Slope	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₆	Attractive Sector Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₇	Step Ellipsoidal Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₈	Rosenbrock Function, original	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₉	Rosenbrock Function, rotated	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₀	Ellipsoidal Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₁	Discus Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₂	Bent Cigar Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₃	Sharp Ridge Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₄	Different Powers Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₅	Rastrigin Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₆	Weierstrass Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₇	Schaffer’s F7 Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₈	Schaffer’s F7 Function, moderately ill-conditioned	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₁₉	Composite Griewank–Rosenbrock Function F8F2	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂₀	Schwefel Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂₁	Gallagher’s Gaussian 101-me Peaks Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂₂	Gallagher’s Gaussian 21-hi Peaks Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂₃	Katsuura Function	2, 3, 5, 10, 20, 40	[−5 to 5]
F ₂₄	Lunacek bi-Rastrigin Function	2, 3, 5, 10, 20, 40	[−5 to 5]

4.3. Impact of Different Strategies on the Algorithm

This section gives an analysis of the reasonableness and applicability of three strategies and discusses in detail their impact on the algorithm. The BBOB at dimension 10 is used as the benchmark function. The Sine–Tent–Cosine map is integrated with the basic WOA in the approach named SWOA. The gaining–sharing knowledge-based algorithm is introduced in the approach known as GWOA. Additionally, Dynamic Opposition-Based Learning is combined in the approach referred to as DWOA. In the case of dimension 10, they are compared to the original WOA and DGSWOA, respectively, through simulation experiments with BBOB. The results obtained from the experiments have been provided in Table 3, which clearly shows the performance of the considered strategies.

Table 3. Effects of various improvements (dimension 10).

Function	Criteria	WOA	SWOA	GWOA	DWOA	DGSWOA
F ₁	Mean	-9.18×10^1	-9.17×10^1	-9.19×10^1	-9.15×10^1	-9.18×10^1
	Std	3.88×10^{-1}	5.67×10^{-1}	3.83×10^{-1}	5.79×10^{-1}	4.12×10^{-1}
	Best	-9.23×10^1	-9.23×10^1	-9.26×10^1	-9.22×10^1	-9.26×10^1
	Worst	-9.11×10^1	-9.13×10^1	-9.13×10^1	-9.02×10^1	-9.10×10^1
	rank	2	4	1	5	3
F ₂	Mean	7.90×10^3	9.22×10^3	9.30×10^3	5.61×10^3	7.23×10^3
	Std	3.92×10^3	5.12×10^3	6.70×10^3	1.33×10^3	2.31×10^3
	Best	3.22×10^3	3.70×10^3	5.43×10^3	2.03×10^3	5.72×10^3
	Worst	1.67×10^4	2.63×10^4	2.63×10^4	6.99×10^3	1.23×10^4
	rank	3	4	5	1	2
F ₃	Mean	6.94×10^1	7.58×10^1	7.35×10^1	8.02×10^1	6.91×10^1
	Std	9.72×10^0	1.08×10^1	8.73×10^0	1.56×10^1	9.24×10^0
	Best	5.06×10^1	5.37×10^1	5.97×10^1	6.36×10^1	5.59×10^1
	Worst	8.12×10^1	9.15×10^1	9.15×10^1	1.12×10^2	8.51×10^1
	rank	2	4	3	5	1
F ₄	Mean	10.00×10^1	1.06×10^2	9.89×10^1	9.99×10^1	9.39×10^1
	Std	1.24×10^1	1.35×10^1	2.23×10^1	1.66×10^1	9.63×10^0
	Best	8.05×10^1	9.31×10^1	5.14×10^1	6.89×10^1	7.70×10^1
	Worst	1.19×10^2	1.29×10^2	1.29×10^2	1.21×10^2	1.05×10^2
	rank	4	5	2	3	1
F ₅	Mean	5.19×10^1	5.18×10^1	5.20×10^1	5.17×10^1	5.19×10^1
	Std	6.38×10^{-1}	3.74×10^{-1}	9.33×10^{-1}	3.68×10^{-1}	7.29×10^{-1}
	Best	5.15×10^2	5.15×10^1	5.15×10^0	5.15×10^1	5.15×10^2
	Worst	5.33×10^1	5.45×10^1	5.45×10^1	5.27×10^1	5.39×10^1
	rank	3	2	5	1	4
F ₆	Mean	1.06×10^2	9.96×10^1	9.95×10^1	1.04×10^2	9.40×10^1
	Std	1.22×10^1	6.94×10^0	5.86×10^0	1.02×10^1	5.93×10^0
	Best	8.71×10^1	8.70×10^1	8.68×10^1	9.13×10^1	8.50×10^1
	Worst	1.26×10^2	1.08×10^2	1.08×10^2	1.26×10^2	1.02×10^2
	rank	5	3	2	4	1
F ₇	Mean	-7.01×10^1	-7.00×10^1	-7.44×10^1	-7.41×10^1	-7.68×10^1
	Std	5.74×10^0	3.70×10^0	4.70×10^0	5.50×10^0	3.87×10^0
	Best	-8.06×10^1	-7.77×10^1	-7.94×10^1	-8.19×10^1	-8.16×10^1
	Worst	-6.17×10^1	-6.36×10^1	-6.36×10^1	-6.42×10^1	-6.88×10^1
	rank	4	5	2	3	1
F ₈	Mean	1.93×10^0	9.61×10^1	-9.08×10^1	-6.03×10^1	-3.79×10^1
	Std	1.25×10^2	1.96×10^2	3.23×10^1	5.97×10^1	7.36×10^1
	Best	-1.00×10^2	-1.23×10^2	-1.31×10^2	-1.32×10^2	-1.16×10^2
	Worst	2.39×10^2	4.66×10^2	-3.03×10^0	-3.03×10^1	9.40×10^1
	rank	4	5	1	2	3
F ₉	Mean	-3.47×10^2	-3.48×10^2	-3.51×10^2	-3.45×10^2	-3.49×10^2
	Std	4.37×10^0	4.54×10^0	2.79×10^0	6.72×10^0	4.07×10^0
	Best	-3.56×10^2	-3.55×10^2	-3.56×10^2	-3.55×10^2	-3.56×10^2
	Worst	-3.39×10^2	-3.47×10^2	-3.47×10^3	-3.35×10^2	-3.43×10^2
	rank	4	3	1	5	2

Table 3. Cont.

Function	Criteria	WOA	SWOA	GWOA	DWOA	DGSWOA
F ₁₀	Mean	9.12×10^3	8.36×10^3	8.91×10^3	1.27×10^4	7.51×10^3
	Std	3.50×10^3	6.20×10^3	5.25×10^3	7.66×10^3	4.45×10^3
	Best	4.48×10^3	9.03×10^2	1.22×10^3	5.29×10^3	7.13×10^2
	Worst	1.58×10^4	1.92×10^4	1.92×10^4	3.34×10^4	1.66×10^4
	rank	4	2	3	5	1
F ₁₁	Mean	-3.99×10^1	-3.68×10^1	-4.14×10^1	-4.54×10^1	-4.79×10^1
	Std	5.68×10^0	1.09×10^1	1.10×10^1	6.99×10^0	9.72×10^0
	Best	-5.13×10^1	-4.77×10^1	-6.27×10^1	-5.56×10^1	-6.32×10^1
	Worst	-3.34×10^1	-2.49×10^1	-2.49×10^1	-2.81×10^1	-3.03×10^1
	rank	4	5	3	2	1
F ₁₂	Mean	4.48×10^5	3.01×10^5	6.12×10^5	3.75×10^5	5.00×10^5
	Std	5.34×10^5	2.77×10^5	6.07×10^5	1.81×10^5	3.32×10^5
	Best	1.11×10^3	1.80×10^3	4.25×10^3	1.07×10^5	3.40×10^3
	Worst	1.88×10^6	2.32×10^6	2.32×10^6	5.80×10^5	1.29×10^6
	rank	3	1	5	2	4
F ₁₃	Mean	1.10×10^2	9.89×10^1	1.19×10^2	1.19×10^2	8.12×10^1
	Std	3.80×10^1	4.71×10^1	6.02×10^1	4.30×10^1	5.91×10^1
	Best	5.56×10^1	3.80×10^1	-1.72×10^1	4.35×10^1	-3.90×10^1
	Worst	1.57×10^2	1.87×10^2	1.87×10^2	2.00×10^2	1.64×10^2
	rank	3	2	5	4	1
F ₁₄	Mean	-5.73×10^1	-5.72×10^1	-5.74×10^1	-5.74×10^1	-5.74×10^1
	Std	3.38×10^{-1}	2.35×10^{-1}	2.96×10^{-1}	3.29×10^{-1}	2.46×10^{-1}
	Best	-5.78×10^1	-5.77×10^1	-5.77×10^1	-5.78×10^1	-5.79×10^1
	Worst	-5.65×10^1	-5.70×10^1	-5.70×10^1	-5.68×10^1	-5.71×10^1
	rank	4	5	1	3	2
F ₁₅	Mean	1.57×10^1	1.77×10^1	1.99×10^1	1.94×10^1	1.80×10^1
	Std	7.15×10^0	9.95×10^0	1.24×10^1	8.13×10^0	1.23×10^1
	Best	3.01×10^0	5.80×10^0	1.13×10^0	7.08×10^0	-7.62×10^0
	Worst	2.43×10^1	5.08×10^1	5.08×10^1	3.78×10^1	3.43×10^1
	rank	1	2	5	4	3
F ₁₆	Mean	-2.55×10^2	-2.56×10^2	-2.53×10^2	-2.54×10^2	-2.56×10^2
	Std	1.51×10^0	1.89×10^0	1.97×10^0	2.75×10^0	2.31×10^0
	Best	-2.57×10^2	-2.59×10^2	-2.57×10^2	-2.59×10^2	-2.59×10^2
	Worst	-2.52×10^2	-2.51×10^2	-2.51×10^2	-2.49×10^2	-2.51×10^2
	rank	3	2	5	4	1
F ₁₇	Mean	-3.73×10^1	-3.70×10^1	-3.70×10^1	-3.70×10^1	-3.69×10^1
	Std	6.09×10^{-1}	5.98×10^{-1}	3.91×10^{-1}	5.33×10^{-1}	3.40×10^{-1}
	Best	-3.85×10^1	-3.80×10^1	-3.77×10^1	-3.82×10^1	-3.75×10^1
	Worst	-3.62×10^1	-3.64×10^1	-3.64×10^2	-3.62×10^1	-3.63×10^1
	rank	1	3	4	2	5
F ₁₈	Mean	-3.30×10^1	-3.22×10^1	-3.36×10^1	-3.36×10^1	-3.37×10^1
	Std	1.70×10^0	1.38×10^0	1.72×10^0	1.91×10^0	7.92×10^{-1}
	Best	-3.51×10^1	-3.39×10^1	-3.60×10^1	-3.57×10^1	-3.49×10^1
	Worst	-2.92×10^1	-2.91×10^1	-3.02×10^1	-3.02×10^1	-3.23×10^1
	rank	4	5	3	2	1
F ₁₉	Mean	4.13×10^1	4.10×10^1	4.13×10^1	4.06×10^1	4.06×10^1
	Std	5.43×10^{-1}	3.52×10^{-1}	3.48×10^{-1}	3.76×10^{-2}	4.11×10^{-2}
	Best	4.07×10^1	4.05×10^1	4.09×10^1	4.05×10^1	4.05×10^1
	Worst	4.23×10^1	4.21×10^1	4.21×10^1	4.06×10^1	4.07×10^1
	rank	4	3	5	1	2
F ₂₀	Mean	1.85×10^2	1.85×10^2	1.85×10^2	1.85×10^2	1.85×10^2
	Std	2.44×10^{-1}	3.33×10^{-1}	3.30×10^{-1}	2.81×10^{-1}	3.25×10^{-1}
	Best	1.85×10^2	1.85×10^2	1.85×10^2	1.85×10^2	1.85×10^2
	Worst	1.86×10^2	1.86×10^2	1.86×10^2	1.86×10^2	1.86×10^2
	rank	5	2	4	3	1
F ₂₁	Mean	3.13×10^2	3.14×10^2	3.15×10^2	3.15×10^2	3.14×10^2
	Std	1.37×10^0	2.58×10^0	2.01×10^0	2.86×10^0	1.98×10^0
	Best	3.11×10^2	3.11×10^2	3.13×10^2	3.13×10^2	3.11×10^2
	Worst	3.17×10^2	3.18×10^2	3.18×10^2	3.22×10^2	3.17×10^2
	rank	1	2	5	4	3

Table 3. Cont.

Function	Criteria	WOA	SWOA	GWOA	DWOA	DGSWOA
F ₂₂	Mean	4.94×10^1	4.90×10^1	4.92×10^1	4.94×10^1	4.58×10^1
	Std	5.92×10^0	3.21×10^0	4.68×10^0	5.72×10^0	5.73×10^{-1}
	Best	4.50×10^1	4.49×10^1	4.53×10^1	4.53×10^1	4.48×10^1
	Worst	6.55×10^1	6.10×10^1	6.10×10^1	6.52×10^1	4.68×10^1
	rank	5	2	3	4	1
F ₂₃	Mean	2.11×10^2	2.11×10^2	2.11×10^2	2.11×10^2	2.12×10^2
	Std	2.88×10^{-1}	3.16×10^{-1}	3.41×10^{-1}	3.53×10^{-1}	2.59×10^{-1}
	Best	2.11×10^2	2.11×10^2	2.11×10^2	2.11×10^2	2.11×10^2
	Worst	2.12×10^2	2.12×10^2	2.12×10^2	2.12×10^2	2.12×10^2
	rank	4	3	1	2	5
F ₂₄	Mean	1.15×10^2	1.15×10^2	1.12×10^2	1.12×10^2	1.11×10^2
	Std	4.00×10^0	4.46×10^0	4.81×10^0	5.36×10^0	5.06×10^0
	Best	1.07×10^2	1.08×10^2	1.03×10^2	1.05×10^2	1.03×10^2
	Worst	1.21×10^2	1.20×10^2	1.20×10^2	1.24×10^2	1.19×10^2
	rank	4	5	3	2	1
Average Rank		3.38	3.29	3.21	3.04	2.08
Combined Rank		5	4	3	2	1

Note: Some similar data are due to rounding to two decimal places. Differences exist beyond this precision.

SWOA ranks in the top two for F₅, F₁₀, F₁₃, F₁₅, F₁₆, and F₂₀–F₂₂, with the highest level of improvement for F₁₂, which ranks first. GWOA ranks first for optimization in F₁, F₈, F₉, F₁₄, and F₂₃. DWOA performs better in most of the cases, where it ranks first on F₂, F₅, and F₁₉. Overall, SWOA is more adept at solving single-peak problems and specific types of multi-peak problems with strong local search capabilities. GWOA is obviously better at solving multi-peak problems and can effectively avoid falling into local optima. And DWOA is very comprehensive and universal, and it can deal with single-peak problems well and solve multi-peak problems effectively, indicating that it has good global search ability and adaptability.

The average ranking is calculated by dividing the cumulative ranking by the total number of benchmark functions. The algorithms are then ranked according to the average ranking. The algorithms with the smallest average ranking perform the best and have the highest combined performance ranking. From the data, all the three improved algorithms outperform the original WOA. Dynamic Opposition-Based Learning has the highest performance improvement followed by the gaining–sharing knowledge based algorithm and finally the Sine–Tent–Cosine map. Once the three strategies are fused together, the DGSWOA proposed in this paper can achieve the best performance. This also indicates that the DGSWOA is an effective multi-strategy improvement algorithm.

4.4. Optimization Results Comparison

In this subsection, we analyze the performance of the algorithm in detail. It starts with an in-depth study of various performance criteria. Subsequently, we present the results of the Wilcoxon Signed-Rank test, a statistical method used to compare the results of improved algorithms with those of other well-established algorithms.

4.4.1. Algorithm Performance Criteria Analysis

This subsection is used to compare the effectiveness of the performance of the proposed DGSWOA. Eight well-known algorithms were run on BBOB and the data were analyzed, as shown in Tables 4–9. In Table 10, the overall rank data for the compared algorithms are described. DGSWOA holds the top ranking in all six dimensions, demonstrating its ability to perform well on problems of varying complexity. Even as the dimensions increase, DGSWOA keeps the top overall ranking, indicating that the algorithm has good stability and robustness to changes in dimensionality. Meanwhile, DGSWOA demonstrates an excellent global search capability, especially when dealing with multimodal functions. When the dimension is 2, the DGSWOA is able to find the optimal solutions in F₁₅, F₁₉, F₂₀,

F₂₁, F₂₃, and F₂₄ in the first rank. The algorithm performs well on multimodal functions such as F₁₆, F₁₇, F₁₈, and F₁₉ on 5- and 10-dimensional problems. At 20 and 40 dimensions, DGSWOA continues to lead on highly complex multimodal functions such as F₁₆, F₂₂, and F₂₃. This demonstrates DGSWOA’s excellent ability to avoid local optimal solutions. And it is able to maintain efficient and stable performance in different problems and dimensions. The experimental data clearly show that the improved algorithm is effective and successfully enhances the global search capability.

Table 4. Comparative experimental results (dimension = 2).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	-9.26×10^1	2.04×10^{-3}	-9.26×10^1	-9.26×10^1	8	1.86×10^{-9}	+
	GA	-9.26×10^1	2.22×10^{-4}	-9.26×10^1	-9.26×10^1	7	1.86×10^{-9}	+
	GWO	-9.26×10^1	1.52×10^{-7}	-9.26×10^1	-9.26×10^1	1	1.35×10^{-1}	≈
	WOA	-9.26×10^1	6.15×10^{-7}	-9.26×10^1	-9.26×10^1	4	1.00×10^{-1}	≈
	BOA	-9.17×10^1	8.30×10^{-1}	-9.26×10^1	-8.92×10^1	9	1.86×10^{-9}	+
	SOA	-9.26×10^1	1.58×10^{-5}	-9.26×10^1	-9.26×10^1	5	9.31×10^{-9}	+
	LWOA	-9.26×10^1	2.20×10^{-4}	-9.26×10^1	-9.26×10^1	6	1.86×10^{-9}	+
	MSWOA	-9.26×10^1	6.00×10^{-7}	-9.26×10^1	-9.26×10^1	3	5.43×10^{-1}	≈
	DGSWOA	-9.26×10^1	2.00×10^{-7}	-9.26×10^1	-9.26×10^1	2		
F ₂	PSO	2.78×10^2	1.93×10^0	2.76×10^2	2.85×10^2	7	1.86×10^{-9}	+
	GA	2.77×10^2	8.55×10^{-1}	2.76×10^2	2.80×10^2	3	5.78×10^{-3}	+
	GWO	2.77×10^2	5.96×10^{-1}	2.76×10^2	2.78×10^2	4	2.61×10^{-8}	+
	WOA	2.77×10^2	3.59×10^{-1}	2.76×10^2	2.78×10^2	2	2.34×10^{-2}	+
	BOA	2.88×10^2	4.15×10^1	2.76×10^2	5.10×10^2	9	1.86×10^{-9}	+
	SOA	2.78×10^2	2.28×10^0	2.76×10^2	2.86×10^2	5	2.69×10^{-5}	+
	LWOA	2.78×10^2	2.10×10^0	2.76×10^2	2.85×10^2	6	1.30×10^{-8}	+
	MSWOA	2.79×10^2	3.05×10^0	2.76×10^2	2.88×10^2	8	3.15×10^{-7}	+
	DGSWOA	2.76×10^2	1.35×10^{-1}	2.76×10^2	2.77×10^2	1		
F ₃	PSO	2.17×10^1	4.56×10^{-1}	2.10×10^1	2.25×10^1	6	8.33×10^{-7}	+
	GA	2.20×10^1	6.19×10^{-1}	2.10×10^1	2.35×10^1	7	1.86×10^{-9}	+
	GWO	2.14×10^1	3.57×10^{-1}	2.09×10^1	2.20×10^1	4	7.99×10^{-6}	+
	WOA	2.10×10^1	1.57×10^{-1}	2.09×10^1	2.15×10^1	2	3.64×10^{-2}	+
	BOA	2.29×10^1	1.33×10^0	2.11×10^1	2.60×10^1	9	9.31×10^{-9}	+
	SOA	2.24×10^1	2.18×10^0	2.09×10^1	2.90×10^1	8	6.91×10^{-7}	+
	LWOA	2.14×10^1	3.44×10^{-1}	2.09×10^1	2.20×10^1	5	2.35×10^{-6}	+
	MSWOA	2.10×10^1	2.98×10^{-1}	2.09×10^1	2.19×10^1	3	4.03×10^{-3}	−
	DGSWOA	2.10×10^1	2.18×10^{-1}	2.09×10^1	2.21×10^1	1		
F ₄	PSO	2.23×10^1	7.99×10^{-1}	2.10×10^1	2.49×10^1	5	1.86×10^{-9}	+
	GA	2.30×10^1	8.45×10^{-1}	2.17×10^1	2.48×10^1	8	3.73×10^{-9}	+
	GWO	2.24×10^1	2.07×10^0	2.10×10^1	2.99×10^1	7	6.92×10^{-6}	+
	WOA	2.11×10^1	1.76×10^{-1}	2.09×10^1	2.16×10^1	1	5.56×10^{-1}	≈
	BOA	2.24×10^1	1.40×10^0	2.09×10^1	2.60×10^1	6	2.08×10^{-5}	+
	SOA	2.34×10^1	3.06×10^0	2.09×10^1	3.10×10^1	9	4.42×10^{-6}	+
	LWOA	2.18×10^1	4.59×10^{-1}	2.10×10^1	2.25×10^1	4	6.15×10^{-8}	+
	MSWOA	2.11×10^1	3.98×10^{-1}	2.09×10^1	2.19×10^1	2	5.23×10^{-2}	≈
	DGSWOA	2.11×10^1	2.87×10^{-1}	2.09×10^1	2.21×10^1	3		
F ₅	PSO	5.18×10^1	1.84×10^{-1}	5.16×10^1	5.23×10^1	6	1.86×10^{-9}	+
	GA	5.25×10^1	5.01×10^{-1}	5.17×10^1	5.35×10^1	7	1.86×10^{-9}	+
	GWO	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	WOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	BOA	5.61×10^1	3.66×10^0	5.16×10^1	6.82×10^1	9	NaN	NaN
	SOA	5.26×10^1	2.69×10^0	5.15×10^1	6.15×10^1	8	NaN	NaN
	LWOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	MSWOA	5.15×10^1	2.39×10^{-4}	5.15×10^1	5.15×10^1	5	NaN	NaN
	DGSWOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1		

Table 4. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₆	PSO	8.35 × 10 ¹	2.23 × 10 ⁻²	8.35 × 10 ¹	8.36 × 10 ¹	7	1.86 × 10 ⁻⁹	+
	GA	8.37 × 10 ¹	1.90 × 10 ⁻¹	8.35 × 10 ¹	8.42 × 10 ¹	8	1.86 × 10 ⁻⁹	+
	GWO	8.35 × 10 ¹	1.12 × 10 ⁻⁵	8.35 × 10 ¹	8.35 × 10 ¹	4	5.84 × 10 ⁻¹	≈
	WOA	8.35 × 10 ¹	2.04 × 10 ⁻⁵	8.35 × 10 ¹	8.35 × 10 ¹	2	5.29 × 10 ⁻¹	≈
	BOA	8.52 × 10 ¹	6.37 × 10 ⁰	8.35 × 10 ¹	1.18 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	8.35 × 10 ¹	2.51 × 10 ⁻⁴	8.35 × 10 ¹	8.35 × 10 ¹	5	1.86 × 10 ⁻⁹	+
	LWOA	8.35 × 10 ¹	4.98 × 10 ⁻³	8.35 × 10 ¹	8.35 × 10 ¹	6	1.86 × 10 ⁻⁹	+
	MSWOA	8.35 × 10¹	2.71 × 10⁻⁶	8.35 × 10¹	8.35 × 10¹	1	4.42 × 10 ⁻⁶	-
	DGSwOA	8.35 × 10 ¹	1.25 × 10 ⁻⁵	8.35 × 10 ¹	8.35 × 10 ¹	3		
F ₇	PSO	-8.39 × 10 ¹	6.61 × 10 ⁻³	-8.39 × 10 ¹	-8.38 × 10 ¹	2	4.62 × 10 ⁻²	+
	GA	-8.39 × 10¹	3.53 × 10⁻³	-8.39 × 10 ¹	-8.39 × 10¹	1	2.62 × 10 ⁻¹	≈
	GWO	-8.36 × 10 ¹	6.13 × 10 ⁻¹	-8.39 × 10 ¹	-8.10 × 10 ¹	7	1.55 × 10 ⁻³	+
	WOA	-8.39 × 10 ¹	2.09 × 10 ⁻²	-8.39 × 10¹	-8.38 × 10 ¹	3	1.58 × 10 ⁻¹	≈
	BOA	-7.88 × 10 ¹	4.80 × 10 ⁰	-8.36 × 10 ¹	-6.73 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	SOA	-8.32 × 10 ¹	8.16 × 10 ⁻¹	-8.39 × 10 ¹	-8.09 × 10 ¹	8	4.97 × 10 ⁻⁵	+
	LWOA	-8.39 × 10 ¹	8.46 × 10 ⁻³	-8.39 × 10 ¹	-8.38 × 10 ¹	4	5.04 × 10 ⁻²	≈
	MSWOA	-8.37 × 10 ¹	1.79 × 10 ⁻¹	-8.39 × 10 ¹	-8.34 × 10 ¹	6	5.55 × 10 ⁻⁴	+
	DGSwOA	-8.38 × 10 ¹	3.16 × 10 ⁻¹	-8.39 × 10 ¹	-8.22 × 10 ¹	5		
F ₈	PSO	-1.35 × 10 ²	1.90 × 10 ⁻²	-1.35 × 10 ²	-1.35 × 10 ²	6	1.06 × 10 ⁻⁵	+
	GA	-1.35 × 10 ²	1.13 × 10 ⁻¹	-1.35 × 10 ²	-1.35 × 10 ²	8	4.66 × 10 ⁻⁸	+
	GWO	-1.35 × 10 ²	1.78 × 10 ⁻¹	-1.35 × 10 ²	-1.34 × 10 ²	7	8.79 × 10 ⁻²	≈
	WOA	-1.35 × 10 ²	5.01 × 10 ⁻³	-1.35 × 10 ²	-1.35 × 10 ²	3	9.84 × 10 ⁻¹	≈
	BOA	-1.30 × 10 ²	5.56 × 10 ⁰	-1.35 × 10 ²	-1.10 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	-1.35 × 10²	1.28 × 10⁻³	-1.35 × 10 ²	-1.35 × 10²	1	2.21 × 10 ⁻²	-
	LWOA	-1.35 × 10 ²	2.52 × 10 ⁻³	-1.35 × 10 ²	-1.35 × 10 ²	4	1.77 × 10 ⁻¹	≈
	MSWOA	-1.35 × 10 ²	3.73 × 10 ⁻³	-1.35 × 10²	-1.35 × 10 ²	5	2.13 × 10 ⁻¹	≈
	DGSwOA	-1.35 × 10 ²	4.39 × 10 ⁻³	-1.35 × 10 ²	-1.35 × 10 ²	2		
F ₉	PSO	-3.59 × 10 ²	1.90 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	4	1.86 × 10 ⁻⁹	+
	GA	-3.59 × 10 ²	8.38 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	7	9.31 × 10 ⁻⁹	+
	GWO	-3.59 × 10 ²	1.64 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	5	1.30 × 10 ⁻⁸	+
	WOA	-3.59 × 10 ²	2.11 × 10 ⁻³	-3.59 × 10²	-3.59 × 10 ²	2	1.77 × 10 ⁻¹	≈
	BOA	-3.43 × 10 ²	2.20 × 10 ¹	-3.59 × 10 ²	-2.73 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	-3.59 × 10 ²	7.93 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	8	3.73 × 10 ⁻⁹	+
	LWOA	-3.59 × 10 ²	1.22 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	3	1.86 × 10 ⁻⁹	+
	MSWOA	-3.59 × 10 ²	2.75 × 10 ⁻²	-3.59 × 10 ²	-3.59 × 10 ²	6	1.86 × 10 ⁻⁹	+
	DGSwOA	-3.59 × 10²	9.34 × 10⁻⁴	-3.59 × 10 ²	-3.59 × 10²	1		
F ₁₀	PSO	-7.61 × 10 ¹	1.98 × 10 ⁰	-7.86 × 10 ¹	-7.21 × 10 ¹	6	1.68 × 10 ⁻⁶	+
	GA	-7.54 × 10 ¹	6.26 × 10 ⁰	-7.90 × 10 ¹	-5.10 × 10 ¹	7	8.72 × 10 ⁻⁴	+
	GWO	-7.74 × 10 ¹	7.51 × 10 ⁻¹	-7.89 × 10 ¹	-7.68 × 10 ¹	4	3.54 × 10 ⁻⁸	+
	WOA	-7.83 × 10 ¹	6.92 × 10 ⁻¹	-7.90 × 10 ¹	-7.65 × 10 ¹	2	8.55 × 10 ⁻¹	≈
	BOA	4.25 × 10 ²	1.18 × 10 ³	-7.88 × 10 ¹	5.75 × 10 ³	9	3.73 × 10 ⁻⁹	+
	SOA	-7.34 × 10 ¹	7.33 × 10 ⁰	-7.90 × 10¹	-5.60 × 10 ¹	8	3.45 × 10 ⁻⁵	+
	LWOA	-7.72 × 10 ¹	1.80 × 10 ⁰	-7.89 × 10 ¹	-7.03 × 10 ¹	5	1.89 × 10 ⁻⁴	+
	MSWOA	-7.76 × 10 ¹	1.78 × 10 ⁰	-7.90 × 10 ¹	-7.06 × 10 ¹	3	4.05 × 10 ⁻²	+
	DGSwOA	-7.85 × 10¹	4.78 × 10⁻¹	-7.90 × 10 ¹	-7.71 × 10¹	1		
F ₁₁	PSO	-9.85 × 10 ¹	2.13 × 10 ⁰	-1.01 × 10 ²	-9.26 × 10 ¹	6	4.04 × 10 ⁻¹	≈
	GA	-9.93 × 10 ¹	1.60 × 10 ⁰	-1.01 × 10 ²	-9.50 × 10¹	2	8.24 × 10 ⁻¹	≈
	GWO	-9.65 × 10 ¹	1.85 × 10 ⁰	-1.00 × 10 ²	-9.22 × 10 ¹	7	2.35 × 10 ⁻⁶	+
	WOA	-9.91 × 10 ¹	1.58 × 10⁰	-1.01 × 10 ²	-9.44 × 10 ¹	3	9.84 × 10 ⁻¹	≈
	BOA	1.21 × 10 ⁴	2.54 × 10 ⁴	-9.37 × 10 ¹	1.05 × 10 ⁵	9	1.86 × 10 ⁻⁹	+
	SOA	4.80 × 10 ¹	6.75 × 10 ²	-1.01 × 10 ²	3.64 × 10 ³	8	6.08 × 10 ⁻⁴	+
	LWOA	-9.90 × 10 ¹	1.64 × 10 ⁰	-1.01 × 10 ²	-9.37 × 10 ¹	5	5.29 × 10 ⁻¹	≈
	MSWOA	-9.96 × 10¹	2.42 × 10 ⁰	-1.01 × 10²	-9.27 × 10 ¹	1	5.49 × 10 ⁻²	≈
	DGSwOA	-9.91 × 10 ¹	1.84 × 10 ⁰	-1.01 × 10 ²	-9.44 × 10 ¹	4		

Table 4. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₂	PSO	2.98×10^2	2.44×10^0	2.95×10^2	3.06×10^2	7	3.79×10^{-6}	+
	GA	2.96×10^2	1.40×10^0	2.95×10^2	3.00×10^2	3	5.29×10^{-1}	≈
	GWO	2.96×10^2	1.88×10^0	2.95×10^2	3.04×10^2	4	1.24×10^{-1}	≈
	WOA	2.96×10^2	6.73×10^{-1}	2.95×10^2	2.98×10^2	2	1.24×10^{-1}	≈
	BOA	3.06×10^2	2.70×10^1	2.96×10^2	4.26×10^2	9	1.86×10^{-9}	+
	SOA	2.97×10^2	1.60×10^0	2.95×10^2	3.01×10^2	5	2.93×10^{-2}	+
	LWOA	2.97×10^2	1.74×10^0	2.95×10^2	3.02×10^2	6	2.08×10^{-5}	+
	MSWOA	2.99×10^2	1.83×10^1	2.95×10^2	3.97×10^2	8	2.71×10^{-1}	≈
	DGSwOA	2.96×10^2	5.56×10^{-1}	2.95×10^2	2.98×10^2	1		
F ₁₃	PSO	-5.10×10^1	5.06×10^{-1}	-5.17×10^1	-5.00×10^1	4	9.61×10^{-2}	≈
	GA	-5.09×10^1	6.96×10^{-1}	-5.17×10^1	-4.86×10^1	5	6.36×10^{-2}	≈
	GWO	-4.95×10^1	2.66×10^0	-5.17×10^1	-4.26×10^1	6	3.48×10^{-3}	+
	WOA	-5.14×10^1	2.61×10^{-1}	-5.17×10^1	-5.07×10^1	1	2.45×10^{-1}	≈
	BOA	-3.03×10^1	1.09×10^1	-4.93×10^1	-1.37×10^1	9	1.86×10^{-9}	+
	SOA	-4.18×10^1	1.34×10^1	-5.17×10^1	-1.19×10^1	8	1.72×10^{-3}	+
	LWOA	-5.12×10^1	3.39×10^{-1}	-5.16×10^1	-5.03×10^1	3	3.49×10^{-1}	≈
	MSWOA	-4.60×10^1	5.61×10^0	-5.17×10^1	-3.63×10^1	7	6.92×10^{-6}	+
	DGSwOA	-5.12×10^1	5.06×10^{-1}	-5.17×10^1	-4.97×10^1	2		
F ₁₄	PSO	-5.79×10^1	5.35×10^{-3}	-5.79×10^1	-5.79×10^1	8	1.86×10^{-9}	+
	GA	-5.79×10^1	1.56×10^{-3}	-5.79×10^1	-5.79×10^1	7	1.86×10^{-9}	+
	GWO	-5.79×10^1	6.55×10^{-5}	-5.79×10^1	-5.79×10^1	5	3.28×10^{-1}	≈
	WOA	-5.79×10^1	3.77×10^{-5}	-5.79×10^1	-5.79×10^1	2	5.70×10^{-1}	≈
	BOA	-5.70×10^1	6.02×10^{-1}	-5.78×10^1	-5.51×10^1	9	1.86×10^{-9}	+
	SOA	-5.79×10^1	5.02×10^{-5}	-5.79×10^1	-5.79×10^1	3	5.98×10^{-1}	≈
	LWOA	-5.79×10^1	1.30×10^{-3}	-5.79×10^1	-5.79×10^1	6	1.86×10^{-9}	+
	MSWOA	-5.79×10^1	3.09×10^{-5}	-5.79×10^1	-5.79×10^1	1	1.58×10^{-3}	-
	DGSwOA	-5.79×10^1	3.69×10^{-5}	-5.79×10^1	-5.79×10^1	4		
F ₁₅	PSO	-4.40×10^1	4.83×10^{-1}	-4.48×10^1	-4.28×10^1	6	9.22×10^{-6}	+
	GA	-4.42×10^1	6.21×10^{-1}	-4.48×10^1	-4.20×10^1	5	3.22×10^{-3}	+
	GWO	-4.43×10^1	8.75×10^{-1}	-4.48×10^1	-4.04×10^1	4	2.05×10^{-1}	≈
	WOA	-4.44×10^1	3.63×10^{-1}	-4.48×10^1	-4.37×10^1	2	3.84×10^{-2}	+
	BOA	-2.89×10^1	7.26×10^0	-4.34×10^1	-1.84×10^1	9	1.86×10^{-9}	+
	SOA	-4.30×10^1	3.21×10^0	-4.48×10^1	-3.18×10^1	7	1.34×10^{-3}	+
	LWOA	-4.43×10^1	3.53×10^{-1}	-4.47×10^1	-4.34×10^1	3	7.11×10^{-3}	+
	MSWOA	-4.14×10^1	3.15×10^0	-4.48×10^1	-3.18×10^1	8	1.99×10^{-6}	+
	DGSwOA	-4.45×10^1	6.24×10^{-1}	-4.48×10^1	-4.13×10^1	1		
F ₁₆	PSO	-2.60×10^2	2.31×10^{-2}	-2.60×10^2	-2.60×10^2	4	1.86×10^{-9}	+
	GA	-2.60×10^2	2.87×10^{-2}	-2.60×10^2	-2.60×10^2	3	2.35×10^{-6}	+
	GWO	-2.60×10^2	1.42×10^{-1}	-2.60×10^2	-2.59×10^2	5	7.15×10^{-1}	≈
	WOA	-2.60×10^2	2.46×10^{-4}	-2.60×10^2	-2.60×10^2	1	5.29×10^{-1}	≈
	BOA	-2.54×10^2	4.77×10^0	-2.60×10^2	-2.44×10^2	9	1.86×10^{-9}	+
	SOA	-2.60×10^2	5.37×10^{-2}	-2.60×10^2	-2.60×10^2	8	1.86×10^{-9}	+
	LWOA	-2.60×10^2	6.84×10^{-2}	-2.60×10^2	-2.60×10^2	7	9.31×10^{-9}	+
	MSWOA	-2.60×10^2	7.14×10^{-2}	-2.60×10^2	-2.60×10^2	6	5.05×10^{-4}	+
	DGSwOA	-2.60×10^2	4.18×10^{-3}	-2.60×10^2	-2.60×10^2	2		
F ₁₇	PSO	-3.86×10^1	6.35×10^{-2}	-3.87×10^1	-3.84×10^1	8	1.86×10^{-9}	+
	GA	-3.87×10^1	2.10×10^{-2}	-3.87×10^1	-3.86×10^1	5	1.86×10^{-9}	+
	GWO	-3.87×10^1	9.71×10^{-4}	-3.87×10^1	-3.87×10^1	1	1.06×10^{-2}	-
	WOA	-3.87×10^1	1.07×10^{-2}	-3.87×10^1	-3.87×10^1	3	8.08×10^{-1}	≈
	BOA	-3.62×10^1	1.18×10^0	-3.82×10^1	-3.33×10^1	9	1.86×10^{-9}	+
	SOA	-3.87×10^1	1.41×10^{-1}	-3.87×10^1	-3.80×10^1	7	1.86×10^{-9}	+
	LWOA	-3.87×10^1	3.69×10^{-2}	-3.87×10^1	-3.86×10^1	6	1.86×10^{-9}	+
	MSWOA	-3.87×10^1	2.71×10^{-2}	-3.87×10^1	-3.86×10^1	4	3.86×10^{-7}	+
	DGSwOA	-3.87×10^1	3.66×10^{-3}	-3.87×10^1	-3.87×10^1	2		

Table 4. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₈	PSO	-3.84×10^1	1.47×10^{-1}	-3.86×10^1	-3.80×10^1	5	1.77×10^{-1}	≈
	GA	-3.85×10^1	2.02×10^{-1}	-3.87×10^1	-3.79×10^1	1	3.64×10^{-2}	–
	GWO	-3.77×10^1	7.32×10^{-1}	-3.86×10^1	-3.56×10^1	8	1.06×10^{-5}	+
	WOA	-3.82×10^1	2.85×10^{-1}	-3.87×10^1	-3.76×10^1	6	1.37×10^{-2}	+
	BOA	-2.91×10^1	9.34×10^0	-3.73×10^1	-4.05×10^0	9	1.86×10^{-9}	+
	SOA	-3.80×10^1	5.74×10^{-1}	-3.87×10^1	-3.69×10^1	7	1.37×10^{-2}	+
	LWOA	-3.84×10^1	1.97×10^{-1}	-3.87×10^1	-3.79×10^1	3	7.30×10^{-1}	≈
	MSWOA	-3.85×10^1	1.83×10^{-1}	-3.87×10^1	-3.80×10^1	2	2.13×10^{-1}	≈
	DGSwOA	-3.84×10^1	3.35×10^{-1}	-3.87×10^1	-3.72×10^1	4		
F ₁₉	PSO	4.05×10^1	3.80×10^{-3}	4.05×10^1	4.05×10^1	8	1.86×10^{-9}	+
	GA	4.05×10^1	6.21×10^{-3}	4.05×10^1	4.05×10^1	9	1.86×10^{-9}	+
	GWO	4.05×10^1	5.00×10^{-3}	4.05×10^1	4.05×10^1	5	4.60×10^{-4}	+
	WOA	4.05×10^1	6.68×10^{-4}	4.05×10^1	4.05×10^1	2	1.52×10^{-1}	≈
	BOA	4.05×10^1	1.82×10^{-3}	4.05×10^1	4.05×10^1	3	4.66×10^{-8}	+
	SOA	4.05×10^1	5.39×10^{-3}	4.05×10^1	4.05×10^1	7	1.30×10^{-8}	+
	LWOA	4.05×10^1	3.60×10^{-3}	4.05×10^1	4.05×10^1	6	3.73×10^{-9}	+
	MSWOA	4.05×10^1	3.97×10^{-3}	4.05×10^1	4.05×10^1	4	4.42×10^{-6}	+
	DGSwOA	4.05×10^1	3.19×10^{-6}	4.05×10^1	4.05×10^1	1		
F ₂₀	PSO	1.83×10^2	1.33×10^{-1}	1.83×10^2	1.84×10^2	4	1.30×10^{-8}	+
	GA	1.83×10^2	1.60×10^{-1}	1.83×10^2	1.84×10^2	5	1.86×10^{-9}	+
	GWO	1.83×10^2	4.22×10^{-1}	1.83×10^2	1.85×10^2	7	1.64×10^{-7}	+
	WOA	1.83×10^2	5.43×10^{-2}	1.83×10^2	1.83×10^2	2	3.74×10^{-3}	+
	BOA	1.84×10^2	4.21×10^{-1}	1.83×10^2	1.85×10^2	9	1.86×10^{-9}	+
	SOA	1.84×10^2	3.86×10^{-1}	1.83×10^2	1.84×10^2	8	6.15×10^{-8}	+
	LWOA	1.83×10^2	1.15×10^{-1}	1.83×10^2	1.84×10^2	3	6.91×10^{-7}	+
	MSWOA	1.83×10^2	2.95×10^{-1}	1.83×10^2	1.84×10^2	6	4.73×10^{-2}	+
	DGSwOA	1.83×10^2	1.39×10^{-2}	1.83×10^2	1.83×10^2	1		
F ₂₁	PSO	3.11×10^2	4.24×10^{-5}	3.11×10^2	3.11×10^2	4	1.86×10^{-9}	+
	GA	3.11×10^2	4.39×10^{-3}	3.11×10^2	3.11×10^2	5	1.86×10^{-9}	+
	GWO	3.11×10^2	3.50×10^{-1}	3.11×10^2	3.13×10^2	7	3.87×10^{-1}	≈
	WOA	3.11×10^2	8.13×10^{-9}	3.11×10^2	3.11×10^2	2	9.43×10^{-1}	≈
	BOA	3.11×10^2	8.67×10^{-3}	3.11×10^2	3.11×10^2	6	1.86×10^{-9}	+
	SOA	3.11×10^2	2.56×10^{-1}	3.11×10^2	3.11×10^2	8	1.02×10^{-7}	+
	LWOA	3.11×10^2	1.98×10^{-5}	3.11×10^2	3.11×10^2	3	1.86×10^{-9}	+
	MSWOA	3.11×10^2	3.43×10^{-1}	3.11×10^2	3.11×10^2	9	4.71×10^{-7}	+
	DGSwOA	3.11×10^2	1.86×10^{-9}	3.11×10^2	3.11×10^2	1		
F ₂₂	PSO	4.30×10^1	5.59×10^{-5}	4.30×10^1	4.30×10^1	5	5.59×10^{-9}	+
	GA	4.30×10^1	7.10×10^{-4}	4.30×10^1	4.30×10^1	7	1.86×10^{-9}	+
	GWO	4.30×10^1	3.72×10^{-2}	4.30×10^1	4.31×10^1	8	9.31×10^{-9}	+
	WOA	4.30×10^1	1.72×10^{-5}	4.30×10^1	4.30×10^1	3	8.08×10^{-1}	≈
	BOA	4.30×10^1	1.64×10^{-4}	4.30×10^1	4.30×10^1	6	3.73×10^{-9}	+
	SOA	4.31×10^1	4.45×10^{-1}	4.30×10^1	4.55×10^1	9	9.35×10^{-1}	≈
	LWOA	4.30×10^1	2.44×10^{-5}	4.30×10^1	4.30×10^1	4	3.24×10^{-6}	+
	MSWOA	4.30×10^1	6.44×10^{-10}	4.30×10^1	4.30×10^1	1	1.23×10^{-3}	–
	DGSwOA	4.30×10^1	1.73×10^{-7}	4.30×10^1	4.30×10^1	2		
F ₂₃	PSO	2.11×10^2	1.59×10^{-1}	2.11×10^2	2.11×10^2	6	3.73×10^{-9}	+
	GA	2.11×10^2	3.03×10^{-1}	2.11×10^2	2.12×10^2	9	1.86×10^{-9}	+
	GWO	2.11×10^2	3.00×10^{-1}	2.10×10^2	2.11×10^2	4	6.64×10^{-3}	+
	WOA	2.11×10^2	1.15×10^{-1}	2.10×10^2	2.11×10^2	2	1.45×10^{-2}	+
	BOA	2.11×10^2	1.87×10^{-1}	2.10×10^2	2.11×10^2	8	1.86×10^{-9}	+
	SOA	2.11×10^2	2.00×10^{-1}	2.10×10^2	2.11×10^2	5	9.31×10^{-9}	+
	LWOA	2.11×10^2	1.88×10^{-1}	2.11×10^2	2.11×10^2	7	1.86×10^{-9}	+
	MSWOA	2.11×10^2	1.30×10^{-1}	2.10×10^2	2.11×10^2	3	1.04×10^{-3}	+
	DGSwOA	2.10×10^2	4.42×10^{-2}	2.10×10^2	2.11×10^2	1		

Table 4. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂₄	PSO	4.85 × 10 ¹	5.70 × 10 ⁻¹	4.77 × 10 ¹	5.01 × 10 ¹	3	8.01 × 10 ⁻⁸	+
	GA	4.86 × 10 ¹	6.47 × 10 ⁻¹	4.78 × 10 ¹	4.99 × 10 ¹	4	1.86 × 10 ⁻⁸	+
	GWO	4.91 × 10 ¹	1.00 × 10 ⁰	4.76 × 10 ¹	5.05 × 10 ¹	7	3.79 × 10 ⁻⁶	+
	WOA	4.87 × 10 ¹	8.00 × 10 ⁻¹	4.77 × 10 ¹	5.02 × 10 ¹	5	5.14 × 10 ⁻⁶	+
	BOA	4.80 × 10 ¹	3.07 × 10 ⁻¹	4.76 × 10¹	4.89 × 10¹	2	2.62 × 10 ⁻²	+
	SOA	4.88 × 10 ¹	1.06 × 10 ⁰	4.77 × 10 ¹	5.09 × 10 ¹	6	2.09 × 10 ⁻⁴	+
	LWOA	4.92 × 10 ¹	6.94 × 10 ⁻¹	4.79 × 10 ¹	5.01 × 10 ¹	8	1.02 × 10 ⁻⁷	+
	MSWOA	4.96 × 10 ¹	5.67 × 10 ⁻¹	4.77 × 10 ¹	5.04 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	DGSwOA	4.79 × 10¹	2.43 × 10⁻¹	4.77 × 10 ¹	4.90 × 10 ¹	1		

Table 5. Comparative experimental results (dimension = 3).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	-9.26 × 10 ¹	3.52 × 10 ⁻²	-9.26 × 10 ¹	-9.25 × 10 ¹	8	1.86 × 10 ⁻⁹	+
	GA	-9.26 × 10 ¹	4.29 × 10 ⁻³	-9.26 × 10 ¹	-9.26 × 10 ¹	7	1.86 × 10 ⁻⁹	+
	GWO	-9.26 × 10 ¹	2.71 × 10 ⁻³	-9.26 × 10 ¹	-9.26 × 10 ¹	5	7.61 × 10 ⁻³	-
	WOA	-9.26 × 10 ¹	1.46 × 10 ⁻⁵	-9.26 × 10 ¹	-9.26 × 10¹	3	7.00 × 10 ⁻¹	≈
	BOA	-8.93 × 10 ¹	2.16 × 10 ⁰	-9.20 × 10 ¹	-8.45 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	SOA	-9.26 × 10 ¹	8.89 × 10 ⁻⁴	-9.26 × 10 ¹	-9.26 × 10 ¹	4	9.31 × 10 ⁻⁹	+
	LWOA	-9.26 × 10 ¹	3.68 × 10⁻³	-9.26 × 10¹	-9.26 × 10 ¹	6	1.86 × 10 ⁻⁹	+
	MSWOA	-9.26 × 10 ¹	1.34 × 10 ⁻⁵	-9.26 × 10 ¹	-9.26 × 10 ¹	2	5.16 × 10 ⁻¹	≈
	DGSwOA	-9.26 × 10¹	1.62 × 10 ⁻⁵	-9.26 × 10 ¹	-9.26 × 10 ¹	1		
F ₂	PSO	3.40 × 10 ²	5.22 × 10 ¹	2.77 × 10 ²	4.57 × 10 ²	5	3.73 × 10 ⁻⁹	+
	GA	2.81 × 10 ²	6.12 × 10 ⁰	2.76 × 10²	3.07 × 10 ²	2	4.05 × 10 ⁻²	+
	GWO	3.49 × 10 ²	7.00 × 10 ¹	2.79 × 10 ²	5.34 × 10 ²	6	1.86 × 10 ⁻⁹	+
	WOA	2.82 × 10 ²	8.56 × 10 ⁰	2.76 × 10 ²	3.19 × 10 ²	3	4.60 × 10 ⁻⁴	+
	BOA	7.02 × 10 ²	5.78 × 10 ²	2.89 × 10 ²	3.05 × 10 ³	9	1.86 × 10 ⁻⁹	+
	SOA	3.93 × 10 ²	1.46 × 10 ²	2.76 × 10 ²	7.26 × 10 ²	8	4.71 × 10 ⁻⁷	+
	LWOA	3.10 × 10 ²	2.32 × 10 ¹	2.77 × 10 ²	3.66 × 10 ²	4	3.73 × 10 ⁻⁹	+
	MSWOA	3.72 × 10 ²	1.78 × 10 ²	2.76 × 10 ²	7.69 × 10 ²	7	2.37 × 10 ⁻³	+
	DGSwOA	2.79 × 10²	4.09 × 10⁰	2.76 × 10 ²	3.00 × 10²	1		
F ₃	PSO	2.56 × 10 ¹	1.68 × 10 ⁰	2.26 × 10 ¹	2.88 × 10 ¹	6	5.59 × 10 ⁻⁹	+
	GA	2.64 × 10 ¹	1.67 × 10 ⁰	2.33 × 10 ¹	3.08 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	GWO	2.41 × 10 ¹	1.79 × 10 ⁰	2.20 × 10 ¹	3.09 × 10 ¹	4	1.42 × 10 ⁻⁶	+
	WOA	2.29 × 10 ¹	9.78 × 10 ⁻¹	2.09 × 10 ¹	2.56 × 10 ¹	2	7.06 × 10 ⁻⁵	+
	BOA	2.62 × 10 ¹	3.67 × 10 ⁰	2.21 × 10 ¹	3.61 × 10 ¹	8	1.86 × 10 ⁻⁹	+
	SOA	2.59 × 10 ¹	3.66 × 10 ⁰	2.16 × 10 ¹	3.26 × 10 ¹	7	1.68 × 10 ⁻⁶	+
	LWOA	2.34 × 10 ¹	8.31 × 10 ⁻¹	2.14 × 10¹	2.51 × 10 ¹	3	1.68 × 10 ⁻⁶	+
	MSWOA	2.49 × 10 ¹	3.40 × 10 ⁰	2.09 × 10 ¹	3.21 × 10 ¹	5	1.13 × 10 ⁻³	+
	DGSwOA	2.21 × 10¹	5.74 × 10⁻¹	2.10 × 10 ¹	2.35 × 10¹	1		
F ₄	PSO	2.90 × 10 ¹	2.93 × 10 ⁰	2.28 × 10 ¹	3.57 × 10 ¹	8	3.73 × 10 ⁻⁹	+
	GA	3.00 × 10 ¹	2.59 × 10 ⁰	2.34 × 10 ¹	3.44 × 10 ¹	9	3.73 × 10 ⁻⁹	+
	GWO	2.63 × 10 ¹	2.78 × 10 ⁰	2.20 × 10 ¹	3.32 × 10 ¹	5	7.99 × 10 ⁻⁶	+
	WOA	2.39 × 10 ¹	1.43 × 10 ⁰	2.13 × 10 ¹	2.92 × 10 ¹	2	7.30 × 10 ⁻¹	≈
	BOA	2.81 × 10 ¹	2.52 × 10 ⁰	2.42 × 10 ¹	3.37 × 10 ¹	6	1.86 × 10 ⁻⁹	+
	SOA	2.90 × 10 ¹	4.79 × 10 ⁰	2.30 × 10 ¹	3.74 × 10 ¹	7	1.68 × 10 ⁻⁶	+
	LWOA	2.54 × 10 ¹	1.72 × 10 ⁰	2.12 × 10 ¹	2.79 × 10 ¹	3	1.40 × 10 ⁻⁵	+
	MSWOA	2.55 × 10 ¹	3.29 × 10 ⁰	2.20 × 10¹	3.80 × 10 ¹	4	2.77 × 10 ⁻³	+
	DGSwOA	2.36 × 10¹	6.65 × 10⁻¹	2.20 × 10 ¹	2.55 × 10 ¹	1		

Table 5. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₅	PSO	5.33×10^1	7.95×10^{-1}	5.22×10^1	5.57×10^1	6	1.86×10^{-9}	+
	GA	5.60×10^1	1.48×10^0	5.31×10^1	5.88×10^1	8	1.86×10^{-9}	+
	GWO	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	WOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	BOA	6.53×10^1	5.84×10^0	5.24×10^1	7.51×10^1	9	NaN	NaN
	SOA	5.34×10^1	3.45×10^0	5.15×10^1	6.15×10^1	7	NaN	NaN
	LWOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	MSWOA	5.19×10^1	1.79×10^0	5.15×10^1	6.15×10^1	5	NaN	NaN
	DGSwOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1		
F ₆	PSO	8.43×10^1	5.40×10^{-1}	8.36×10^1	8.58×10^1	5	1.86×10^{-9}	+
	GA	8.54×10^1	1.01×10^0	8.39×10^1	8.75×10^1	7	1.86×10^{-9}	+
	GWO	8.35×10^1	2.88×10^{-2}	8.35×10^1	8.36×10^1	3	6.26×10^{-1}	≈
	WOA	8.35×10^1	9.61×10^{-3}	8.35×10^1	8.35×10^1	1	8.39×10^{-1}	≈
	BOA	1.15×10^3	2.58×10^3	8.42×10^1	1.12×10^4	9	1.86×10^{-9}	+
	SOA	8.53×10^1	3.19×10^0	8.35×10^1	9.42×10^1	6	5.72×10^{-7}	+
	LWOA	8.37×10^1	9.02×10^{-2}	8.35×10^1	8.39×10^1	4	5.59×10^{-9}	+
	MSWOA	8.58×10^1	3.91×10^0	8.35×10^1	9.37×10^1	8	1.86×10^{-9}	+
	DGSwOA	8.35×10^1	1.50×10^{-2}	8.35×10^1	8.35×10^1	2		
F ₇	PSO	-8.37×10^1	1.59×10^{-1}	-8.38×10^1	-8.32×10^1	6	1.86×10^{-9}	+
	GA	-8.38×10^1	6.26×10^{-2}	-8.39×10^1	-8.36×10^1	3	8.14×10^{-5}	+
	GWO	-8.37×10^1	3.51×10^{-1}	-8.39×10^1	-8.19×10^1	5	1.68×10^{-6}	+
	WOA	-8.38×10^1	4.13×10^{-2}	-8.39×10^1	-8.36×10^1	2	6.19×10^{-3}	+
	BOA	-7.13×10^1	7.16×10^0	-8.31×10^1	-5.24×10^1	9	1.86×10^{-9}	+
	SOA	-8.24×10^1	2.36×10^0	-8.39×10^1	-7.10×10^1	8	5.59×10^{-9}	+
	LWOA	-8.38×10^1	3.86×10^{-2}	-8.39×10^1	-8.37×10^1	4	3.73×10^{-9}	+
	MSWOA	-8.30×10^1	8.09×10^{-1}	-8.39×10^1	-8.12×10^1	7	1.86×10^{-9}	+
	DGSwOA	-8.39×10^1	6.03×10^{-3}	-8.39×10^1	-8.38×10^1	1		
F ₈	PSO	-1.33×10^2	1.31×10^0	-1.35×10^2	-1.30×10^2	8	1.86×10^{-9}	+
	GA	-1.34×10^2	4.96×10^{-1}	-1.35×10^2	-1.34×10^2	7	4.66×10^{-8}	+
	GWO	-1.35×10^2	6.72×10^{-2}	-1.35×10^2	-1.35×10^2	5	2.08×10^{-5}	+
	WOA	-1.35×10^2	4.47×10^{-2}	-1.35×10^2	-1.35×10^2	3	4.52×10^{-1}	≈
	BOA	3.94×10^2	9.13×10^2	-1.28×10^2	3.72×10^3	9	1.86×10^{-9}	+
	SOA	-1.35×10^2	1.12×10^{-1}	-1.35×10^2	-1.35×10^2	4	1.13×10^{-2}	+
	LWOA	-1.35×10^2	1.39×10^{-1}	-1.35×10^2	-1.35×10^2	6	1.64×10^{-7}	+
	MSWOA	-1.35×10^2	5.48×10^{-2}	-1.35×10^2	-1.35×10^2	1	5.56×10^{-1}	≈
	DGSwOA	-1.35×10^2	4.06×10^{-2}	-1.35×10^2	-1.35×10^2	2		
F ₉	PSO	-3.58×10^2	1.06×10^0	-3.59×10^2	-3.54×10^2	8	1.86×10^{-9}	+
	GA	-3.59×10^2	4.81×10^{-1}	-3.59×10^2	-3.57×10^2	6	1.86×10^{-9}	+
	GWO	-3.59×10^2	9.74×10^{-2}	-3.59×10^2	-3.59×10^2	3	3.73×10^{-9}	+
	WOA	-3.59×10^2	2.94×10^{-2}	-3.59×10^2	-3.59×10^2	2	2.37×10^{-3}	+
	BOA	-2.31×10^2	4.59×10^1	-3.51×10^2	-1.65×10^2	9	1.86×10^{-9}	+
	SOA	-3.58×10^2	2.10×10^0	-3.59×10^2	-3.52×10^2	7	8.01×10^{-8}	+
	LWOA	-3.59×10^2	2.49×10^{-1}	-3.59×10^2	-3.58×10^2	5	1.86×10^{-9}	+
	MSWOA	-3.59×10^2	2.45×10^{-1}	-3.59×10^2	-3.59×10^2	4	1.86×10^{-9}	+
	DGSwOA	-3.59×10^2	1.83×10^{-2}	-3.59×10^2	-3.59×10^2	1		
F ₁₀	PSO	-2.72×10^1	3.72×10^1	-7.70×10^1	6.71×10^1	7	1.19×10^{-6}	+
	GA	-5.89×10^1	2.51×10^1	-7.78×10^1	1.33×10^1	5	7.32×10^{-2}	≈
	GWO	6.02×10^2	2.80×10^3	-7.63×10^1	1.56×10^4	8	3.15×10^{-7}	+
	WOA	-6.93×10^1	8.64×10^0	-7.80×10^1	-4.82×10^1	1	9.52×10^{-1}	≈
	BOA	1.88×10^3	2.06×10^3	-3.44×10^1	8.52×10^3	9	1.86×10^{-9}	+
	SOA	-6.00×10^1	1.54×10^1	-7.84×10^1	-4.01×10^1	4	3.10×10^{-2}	+
	LWOA	-5.04×10^1	1.87×10^1	-7.26×10^1	1.14×10^1	6	5.14×10^{-6}	+
	MSWOA	-6.55×10^1	1.36×10^1	-7.90×10^1	-4.03×10^1	3	2.99×10^{-1}	≈
	DGSwOA	-6.88×10^1	1.07×10^1	-7.82×10^1	-2.25×10^1	2		

Table 5. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₁	PSO	-9.42×10^1	5.50×10^0	-1.00×10^2	-8.00×10^1	1	7.00×10^{-1}	≈
	GA	-8.56×10^1	1.23×10^1	-1.00×10^2	-5.98×10^1	5	1.86×10^{-3}	+
	GWO	-8.33×10^1	5.18×10^0	-9.90×10^1	-7.50×10^1	6	4.66×10^{-8}	+
	WOA	-9.37×10^1	6.12×10^0	-1.00×10^2	-8.02×10^1	4	8.71×10^{-1}	≈
	BOA	-6.65×10^1	3.68×10^0	-7.67×10^1	-5.81×10^1	8	1.86×10^{-9}	+
	SOA	-6.64×10^1	2.81×10^1	-1.01×10^2	5.14×10^0	9	1.42×10^{-6}	+
	LWOA	-9.41×10^1	7.78×10^0	-1.00×10^2	-6.64×10^1	3	2.45×10^{-1}	≈
	MSWOA	-7.75×10^1	1.30×10^1	-1.00×10^2	-3.21×10^1	7	6.91×10^{-7}	+
	DGSwOA	-9.41×10^1	3.96×10^0	-1.01×10^2	-8.47×10^1	2		
F ₁₂	PSO	2.38×10^3	1.75×10^3	4.33×10^2	7.08×10^3	8	1.86×10^{-9}	+
	GA	3.33×10^2	3.89×10^1	2.99×10^2	4.53×10^2	6	1.30×10^{-8}	+
	GWO	2.99×10^2	4.09×10^{-1}	2.98×10^2	3.00×10^2	1	2.45×10^{-1}	≈
	WOA	3.01×10^2	7.53×10^0	2.95×10^2	3.38×10^2	3	7.77×10^{-1}	≈
	BOA	2.07×10^5	2.72×10^5	1.78×10^3	1.14×10^6	9	1.86×10^{-9}	+
	SOA	3.13×10^2	2.04×10^1	2.95×10^2	4.04×10^2	5	1.70×10^{-4}	+
	LWOA	6.12×10^2	3.16×10^2	3.10×10^2	1.97×10^3	7	1.86×10^{-9}	+
	MSWOA	3.03×10^2	1.25×10^1	2.95×10^2	3.45×10^2	4	7.46×10^{-1}	≈
	DGSwOA	3.00×10^2	3.15×10^0	2.96×10^2	3.15×10^2	2		
F ₁₃	PSO	-3.95×10^1	5.12×10^0	-4.81×10^1	-2.82×10^1	7	1.86×10^{-9}	+
	GA	-4.87×10^1	2.63×10^0	-5.14×10^1	-4.11×10^1	2	9.84×10^{-1}	≈
	GWO	-4.73×10^1	3.40×10^0	-4.84×10^1	-2.90×10^1	4	5.59×10^{-5}	+
	WOA	-4.82×10^1	2.22×10^0	-5.16×10^1	-4.06×10^1	3	1.35×10^{-1}	≈
	BOA	-7.24×10^0	1.54×10^1	-3.75×10^1	3.79×10^1	9	1.86×10^{-9}	+
	SOA	-3.90×10^1	1.50×10^1	-5.14×10^1	-3.87×10^0	8	1.55×10^{-2}	+
	LWOA	-4.64×10^1	2.69×10^0	-5.05×10^1	-3.97×10^1	5	3.15×10^{-7}	+
	MSWOA	-4.24×10^1	1.52×10^1	-5.17×10^1	-2.72×10^0	6	2.89×10^{-1}	≈
	DGSwOA	-4.90×10^1	1.21×10^0	-5.15×10^1	-4.67×10^1	1		
F ₁₄	PSO	-5.78×10^1	4.32×10^{-2}	-5.79×10^1	-5.77×10^1	7	1.86×10^{-9}	+
	GA	-5.79×10^1	7.07×10^{-3}	-5.79×10^1	-5.79×10^1	5	1.86×10^{-9}	+
	GWO	-5.79×10^1	1.46×10^{-1}	-5.79×10^1	-5.71×10^1	6	9.19×10^{-1}	≈
	WOA	-5.79×10^1	1.81×10^{-4}	-5.79×10^1	-5.79×10^1	1	7.30×10^{-1}	≈
	BOA	-5.60×10^1	1.22×10^0	-5.78×10^1	-5.17×10^1	9	1.86×10^{-9}	+
	SOA	-5.77×10^1	4.23×10^{-1}	-5.79×10^1	-5.62×10^1	8	1.86×10^{-9}	+
	LWOA	-5.79×10^1	4.98×10^{-3}	-5.79×10^1	-5.79×10^1	4	1.86×10^{-9}	+
	MSWOA	-5.79×10^1	2.85×10^{-3}	-5.79×10^1	-5.79×10^1	3	9.22×10^{-6}	+
	DGSwOA	-5.79×10^1	2.07×10^{-4}	-5.79×10^1	-5.79×10^1	2		
F ₁₅	PSO	-4.03×10^1	1.55×10^0	-4.28×10^1	-3.77×10^1	8	3.73×10^{-9}	+
	GA	-4.29×10^1	7.54×10^{-1}	-4.42×10^1	-4.12×10^1	4	3.71×10^{-1}	≈
	GWO	-4.26×10^1	7.50×10^{-1}	-4.43×10^1	-4.13×10^1	5	8.79×10^{-2}	≈
	WOA	-4.30×10^1	5.83×10^{-1}	-4.47×10^1	-4.22×10^1	2	9.84×10^{-1}	≈
	BOA	-2.22×10^1	6.50×10^0	-3.46×10^1	-1.23×10^1	9	1.86×10^{-9}	+
	SOA	-4.13×10^1	2.99×10^0	-4.46×10^1	-3.07×10^1	7	6.64×10^{-3}	+
	LWOA	-4.29×10^1	5.31×10^{-1}	-4.36×10^1	-4.14×10^1	3	4.40×10^{-1}	≈
	MSWOA	-4.24×10^1	2.73×10^0	-4.48×10^1	-3.13×10^1	6	8.39×10^{-1}	≈
	DGSwOA	-4.31×10^1	7.62×10^{-1}	-4.47×10^1	-4.13×10^1	1		
F ₁₆	PSO	-2.60×10^2	2.30×10^{-1}	-2.60×10^2	-2.59×10^2	5	3.24×10^{-6}	+
	GA	-2.60×10^2	3.27×10^{-1}	-2.60×10^2	-2.59×10^2	4	2.56×10^{-3}	+
	GWO	-2.60×10^2	5.33×10^{-1}	-2.60×10^2	-2.58×10^2	6	4.18×10^{-4}	+
	WOA	-2.60×10^2	2.97×10^{-1}	-2.60×10^2	-2.59×10^2	2	9.61×10^{-2}	≈
	BOA	-2.48×10^2	6.69×10^0	-2.56×10^2	-2.25×10^2	9	1.86×10^{-9}	+
	SOA	-2.59×10^2	1.04×10^0	-2.60×10^2	-2.56×10^2	8	1.64×10^{-7}	+
	LWOA	-2.60×10^2	1.64×10^{-1}	-2.60×10^2	-2.59×10^2	3	1.99×10^{-6}	+
	MSWOA	-2.60×10^2	8.83×10^{-1}	-2.60×10^2	-2.56×10^2	7	1.55×10^{-2}	+
	DGSwOA	-2.60×10^2	9.62×10^{-2}	-2.60×10^2	-2.60×10^2	1		

Table 5. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₇	PSO	-3.82×10^1	1.88×10^{-1}	-3.85×10^1	-3.77×10^1	7	1.86×10^{-9}	+
	GA	-3.86×10^1	6.55×10^{-2}	-3.87×10^1	-3.84×10^1	5	3.15×10^{-7}	+
	GWO	-3.86×10^1	4.36×10^{-2}	-3.87×10^1	-3.85×10^1	3	1.82×10^{-5}	+
	WOA	-3.87×10^1	4.45×10^{-2}	-3.87×10^1	-3.86×10^1	1	8.71×10^{-1}	≈
	BOA	-3.38×10^1	2.42×10^0	-3.80×10^1	-2.90×10^1	9	1.86×10^{-9}	+
	SOA	-3.82×10^1	5.10×10^{-1}	-3.87×10^1	-3.68×10^1	8	8.86×10^{-5}	+
	LWOA	-3.86×10^1	8.13×10^{-2}	-3.87×10^1	-3.84×10^1	4	7.06×10^{-5}	+
	MSWOA	-3.84×10^1	4.05×10^{-1}	-3.87×10^1	-3.73×10^1	6	1.24×10^{-1}	≈
	DGSwOA	-3.86×10^1	5.27×10^{-2}	-3.87×10^1	-3.85×10^1	2		
F ₁₈	PSO	-3.71×10^1	5.95×10^{-1}	-3.82×10^1	-3.59×10^1	7	4.66×10^{-8}	+
	GA	-3.84×10^1	1.92×10^{-1}	-3.86×10^1	-3.80×10^1	3	9.19×10^{-1}	≈
	GWO	-3.84×10^1	3.45×10^{-1}	-3.86×10^1	-3.70×10^1	2	5.03×10^{-1}	≈
	WOA	-3.85×10^1	5.90×10^{-2}	-3.87×10^1	-3.84×10^1	1	5.78×10^{-3}	−
	BOA	-2.10×10^1	6.50×10^0	-3.33×10^1	-9.05×10^0	9	1.86×10^{-9}	+
	SOA	-3.61×10^1	2.22×10^0	-3.87×10^1	-3.16×10^1	8	7.99×10^{-6}	+
	LWOA	-3.81×10^1	1.96×10^{-1}	-3.86×10^1	-3.77×10^1	5	1.85×10^{-2}	+
	MSWOA	-3.80×10^1	7.37×10^{-1}	-3.87×10^1	-3.55×10^1	6	7.32×10^{-2}	≈
	DGSwOA	-3.83×10^1	3.73×10^{-1}	-3.87×10^1	-3.73×10^1	4		
F ₁₉	PSO	4.07×10^1	1.32×10^{-1}	4.05×10^1	4.11×10^1	9	1.86×10^{-9}	+
	GA	4.06×10^1	1.27×10^{-1}	4.05×10^1	4.09×10^1	8	5.59×10^{-9}	+
	GWO	4.05×10^1	1.60×10^{-2}	4.05×10^1	4.05×10^1	5	8.33×10^{-7}	+
	WOA	4.05×10^1	1.83×10^{-2}	4.05×10^1	4.06×10^1	4	2.02×10^{-3}	+
	BOA	4.05×10^1	4.72×10^{-2}	4.05×10^1	4.07×10^1	6	9.31×10^{-9}	+
	SOA	4.05×10^1	6.16×10^{-3}	4.05×10^1	4.05×10^1	3	2.21×10^{-2}	+
	LWOA	4.06×10^1	5.34×10^{-2}	4.05×10^1	4.07×10^1	7	1.86×10^{-9}	+
	MSWOA	4.05×10^1	6.32×10^{-3}	4.05×10^1	4.05×10^1	1	3.82×10^{-1}	≈
	DGSwOA	4.05×10^1	5.90×10^{-3}	4.05×10^1	4.05×10^1	2		
F ₂₀	PSO	1.84×10^2	2.94×10^{-1}	1.83×10^2	1.85×10^2	5	3.86×10^{-7}	+
	GA	1.84×10^2	3.47×10^{-1}	1.83×10^2	1.85×10^2	7	2.76×10^{-6}	+
	GWO	1.84×10^2	3.66×10^{-1}	1.84×10^2	1.85×10^2	6	4.41×10^{-5}	+
	WOA	1.84×10^2	2.47×10^{-1}	1.83×10^2	1.84×10^2	1	7.92×10^{-1}	≈
	BOA	1.85×10^2	5.25×10^{-1}	1.83×10^2	1.86×10^2	9	1.86×10^{-8}	+
	SOA	1.84×10^2	5.43×10^{-1}	1.83×10^2	1.86×10^2	8	3.90×10^{-5}	+
	LWOA	1.84×10^2	2.90×10^{-1}	1.83×10^2	1.84×10^2	3	8.71×10^{-3}	+
	MSWOA	1.84×10^2	4.30×10^{-1}	1.84×10^2	1.85×10^2	4	2.08×10^{-5}	+
	DGSwOA	1.84×10^2	1.81×10^{-1}	1.83×10^2	1.84×10^2	2		
F ₂₁	PSO	3.11×10^2	2.23×10^{-2}	3.11×10^2	3.11×10^2	2	3.60×10^{-1}	≈
	GA	3.11×10^2	1.40×10^{-1}	3.11×10^2	3.11×10^2	6	7.99×10^{-6}	+
	GWO	3.12×10^2	9.60×10^{-1}	3.11×10^2	3.13×10^2	7	2.05×10^{-7}	+
	WOA	3.11×10^2	1.99×10^{-1}	3.11×10^2	3.11×10^2	5	2.99×10^{-1}	≈
	BOA	3.11×10^2	1.48×10^{-1}	3.11×10^2	3.11×10^2	3	4.16×10^{-1}	≈
	SOA	3.12×10^2	7.43×10^{-1}	3.11×10^2	3.13×10^2	9	2.55×10^{-7}	+
	LWOA	3.11×10^2	1.49×10^{-1}	3.11×10^2	3.11×10^2	4	5.23×10^{-2}	≈
	MSWOA	3.12×10^2	6.71×10^{-1}	3.11×10^2	3.13×10^2	8	1.86×10^{-8}	+
	DGSwOA	3.11×10^2	2.76×10^{-2}	3.11×10^2	3.11×10^2	1		
F ₂₂	PSO	4.30×10^1	1.31×10^{-2}	4.30×10^1	4.30×10^1	3	1.53×10^{-4}	+
	GA	4.30×10^1	7.89×10^{-2}	4.30×10^1	4.33×10^1	5	9.31×10^{-9}	+
	GWO	4.46×10^1	1.00×10^0	4.30×10^1	4.56×10^1	9	1.86×10^{-9}	+
	WOA	4.31×10^1	1.51×10^{-1}	4.30×10^1	4.37×10^1	7	1.30×10^{-7}	+
	BOA	4.30×10^1	4.12×10^{-2}	4.30×10^1	4.32×10^1	4	1.40×10^{-5}	+
	SOA	4.39×10^1	7.71×10^{-1}	4.30×10^1	4.54×10^1	8	3.86×10^{-7}	+
	LWOA	4.30×10^1	1.14×10^{-1}	4.30×10^1	4.35×10^1	6	2.08×10^{-5}	+
	MSWOA	4.30×10^1	5.83×10^{-3}	4.30×10^1	4.30×10^1	1	2.21×10^{-2}	−
	DGSwOA	4.30×10^1	4.67×10^{-3}	4.30×10^1	4.30×10^1	2		

Table 5. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂₃	PSO	2.11×10^2	2.53×10^{-1}	2.11×10^2	2.12×10^2	5	2.56×10^{-4}	+
	GA	2.11×10^2	3.45×10^{-1}	2.11×10^2	2.12×10^2	8	8.33×10^{-7}	+
	GWO	2.11×10^2	4.10×10^{-1}	2.11×10^2	2.13×10^2	7	2.08×10^{-5}	+
	WOA	2.11×10^2	2.18×10^{-1}	2.10×10^2	2.11×10^2	2	1.91×10^{-1}	≈
	BOA	2.11×10^2	3.35×10^{-1}	2.11×10^2	2.12×10^2	9	1.64×10^{-7}	+
	SOA	2.11×10^2	3.37×10^{-1}	2.11×10^2	2.12×10^2	6	1.60×10^{-5}	+
	LWOA	2.11×10^2	2.59×10^{-1}	2.11×10^2	2.12×10^2	4	1.34×10^{-3}	+
	MSWOA	2.11×10^2	2.88×10^{-1}	2.10×10^2	2.12×10^2	3	3.71×10^{-1}	≈
	DGSwOA	2.11×10^2	2.29×10^{-1}	2.10×10^2	2.11×10^2	1		
F ₂₄	PSO	5.25×10^1	1.46×10^0	4.97×10^1	5.51×10^1	7	4.66×10^{-8}	+
	GA	5.31×10^1	1.71×10^0	4.97×10^1	5.59×10^1	8	1.30×10^{-8}	+
	GWO	5.34×10^1	2.04×10^0	4.96×10^1	5.80×10^1	9	1.86×10^{-9}	+
	WOA	5.14×10^1	1.53×10^0	4.85×10^1	5.39×10^1	6	1.40×10^{-5}	+
	BOA	5.11×10^1	1.16×10^0	4.92×10^1	5.35×10^1	4	1.82×10^{-5}	+
	SOA	4.81×10^1	5.96×10^{-1}	4.76×10^1	4.95×10^1	2	5.72×10^{-7}	−
	LWOA	5.11×10^1	1.32×10^0	4.82×10^1	5.30×10^1	5	5.59×10^{-5}	+
	MSWOA	4.79×10^1	4.33×10^{-1}	4.76×10^1	4.89×10^1	1	1.86×10^{-9}	−
	DGSwOA	4.96×10^1	8.36×10^{-1}	4.79×10^1	5.12×10^1	3		

Table 6. Comparative experimental results (dimension = 5).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	-9.17×10^1	3.51×10^{-1}	-9.23×10^1	-9.09×10^1	7	1.86×10^{-9}	+
	GA	-9.25×10^1	7.64×10^{-2}	-9.26×10^1	-9.23×10^1	4	1.60×10^{-5}	+
	GWO	-9.25×10^1	1.33×10^{-1}	-9.26×10^1	-9.21×10^1	5	9.31×10^{-9}	+
	WOA	-9.26×10^1	2.98×10^{-2}	-9.26×10^1	-9.25×10^1	1	6.70×10^{-1}	≈
	BOA	-8.17×10^1	5.70×10^0	-9.17×10^1	-6.53×10^1	9	1.86×10^{-9}	+
	SOA	-9.03×10^1	2.61×10^0	-9.26×10^1	-8.24×10^1	8	6.15×10^{-8}	+
	LWOA	-9.26×10^1	3.13×10^{-2}	-9.26×10^1	-9.25×10^1	3	4.05×10^{-2}	+
	MSWOA	-9.23×10^1	1.20×10^0	-9.26×10^1	-8.60×10^1	6	8.39×10^{-1}	≈
	DGSwOA	-9.26×10^1	3.45×10^{-2}	-9.26×10^1	-9.25×10^1	2		
F ₂	PSO	2.01×10^3	9.76×10^2	6.11×10^2	3.82×10^3	6	1.86×10^{-9}	+
	GA	3.16×10^2	3.62×10^1	2.82×10^2	4.25×10^2	1	3.45×10^{-5}	−
	GWO	1.66×10^3	6.58×10^2	3.65×10^2	2.40×10^3	5	3.54×10^{-8}	+
	WOA	6.58×10^2	3.90×10^2	2.95×10^2	1.98×10^3	3	8.03×10^{-2}	≈
	BOA	8.58×10^4	1.19×10^5	2.48×10^3	4.74×10^5	9	1.86×10^{-9}	+
	SOA	7.45×10^3	5.78×10^3	5.60×10^2	2.29×10^4	8	1.86×10^{-9}	+
	LWOA	1.57×10^3	6.94×10^2	5.91×10^2	3.64×10^3	4	5.59×10^{-9}	+
	MSWOA	2.97×10^3	2.96×10^3	3.00×10^2	1.20×10^4	7	2.35×10^{-6}	+
	DGSwOA	5.32×10^2	2.39×10^2	2.94×10^2	1.15×10^3	2		
F ₃	PSO	4.88×10^1	5.84×10^0	3.62×10^1	5.87×10^1	8	1.86×10^{-9}	+
	GA	4.12×10^1	4.31×10^0	2.86×10^1	4.90×10^1	5	8.01×10^{-8}	+
	GWO	3.37×10^1	4.82×10^0	2.64×10^1	4.72×10^1	3	1.85×10^{-2}	+
	WOA	3.14×10^1	3.93×10^0	2.49×10^1	3.98×10^1	1	7.30×10^{-1}	≈
	BOA	6.29×10^1	1.55×10^1	3.47×10^1	1.08×10^2	9	1.86×10^{-9}	+
	SOA	4.18×10^1	1.18×10^1	2.84×10^1	8.35×10^1	6	5.97×10^{-6}	+
	LWOA	3.45×10^1	3.07×10^0	2.67×10^1	4.15×10^1	4	5.38×10^{-3}	+
	MSWOA	4.22×10^1	1.60×10^1	2.50×10^1	8.66×10^1	7	3.13×10^{-4}	+
	DGSwOA	3.17×10^1	3.35×10^0	2.43×10^1	3.74×10^1	2		

Table 6. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₄	PSO	5.33×10^1	8.81×10^0	3.45×10^1	7.08×10^1	7	1.86×10^{-9}	+
	GA	5.40×10^1	8.18×10^0	3.33×10^1	6.67×10^1	8	1.86×10^{-9}	+
	GWO	4.18×10^1	4.84×10^0	3.49×10^1	5.24×10^1	6	1.86×10^{-9}	+
	WOA	3.48×10^1	3.93×10^0	2.61×10^1	4.36×10^1	3	2.48×10^{-2}	+
	BOA	6.84×10^1	1.56×10^1	4.55×10^1	1.00×10^2	9	1.86×10^{-9}	+
	SOA	4.09×10^1	1.11×10^1	2.84×10^1	7.88×10^1	5	1.06×10^{-5}	+
	LWOA	3.82×10^1	4.91×10^0	2.75×10^1	5.02×10^1	4	7.99×10^{-6}	+
	MSWOA	3.43×10^1	4.98×10^0	2.73×10^1	4.58×10^1	2	1.64×10^{-1}	≈
	DGSwOA	3.23×10^1	2.71×10^0	2.61×10^1	3.76×10^1	1		
F ₅	PSO	6.29×10^1	2.19×10^0	5.75×10^1	6.66×10^1	7	1.86×10^{-9}	+
	GA	6.80×10^1	3.38×10^0	6.16×10^1	7.55×10^1	8	1.86×10^{-9}	+
	GWO	5.19×10^1	1.40×10^0	5.15×10^1	5.82×10^1	4	1.80×10^{-1}	≈
	WOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	BOA	9.14×10^1	1.15×10^1	6.46×10^1	1.18×10^2	9	NaN	NaN
	SOA	5.90×10^1	3.35×10^0	5.15×10^1	6.15×10^1	6	NaN	NaN
	LWOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	NaN	NaN
	MSWOA	5.49×10^1	4.71×10^0	5.15×10^1	6.15×10^1	5	NaN	NaN
	DGSwOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1		
F ₆	PSO	9.28×10^1	3.32×10^0	8.57×10^1	9.71×10^1	6	1.86×10^{-9}	+
	GA	8.99×10^1	2.38×10^0	8.59×10^1	9.58×10^1	5	1.86×10^{-9}	+
	GWO	8.41×10^1	4.68×10^{-1}	8.37×10^1	8.48×10^1	3	1.89×10^{-4}	+
	WOA	8.39×10^1	3.43×10^{-1}	8.35×10^1	8.48×10^1	2	3.09×10^{-1}	≈
	BOA	5.56×10^3	8.12×10^3	9.05×10^1	3.43×10^4	9	1.86×10^{-9}	+
	SOA	3.61×10^2	8.10×10^2	8.46×10^1	3.80×10^3	7	1.86×10^{-9}	+
	LWOA	8.57×10^1	9.29×10^{-1}	8.42×10^1	8.73×10^1	4	5.59×10^{-9}	+
	MSWOA	4.48×10^2	1.67×10^3	8.37×10^1	9.35×10^3	8	1.86×10^{-9}	+
	DGSwOA	8.38×10^1	2.83×10^{-1}	8.35×10^1	8.47×10^1	1		
F ₇	PSO	-8.07×10^1	1.32×10^0	-8.29×10^1	-7.77×10^1	7	1.86×10^{-9}	+
	GA	-8.35×10^1	2.49×10^{-1}	-8.38×10^1	-8.25×10^1	3	8.08×10^{-1}	≈
	GWO	-8.29×10^1	3.54×10^{-1}	-8.36×10^1	-8.21×10^1	5	1.86×10^{-8}	+
	WOA	-8.33×10^1	3.78×10^{-1}	-8.38×10^1	-8.25×10^1	4	6.06×10^{-2}	≈
	BOA	-4.78×10^1	1.22×10^1	-7.24×10^1	-2.38×10^1	9	1.86×10^{-9}	+
	SOA	-8.14×10^1	2.64×10^0	-8.38×10^1	-7.22×10^1	6	3.86×10^{-7}	+
	LWOA	-8.35×10^1	2.63×10^{-1}	-8.38×10^1	-8.30×10^1	2	9.84×10^{-1}	≈
	MSWOA	-7.97×10^1	8.81×10^0	-8.39×10^1	-3.51×10^1	8	3.05×10^{-5}	+
	DGSwOA	-8.35×10^1	2.05×10^{-1}	-8.39×10^1	-8.31×10^1	1		
F ₈	PSO	-6.58×10^1	3.33×10^1	-1.24×10^2	1.32×10^1	7	1.86×10^{-9}	+
	GA	-1.31×10^2	1.39×10^0	-1.34×10^2	-1.26×10^2	2	8.08×10^{-1}	≈
	GWO	-1.28×10^2	8.81×10^0	-1.35×10^2	-1.09×10^2	5	4.28×10^{-1}	≈
	WOA	-1.34×10^2	2.13×10^0	-1.35×10^2	-1.27×10^2	1	6.06×10^{-2}	≈
	BOA	1.92×10^3	2.49×10^3	-2.94×10^1	9.82×10^3	9	1.86×10^{-9}	+
	SOA	3.75×10^2	2.22×10^3	-1.34×10^2	1.23×10^4	8	6.15×10^{-8}	+
	LWOA	-1.30×10^2	2.51×10^0	-1.34×10^2	-1.23×10^2	4	3.39×10^{-1}	≈
	MSWOA	-1.26×10^2	3.20×10^1	-1.35×10^2	4.64×10^1	6	1.00×10^0	≈
	DGSwOA	-1.31×10^2	5.42×10^0	-1.35×10^2	-1.19×10^2	3		
F ₉	PSO	-2.85×10^2	3.17×10^1	-3.33×10^2	-2.04×10^2	8	1.86×10^{-9}	+
	GA	-3.55×10^2	1.78×10^0	-3.58×10^2	-3.48×10^2	6	1.86×10^{-9}	+
	GWO	-3.58×10^2	1.20×10^0	-3.59×10^2	-3.55×10^2	3	2.61×10^{-8}	+
	WOA	-3.58×10^2	1.13×10^0	-3.59×10^2	-3.55×10^2	2	3.45×10^{-5}	+
	BOA	-1.69×10^2	2.74×10^1	-2.33×10^2	-9.36×10^1	9	1.86×10^{-9}	+
	SOA	-3.55×10^2	3.92×10^0	-3.59×10^2	-3.44×10^2	7	2.61×10^{-8}	+
	LWOA	-3.55×10^2	1.69×10^0	-3.59×10^2	-3.51×10^2	5	3.73×10^{-9}	+
	MSWOA	-3.57×10^2	1.62×10^0	-3.59×10^2	-3.55×10^2	4	4.97×10^{-5}	+
	DGSwOA	-3.59×10^2	2.98×10^{-1}	-3.59×10^2	-3.58×10^2	1		

Table 6. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₀	PSO	1.60 × 10 ³	8.61 × 10 ²	2.65 × 10 ²	4.30 × 10 ³	5	6.15 × 10 ⁻⁸	+
	GA	3.20 × 10 ²	2.10 × 10²	-5.30 × 10 ⁰	9.32 × 10²	2	9.68 × 10 ⁻¹	≈
	GWO	2.24 × 10 ³	3.52 × 10 ³	-1.57 × 10 ¹	1.85 × 10 ⁴	7	3.79 × 10 ⁻⁶	+
	WOA	2.84 × 10²	2.53 × 10 ²	-4.70 × 10¹	1.07 × 10 ³	1	6.70 × 10 ⁻¹	≈
	BOA	1.10 × 10 ⁴	6.99 × 10 ³	1.12 × 10 ³	2.72 × 10 ⁴	9	1.86 × 10 ⁻⁹	+
	SOA	3.66 × 10 ³	5.82 × 10 ³	1.97 × 10 ²	2.75 × 10 ⁴	8	4.66 × 10 ⁻⁸	+
	LWOA	5.47 × 10 ²	2.92 × 10 ²	1.22 × 10 ²	1.19 × 10 ³	4	5.01 × 10 ⁻³	+
	MSWOA	1.70 × 10 ³	1.54 × 10 ³	-3.13 × 10 ¹	6.68 × 10 ³	6	6.91 × 10 ⁻⁷	+
	DGSwOA	3.29 × 10 ²	2.74 × 10 ²	2.18 × 10 ¹	1.04 × 10 ³	3		
F ₁₁	PSO	-8.19 × 10 ¹	1.09 × 10 ¹	-9.59 × 10 ¹	-6.00 × 10 ¹	5	7.00 × 10 ⁻¹	≈
	GA	-8.86 × 10¹	6.07 × 10⁰	-9.93 × 10¹	-7.57 × 10¹	1	6.64 × 10 ⁻³	-
	GWO	-6.59 × 10 ¹	1.34 × 10 ¹	-8.92 × 10 ¹	-3.75 × 10 ¹	7	1.68 × 10 ⁻⁶	+
	WOA	-8.31 × 10 ¹	7.98 × 10 ⁰	-9.89 × 10 ¹	-6.24 × 10 ¹	3	1.00 × 10 ⁰	≈
	BOA	3.37 × 10 ³	7.73 × 10 ³	-7.93 × 10 ¹	3.27 × 10 ⁴	9	9.31 × 10 ⁻⁹	+
	SOA	-6.44 × 10 ¹	1.91 × 10 ¹	-9.39 × 10 ¹	-3.52 × 10 ⁰	8	3.45 × 10 ⁻⁵	+
	LWOA	-8.41 × 10 ¹	7.37 × 10 ⁰	-9.92 × 10 ¹	-6.55 × 10 ¹	2	4.52 × 10 ⁻¹	≈
	MSWOA	-7.03 × 10 ¹	1.72 × 10 ¹	-9.86 × 10 ¹	-6.73 × 10 ⁰	6	7.30 × 10 ⁻⁴	+
	DGSwOA	-8.26 × 10 ¹	8.14 × 10 ⁰	-9.84 × 10 ¹	-6.53 × 10 ¹	4		
F ₁₂	PSO	3.56 × 10 ⁵	2.17 × 10 ⁵	3.34 × 10 ⁴	8.95 × 10 ⁵	7	3.73 × 10 ⁻⁹	+
	GA	3.08 × 10 ⁴	5.30 × 10 ⁴	5.07 × 10 ²	2.72 × 10 ⁵	5	1.00 × 10 ⁻¹	≈
	GWO	2.49 × 10 ⁴	5.94 × 10 ⁴	3.00 × 10²	3.14 × 10 ⁵	3	8.08 × 10 ⁻¹	≈
	WOA	7.41 × 10³	1.50 × 10 ⁴	3.13 × 10 ²	7.53 × 10 ⁴	1	2.93 × 10 ⁻²	-
	BOA	5.86 × 10 ⁶	4.03 × 10 ⁶	3.91 × 10 ⁵	1.57 × 10 ⁷	9	1.86 × 10 ⁻⁹	+
	SOA	8.08 × 10 ⁵	1.43 × 10 ⁶	1.94 × 10 ³	7.59 × 10 ⁶	8	2.61 × 10 ⁻⁸	+
	LWOA	2.51 × 10 ⁴	1.43 × 10 ⁴	4.59 × 10 ³	5.88 × 10 ⁴	4	1.58 × 10 ⁻³	+
	MSWOA	2.50 × 10 ⁵	4.22 × 10 ⁵	4.22 × 10 ³	1.24 × 10 ⁶	6	3.15 × 10 ⁻⁷	+
	DGSwOA	1.23 × 10 ⁴	1.23 × 10⁴	3.07 × 10 ²	4.15 × 10⁴	2		
F ₁₃	PSO	6.61 × 10 ¹	2.97 × 10 ¹	1.94 × 10 ¹	1.32 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GA	3.42 × 10 ¹	2.21 × 10 ¹	-6.67 × 10 ⁰	8.61 × 10 ¹	6	1.86 × 10 ⁻⁹	+
	GWO	-1.42 × 10 ¹	2.18 × 10 ¹	-4.56 × 10 ¹	3.25 × 10 ¹	4	3.90 × 10 ⁻⁵	+
	WOA	-2.79 × 10 ¹	1.30 × 10 ¹	-5.05 × 10¹	-1.35 × 10 ⁻¹	2	5.23 × 10 ⁻²	≈
	BOA	2.00 × 10 ²	1.09 × 10 ²	-1.07 × 10 ¹	4.46 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	8.70 × 10 ¹	9.81 × 10 ¹	-2.47 × 10 ¹	3.33 × 10 ²	8	3.73 × 10 ⁻⁹	+
	LWOA	-1.54 × 10 ¹	1.07 × 10 ¹	-3.10 × 10 ¹	8.65 × 10 ⁰	3	1.86 × 10 ⁻⁹	+
	MSWOA	1.72 × 10 ¹	7.12 × 10 ¹	-4.16 × 10 ¹	3.31 × 10 ²	5	8.01 × 10 ⁻⁸	+
	DGSwOA	-3.51 × 10¹	8.94 × 10⁰	-4.82 × 10 ¹	-1.34 × 10¹	1		
F ₁₄	PSO	-5.73 × 10 ¹	2.04 × 10 ⁻¹	-5.77 × 10 ¹	-5.68 × 10 ¹	7	1.86 × 10 ⁻⁹	+
	GA	-5.78 × 10 ¹	4.01 × 10 ⁻²	-5.79 × 10 ¹	-5.77 × 10 ¹	4	1.02 × 10 ⁻⁷	+
	GWO	-5.78 × 10 ¹	1.54 × 10 ⁻¹	-5.79 × 10¹	-5.73 × 10 ¹	5	1.14 × 10 ⁻¹	≈
	WOA	-5.79 × 10 ¹	5.13 × 10 ⁻²	-5.79 × 10 ¹	-5.77 × 10 ¹	2	8.08 × 10 ⁻¹	≈
	BOA	-5.09 × 10 ¹	3.13 × 10 ⁰	-5.56 × 10 ¹	-4.56 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	SOA	-5.64 × 10 ¹	1.30 × 10 ⁰	-5.79 × 10 ¹	-5.06 × 10 ¹	8	5.59 × 10 ⁻⁹	+
	LWOA	-5.78 × 10 ¹	2.82 × 10 ⁻²	-5.79 × 10 ¹	-5.78 × 10 ¹	3	6.92 × 10 ⁻⁶	+
	MSWOA	-5.77 × 10 ¹	3.91 × 10 ⁻¹	-5.79 × 10 ¹	-5.61 × 10 ¹	6	1.06 × 10 ⁻⁵	+
	DGSwOA	-5.79 × 10¹	2.66 × 10⁻²	-5.79 × 10 ¹	-5.78 × 10¹	1		
F ₁₅	PSO	-1.85 × 10 ¹	5.83 × 10 ⁰	-3.02 × 10 ¹	-7.60 × 10 ⁰	8	1.86 × 10 ⁻⁹	+
	GA	-3.23 × 10 ¹	3.71 × 10 ⁰	-4.01 × 10 ¹	-2.63 × 10 ¹	4	7.67 × 10 ⁻²	≈
	GWO	-3.23 × 10 ¹	3.76 × 10 ⁰	-4.04 × 10 ¹	-2.44 × 10 ¹	3	6.67 × 10 ⁻²	≈
	WOA	-3.29 × 10 ¹	4.65 × 10 ⁰	-4.16 × 10 ¹	-2.35 × 10 ¹	2	3.09 × 10 ⁻¹	≈
	BOA	-2.39 × 10 ⁰	1.03 × 10 ¹	-1.77 × 10 ¹	3.11 × 10 ¹	9	1.86 × 10 ⁻⁹	+
	SOA	-3.07 × 10 ¹	1.05 × 10 ¹	-4.05 × 10 ¹	1.91 × 10 ¹	5	1.19 × 10 ⁻¹	≈
	LWOA	-3.07 × 10 ¹	3.76 × 10 ⁰	-4.09 × 10 ¹	-2.29 × 10 ¹	6	4.03 × 10 ⁻³	+
	MSWOA	-2.29 × 10 ¹	1.54 × 10 ¹	-4.17 × 10¹	1.62 × 10 ¹	7	1.13 × 10 ⁻³	+
	DGSwOA	-3.41 × 10¹	3.36 × 10⁰	-4.05 × 10 ¹	-2.76 × 10¹	1		

Table 6. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₆	PSO	-2.58×10^2	8.35×10^{-1}	-2.59×10^2	-2.55×10^2	6	3.73×10^{-9}	+
	GA	-2.57×10^2	1.15×10^0	-2.60×10^2	-2.55×10^2	8	1.86×10^{-9}	+
	GWO	-2.58×10^2	1.44×10^0	-2.60×10^2	-2.54×10^2	4	4.41×10^{-5}	+
	WOA	-2.59×10^2	6.53×10^{-1}	-2.60×10^2	-2.58×10^2	2	7.15×10^{-1}	≈
	BOA	-2.41×10^2	7.47×10^0	-2.56×10^2	-2.27×10^2	9	1.86×10^{-9}	+
	SOA	-2.57×10^2	1.82×10^0	-2.60×10^2	-2.52×10^2	7	2.55×10^{-7}	+
	LWOA	-2.58×10^2	8.87×10^{-1}	-2.60×10^2	-2.56×10^2	5	4.66×10^{-8}	+
	MSWOA	-2.59×10^2	1.39×10^0	-2.60×10^2	-2.54×10^2	3	8.14×10^{-3}	+
	DGSwOA	-2.59×10^2	5.82×10^{-1}	-2.60×10^2	-2.58×10^2	1		
F ₁₇	PSO	-3.70×10^1	4.20×10^{-1}	-3.78×10^1	-3.62×10^1	8	1.86×10^{-9}	+
	GA	-3.78×10^1	2.20×10^{-1}	-3.83×10^1	-3.72×10^1	5	1.86×10^{-9}	+
	GWO	-3.84×10^1	1.64×10^{-1}	-3.86×10^1	-3.76×10^1	3	1.23×10^{-4}	+
	WOA	-3.84×10^1	1.34×10^{-1}	-3.86×10^1	-3.81×10^1	2	3.84×10^{-2}	+
	BOA	-3.12×10^1	1.77×10^0	-3.49×10^1	-2.80×10^1	9	1.86×10^{-9}	+
	SOA	-3.76×10^1	8.67×10^{-1}	-3.84×10^1	-3.52×10^1	6	1.86×10^{-9}	+
	LWOA	-3.82×10^1	1.68×10^{-1}	-3.85×10^1	-3.78×10^1	4	3.15×10^{-7}	+
	MSWOA	-3.76×10^1	6.34×10^{-1}	-3.87×10^1	-3.57×10^1	7	3.54×10^{-8}	+
	DGSwOA	-3.85×10^1	1.13×10^{-1}	-3.87×10^1	-3.83×10^1	1		
F ₁₈	PSO	-3.33×10^1	1.22×10^0	-3.57×10^1	-3.13×10^1	8	1.86×10^{-9}	+
	GA	-3.68×10^1	5.52×10^{-1}	-3.80×10^1	-3.58×10^1	5	1.02×10^{-7}	+
	GWO	-3.77×10^1	7.52×10^{-1}	-3.84×10^1	-3.55×10^1	3	1.35×10^{-1}	≈
	WOA	-3.79×10^1	7.13×10^{-1}	-3.86×10^1	-3.51×10^1	2	7.61×10^{-1}	≈
	BOA	-1.67×10^1	6.19×10^0	-2.89×10^1	-6.64×10^0	9	1.86×10^{-9}	+
	SOA	-3.41×10^1	3.29×10^0	-3.83×10^1	-2.46×10^1	7	8.01×10^{-8}	+
	LWOA	-3.69×10^1	5.28×10^{-1}	-3.75×10^1	-3.55×10^1	4	1.68×10^{-6}	+
	MSWOA	-3.55×10^1	1.80×10^0	-3.82×10^1	-3.12×10^1	6	5.59×10^{-9}	+
	DGSwOA	-3.79×10^1	5.84×10^{-1}	-3.85×10^1	-3.54×10^1	1		
F ₁₉	PSO	4.21×10^1	6.49×10^{-1}	4.09×10^1	4.37×10^1	9	1.86×10^{-9}	+
	GA	4.17×10^1	3.30×10^{-1}	4.09×10^1	4.22×10^1	8	1.86×10^{-9}	+
	GWO	4.06×10^1	8.60×10^{-2}	4.05×10^1	4.08×10^1	5	2.05×10^{-7}	+
	WOA	4.06×10^1	6.84×10^{-2}	4.05×10^1	4.07×10^1	2	4.71×10^{-7}	+
	BOA	4.09×10^1	1.86×10^{-1}	4.06×10^1	4.13×10^1	6	1.86×10^{-9}	+
	SOA	4.06×10^1	6.30×10^{-2}	4.05×10^1	4.07×10^1	4	1.86×10^{-9}	+
	LWOA	4.15×10^1	3.55×10^{-1}	4.07×10^1	4.22×10^1	7	1.86×10^{-9}	+
	MSWOA	4.06×10^1	7.77×10^{-2}	4.05×10^1	4.07×10^1	3	1.86×10^{-9}	+
	DGSwOA	4.05×10^1	4.83×10^{-3}	4.05×10^1	4.05×10^1	1		
F ₂₀	PSO	1.86×10^2	4.83×10^{-1}	1.85×10^2	1.86×10^2	8	3.73×10^{-9}	+
	GA	1.85×10^2	2.20×10^{-1}	1.84×10^2	1.85×10^2	7	3.54×10^{-8}	+
	GWO	1.85×10^2	1.55×10^{-1}	1.84×10^2	1.85×10^2	4	2.69×10^{-5}	+
	WOA	1.85×10^2	1.53×10^{-1}	1.84×10^2	1.85×10^2	2	2.19×10^{-3}	+
	BOA	1.92×10^2	3.52×10^1	1.84×10^2	3.81×10^2	9	1.86×10^{-9}	+
	SOA	1.85×10^2	4.81×10^{-1}	1.83×10^2	1.86×10^2	5	5.01×10^{-3}	+
	LWOA	1.85×10^2	3.18×10^{-1}	1.84×10^2	1.85×10^2	3	1.72×10^{-3}	+
	MSWOA	1.85×10^2	6.07×10^{-1}	1.84×10^2	1.86×10^2	6	4.18×10^{-4}	+
	DGSwOA	1.84×10^2	1.73×10^{-1}	1.84×10^2	1.85×10^2	1		
F ₂₁	PSO	3.12×10^2	5.62×10^{-1}	3.11×10^2	3.13×10^2	5	8.14×10^{-3}	+
	GA	3.12×10^2	8.19×10^{-1}	3.11×10^2	3.14×10^2	6	1.37×10^{-4}	+
	GWO	3.12×10^2	1.39×10^0	3.11×10^2	3.16×10^2	7	3.05×10^{-5}	+
	WOA	3.11×10^2	6.23×10^{-1}	3.11×10^2	3.13×10^2	4	9.84×10^{-1}	≈
	BOA	3.11×10^2	7.13×10^{-1}	3.11×10^2	3.13×10^2	3	9.35×10^{-1}	≈
	SOA	3.15×10^2	3.26×10^0	3.11×10^2	3.24×10^2	9	3.79×10^{-6}	+
	LWOA	3.11×10^2	4.06×10^{-1}	3.11×10^2	3.12×10^2	1	3.80×10^{-4}	−
	MSWOA	3.13×10^2	1.89×10^0	3.11×10^2	3.18×10^2	8	2.99×10^{-3}	+
	DGSwOA	3.11×10^2	4.74×10^{-1}	3.11×10^2	3.12×10^2	2		

Table 6. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂₂	PSO	4.38×10^1	5.99×10^{-1}	4.30×10^1	4.50×10^1	3	6.99×10^{-2}	≈
	GA	4.53×10^1	2.00×10^0	4.31×10^1	5.08×10^1	6	4.34×10^{-3}	+
	GWO	4.67×10^1	4.33×10^0	4.37×10^1	5.85×10^1	7	6.64×10^{-3}	+
	WOA	4.37×10^1	6.77×10^{-1}	4.30×10^1	4.57×10^1	2	1.28×10^{-2}	−
	BOA	4.36×10^1	8.21×10^{-1}	4.30×10^1	4.68×10^1	1	1.13×10^{-2}	−
	SOA	5.33×10^1	6.30×10^0	4.36×10^1	7.06×10^1	9	4.66×10^{-8}	+
	LWOA	4.40×10^1	5.55×10^{-1}	4.30×10^1	4.51×10^1	4	9.52×10^{-1}	≈
	MSWOA	4.70×10^1	5.49×10^0	4.30×10^1	6.18×10^1	8	1.24×10^{-1}	≈
	DGSwOA	4.41×10^1	6.63×10^{-1}	4.30×10^1	4.58×10^1	5		
F ₂₃	PSO	2.11×10^2	2.79×10^{-1}	2.11×10^2	2.12×10^2	6	3.90×10^{-5}	+
	GA	2.12×10^2	3.33×10^{-1}	2.11×10^2	2.12×10^2	7	2.55×10^{-7}	+
	GWO	2.11×10^2	3.78×10^{-1}	2.11×10^2	2.12×10^2	4	1.19×10^{-1}	≈
	WOA	2.11×10^2	2.82×10^{-1}	2.10×10^2	2.12×10^2	2	9.19×10^{-1}	≈
	BOA	2.12×10^2	3.44×10^{-1}	2.11×10^2	2.12×10^2	8	3.54×10^{-8}	+
	SOA	2.12×10^2	3.63×10^{-1}	2.11×10^2	2.12×10^2	9	1.02×10^{-7}	+
	LWOA	2.11×10^2	2.15×10^{-1}	2.11×10^2	2.12×10^2	5	4.41×10^{-5}	+
	MSWOA	2.11×10^2	2.76×10^{-1}	2.11×10^2	2.12×10^2	1	2.34×10^{-2}	−
	DGSwOA	2.11×10^2	1.66×10^{-1}	2.11×10^2	2.12×10^2	3		
F ₂₄	PSO	7.02×10^1	4.20×10^0	6.01×10^1	7.73×10^1	9	3.73×10^{-9}	+
	GA	6.85×10^1	4.29×10^0	6.00×10^1	7.60×10^1	8	5.72×10^{-7}	+
	GWO	6.67×10^1	3.52×10^0	6.00×10^1	7.44×10^1	7	5.14×10^{-6}	+
	WOA	6.48×10^1	3.62×10^0	5.30×10^1	7.11×10^1	4	8.72×10^{-4}	+
	BOA	6.45×10^1	3.78×10^0	5.70×10^1	7.28×10^1	3	1.85×10^{-2}	+
	SOA	6.59×10^1	9.30×10^0	4.97×10^1	7.99×10^1	5	7.67×10^{-2}	≈
	LWOA	6.39×10^1	3.69×10^0	5.48×10^1	7.06×10^1	2	5.77×10^{-2}	≈
	MSWOA	6.66×10^1	7.88×10^0	5.48×10^1	8.36×10^1	6	1.28×10^{-2}	+
	DGSwOA	6.22×10^1	2.85×10^0	5.49×10^1	6.75×10^1	1		

Table 7. Comparative experimental results (dimension = 10).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	-8.13×10^1	2.95×10^0	-8.76×10^1	-7.60×10^1	7	1.86×10^{-9}	+
	GA	-9.06×10^1	6.50×10^{-1}	-9.16×10^1	-8.93×10^1	5	1.86×10^{-9}	+
	GWO	-9.13×10^1	6.23×10^{-1}	-9.22×10^1	-9.01×10^1	4	4.66×10^{-3}	+
	WOA	-9.16×10^1	5.14×10^{-1}	-9.26×10^1	-8.98×10^1	3	5.29×10^{-1}	≈
	BOA	-4.18×10^1	1.20×10^1	-6.35×10^1	-1.53×10^1	9	1.86×10^{-9}	+
	SOA	-7.94×10^1	6.07×10^0	-9.02×10^1	-6.38×10^1	8	1.86×10^{-9}	+
	LWOA	-9.18×10^1	3.24×10^{-1}	-9.24×10^1	-9.12×10^1	1	2.37×10^{-1}	≈
	MSWOA	-8.80×10^1	3.56×10^0	-9.24×10^1	-7.75×10^1	6	1.02×10^{-7}	+
	DGSwOA	-9.17×10^1	4.85×10^{-1}	-9.26×10^1	-9.09×10^1	2		
F ₂	PSO	5.73×10^4	2.01×10^4	1.56×10^4	9.64×10^4	7	1.86×10^{-9}	+
	GA	5.93×10^3	2.97×10^3	2.09×10^3	1.56×10^4	1	3.60×10^{-1}	≈
	GWO	4.15×10^4	3.09×10^4	5.87×10^3	1.04×10^5	6	1.86×10^{-8}	+
	WOA	1.02×10^4	8.11×10^3	2.00×10^3	3.23×10^4	3	9.61×10^{-2}	≈
	BOA	5.46×10^5	3.72×10^5	5.26×10^4	1.64×10^6	9	1.86×10^{-9}	+
	SOA	1.30×10^5	1.22×10^5	2.59×10^4	4.50×10^5	8	1.86×10^{-9}	+
	LWOA	2.03×10^4	9.04×10^3	4.27×10^3	3.77×10^4	4	1.06×10^{-5}	+
	MSWOA	3.62×10^4	1.75×10^4	1.14×10^4	8.73×10^4	5	3.73×10^{-9}	+
	DGSwOA	7.34×10^3	5.19×10^3	1.80×10^3	2.85×10^4	2		

Table 7. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₃	PSO	1.42×10^2	1.74×10^1	1.09×10^2	1.76×10^2	5	1.86×10^{-9}	+
	GA	1.56×10^2	1.78×10^1	1.20×10^2	1.93×10^2	7	1.86×10^{-9}	+
	GWO	6.98×10^1	1.03×10^1	4.71×10^1	9.23×10^1	1	4.77×10^{-1}	≈
	WOA	7.31×10^1	9.82×10^0	4.70×10^1	8.85×10^1	3	7.00×10^{-1}	≈
	BOA	2.88×10^2	7.24×10^1	1.57×10^2	4.36×10^2	9	1.86×10^{-9}	+
	SOA	1.54×10^2	5.63×10^1	9.63×10^1	3.03×10^2	6	1.86×10^{-9}	+
	LWOA	8.03×10^1	7.12×10^0	6.78×10^1	9.19×10^1	4	6.64×10^{-3}	+
	MSWOA	1.75×10^2	8.92×10^1	5.35×10^1	5.40×10^2	8	6.15×10^{-8}	+
	DGSwOA	7.25×10^1	1.07×10^1	5.61×10^1	9.67×10^1	2		
F ₄	PSO	1.79×10^2	1.85×10^1	1.34×10^2	2.15×10^2	7	1.86×10^{-9}	+
	GA	1.86×10^2	1.92×10^1	1.53×10^2	2.31×10^2	8	1.86×10^{-9}	+
	GWO	9.22×10^1	1.98×10^1	6.02×10^1	1.45×10^2	2	8.08×10^{-1}	≈
	WOA	9.21×10^1	1.73×10^1	4.83×10^1	1.22×10^2	1	6.70×10^{-1}	≈
	BOA	2.53×10^2	4.09×10^1	1.70×10^2	3.40×10^2	9	1.86×10^{-9}	+
	SOA	1.47×10^2	4.60×10^1	6.28×10^1	2.64×10^2	6	1.30×10^{-8}	+
	LWOA	9.90×10^1	9.75×10^0	7.25×10^1	1.23×10^2	4	6.99×10^{-2}	≈
	MSWOA	1.28×10^2	4.07×10^1	6.74×10^1	2.28×10^2	5	9.90×10^{-5}	+
	DGSwOA	9.36×10^1	1.45×10^1	6.47×10^1	1.29×10^2	3		
F ₅	PSO	1.03×10^2	8.34×10^0	8.17×10^1	1.19×10^2	7	1.86×10^{-9}	+
	GA	1.22×10^2	7.96×10^0	1.06×10^2	1.37×10^2	8	1.86×10^{-9}	+
	GWO	6.00×10^1	4.37×10^0	5.15×10^1	6.98×10^1	4	3.73×10^{-9}	+
	WOA	5.19×10^1	6.63×10^{-1}	5.15×10^1	5.49×10^1	3	6.03×10^{-1}	≈
	BOA	1.60×10^2	1.92×10^1	1.13×10^2	1.94×10^2	9	1.86×10^{-9}	+
	SOA	7.93×10^1	2.18×10^1	5.15×10^1	1.08×10^2	6	8.01×10^{-8}	+
	LWOA	5.15×10^1	7.11×10^{-15}	5.15×10^1	5.15×10^1	1	9.82×10^{-4}	−
	MSWOA	7.52×10^1	1.85×10^1	5.15×10^1	1.17×10^2	5	3.54×10^{-8}	+
	DGSwOA	5.18×10^1	4.73×10^{-1}	5.15×10^1	5.38×10^1	2		
F ₆	PSO	1.72×10^2	2.13×10^1	1.24×10^2	2.03×10^2	7	1.86×10^{-9}	+
	GA	1.30×10^2	8.88×10^0	1.08×10^2	1.45×10^2	5	3.73×10^{-9}	+
	GWO	1.03×10^2	7.80×10^0	8.64×10^1	1.29×10^2	3	1.52×10^{-1}	≈
	WOA	9.90×10^1	8.53×10^0	8.55×10^1	1.17×10^2	1	5.84×10^{-1}	≈
	BOA	7.77×10^3	7.42×10^3	1.27×10^2	2.95×10^4	9	1.86×10^{-9}	+
	SOA	1.09×10^3	2.59×10^3	1.13×10^2	1.15×10^4	8	1.86×10^{-9}	+
	LWOA	1.05×10^2	6.40×10^0	9.61×10^1	1.18×10^2	4	8.14×10^{-3}	+
	MSWOA	1.72×10^2	1.19×10^2	1.07×10^2	8.00×10^2	6	3.73×10^{-9}	+
	DGSwOA	1.00×10^2	6.11×10^0	8.71×10^1	1.13×10^2	2		
F ₇	PSO	-3.91×10^1	1.38×10^1	-5.83×10^1	-3.03×10^0	7	1.86×10^{-9}	+
	GA	-7.58×10^1	2.52×10^0	-8.03×10^1	-6.86×10^1	1	6.06×10^{-2}	≈
	GWO	-7.18×10^1	7.16×10^0	-8.09×10^1	-5.34×10^1	5	2.37×10^{-1}	≈
	WOA	-7.45×10^1	5.05×10^0	-8.04×10^1	-6.11×10^1	3	8.55×10^{-1}	≈
	BOA	6.05×10^1	5.48×10^1	-2.55×10^1	1.83×10^2	9	1.86×10^{-9}	+
	SOA	-2.44×10^1	3.42×10^1	-6.65×10^1	6.40×10^1	8	1.86×10^{-9}	+
	LWOA	-7.47×10^1	3.15×10^0	-8.03×10^1	-6.89×10^1	2	5.84×10^{-1}	≈
	MSWOA	-5.32×10^1	1.62×10^1	-7.98×10^1	-1.70×10^1	6	1.86×10^{-8}	+
	DGSwOA	-7.41×10^1	4.75×10^0	-8.08×10^1	-6.41×10^1	4		
F ₈	PSO	2.46×10^3	8.62×10^2	1.13×10^3	4.45×10^3	7	1.86×10^{-9}	+
	GA	2.69×10^1	7.10×10^1	-6.86×10^1	1.69×10^2	4	4.42×10^{-6}	+
	GWO	3.74×10^1	1.74×10^2	-1.02×10^2	6.21×10^2	5	2.37×10^{-3}	+
	WOA	-5.11×10^1	9.24×10^1	-1.29×10^2	2.40×10^2	3	3.39×10^{-1}	≈
	BOA	8.36×10^3	4.74×10^3	1.85×10^3	2.06×10^4	9	1.86×10^{-9}	+
	SOA	5.12×10^3	5.39×10^3	2.77×10^1	1.74×10^4	8	1.86×10^{-9}	+
	LWOA	-5.27×10^1	5.85×10^1	-1.16×10^2	2.04×10^2	2	1.29×10^{-1}	≈
	MSWOA	1.94×10^3	4.79×10^3	-5.17×10^1	2.55×10^4	6	1.86×10^{-9}	+
	DGSwOA	-6.40×10^1	4.97×10^1	-1.27×10^2	5.21×10^1	1		

Table 7. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₉	PSO	1.76×10^3	1.01×10^3	1.07×10^2	4.26×10^3	9	1.86×10^{-9}	+
	GA	-2.68×10^2	3.51×10^1	-3.26×10^2	-1.74×10^2	7	1.86×10^{-9}	+
	GWO	-3.45×10^2	5.06×10^0	-3.50×10^2	-3.28×10^2	3	1.23×10^{-4}	+
	WOA	-3.47×10^2	5.08×10^0	-3.54×10^2	-3.32×10^2	2	6.99×10^{-2}	≈
	BOA	-1.07×10^2	1.76×10^1	-1.45×10^2	-7.77×10^1	8	1.86×10^{-9}	+
	SOA	-3.13×10^2	6.52×10^0	-3.28×10^2	-3.05×10^2	5	1.86×10^{-9}	+
	LWOA	-2.99×10^2	2.44×10^1	-3.35×10^2	-2.41×10^2	6	1.86×10^{-9}	+
	MSWOA	-3.18×10^2	9.39×10^0	-3.45×10^2	-3.05×10^2	4	1.86×10^{-9}	+
	DGSwOA	-3.50×10^2	4.77×10^0	-3.59×10^2	-3.41×10^2	1		
F ₁₀	PSO	4.95×10^4	2.16×10^4	6.86×10^3	1.03×10^5	6	3.73×10^{-9}	+
	GA	3.08×10^4	1.26×10^4	6.01×10^3	5.50×10^4	5	1.30×10^{-8}	+
	GWO	1.14×10^4	4.64×10^3	3.77×10^3	2.28×10^4	3	1.28×10^{-2}	+
	WOA	8.57×10^3	5.58×10^3	8.94×10^2	2.79×10^4	2	9.19×10^{-1}	≈
	BOA	1.75×10^5	5.42×10^4	2.09×10^4	2.63×10^5	8	1.86×10^{-9}	+
	SOA	2.17×10^5	1.29×10^5	1.87×10^4	5.99×10^5	9	1.86×10^{-9}	+
	LWOA	2.30×10^4	9.76×10^3	6.61×10^3	4.07×10^4	4	2.05×10^{-7}	+
	MSWOA	1.30×10^5	7.39×10^4	6.73×10^3	2.81×10^5	7	3.73×10^{-9}	+
	DGSwOA	8.04×10^3	3.71×10^3	8.34×10^2	1.53×10^4	1		
F ₁₁	PSO	-3.84×10^1	1.68×10^1	-6.63×10^1	1.80×10^0	4	2.77×10^{-3}	+
	GA	-5.25×10^1	1.33×10^1	-8.80×10^1	-3.40×10^1	1	3.71×10^{-1}	≈
	GWO	-4.00×10^1	9.87×10^0	-5.57×10^1	-2.18×10^1	3	1.04×10^{-3}	+
	WOA	-3.81×10^1	1.38×10^1	-6.15×10^1	-5.62×10^0	5	1.58×10^{-3}	+
	BOA	-3.16×10^1	1.16×10^1	-6.06×10^1	-5.97×10^0	6	3.86×10^{-7}	+
	SOA	1.36×10^1	4.89×10^1	-6.58×10^1	1.32×10^2	9	6.15×10^{-8}	+
	LWOA	-6.35×10^0	2.85×10^1	-5.49×10^1	7.56×10^1	8	3.54×10^{-8}	+
	MSWOA	-1.79×10^1	2.65×10^1	-4.51×10^1	1.02×10^2	7	1.86×10^{-9}	+
	DGSwOA	-4.89×10^1	7.09×10^0	-6.58×10^1	-3.84×10^1	2		
F ₁₂	PSO	1.05×10^7	2.98×10^6	5.92×10^6	1.85×10^7	7	1.86×10^{-9}	+
	GA	6.59×10^6	2.11×10^6	3.27×10^6	1.15×10^7	6	1.86×10^{-9}	+
	GWO	1.26×10^6	1.17×10^6	3.14×10^2	4.33×10^6	4	1.34×10^{-3}	+
	WOA	3.65×10^5	4.12×10^5	7.67×10^2	1.96×10^6	1	9.84×10^{-1}	≈
	BOA	5.17×10^7	2.12×10^7	1.57×10^7	8.79×10^7	9	1.86×10^{-9}	+
	SOA	1.32×10^7	1.09×10^7	5.31×10^5	3.84×10^7	8	1.86×10^{-9}	+
	LWOA	4.26×10^5	1.92×10^5	1.25×10^5	8.37×10^5	3	2.71×10^{-1}	≈
	MSWOA	6.12×10^6	9.09×10^6	1.77×10^5	4.10×10^7	5	2.55×10^{-7}	+
	DGSwOA	4.06×10^5	4.69×10^5	7.47×10^2	2.31×10^6	2		
F ₁₃	PSO	4.76×10^2	7.40×10^1	3.16×10^2	6.16×10^2	7	1.86×10^{-9}	+
	GA	4.06×10^2	6.95×10^1	2.80×10^2	5.43×10^2	6	1.86×10^{-9}	+
	GWO	1.64×10^2	4.42×10^1	8.10×10^1	2.55×10^2	4	5.59×10^{-5}	+
	WOA	1.36×10^2	6.21×10^1	-3.92×10^1	2.90×10^2	3	2.77×10^{-2}	+
	BOA	6.91×10^2	9.10×10^1	4.64×10^2	8.40×10^2	9	1.86×10^{-9}	+
	SOA	4.99×10^2	1.50×10^2	1.55×10^2	7.28×10^2	8	1.86×10^{-9}	+
	LWOA	1.17×10^2	3.42×10^1	2.97×10^1	1.80×10^2	2	4.28×10^{-1}	≈
	MSWOA	3.83×10^2	1.31×10^2	1.91×10^2	5.88×10^2	5	1.86×10^{-9}	+
	DGSwOA	1.08×10^2	4.48×10^1	3.21×10^1	2.04×10^2	1		
F ₁₄	PSO	-5.33×10^1	9.86×10^{-1}	-5.54×10^1	-5.17×10^1	7	1.86×10^{-9}	+
	GA	-5.65×10^1	3.66×10^{-1}	-5.73×10^1	-5.56×10^1	5	1.30×10^{-8}	+
	GWO	-5.70×10^1	4.95×10^{-1}	-5.75×10^1	-5.51×10^1	4	1.30×10^{-7}	+
	WOA	-5.72×10^1	3.53×10^{-1}	-5.79×10^1	-5.61×10^1	3	2.48×10^{-2}	+
	BOA	-3.84×10^1	6.05×10^0	-4.77×10^1	-2.32×10^1	9	1.86×10^{-9}	+
	SOA	-5.33×10^1	2.41×10^0	-5.65×10^1	-4.52×10^1	8	1.86×10^{-9}	+
	LWOA	-5.75×10^1	1.26×10^{-1}	-5.78×10^1	-5.72×10^1	1	3.39×10^{-1}	≈
	MSWOA	-5.61×10^1	1.51×10^0	-5.76×10^1	-5.14×10^1	6	6.91×10^{-7}	+
	DGSwOA	-5.74×10^1	2.79×10^{-1}	-5.78×10^1	-5.68×10^1	2		

Table 7. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₅	PSO	7.64×10^1	1.72×10^1	2.08×10^1	1.03×10^2	8	1.86×10^{-9}	+
	GA	6.16×10^1	1.32×10^1	3.36×10^1	8.07×10^1	6	9.31×10^{-9}	+
	GWO	1.54×10^1	7.51×10^0	7.15×10^{-1}	3.47×10^1	2	4.66×10^{-3}	−
	WOA	1.91×10^1	8.55×10^0	3.32×10^0	3.64×10^1	3	1.64×10^{-1}	≈
	BOA	1.11×10^2	3.30×10^1	4.07×10^1	1.77×10^2	9	1.86×10^{-9}	+
	SOA	7.14×10^1	3.87×10^1	-1.56×10^0	1.77×10^2	7	6.91×10^{-7}	+
	LWOA	1.48×10^1	8.87×10^0	-5.71×10^0	3.29×10^1	1	7.61×10^{-3}	−
	MSWOA	4.52×10^1	2.89×10^1	-6.15×10^0	1.26×10^2	5	1.58×10^{-3}	+
	DGSwOA	2.32×10^1	1.17×10^1	-3.48×10^0	4.54×10^1	4		
F ₁₆	PSO	-2.50×10^2	2.07×10^0	-2.55×10^2	-2.46×10^2	6	1.86×10^{-9}	+
	GA	-2.50×10^2	2.20×10^0	-2.55×10^2	-2.46×10^2	7	1.86×10^{-9}	+
	GWO	-2.54×10^2	2.94×10^0	-2.59×10^2	-2.46×10^2	3	3.27×10^{-2}	+
	WOA	-2.56×10^2	2.30×10^0	-2.59×10^2	-2.51×10^2	2	9.03×10^{-1}	≈
	BOA	-2.28×10^2	7.73×10^0	-2.42×10^2	-2.12×10^2	9	1.86×10^{-9}	+
	SOA	-2.46×10^2	3.60×10^0	-2.54×10^2	-2.41×10^2	8	1.86×10^{-9}	+
	LWOA	-2.51×10^2	2.29×10^0	-2.56×10^2	-2.48×10^2	5	3.15×10^{-7}	+
	MSWOA	-2.52×10^2	4.21×10^0	-2.58×10^2	-2.41×10^2	4	4.41×10^{-5}	+
	DGSwOA	-2.56×10^2	1.75×10^0	-2.59×10^2	-2.51×10^2	1		
F ₁₇	PSO	-3.45×10^1	5.42×10^{-1}	-3.59×10^1	-3.37×10^1	8	1.86×10^{-9}	+
	GA	-3.62×10^1	4.59×10^{-1}	-3.71×10^1	-3.56×10^1	5	2.76×10^{-6}	+
	GWO	-3.72×10^1	5.68×10^{-1}	-3.80×10^1	-3.56×10^1	2	1.24×10^{-1}	≈
	WOA	-3.72×10^1	5.50×10^{-1}	-3.84×10^1	-3.61×10^1	3	3.60×10^{-1}	≈
	BOA	-2.75×10^1	2.59×10^0	-3.37×10^1	-2.16×10^1	9	1.86×10^{-9}	+
	SOA	-3.55×10^1	1.00×10^0	-3.70×10^1	-3.29×10^1	7	8.01×10^{-8}	+
	LWOA	-3.72×10^1	4.76×10^{-1}	-3.83×10^1	-3.61×10^1	1	1.71×10^{-1}	≈
	MSWOA	-3.59×10^1	8.58×10^{-1}	-3.74×10^1	-3.44×10^1	6	1.30×10^{-7}	+
	DGSwOA	-3.70×10^1	5.76×10^{-1}	-3.85×10^1	-3.61×10^1	4		
F ₁₈	PSO	-2.29×10^1	2.23×10^0	-2.74×10^1	-1.88×10^1	8	1.86×10^{-9}	+
	GA	-3.10×10^1	1.65×10^0	-3.46×10^1	-2.79×10^1	5	3.24×10^{-6}	+
	GWO	-3.33×10^1	2.12×10^0	-3.62×10^1	-2.80×10^1	4	3.82×10^{-1}	≈
	WOA	-3.38×10^1	1.55×10^0	-3.63×10^1	-3.04×10^1	2	9.19×10^{-1}	≈
	BOA	-1.03×10^1	3.10×10^0	-1.80×10^1	-6.12×10^0	9	1.86×10^{-9}	+
	SOA	-2.78×10^1	4.01×10^0	-3.54×10^1	-1.97×10^1	7	9.31×10^{-9}	+
	LWOA	-3.36×10^1	1.60×10^0	-3.62×10^1	-3.05×10^1	3	5.29×10^{-1}	≈
	MSWOA	-3.02×10^1	2.95×10^0	-3.55×10^1	-2.35×10^1	6	4.42×10^{-6}	+
	DGSwOA	-3.38×10^1	1.61×10^0	-3.64×10^1	-2.96×10^1	1		
F ₁₉	PSO	4.71×10^1	8.51×10^{-1}	4.50×10^1	4.82×10^1	9	1.86×10^{-9}	+
	GA	4.50×10^1	7.68×10^{-1}	4.22×10^1	4.63×10^1	8	1.86×10^{-9}	+
	GWO	4.12×10^1	6.13×10^{-1}	4.05×10^1	4.28×10^1	4	8.33×10^{-7}	+
	WOA	4.14×10^1	5.73×10^{-1}	4.06×10^1	4.25×10^1	5	8.01×10^{-8}	+
	BOA	4.28×10^1	5.69×10^{-1}	4.14×10^1	4.39×10^1	6	1.86×10^{-9}	+
	SOA	4.07×10^1	1.77×10^{-2}	4.06×10^1	4.07×10^1	3	1.30×10^{-7}	+
	LWOA	4.42×10^1	7.68×10^{-1}	4.20×10^1	4.56×10^1	7	1.86×10^{-9}	+
	MSWOA	4.07×10^1	2.38×10^{-2}	4.06×10^1	4.07×10^1	2	8.33×10^{-7}	+
	DGSwOA	4.06×10^1	5.37×10^{-2}	4.05×10^1	4.07×10^1	1		
F ₂₀	PSO	5.47×10^2	2.83×10^2	1.87×10^2	1.18×10^3	7	1.86×10^{-9}	+
	GA	1.86×10^2	2.00×10^{-1}	1.85×10^2	1.86×10^2	5	2.35×10^{-6}	+
	GWO	1.86×10^2	2.56×10^{-1}	1.85×10^2	1.86×10^2	3	3.48×10^{-3}	+
	WOA	1.85×10^2	2.74×10^{-1}	1.85×10^2	1.86×10^2	2	2.45×10^{-1}	≈
	BOA	8.34×10^2	7.82×10^2	1.87×10^2	3.37×10^3	8	1.86×10^{-9}	+
	SOA	9.24×10^2	1.43×10^3	1.85×10^2	6.55×10^3	9	1.86×10^{-8}	+
	LWOA	1.86×10^2	2.59×10^{-1}	1.85×10^2	1.86×10^2	4	6.19×10^{-3}	+
	MSWOA	3.53×10^2	7.73×10^2	1.85×10^2	4.50×10^3	6	2.05×10^{-7}	+
	DGSwOA	1.85×10^2	3.58×10^{-1}	1.84×10^2	1.86×10^2	1		

Table 7. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂₁	PSO	3.26×10^2	3.59×10^0	3.19×10^2	3.33×10^2	7	1.86×10^{-9}	+
	GA	3.28×10^2	5.62×10^0	3.18×10^2	3.41×10^2	8	9.31×10^{-9}	+
	GWO	3.18×10^2	5.30×10^0	3.12×10^2	3.37×10^2	4	1.72×10^{-3}	+
	WOA	3.14×10^2	2.49×10^0	3.11×10^2	3.19×10^2	3	8.08×10^{-1}	≈
	BOA	3.18×10^2	6.26×10^0	3.11×10^2	3.38×10^2	5	9.93×10^{-3}	+
	SOA	3.32×10^2	1.47×10^1	3.11×10^2	3.61×10^2	9	2.55×10^{-7}	+
	LWOA	3.13×10^2	2.84×10^0	3.11×10^2	3.26×10^2	1	7.61×10^{-3}	−
	MSWOA	3.24×10^2	8.03×10^0	3.12×10^2	3.41×10^2	6	6.15×10^{-8}	+
	DGSwOA	3.14×10^2	2.39×10^0	3.11×10^2	3.19×10^2	2		
F ₂₂	PSO	6.28×10^1	6.52×10^0	5.11×10^1	7.75×10^1	5	3.73×10^{-9}	+
	GA	6.76×10^1	6.45×10^0	5.20×10^1	8.00×10^1	7	1.86×10^{-9}	+
	GWO	4.98×10^1	5.43×10^0	4.52×10^1	6.61×10^1	4	4.97×10^{-2}	+
	WOA	4.87×10^1	4.16×10^0	4.45×10^1	6.40×10^1	3	2.21×10^{-1}	≈
	BOA	6.67×10^1	1.19×10^1	4.50×10^1	1.02×10^2	6	5.59×10^{-9}	+
	SOA	8.00×10^1	2.12×10^1	4.50×10^1	1.12×10^2	9	6.15×10^{-8}	+
	LWOA	4.80×10^1	3.98×10^0	4.31×10^1	6.61×10^1	2	3.28×10^{-1}	≈
	MSWOA	7.11×10^1	1.88×10^1	4.44×10^1	1.08×10^2	8	8.01×10^{-8}	+
	DGSwOA	4.73×10^1	2.58×10^0	4.34×10^1	5.43×10^1	1		
F ₂₃	PSO	2.12×10^2	3.06×10^{-1}	2.11×10^2	2.13×10^2	5	6.91×10^{-7}	+
	GA	2.12×10^2	3.27×10^{-1}	2.12×10^2	2.13×10^2	8	2.61×10^{-8}	+
	GWO	2.12×10^2	4.79×10^{-1}	2.11×10^2	2.13×10^2	4	2.02×10^{-3}	+
	WOA	2.11×10^2	3.80×10^{-1}	2.11×10^2	2.12×10^2	2	3.39×10^{-1}	≈
	BOA	2.12×10^2	3.50×10^{-1}	2.12×10^2	2.13×10^2	9	5.59×10^{-9}	+
	SOA	2.12×10^2	4.34×10^{-1}	2.11×10^2	2.13×10^2	7	1.02×10^{-7}	+
	LWOA	2.12×10^2	3.16×10^{-1}	2.11×10^2	2.13×10^2	6	1.02×10^{-7}	+
	MSWOA	2.12×10^2	3.18×10^{-1}	2.11×10^2	2.12×10^2	3	8.71×10^{-3}	+
	DGSwOA	2.11×10^2	2.88×10^{-1}	2.11×10^2	2.12×10^2	1		
F ₂₄	PSO	1.54×10^2	1.04×10^1	1.33×10^2	1.73×10^2	9	1.86×10^{-9}	+
	GA	1.32×10^2	1.11×10^1	1.00×10^2	1.47×10^2	8	9.31×10^{-9}	+
	GWO	1.15×10^2	6.89×10^0	9.93×10^1	1.25×10^2	3	2.99×10^{-3}	+
	WOA	1.17×10^2	5.73×10^0	1.07×10^2	1.26×10^2	4	9.52×10^{-4}	+
	BOA	1.19×10^2	8.82×10^0	9.84×10^1	1.34×10^2	6	6.29×10^{-5}	+
	SOA	1.17×10^2	1.34×10^1	8.53×10^1	1.37×10^2	5	2.08×10^{-2}	+
	LWOA	1.15×10^2	9.49×10^0	9.28×10^1	1.30×10^2	2	3.84×10^{-2}	+
	MSWOA	1.20×10^2	1.24×10^1	8.71×10^1	1.40×10^2	7	6.08×10^{-4}	+
	DGSwOA	1.10×10^2	7.40×10^0	8.38×10^1	1.20×10^2	1		

Table 8. Comparative experimental results (dimension = 20).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	-3.27×10^1	7.25×10^0	-4.27×10^1	-1.65×10^1	8	1.86×10^{-9}	+
	GA	-7.66×10^1	2.57×10^0	-8.30×10^1	-7.17×10^1	5	1.86×10^{-8}	+
	GWO	-8.29×10^1	2.35×10^0	-8.63×10^1	-7.49×10^1	4	5.49×10^{-2}	≈
	WOA	-8.32×10^1	3.22×10^0	-8.82×10^1	-7.35×10^1	3	8.03×10^{-2}	≈
	BOA	-7.02×10^0	2.58×10^0	-1.56×10^1	-3.47×10^0	9	1.86×10^{-9}	+
	SOA	-4.47×10^1	1.36×10^1	-6.49×10^1	-1.74×10^1	7	1.86×10^{-9}	+
	LWOA	-8.65×10^1	2.06×10^0	-8.94×10^1	-8.15×10^1	1	8.03×10^{-2}	≈
	MSWOA	-6.78×10^1	8.85×10^0	-8.08×10^1	-4.28×10^1	6	3.73×10^{-9}	+
	DGSwOA	-8.49×10^1	3.54×10^0	-9.08×10^1	-7.58×10^1	2		

Table 8. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂	PSO	5.53 × 10 ⁵	1.19 × 10 ⁵	3.36 × 10 ⁵	8.83 × 10 ⁵	7	1.86 × 10 ⁻⁹	+
	GA	1.96 × 10 ⁵	6.23 × 10 ⁴	7.79 × 10 ⁴	3.17 × 10 ⁵	5	1.86 × 10 ⁻⁸	+
	GWO	1.79 × 10 ⁵	7.22 × 10 ⁴	8.21 × 10 ⁴	2.91 × 10 ⁵	4	7.99 × 10 ⁻⁶	+
	WOA	1.11 × 10 ⁵	5.08 × 10 ⁴	5.40 × 10 ⁴	2.61 × 10 ⁵	2	7.67 × 10 ⁻²	≈
	BOA	1.91 × 10 ⁶	1.19 × 10 ⁶	2.73 × 10 ⁵	4.70 × 10 ⁶	9	1.86 × 10 ⁻⁹	+
	SOA	6.86 × 10 ⁵	4.39 × 10 ⁵	1.50 × 10 ⁵	1.81 × 10 ⁶	8	1.86 × 10 ⁻⁹	+
	LWOA	1.42 × 10 ⁵	5.04 × 10 ⁴	6.69 × 10 ⁴	3.09 × 10 ⁵	3	2.56 × 10 ⁻⁴	+
	MSWOA	4.19 × 10 ⁵	3.95 × 10 ⁵	6.73 × 10 ⁴	1.82 × 10 ⁶	6	3.73 × 10 ⁻⁹	+
	DGSwOA	9.48 × 10⁴	2.99 × 10⁴	4.49 × 10⁴	1.65 × 10⁵	1		
F ₃	PSO	4.79 × 10 ²	5.37 × 10 ¹	3.21 × 10 ²	5.82 × 10 ²	6	1.86 × 10 ⁻⁹	+
	GA	4.71 × 10 ²	4.68 × 10 ¹	3.85 × 10 ²	5.78 × 10 ²	5	1.86 × 10 ⁻⁹	+
	GWO	2.49 × 10 ²	3.63 × 10 ¹	1.59 × 10²	3.35 × 10 ²	2	5.38 × 10 ⁻³	-
	WOA	2.84 × 10 ²	3.39 × 10 ¹	2.11 × 10 ²	3.79 × 10 ²	4	2.62 × 10 ⁻¹	≈
	BOA	7.82 × 10 ²	1.42 × 10 ²	4.05 × 10 ²	1.04 × 10 ³	9	1.86 × 10 ⁻⁹	+
	SOA	5.79 × 10 ²	1.33 × 10 ²	2.89 × 10 ²	8.23 × 10 ²	7	1.86 × 10 ⁻⁹	+
	LWOA	2.16 × 10²	2.58 × 10¹	1.67 × 10 ²	2.72 × 10²	1	3.15 × 10 ⁻⁷	-
	MSWOA	6.16 × 10 ²	1.46 × 10 ²	3.53 × 10 ²	9.29 × 10 ²	8	1.86 × 10 ⁻⁹	+
	DGSwOA	2.74 × 10 ²	3.35 × 10 ¹	1.94 × 10 ²	3.57 × 10 ²	3		
F ₄	PSO	5.83 × 10 ²	4.92 × 10 ¹	4.34 × 10 ²	6.90 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GA	5.20 × 10 ²	4.21 × 10 ¹	4.17 × 10 ²	5.87 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GWO	3.68 × 10 ²	3.77 × 10 ¹	3.22 × 10 ²	4.75 × 10 ²	4	1.35 × 10 ⁻¹	≈
	WOA	3.41 × 10 ²	4.05 × 10 ¹	2.70 × 10 ²	4.24 × 10 ²	2	3.49 × 10 ⁻¹	≈
	BOA	5.98 × 10 ²	9.22 × 10 ¹	3.19 × 10 ²	7.60 × 10 ²	9	9.31 × 10 ⁻⁹	+
	SOA	4.65 × 10 ²	1.01 × 10 ²	3.11 × 10 ²	6.53 × 10 ²	6	6.92 × 10 ⁻⁶	+
	LWOA	2.80 × 10²	2.46 × 10¹	2.27 × 10 ²	3.35 × 10²	1	4.66 × 10 ⁻⁸	-
	MSWOA	3.97 × 10 ²	8.90 × 10 ¹	2.05 × 10²	5.71 × 10 ²	5	1.97 × 10 ⁻²	+
	DGSwOA	3.51 × 10 ²	4.63 × 10 ¹	2.49 × 10 ²	4.50 × 10 ²	3		
F ₅	PSO	2.22 × 10 ²	1.37 × 10 ¹	1.91 × 10 ²	2.45 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GA	2.56 × 10 ²	1.57 × 10 ¹	2.26 × 10 ²	2.95 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GWO	1.13 × 10 ²	1.12 × 10 ¹	8.98 × 10 ¹	1.34 × 10 ²	4	1.86 × 10 ⁻⁹	+
	WOA	7.47 × 10 ¹	9.52 × 10 ⁰	5.45 × 10 ¹	9.07 × 10 ¹	3	2.80 × 10 ⁻¹	≈
	BOA	3.17 × 10 ²	3.02 × 10 ¹	2.56 × 10 ²	3.65 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	2.06 × 10 ²	4.65 × 10 ¹	1.26 × 10 ²	2.85 × 10 ²	6	1.86 × 10 ⁻⁹	+
	LWOA	5.86 × 10¹	7.18 × 10⁰	5.15 × 10¹	8.13 × 10¹	1	6.92 × 10 ⁻⁶	-
	MSWOA	1.49 × 10 ²	3.47 × 10 ¹	8.62 × 10 ¹	2.08 × 10 ²	5	1.86 × 10 ⁻⁹	+
	DGSwOA	7.32 × 10 ¹	1.07 × 10 ¹	5.31 × 10 ¹	1.00 × 10 ²	2		
F ₆	PSO	8.21 × 10 ⁴	2.37 × 10 ⁴	4.27 × 10 ⁴	1.33 × 10 ⁵	7	1.86 × 10 ⁻⁹	+
	GA	7.70 × 10 ⁴	2.01 × 10 ⁴	3.34 × 10 ⁴	1.17 × 10 ⁵	6	1.86 × 10 ⁻⁹	+
	GWO	3.08 × 10 ²	2.50 × 10 ²	1.44 × 10 ²	1.09 × 10 ³	4	1.71 × 10 ⁻¹	≈
	WOA	2.10 × 10²	9.20 × 10 ¹	1.44 × 10 ²	5.84 × 10 ²	1	2.99 × 10 ⁻¹	≈
	BOA	2.21 × 10 ⁵	4.12 × 10 ⁴	1.42 × 10 ⁵	2.86 × 10 ⁵	9	1.86 × 10 ⁻⁹	+
	SOA	1.50 × 10 ⁵	7.25 × 10 ⁴	3.50 × 10 ⁴	2.97 × 10 ⁵	8	1.86 × 10 ⁻⁹	+
	LWOA	2.33 × 10 ²	4.74 × 10¹	1.59 × 10 ²	3.13 × 10²	3	1.09 × 10 ⁻¹	≈
	MSWOA	6.57 × 10 ⁴	4.90 × 10 ⁴	3.69 × 10 ²	1.78 × 10 ⁵	5	1.86 × 10 ⁻⁹	+
	DGSwOA	2.12 × 10 ²	6.44 × 10 ¹	1.38 × 10²	4.80 × 10 ²	2		
F ₇	PSO	1.97 × 10 ²	4.53 × 10 ¹	1.21 × 10 ²	2.86 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GA	1.25 × 10 ²	3.90 × 10 ¹	3.44 × 10 ¹	2.10 × 10 ²	5	1.86 × 10 ⁻⁹	+
	GWO	-3.07 × 10 ¹	2.09 × 10 ¹	-7.03 × 10¹	3.62 × 10 ¹	2	8.55 × 10 ⁻¹	≈
	WOA	-2.29 × 10 ¹	2.39 × 10 ¹	-6.18 × 10 ¹	5.34 × 10 ¹	4	3.09 × 10 ⁻¹	≈
	BOA	3.26 × 10 ²	6.69 × 10 ¹	1.99 × 10 ²	4.65 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	2.42 × 10 ²	8.61 × 10 ¹	2.25 × 10 ¹	4.12 × 10 ²	8	1.86 × 10 ⁻⁹	+
	LWOA	-3.83 × 10¹	1.82 × 10¹	-6.34 × 10 ¹	2.53 × 10¹	1	6.36 × 10 ⁻²	≈
	MSWOA	1.57 × 10 ²	7.76 × 10 ¹	1.60 × 10 ¹	3.52 × 10 ²	6	1.86 × 10 ⁻⁹	+
	DGSwOA	-2.76 × 10 ¹	2.19 × 10 ¹	-6.49 × 10 ¹	2.68 × 10 ¹	3		

Table 8. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₈	PSO	3.35×10^4	9.39×10^3	1.51×10^4	5.31×10^4	8	1.86×10^{-9}	+
	GA	9.86×10^3	3.43×10^3	3.03×10^3	1.59×10^4	5	1.86×10^{-9}	+
	GWO	1.75×10^3	8.05×10^2	1.01×10^2	3.49×10^3	4	1.46×10^{-3}	+
	WOA	1.42×10^3	8.26×10^2	1.12×10^2	3.52×10^3	3	3.84×10^{-2}	+
	BOA	3.85×10^4	1.01×10^4	2.34×10^4	5.86×10^4	9	1.86×10^{-9}	+
	SOA	1.98×10^4	8.20×10^3	4.12×10^3	3.82×10^4	7	1.86×10^{-9}	+
	LWOA	8.23×10^2	4.35×10^2	1.90×10^2	1.77×10^3	1	2.05×10^{-1}	≈
	MSWOA	1.64×10^4	7.42×10^3	1.61×10^3	2.89×10^4	6	1.86×10^{-9}	+
	DGSwOA	1.02×10^3	6.42×10^2	-6.77×10^0	2.43×10^3	2		
F ₉	PSO	2.82×10^4	7.58×10^3	9.46×10^3	4.20×10^4	9	1.86×10^{-9}	+
	GA	1.24×10^3	4.98×10^2	4.96×10^2	2.50×10^3	8	1.86×10^{-9}	+
	GWO	-2.83×10^2	1.61×10^1	-3.19×10^2	-2.57×10^2	1	4.77×10^{-1}	≈
	WOA	-2.81×10^2	1.49×10^1	-3.17×10^2	-2.52×10^2	2	7.61×10^{-1}	≈
	BOA	-6.29×10^1	5.91×10^0	-7.83×10^1	-4.82×10^1	6	1.86×10^{-9}	+
	SOA	-2.38×10^2	1.54×10^0	-2.43×10^2	-2.36×10^2	5	1.86×10^{-9}	+
	LWOA	5.58×10^1	1.27×10^2	-1.95×10^2	2.93×10^2	7	1.86×10^{-9}	+
	MSWOA	-2.41×10^2	3.11×10^0	-2.50×10^2	-2.37×10^2	4	1.86×10^{-9}	+
	DGSwOA	-2.79×10^2	1.39×10^1	-3.13×10^2	-2.55×10^2	3		
F ₁₀	PSO	5.81×10^5	1.62×10^5	2.68×10^5	9.24×10^5	6	1.86×10^{-9}	+
	GA	2.98×10^5	1.07×10^5	1.10×10^5	4.85×10^5	5	1.86×10^{-9}	+
	GWO	7.37×10^4	3.61×10^4	2.61×10^4	1.93×10^5	3	1.20×10^{-2}	+
	WOA	6.33×10^4	4.28×10^4	1.35×10^4	1.94×10^5	2	7.46×10^{-1}	≈
	BOA	3.33×10^6	1.38×10^6	1.55×10^6	6.61×10^6	9	1.86×10^{-9}	+
	SOA	1.52×10^6	9.03×10^5	1.59×10^5	3.95×10^6	8	1.86×10^{-9}	+
	LWOA	1.48×10^5	5.41×10^4	4.45×10^4	2.77×10^5	4	5.59×10^{-9}	+
	MSWOA	6.22×10^5	6.21×10^5	1.03×10^5	3.10×10^6	7	1.86×10^{-9}	+
	DGSwOA	5.37×10^4	1.90×10^4	1.57×10^4	9.30×10^4	1		
F ₁₁	PSO	5.56×10^1	3.07×10^1	-4.83×10^0	1.19×10^2	5	5.72×10^{-7}	+
	GA	-1.34×10^1	1.32×10^1	-3.37×10^1	1.53×10^1	1	3.13×10^{-4}	−
	GWO	-1.81×10^0	1.86×10^1	-2.89×10^1	5.49×10^1	2	8.79×10^{-2}	≈
	WOA	1.30×10^1	2.08×10^1	-2.65×10^1	6.53×10^1	4	5.98×10^{-1}	≈
	BOA	6.85×10^4	3.02×10^5	-1.80×10^0	1.68×10^6	9	1.86×10^{-8}	+
	SOA	2.88×10^2	1.21×10^2	5.37×10^1	4.19×10^2	8	1.86×10^{-9}	+
	LWOA	7.76×10^1	3.42×10^1	-3.27×10^0	1.40×10^2	6	9.31×10^{-9}	+
	MSWOA	1.29×10^2	1.13×10^2	4.71×10^0	3.52×10^2	7	5.59×10^{-9}	+
	DGSwOA	8.72×10^0	2.38×10^1	-3.42×10^1	6.40×10^1	3		
F ₁₂	PSO	7.23×10^7	1.24×10^7	4.22×10^7	8.99×10^7	7	1.86×10^{-9}	+
	GA	5.00×10^7	9.81×10^6	2.44×10^7	6.43×10^7	6	1.86×10^{-9}	+
	GWO	1.06×10^7	5.09×10^6	3.21×10^6	2.69×10^7	4	1.64×10^{-2}	+
	WOA	8.30×10^6	4.23×10^6	9.57×10^5	1.87×10^7	3	5.98×10^{-1}	≈
	BOA	9.21×10^7	1.49×10^7	6.10×10^7	1.30×10^8	9	1.86×10^{-9}	+
	SOA	7.49×10^7	1.35×10^7	5.16×10^7	1.07×10^8	8	1.86×10^{-9}	+
	LWOA	4.95×10^6	1.54×10^6	2.39×10^6	8.65×10^6	1	4.34×10^{-3}	−
	MSWOA	4.19×10^7	1.56×10^7	1.75×10^7	7.16×10^7	5	1.86×10^{-9}	+
	DGSwOA	7.68×10^6	4.05×10^6	2.10×10^6	1.73×10^7	2		
F ₁₃	PSO	1.30×10^3	9.36×10^1	1.10×10^3	1.47×10^3	9	1.86×10^{-9}	+
	GA	1.07×10^3	9.45×10^1	8.75×10^2	1.20×10^3	6	1.86×10^{-9}	+
	GWO	5.05×10^2	7.40×10^1	3.56×10^2	6.24×10^2	3	7.30×10^{-4}	+
	WOA	5.29×10^2	1.32×10^2	2.20×10^2	8.31×10^2	4	4.18×10^{-4}	+
	BOA	1.25×10^3	6.02×10^1	1.13×10^3	1.36×10^3	8	1.86×10^{-9}	+
	SOA	1.15×10^3	8.13×10^1	9.80×10^2	1.33×10^3	7	1.86×10^{-9}	+
	LWOA	3.91×10^2	7.91×10^1	2.58×10^2	5.79×10^2	1	5.70×10^{-1}	≈
	MSWOA	9.18×10^2	1.48×10^2	6.44×10^2	1.18×10^3	5	1.86×10^{-9}	+
	DGSwOA	4.04×10^2	1.24×10^2	1.54×10^2	7.18×10^2	2		

Table 8. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₄	PSO	-3.98×10^1	2.89×10^0	-4.62×10^1	-3.56×10^1	8	1.86×10^{-9}	+
	GA	-5.03×10^1	1.01×10^0	-5.25×10^1	-4.83×10^1	5	1.86×10^{-9}	+
	GWO	-5.38×10^1	1.24×10^0	-5.60×10^1	-5.16×10^1	3	3.71×10^{-1}	≈
	WOA	-5.36×10^1	1.41×10^0	-5.59×10^1	-5.01×10^1	4	7.32×10^{-2}	≈
	BOA	-1.45×10^1	5.26×10^0	-2.66×10^1	-8.22×10^0	9	1.86×10^{-9}	+
	SOA	-4.19×10^1	3.68×10^0	-4.83×10^1	-3.40×10^1	7	1.86×10^{-9}	+
	LWOA	-5.55×10^1	5.41×10^{-1}	-5.64×10^1	-5.43×10^1	1	4.42×10^{-6}	−
	MSWOA	-4.77×10^1	2.67×10^0	-5.24×10^1	-4.22×10^1	6	1.86×10^{-9}	+
	DGSwOA	-5.41×10^1	1.27×10^0	-5.66×10^1	-5.13×10^1	2		
F ₁₅	PSO	3.86×10^2	2.84×10^1	3.28×10^2	4.45×10^2	7	1.86×10^{-9}	+
	GA	3.07×10^2	2.55×10^1	2.18×10^2	3.58×10^2	5	1.86×10^{-9}	+
	GWO	1.50×10^2	2.08×10^1	1.03×10^2	2.03×10^2	1	1.22×10^{-5}	−
	WOA	1.73×10^2	2.35×10^1	1.32×10^2	2.27×10^2	3	2.21×10^{-1}	≈
	BOA	3.92×10^2	3.86×10^1	3.21×10^2	4.90×10^2	9	1.86×10^{-9}	+
	SOA	3.86×10^2	7.12×10^1	2.20×10^2	4.91×10^2	8	3.73×10^{-9}	+
	LWOA	1.69×10^2	2.00×10^1	1.39×10^2	2.33×10^2	2	4.05×10^{-2}	−
	MSWOA	3.80×10^2	7.29×10^1	2.69×10^2	5.38×10^2	6	1.86×10^{-9}	+
	DGSwOA	1.80×10^2	2.18×10^1	1.35×10^2	2.28×10^2	4		
F ₁₆	PSO	-2.39×10^2	2.84×10^0	-2.47×10^2	-2.35×10^2	6	1.86×10^{-9}	+
	GA	-2.38×10^2	2.45×10^0	-2.45×10^2	-2.35×10^2	7	1.86×10^{-9}	+
	GWO	-2.47×10^2	3.66×10^0	-2.56×10^2	-2.36×10^2	3	2.77×10^{-2}	+
	WOA	-2.47×10^2	3.19×10^0	-2.56×10^2	-2.41×10^2	2	3.27×10^{-2}	+
	BOA	-2.19×10^2	6.82×10^0	-2.32×10^2	-2.04×10^2	9	1.86×10^{-9}	+
	SOA	-2.38×10^2	5.97×10^0	-2.47×10^2	-2.24×10^2	8	3.54×10^{-8}	+
	LWOA	-2.39×10^2	2.42×10^0	-2.45×10^2	-2.35×10^2	5	3.73×10^{-9}	+
	MSWOA	-2.44×10^2	4.35×10^0	-2.52×10^2	-2.36×10^2	4	2.32×10^{-4}	+
	DGSwOA	-2.49×10^2	2.83×10^0	-2.53×10^2	-2.43×10^2	1		
F ₁₇	PSO	-3.05×10^1	4.74×10^{-1}	-3.15×10^1	-2.96×10^1	8	1.86×10^{-9}	+
	GA	-3.28×10^1	5.36×10^{-1}	-3.40×10^1	-3.18×10^1	5	4.42×10^{-6}	+
	GWO	-3.47×10^1	7.32×10^{-1}	-3.60×10^1	-3.32×10^1	1	1.37×10^{-4}	−
	WOA	-3.39×10^1	7.20×10^{-1}	-3.53×10^1	-3.24×10^1	3	4.90×10^{-1}	≈
	BOA	-2.39×10^1	1.83×10^0	-2.82×10^1	-2.12×10^1	9	1.86×10^{-9}	+
	SOA	-3.16×10^1	1.01×10^0	-3.34×10^1	-2.93×10^1	7	3.73×10^{-9}	+
	LWOA	-3.45×10^1	9.38×10^{-1}	-3.59×10^1	-3.25×10^1	2	5.55×10^{-4}	−
	MSWOA	-3.17×10^1	1.08×10^0	-3.38×10^1	-3.00×10^1	6	6.15×10^{-8}	+
	DGSwOA	-3.38×10^1	6.59×10^{-1}	-3.48×10^1	-3.23×10^1	4		
F ₁₈	PSO	-8.34×10^0	2.61×10^0	-1.57×10^1	-3.63×10^0	8	1.86×10^{-9}	+
	GA	-1.80×10^1	2.34×10^0	-2.48×10^1	-1.42×10^1	5	3.45×10^{-5}	+
	GWO	-2.43×10^1	2.01×10^0	-2.86×10^1	-1.95×10^1	1	1.68×10^{-6}	−
	WOA	-2.22×10^1	2.64×10^0	-2.86×10^1	-1.67×10^1	3	1.24×10^{-1}	≈
	BOA	-4.97×10^0	1.84×10^0	-9.34×10^0	-1.90×10^0	9	1.86×10^{-9}	+
	SOA	-1.10×10^1	4.77×10^0	-2.08×10^1	-3.86×10^0	6	9.31×10^{-9}	+
	LWOA	-2.32×10^1	3.35×10^0	-3.09×10^1	-1.47×10^1	2	1.06×10^{-2}	−
	MSWOA	-9.35×10^0	3.42×10^0	-1.66×10^1	-3.00×10^0	7	1.86×10^{-9}	+
	DGSwOA	-2.09×10^1	2.51×10^0	-2.54×10^1	-1.41×10^1	4		
F ₁₉	PSO	5.32×10^1	1.25×10^0	4.96×10^1	5.51×10^1	9	1.86×10^{-9}	+
	GA	4.76×10^1	6.71×10^{-1}	4.62×10^1	4.88×10^1	8	1.86×10^{-9}	+
	GWO	4.26×10^1	1.15×10^0	4.07×10^1	4.44×10^1	4	3.73×10^{-9}	+
	WOA	4.28×10^1	8.48×10^{-1}	4.07×10^1	4.42×10^1	5	1.86×10^{-9}	+
	BOA	4.46×10^1	5.07×10^{-1}	4.34×10^1	4.54×10^1	6	1.86×10^{-9}	+
	SOA	4.07×10^1	2.16×10^{-3}	4.07×10^1	4.07×10^1	3	1.86×10^{-9}	+
	LWOA	4.66×10^1	5.54×10^{-1}	4.54×10^1	4.76×10^1	7	1.86×10^{-9}	+
	MSWOA	4.07×10^1	3.40×10^{-3}	4.07×10^1	4.07×10^1	2	3.73×10^{-9}	+
	DGSwOA	4.07×10^1	1.35×10^{-2}	4.07×10^1	4.07×10^1	1		

Table 8. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₂₀	PSO	1.26 × 10 ⁴	3.30 × 10 ³	5.85 × 10 ³	1.75 × 10 ⁴	9	1.86 × 10 ⁻⁹	+
	GA	3.63 × 10 ²	1.69 × 10 ²	1.87 × 10 ²	8.74 × 10 ²	5	3.73 × 10 ⁻⁹	+
	GWO	2.06 × 10 ²	5.43 × 10 ¹	1.85 × 10²	4.58 × 10 ²	3	1.71 × 10 ⁻¹	≈
	WOA	2.77 × 10 ²	2.45 × 10 ²	1.86 × 10 ²	1.26 × 10 ³	4	5.43 × 10 ⁻¹	≈
	BOA	4.75 × 10 ³	2.34 × 10 ³	1.09 × 10 ³	9.58 × 10 ³	8	1.86 × 10 ⁻⁹	+
	SOA	3.87 × 10 ³	2.80 × 10 ³	1.86 × 10 ²	1.12 × 10 ⁴	7	3.73 × 10 ⁻⁹	+
	LWOA	1.88 × 10²	5.81 × 10⁰	1.86 × 10 ²	2.19 × 10 ²	1	2.21 × 10 ⁻¹	≈
	MSWOA	2.51 × 10 ³	2.57 × 10 ³	1.86 × 10 ²	1.02 × 10 ⁴	6	3.73 × 10 ⁻⁹	+
	DGSwOA	1.89 × 10 ²	6.58 × 10 ⁰	1.86 × 10 ²	2.19 × 10²	2		
F ₂₁	PSO	3.71 × 10 ²	4.41 × 10⁰	3.58 × 10 ²	3.78 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GA	3.69 × 10 ²	5.53 × 10 ⁰	3.54 × 10 ²	3.77 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GWO	3.27 × 10 ²	8.80 × 10 ⁰	3.15 × 10 ²	3.55 × 10 ²	4	9.61 × 10 ⁻²	≈
	WOA	3.25 × 10 ²	1.09 × 10 ¹	3.13 × 10²	3.57 × 10 ²	3	9.84 × 10 ⁻¹	≈
	BOA	3.54 × 10 ²	1.07 × 10 ¹	3.32 × 10 ²	3.79 × 10 ²	5	1.86 × 10 ⁻⁹	+
	SOA	3.75 × 10 ²	1.02 × 10 ¹	3.47 × 10 ²	3.85 × 10 ²	9	1.86 × 10 ⁻⁹	+
	LWOA	3.23 × 10²	6.75 × 10 ⁰	3.14 × 10 ²	3.44 × 10 ²	1	7.00 × 10 ⁻¹	≈
	MSWOA	3.60 × 10 ²	1.26 × 10 ¹	3.33 × 10 ²	3.79 × 10 ²	6	3.73 × 10 ⁻⁹	+
	DGSwOA	3.23 × 10 ²	4.53 × 10 ⁰	3.15 × 10 ²	3.34 × 10²	2		
F ₂₂	PSO	1.12 × 10 ²	3.77 × 10⁰	9.71 × 10 ¹	1.16 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GA	1.06 × 10 ²	7.33 × 10 ⁰	8.14 × 10 ¹	1.15 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GWO	6.50 × 10 ¹	1.76 × 10 ¹	4.54 × 10 ¹	1.05 × 10 ²	4	2.93 × 10 ⁻²	+
	WOA	6.01 × 10 ¹	1.20 × 10 ¹	4.91 × 10 ¹	8.98 × 10 ¹	2	1.05 × 10 ⁻¹	≈
	BOA	9.29 × 10 ¹	1.21 × 10 ¹	6.53 × 10 ¹	1.13 × 10 ²	6	1.86 × 10 ⁻⁹	+
	SOA	1.16 × 10 ²	5.45 × 10 ⁰	9.68 × 10 ¹	1.24 × 10 ²	9	1.86 × 10 ⁻⁹	+
	LWOA	6.10 × 10 ¹	1.67 × 10 ¹	4.69 × 10 ¹	9.94 × 10 ¹	3	1.35 × 10 ⁻¹	≈
	MSWOA	9.16 × 10 ¹	1.70 × 10 ¹	6.38 × 10 ¹	1.18 × 10 ²	5	3.73 × 10 ⁻⁹	+
	DGSwOA	5.43 × 10¹	7.97 × 10 ⁰	4.35 × 10¹	6.94 × 10¹	1		
F ₂₃	PSO	2.13 × 10 ²	3.50 × 10 ⁻¹	2.12 × 10 ²	2.14 × 10 ²	6	6.15 × 10 ⁻⁸	+
	GA	2.13 × 10 ²	4.62 × 10 ⁻¹	2.12 × 10 ²	2.14 × 10 ²	5	2.55 × 10 ⁻⁷	+
	GWO	2.12 × 10 ²	6.49 × 10 ⁻¹	2.11 × 10 ²	2.13 × 10 ²	3	2.21 × 10 ⁻²	+
	WOA	2.12 × 10 ²	3.73 × 10 ⁻¹	2.11 × 10 ²	2.13 × 10²	2	9.52 × 10 ⁻⁴	+
	BOA	2.13 × 10 ²	5.21 × 10 ⁻¹	2.12 × 10 ²	2.14 × 10 ²	9	3.73 × 10 ⁻⁹	+
	SOA	2.13 × 10 ²	2.98 × 10⁻¹	2.12 × 10 ²	2.13 × 10 ²	7	3.73 × 10 ⁻⁹	+
	LWOA	2.13 × 10 ²	3.19 × 10 ⁻¹	2.12 × 10 ²	2.14 × 10 ²	8	3.73 × 10 ⁻⁹	+
	MSWOA	2.12 × 10 ²	3.68 × 10 ⁻¹	2.11 × 10 ²	2.13 × 10 ²	4	1.86 × 10 ⁻³	+
	DGSwOA	2.12 × 10²	4.51 × 10 ⁻¹	2.11 × 10²	2.13 × 10 ²	1		
F ₂₄	PSO	4.06 × 10 ²	2.45 × 10 ¹	3.54 × 10 ²	4.54 × 10 ²	9	1.86 × 10 ⁻⁹	+
	GA	3.00 × 10 ²	2.05 × 10 ¹	2.51 × 10 ²	3.33 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GWO	2.33 × 10 ²	1.25 × 10 ¹	2.04 × 10 ²	2.55 × 10 ²	2	8.71 × 10 ⁻³	+
	WOA	2.33 × 10 ²	1.00 × 10¹	2.11 × 10 ²	2.55 × 10 ²	3	9.30 × 10 ⁻³	+
	BOA	2.47 × 10 ²	1.43 × 10 ¹	2.15 × 10 ²	2.70 × 10 ²	6	8.01 × 10 ⁻⁸	+
	SOA	2.57 × 10 ²	1.51 × 10 ¹	2.22 × 10 ²	2.82 × 10 ²	7	9.31 × 10 ⁻⁹	+
	LWOA	2.46 × 10 ²	1.47 × 10 ¹	2.19 × 10 ²	2.71 × 10 ²	5	9.98 × 10 ⁻⁷	+
	MSWOA	2.43 × 10 ²	1.34 × 10 ¹	2.16 × 10 ²	2.66 × 10 ²	4	2.35 × 10 ⁻⁶	+
	DGSwOA	2.25 × 10²	1.06 × 10 ¹	2.02 × 10²	2.41 × 10²	1		

Table 9. Comparative experimental results (dimension = 40).

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁	PSO	1.27 × 10 ²	1.54 × 10 ¹	1.02 × 10 ²	1.60 × 10 ²	9	1.86 × 10 ⁻⁹	+
	GA	6.47 × 10 ¹	1.48 × 10 ¹	2.67 × 10 ¹	8.55 × 10 ¹	6	1.86 × 10 ⁻⁹	+
	GWO	-4.59 × 10 ¹	9.33 × 10 ⁰	-6.74 × 10 ¹	-2.50 × 10 ¹	3	6.99 × 10 ⁻²	≈
	WOA	-4.41 × 10 ¹	1.24 × 10 ¹	-6.11 × 10 ¹	-1.79 × 10 ¹	4	6.19 × 10 ⁻³	+
	BOA	9.57 × 10 ¹	9.23 × 10 ⁰	7.39 × 10 ¹	1.10 × 10 ²	8	1.86 × 10 ⁻⁹	+
	SOA	7.11 × 10 ¹	1.62 × 10 ¹	2.83 × 10 ¹	9.70 × 10 ¹	7	1.86 × 10 ⁻⁹	+
	LWOA	-5.88 × 10 ¹	6.92 × 10 ⁰	-7.26 × 10 ¹	-4.52 × 10 ¹	1	5.23 × 10 ⁻²	≈
	MSWOA	3.38 × 10 ¹	1.87 × 10 ¹	-1.09 × 10 ¹	6.74 × 10 ¹	5	1.86 × 10 ⁻⁹	+
	DGSwOA	-5.13 × 10 ¹	1.45 × 10 ¹	-7.29 × 10 ¹	-1.58 × 10 ¹	2		
F ₂	PSO	3.81 × 10 ⁶	5.86 × 10 ⁵	2.55 × 10 ⁶	5.47 × 10 ⁶	7	1.86 × 10 ⁻⁹	+
	GA	2.97 × 10 ⁶	5.25 × 10 ⁵	1.70 × 10 ⁶	3.91 × 10 ⁶	6	1.86 × 10 ⁻⁹	+
	GWO	8.32 × 10 ⁵	3.92 × 10 ⁵	4.63 × 10 ⁵	2.73 × 10 ⁶	3	3.27 × 10 ⁻²	+
	WOA	6.76 × 10 ⁵	2.05 × 10 ⁵	3.60 × 10 ⁵	1.25 × 10 ⁶	2	7.77 × 10 ⁻¹	≈
	BOA	8.86 × 10 ⁶	2.15 × 10 ⁶	5.08 × 10 ⁶	1.57 × 10 ⁷	9	1.86 × 10 ⁻⁹	+
	SOA	4.93 × 10 ⁶	2.42 × 10 ⁶	1.22 × 10 ⁶	1.08 × 10 ⁷	8	1.86 × 10 ⁻⁹	+
	LWOA	8.56 × 10 ⁵	2.83 × 10 ⁵	3.49 × 10 ⁵	1.30 × 10 ⁶	4	2.77 × 10 ⁻²	+
	MSWOA	2.94 × 10 ⁶	1.67 × 10 ⁶	7.99 × 10 ⁵	6.89 × 10 ⁶	5	1.86 × 10 ⁻⁹	+
	DGSwOA	6.74 × 10 ⁵	1.87 × 10 ⁵	2.78 × 10 ⁵	1.09 × 10 ⁶	1		
F ₃	PSO	1.42 × 10 ³	9.88 × 10 ¹	1.23 × 10 ³	1.62 × 10 ³	9	1.86 × 10 ⁻⁹	+
	GA	1.14 × 10 ³	6.80 × 10 ¹	1.02 × 10 ³	1.27 × 10 ³	5	1.86 × 10 ⁻⁹	+
	GWO	6.23 × 10 ²	4.68 × 10 ¹	5.34 × 10 ²	7.32 × 10 ²	1	3.05 × 10 ⁻⁵	-
	WOA	7.20 × 10 ²	5.58 × 10 ¹	6.19 × 10 ²	8.37 × 10 ²	4	2.37 × 10 ⁻¹	≈
	BOA	1.20 × 10 ³	5.47 × 10 ¹	1.08 × 10 ³	1.29 × 10 ³	7	1.86 × 10 ⁻⁹	+
	SOA	1.19 × 10 ³	9.97 × 10 ¹	9.89 × 10 ²	1.39 × 10 ³	6	1.86 × 10 ⁻⁹	+
	LWOA	6.49 × 10 ²	7.51 × 10 ¹	5.27 × 10 ²	8.00 × 10 ²	2	1.55 × 10 ⁻²	-
	MSWOA	1.20 × 10 ³	9.69 × 10 ¹	9.97 × 10 ²	1.36 × 10 ³	8	1.86 × 10 ⁻⁹	+
	DGSwOA	6.96 × 10 ²	6.12 × 10 ¹	5.93 × 10 ²	8.23 × 10 ²	3		
F ₄	PSO	1.71 × 10 ³	1.15 × 10 ²	1.48 × 10 ³	1.98 × 10 ³	9	1.86 × 10 ⁻⁹	+
	GA	1.16 × 10 ³	4.81 × 10 ¹	1.03 × 10 ³	1.24 × 10 ³	8	1.86 × 10 ⁻⁹	+
	GWO	7.13 × 10 ²	3.87 × 10 ¹	6.29 × 10 ²	8.00 × 10 ²	1	9.22 × 10 ⁻⁶	-
	WOA	7.69 × 10 ²	4.95 × 10 ¹	6.54 × 10 ²	8.56 × 10 ²	2	1.24 × 10 ⁻¹	≈
	BOA	1.06 × 10 ³	3.94 × 10 ¹	9.62 × 10 ²	1.14 × 10 ³	7	1.86 × 10 ⁻⁹	+
	SOA	1.02 × 10 ³	7.90 × 10 ¹	8.48 × 10 ²	1.14 × 10 ³	6	1.86 × 10 ⁻⁹	+
	LWOA	8.33 × 10 ²	7.26 × 10 ¹	6.52 × 10 ²	1.00 × 10 ³	4	7.61 × 10 ⁻³	+
	MSWOA	9.65 × 10 ²	7.54 × 10 ¹	8.02 × 10 ²	1.10 × 10 ³	5	2.61 × 10 ⁻⁸	+
	DGSwOA	7.85 × 10 ²	6.59 × 10 ¹	5.95 × 10 ²	8.97 × 10 ²	3		
F ₅	PSO	5.21 × 10 ²	2.10 × 10 ¹	4.60 × 10 ²	5.57 × 10 ²	7	1.86 × 10 ⁻⁹	+
	GA	5.48 × 10 ²	3.07 × 10 ¹	4.57 × 10 ²	5.99 × 10 ²	8	1.86 × 10 ⁻⁹	+
	GWO	3.07 × 10 ²	2.66 × 10 ¹	2.49 × 10 ²	3.56 × 10 ²	4	1.86 × 10 ⁻⁹	+
	WOA	1.99 × 10 ²	2.88 × 10 ¹	1.45 × 10 ²	2.46 × 10 ²	2	2.89 × 10 ⁻¹	≈
	BOA	6.43 × 10 ²	4.77 × 10 ¹	5.16 × 10 ²	7.14 × 10 ²	9	1.86 × 10 ⁻⁹	+
	SOA	4.63 × 10 ²	7.63 × 10 ¹	2.42 × 10 ²	6.50 × 10 ²	6	1.86 × 10 ⁻⁹	+
	LWOA	1.36 × 10 ²	3.38 × 10 ¹	7.60 × 10 ¹	2.03 × 10 ²	1	1.30 × 10 ⁻⁸	-
	MSWOA	4.02 × 10 ²	9.84 × 10 ¹	2.15 × 10 ²	6.55 × 10 ²	5	1.86 × 10 ⁻⁹	+
	DGSwOA	2.07 × 10 ²	3.36 × 10 ¹	1.45 × 10 ²	2.73 × 10 ²	3		
F ₆	PSO	3.15 × 10 ⁵	3.19 × 10 ⁴	2.48 × 10 ⁵	3.90 × 10 ⁵	7	1.86 × 10 ⁻⁹	+
	GA	2.69 × 10 ⁵	4.09 × 10 ⁴	1.93 × 10 ⁵	3.30 × 10 ⁵	6	1.86 × 10 ⁻⁹	+
	GWO	4.11 × 10 ³	6.23 × 10 ³	4.68 × 10 ²	3.15 × 10 ⁴	1	8.24 × 10 ⁻¹	≈
	WOA	6.21 × 10 ³	8.12 × 10 ³	4.47 × 10 ²	3.42 × 10 ⁴	4	6.12 × 10 ⁻¹	≈
	BOA	4.73 × 10 ⁵	8.75 × 10 ⁴	3.24 × 10 ⁵	5.78 × 10 ⁵	9	1.86 × 10 ⁻⁹	+
	SOA	4.05 × 10 ⁵	8.85 × 10 ⁴	2.41 × 10 ⁵	5.79 × 10 ⁵	8	1.86 × 10 ⁻⁹	+
	LWOA	4.45 × 10 ³	3.99 × 10 ³	4.83 × 10 ²	1.48 × 10 ⁴	2	9.35 × 10 ⁻¹	≈
	MSWOA	2.11 × 10 ⁵	8.00 × 10 ⁴	5.45 × 10 ⁴	3.56 × 10 ⁵	5	1.86 × 10 ⁻⁹	+
	DGSwOA	4.90 × 10 ³	7.25 × 10 ³	4.31 × 10 ²	3.42 × 10 ⁴	3		

Table 9. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₇	PSO	8.64×10^2	9.04×10^1	6.24×10^2	1.02×10^3	9	1.86×10^{-9}	+
	GA	5.10×10^2	5.94×10^1	3.98×10^2	6.54×10^2	7	1.86×10^{-9}	+
	GWO	6.82×10^1	2.85×10^1	1.83×10^1	1.32×10^2	1	4.03×10^{-3}	−
	WOA	9.21×10^1	3.77×10^1	2.93×10^1	1.91×10^2	2	9.68×10^{-1}	≈
	BOA	6.00×10^2	7.30×10^1	3.65×10^2	7.06×10^2	8	1.86×10^{-9}	+
	SOA	4.98×10^2	1.10×10^2	2.69×10^2	7.31×10^2	6	1.86×10^{-9}	+
	LWOA	1.24×10^2	3.74×10^1	4.14×10^1	2.00×10^2	4	2.56×10^{-3}	+
	MSWOA	4.65×10^2	1.06×10^2	2.68×10^2	6.92×10^2	5	1.86×10^{-9}	+
	DGSwOA	9.32×10^1	4.13×10^1	1.00×10^1	1.96×10^2	3		
F ₈	PSO	2.75×10^5	3.28×10^4	2.00×10^5	3.32×10^5	9	1.86×10^{-9}	+
	GA	1.09×10^5	1.52×10^4	6.76×10^4	1.45×10^5	7	1.86×10^{-9}	+
	GWO	1.44×10^4	5.23×10^3	9.21×10^3	2.92×10^4	4	6.08×10^{-4}	+
	WOA	8.63×10^3	3.77×10^3	3.89×10^3	1.68×10^4	1	6.85×10^{-1}	≈
	BOA	1.30×10^5	1.46×10^4	9.79×10^4	1.60×10^5	8	1.86×10^{-9}	+
	SOA	5.77×10^4	1.20×10^4	3.16×10^4	7.95×10^4	6	1.86×10^{-9}	+
	LWOA	1.27×10^4	5.33×10^3	4.59×10^3	2.51×10^4	3	4.27×10^{-2}	+
	MSWOA	5.65×10^4	1.21×10^4	2.63×10^4	7.75×10^4	5	1.86×10^{-9}	+
	DGSwOA	9.43×10^3	5.42×10^3	3.58×10^3	2.54×10^4	2		
F ₉	PSO	1.51×10^5	2.14×10^4	1.07×10^5	1.92×10^5	9	1.86×10^{-9}	+
	GA	1.11×10^4	2.37×10^3	6.69×10^3	1.56×10^4	8	1.86×10^{-9}	+
	GWO	-1.35×10^2	1.52×10^1	-1.72×10^2	-1.13×10^2	1	2.48×10^{-2}	−
	WOA	-1.27×10^2	1.17×10^1	-1.53×10^2	-1.14×10^2	3	6.55×10^{-1}	≈
	BOA	-2.24×10^1	2.32×10^0	-2.74×10^1	-1.89×10^1	6	1.86×10^{-9}	+
	SOA	-1.07×10^2	5.59×10^{-1}	-1.08×10^2	-1.06×10^2	5	1.86×10^{-9}	+
	LWOA	1.14×10^3	6.17×10^2	4.31×10^2	2.59×10^3	7	1.86×10^{-9}	+
	MSWOA	-1.08×10^2	1.54×10^0	-1.12×10^2	-1.06×10^2	4	1.86×10^{-9}	+
	DGSwOA	-1.28×10^2	9.74×10^0	-1.67×10^2	-1.14×10^2	2		
F ₁₀	PSO	2.63×10^6	4.42×10^5	1.62×10^6	3.71×10^6	8	1.86×10^{-9}	+
	GA	1.47×10^6	3.22×10^5	8.23×10^5	2.10×10^6	6	1.86×10^{-9}	+
	GWO	2.88×10^5	9.72×10^4	1.40×10^5	5.68×10^5	3	2.32×10^{-4}	+
	WOA	2.15×10^5	7.19×10^4	1.13×10^5	4.65×10^5	2	2.13×10^{-1}	≈
	BOA	3.13×10^6	9.09×10^5	1.29×10^6	4.90×10^6	9	1.86×10^{-9}	+
	SOA	2.06×10^6	8.06×10^5	7.39×10^5	3.59×10^6	7	1.86×10^{-9}	+
	LWOA	3.78×10^5	1.11×10^5	1.90×10^5	6.04×10^5	4	1.64×10^{-7}	+
	MSWOA	1.08×10^6	4.09×10^5	6.15×10^5	2.22×10^6	5	1.86×10^{-9}	+
	DGSwOA	1.89×10^5	9.49×10^4	6.70×10^4	4.86×10^5	1		
F ₁₁	PSO	2.40×10^2	4.26×10^1	1.49×10^2	3.44×10^2	5	1.86×10^{-9}	+
	GA	1.21×10^2	2.52×10^1	4.42×10^1	1.66×10^2	4	1.14×10^{-1}	≈
	GWO	9.81×10^1	2.68×10^1	4.71×10^1	1.59×10^2	1	1.71×10^{-1}	≈
	WOA	1.07×10^2	3.53×10^1	4.63×10^1	1.74×10^2	2	8.08×10^{-1}	≈
	BOA	1.72×10^3	3.43×10^3	1.14×10^2	1.43×10^4	9	1.30×10^{-8}	+
	SOA	4.17×10^2	1.66×10^2	1.16×10^2	7.87×10^2	8	1.86×10^{-9}	+
	LWOA	2.84×10^2	5.71×10^1	1.70×10^2	3.86×10^2	7	1.86×10^{-9}	+
	MSWOA	2.64×10^2	9.54×10^1	1.14×10^2	3.89×10^2	6	1.30×10^{-7}	+
	DGSwOA	1.08×10^2	3.28×10^1	5.14×10^1	1.77×10^2	3		
F ₁₂	PSO	4.33×10^8	6.64×10^7	3.14×10^8	5.60×10^8	7	1.86×10^{-9}	+
	GA	2.74×10^8	3.69×10^7	2.01×10^8	3.59×10^8	5	1.86×10^{-9}	+
	GWO	7.74×10^7	1.84×10^7	4.09×10^7	1.14×10^8	3	8.03×10^{-2}	≈
	WOA	8.11×10^7	2.58×10^7	4.07×10^7	1.42×10^8	4	1.00×10^{-1}	≈
	BOA	8.01×10^8	2.41×10^8	3.79×10^8	1.21×10^9	9	1.86×10^{-9}	+
	SOA	5.66×10^8	1.79×10^8	2.34×10^8	9.59×10^8	8	1.86×10^{-9}	+
	LWOA	4.66×10^7	1.45×10^7	2.55×10^7	8.54×10^7	1	7.06×10^{-5}	−
	MSWOA	3.59×10^8	9.79×10^7	1.75×10^8	5.65×10^8	6	1.86×10^{-9}	+
	DGSwOA	6.95×10^7	2.11×10^7	3.07×10^7	1.24×10^8	2		

Table 9. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₃	PSO	2.66×10^3	1.27×10^2	2.23×10^3	2.85×10^3	8	1.86×10^{-9}	+
	GA	2.40×10^3	1.10×10^2	2.14×10^3	2.63×10^3	6	1.86×10^{-9}	+
	GWO	1.24×10^3	1.01×10^2	1.05×10^3	1.45×10^3	4	1.82×10^{-5}	+
	WOA	1.22×10^3	1.26×10^2	8.05×10^2	1.45×10^3	3	2.37×10^{-5}	+
	BOA	2.70×10^3	1.32×10^2	2.39×10^3	2.98×10^3	9	1.86×10^{-9}	+
	SOA	2.49×10^3	2.04×10^2	1.86×10^3	2.85×10^3	7	1.86×10^{-9}	+
	LWOA	9.62×10^2	1.09×10^2	7.39×10^2	1.18×10^3	1	1.13×10^{-3}	−
	MSWOA	1.93×10^3	1.76×10^2	1.58×10^3	2.37×10^3	5	1.86×10^{-9}	+
	DGSwOA	1.07×10^3	1.24×10^2	8.61×10^2	1.27×10^3	2		
F ₁₄	PSO	-9.04×10^0	4.37×10^0	-1.87×10^1	-1.43×10^0	8	1.86×10^{-9}	+
	GA	-3.86×10^1	2.28×10^0	-4.37×10^1	-3.36×10^1	5	1.86×10^{-9}	+
	GWO	-4.55×10^1	2.25×10^0	-4.89×10^1	-4.00×10^1	3	5.70×10^{-1}	≈
	WOA	-4.48×10^1	1.78×10^0	-4.90×10^1	-4.14×10^1	4	7.11×10^{-3}	+
	BOA	6.74×10^0	1.44×10^1	-6.62×10^0	3.83×10^1	9	1.86×10^{-9}	+
	SOA	-9.64×10^0	1.24×10^1	-3.83×10^1	1.33×10^1	7	1.86×10^{-9}	+
	LWOA	-4.63×10^1	2.68×10^0	-5.15×10^1	-4.08×10^1	1	6.70×10^{-1}	≈
	MSWOA	-2.01×10^1	9.05×10^0	-3.70×10^1	-3.14×10^0	6	1.86×10^{-9}	+
	DGSwOA	-4.60×10^1	1.84×10^0	-4.96×10^1	-4.23×10^1	2		
F ₁₅	PSO	1.26×10^3	8.30×10^1	1.06×10^3	1.38×10^3	9	1.86×10^{-9}	+
	GA	9.70×10^2	7.30×10^1	7.69×10^2	1.07×10^3	5	1.86×10^{-9}	+
	GWO	5.16×10^2	4.89×10^1	4.01×10^2	5.93×10^2	1	1.30×10^{-8}	−
	WOA	6.14×10^2	6.71×10^1	4.89×10^2	8.06×10^2	3	2.77×10^{-2}	−
	BOA	9.92×10^2	4.77×10^1	8.82×10^2	1.07×10^3	6	1.86×10^{-9}	+
	SOA	10.00×10^2	1.02×10^2	8.33×10^2	1.18×10^3	7	1.86×10^{-9}	+
	LWOA	5.67×10^2	7.67×10^1	4.51×10^2	7.25×10^2	2	3.79×10^{-6}	−
	MSWOA	1.02×10^3	9.71×10^1	7.76×10^2	1.17×10^3	8	1.86×10^{-9}	+
	DGSwOA	6.48×10^2	4.94×10^1	5.53×10^2	7.33×10^2	4		
F ₁₆	PSO	-2.27×10^2	2.07×10^0	-2.31×10^2	-2.23×10^2	6	1.86×10^{-9}	+
	GA	-2.26×10^2	1.95×10^0	-2.30×10^2	-2.23×10^2	7	1.86×10^{-9}	+
	GWO	-2.39×10^2	3.91×10^0	-2.46×10^2	-2.33×10^2	3	4.16×10^{-1}	≈
	WOA	-2.40×10^2	3.96×10^0	-2.49×10^2	-2.33×10^2	2	9.84×10^{-1}	≈
	BOA	-2.07×10^2	5.49×10^0	-2.18×10^2	-1.89×10^2	9	1.86×10^{-9}	+
	SOA	-2.22×10^2	5.34×10^0	-2.33×10^2	-2.10×10^2	8	1.86×10^{-9}	+
	LWOA	-2.30×10^2	2.48×10^0	-2.37×10^2	-2.26×10^2	5	9.31×10^{-9}	+
	MSWOA	-2.33×10^2	4.29×10^0	-2.43×10^2	-2.25×10^2	4	3.24×10^{-6}	+
	DGSwOA	-2.40×10^2	3.40×10^0	-2.48×10^2	-2.33×10^2	1		
F ₁₇	PSO	-2.55×10^1	9.47×10^{-1}	-2.87×10^1	-2.41×10^1	8	1.86×10^{-9}	+
	GA	-3.03×10^1	6.32×10^{-1}	-3.16×10^1	-2.91×10^1	5	3.73×10^{-9}	+
	GWO	-3.30×10^1	6.98×10^{-1}	-3.47×10^1	-3.16×10^1	1	4.97×10^{-5}	−
	WOA	-3.17×10^1	4.92×10^{-1}	-3.27×10^1	-3.07×10^1	3	2.45×10^{-1}	≈
	BOA	-1.43×10^1	4.14×10^0	-2.30×10^1	-7.21×10^0	9	1.86×10^{-9}	+
	SOA	-2.62×10^1	1.70×10^0	-2.90×10^1	-2.24×10^1	7	1.86×10^{-9}	+
	LWOA	-3.17×10^1	1.13×10^0	-3.44×10^1	-2.95×10^1	4	6.12×10^{-1}	≈
	MSWOA	-2.68×10^1	1.75×10^0	-3.03×10^1	-2.19×10^1	6	1.86×10^{-9}	+
	DGSwOA	-3.19×10^1	7.50×10^{-1}	-3.40×10^1	-3.06×10^1	2		
F ₁₈	PSO	1.12×10^1	3.91×10^0	2.38×10^0	1.91×10^1	8	1.86×10^{-9}	+
	GA	-2.17×10^0	3.60×10^0	-9.85×10^0	3.51×10^0	5	1.86×10^{-9}	+
	GWO	-1.93×10^1	2.93×10^0	-2.44×10^1	-1.46×10^1	1	1.37×10^{-4}	−
	WOA	-1.50×10^1	3.43×10^0	-2.11×10^1	-8.29×10^0	4	6.41×10^{-1}	≈
	BOA	1.14×10^1	5.96×10^0	-5.60×10^0	2.36×10^1	9	1.86×10^{-9}	+
	SOA	3.73×10^0	7.55×10^0	-9.24×10^0	1.93×10^1	6	1.86×10^{-9}	+
	LWOA	-1.52×10^1	3.34×10^0	-1.99×10^1	-7.84×10^0	3	8.39×10^{-1}	≈
	MSWOA	5.26×10^0	7.59×10^0	-1.13×10^1	1.97×10^1	7	1.86×10^{-9}	+
	DGSwOA	-1.53×10^1	3.98×10^0	-2.18×10^1	-6.81×10^0	2		

Table 9. Cont.

F	Algorithm	Mean	Std	Best	Worst	Rank	p-Value	State
F ₁₉	PSO	5.98×10^1	1.67×10^0	5.57×10^1	6.33×10^1	9	1.86×10^{-9}	+
	GA	5.00×10^1	4.89×10^{-1}	4.84×10^1	5.06×10^1	8	1.86×10^{-9}	+
	GWO	4.42×10^1	9.23×10^{-1}	4.07×10^1	4.53×10^1	4	3.73×10^{-9}	+
	WOA	4.43×10^1	9.53×10^{-1}	4.07×10^1	4.54×10^1	5	1.86×10^{-9}	+
	BOA	4.62×10^1	4.71×10^{-1}	4.50×10^1	4.68×10^1	6	1.86×10^{-9}	+
	SOA	4.07×10^1	4.60×10^{-4}	4.07×10^1	4.07×10^1	3	1.86×10^{-9}	+
	LWOA	4.80×10^1	5.67×10^{-1}	4.62×10^1	4.91×10^1	7	1.86×10^{-9}	+
	MSWOA	4.07×10^1	6.57×10^{-4}	4.07×10^1	4.07×10^1	2	3.54×10^{-8}	+
	DGSwOA	4.07×10^1	1.92×10^{-3}	4.07×10^1	4.07×10^1	1		
F ₂₀	PSO	6.79×10^4	1.02×10^4	4.71×10^4	8.38×10^4	9	1.86×10^{-9}	+
	GA	1.39×10^4	4.51×10^3	6.27×10^3	2.52×10^4	7	1.86×10^{-9}	+
	GWO	1.62×10^3	8.23×10^2	2.89×10^2	3.90×10^3	3	1.64×10^{-2}	+
	WOA	2.02×10^3	1.34×10^3	3.05×10^2	6.44×10^3	4	2.02×10^{-3}	+
	BOA	1.75×10^4	5.38×10^3	6.86×10^3	2.90×10^4	8	1.86×10^{-9}	+
	SOA	1.25×10^4	4.41×10^3	2.28×10^3	2.08×10^4	6	3.73×10^{-9}	+
	LWOA	1.51×10^3	9.12×10^2	1.93×10^2	3.78×10^3	2	9.19×10^{-2}	≈
	MSWOA	9.93×10^3	4.78×10^3	1.84×10^3	2.15×10^4	5	1.86×10^{-9}	+
	DGSwOA	1.10×10^3	9.54×10^2	2.17×10^2	3.88×10^3	1		
F ₂₁	PSO	3.89×10^2	1.82×10^0	3.85×10^2	3.91×10^2	9	1.86×10^{-9}	+
	GA	3.87×10^2	1.38×10^0	3.83×10^2	3.90×10^2	7	1.86×10^{-9}	+
	GWO	3.52×10^2	1.13×10^1	3.31×10^2	3.74×10^2	3	4.52×10^{-1}	≈
	WOA	3.53×10^2	1.29×10^1	3.34×10^2	3.78×10^2	4	5.84×10^{-1}	≈
	BOA	3.85×10^2	1.78×10^0	3.81×10^2	3.89×10^2	5	1.86×10^{-9}	+
	SOA	3.89×10^2	2.04×10^0	3.83×10^2	3.91×10^2	8	1.86×10^{-9}	+
	LWOA	3.44×10^2	1.13×10^1	3.31×10^2	3.74×10^2	1	4.73×10^{-2}	−
	MSWOA	3.85×10^2	2.32×10^0	3.80×10^2	3.90×10^2	6	1.86×10^{-9}	+
	DGSwOA	3.50×10^2	1.41×10^1	3.21×10^2	3.77×10^2	2		
F ₂₂	PSO	1.22×10^2	1.70×10^0	1.17×10^2	1.24×10^2	9	1.86×10^{-9}	+
	GA	1.19×10^2	1.63×10^0	1.15×10^2	1.22×10^2	6	1.86×10^{-9}	+
	GWO	7.83×10^1	1.29×10^1	6.11×10^1	1.15×10^2	4	2.80×10^{-1}	≈
	WOA	7.72×10^1	1.16×10^1	5.66×10^1	1.02×10^2	3	1.71×10^{-1}	≈
	BOA	1.20×10^2	1.88×10^0	1.16×10^2	1.24×10^2	8	1.86×10^{-9}	+
	SOA	1.20×10^2	1.41×10^0	1.17×10^2	1.23×10^2	7	1.86×10^{-9}	+
	LWOA	6.73×10^1	8.87×10^0	5.43×10^1	9.86×10^1	1	1.75×10^{-2}	−
	MSWOA	1.17×10^2	3.21×10^0	1.09×10^2	1.23×10^2	5	1.86×10^{-9}	+
	DGSwOA	7.39×10^1	1.32×10^1	5.56×10^1	1.03×10^2	2		
F ₂₃	PSO	2.14×10^2	3.61×10^{-1}	2.14×10^2	2.15×10^2	6	1.86×10^{-9}	+
	GA	2.14×10^2	4.56×10^{-1}	2.13×10^2	2.15×10^2	5	1.86×10^{-8}	+
	GWO	2.13×10^2	6.55×10^{-1}	2.12×10^2	2.14×10^2	2	5.29×10^{-1}	≈
	WOA	2.14×10^2	7.57×10^{-1}	2.12×10^2	2.14×10^2	4	1.46×10^{-3}	+
	BOA	2.15×10^2	4.24×10^{-1}	2.14×10^2	2.16×10^2	8	3.73×10^{-9}	+
	SOA	2.15×10^2	5.55×10^{-1}	2.14×10^2	2.16×10^2	9	1.86×10^{-9}	+
	LWOA	2.14×10^2	4.64×10^{-1}	2.13×10^2	2.15×10^2	7	3.73×10^{-9}	+
	MSWOA	2.14×10^2	5.01×10^{-1}	2.12×10^2	2.14×10^2	3	1.04×10^{-3}	+
	DGSwOA	2.13×10^2	6.65×10^{-1}	2.12×10^2	2.14×10^2	1		
F ₂₄	PSO	1.04×10^3	4.30×10^1	9.41×10^2	1.12×10^3	9	1.86×10^{-9}	+
	GA	7.13×10^2	2.81×10^1	6.49×10^2	7.57×10^2	8	1.86×10^{-9}	+
	GWO	4.94×10^2	2.27×10^1	4.33×10^2	5.26×10^2	3	2.99×10^{-3}	+
	WOA	4.79×10^2	1.90×10^1	4.26×10^2	5.09×10^2	2	6.41×10^{-1}	≈
	BOA	5.28×10^2	1.98×10^1	4.94×10^2	5.64×10^2	6	1.30×10^{-7}	+
	SOA	5.23×10^2	2.23×10^1	4.64×10^2	5.52×10^2	5	5.72×10^{-7}	+
	LWOA	5.61×10^2	2.80×10^1	4.93×10^2	6.12×10^2	7	1.86×10^{-9}	+
	MSWOA	5.16×10^2	2.33×10^1	4.52×10^2	5.53×10^2	4	3.86×10^{-7}	+
	DGSwOA	4.76×10^2	2.59×10^1	4.15×10^2	5.16×10^2	1		

Table 10. Combined rank of different dimensions.

Dim	Rank	PSO	GA	GWO	WOA	BOA	SOA	LWOA	MSWOA	DGSWOA
2	Average Rank	5.63	5.54	5.08	2.42	8.04	6.71	4.75	4.63	1.96
	Combined Rank	7	6	5	2	9	8	4	3	1
3	Average Rank	6.17	5.79	5.04	2.58	8.00	6.63	4.38	4.54	1.63
	Combined Rank	7	6	5	2	9	8	3	4	1
5	Average Rank	6.83	5.17	4.67	2.13	8.00	6.96	3.67	5.71	1.75
	Combined Rank	7	5	4	2	9	8	3	6	1
10	Average Rank	6.92	5.67	3.50	2.71	8.21	7.33	3.25	5.58	1.83
	Combined Rank	7	6	4	2	9	8	3	5	1
20	Average Rank	7.50	5.79	2.92	2.96	8.25	7.13	2.83	5.46	2.17
	Combined Rank	8	6	3	4	9	7	2	5	1
40	Average Rank	8.04	6.25	2.42	3.04	7.92	6.71	3.38	5.21	2.04
	Combined Rank	9	6	2	3	8	7	4	5	1

Figures 4 and 5 show typical convergence curves selected from the three types of benchmark functions. The curves depicted in this figure represent the average performance of the global best solution across 30 independent runs at each iteration. It is evident from the convergence curves that our algorithm converges faster in most cases. For dimensions 2 and 3 in Figure 4, the iterative curve of the DGSWOA shows a fast initial convergence and then a leveling off, which signifies fast and efficient convergence. For the other dimensions in Figure 5, the iterative curve of DGSWOA shows a convergence rate that outperforms most of the compared algorithms and is able to continuously search for the optimal solution. The convergence curves clearly show that the improved algorithm succeeds in increasing the global optimization capability and convergence speed.

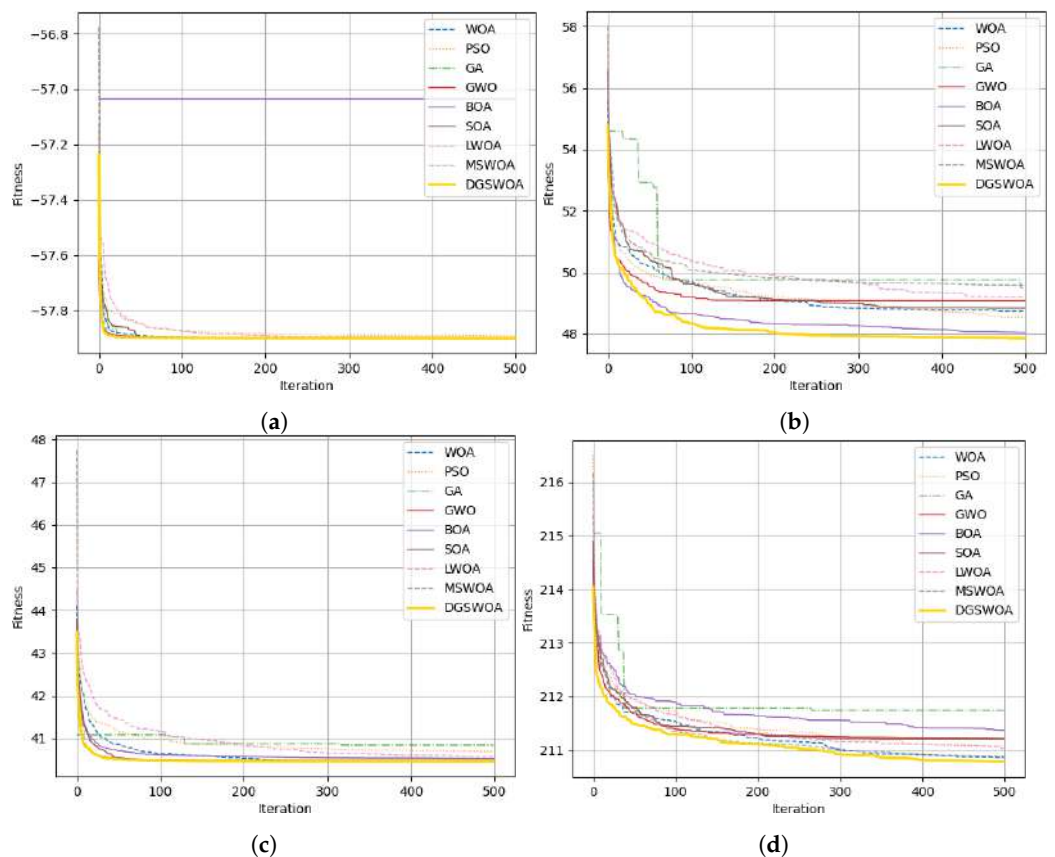


Figure 4. Convergence curves of dimension = 2, 3. (a) F_{14} (dimension = 2). (b) F_{24} (dimension = 2). (c) F_{19} (dimension = 3). (d) F_{23} (dimension = 3).

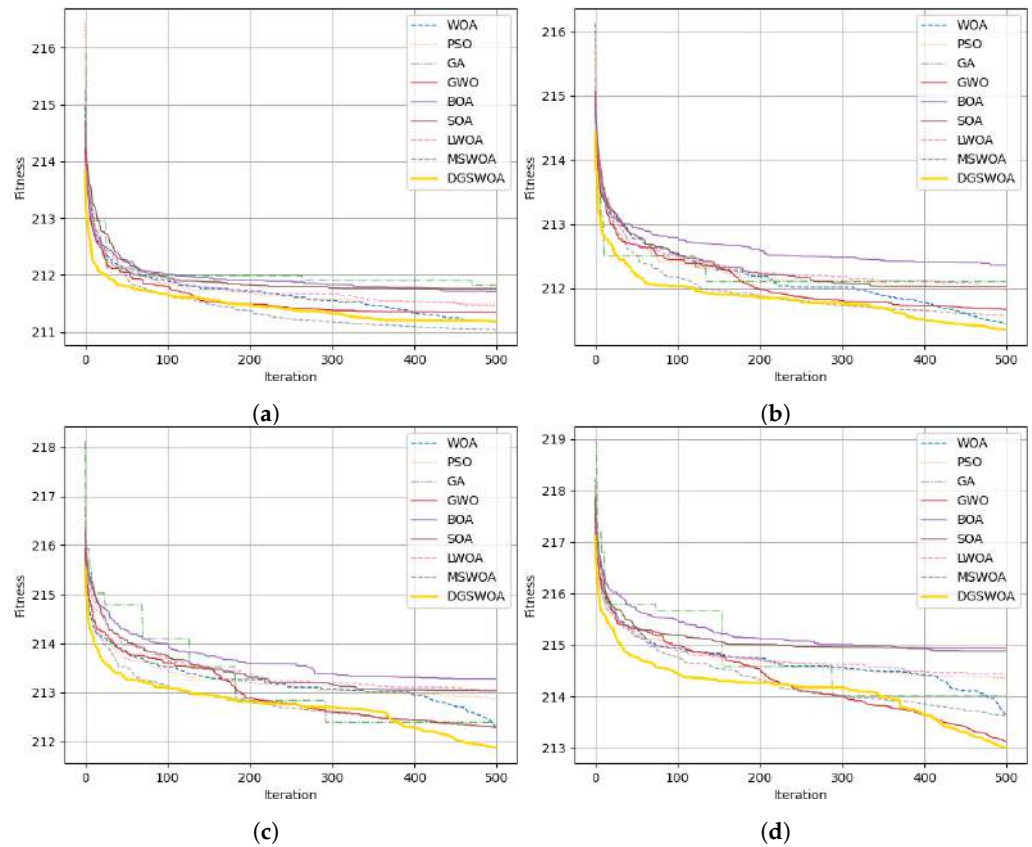


Figure 5. Convergence curves for dimension = 5, 10, 20, 40. (a) F_{23} (dimension = 5). (b) F_{23} (dimension = 10). (c) F_{23} (dimension = 20). (d) F_{23} (dimension = 40).

4.4.2. Wilcoxon Signed-Rank Test Results

We performed the Wilcoxon Signed-Rank test on these data and recorded two parameters, p -value and *State*, displayed in Tables 4–9. *State* is marked as +, −, or ≈, representing statistically significantly better, significantly worse, and not significantly different performance, respectively. Specifically, if the p -value is less than 0.05, the null hypothesis is not accepted and the two groups of data are considered to be statistically significantly different. *State* values of + indicates an enhanced performance by DGSWOA, while a value of − denotes a decline in its performance. Conversely, the algorithms are considered not significantly different and *State* is ≈. NaN denotes a case of non-adaptation.

Most of the markings at dimensions 2, 3, 5, and 10 are +, which indicates that DGSWOA has a significant performance improvement over the other compared algorithms. At dimensions 20 and 40, although some of the markings are −, the overall performance is still boosted. The performance in specific types of functions or under specific conditions is yet to be improved and is labeled as −. As a result, the performance of DGSWOA is significantly improved.

5. Engineering Application

In this section, we apply DGSWOA to concrete engineering challenges, showcasing its practical utility. We discuss its implementation in three-bar truss and pressure vessel design. These cases illustrate the algorithm’s adaptability and effectiveness in solving diverse engineering problems.

5.1. Three-Bar Truss Design

Design optimization of a three-bar truss refers to adjusting parameters such as the size, shape, and connection of the bars so that the structure has the best performance and economy while satisfying certain constraints [36]. The variables x_1 , x_2 , and x_3 are the

cross-sectional areas of the three members, where $x_1 = x_3$. The objective function and constraints of the problem are as follows:

$$f(x) = (2\sqrt{2}x_1 + x_2) \times l \tag{16}$$

$$g_1(x) = \frac{\sqrt{2}x_1 + x_2}{\sqrt{2x_1^2 + 2x_1x_2}} - P - \sigma \leq 0 \tag{17}$$

$$g_2(x) = \frac{x_2}{\sqrt{2x_1^2 + 2x_1x_2}} - P - \sigma \leq 0 \tag{18}$$

$$g_3(x) = \frac{1}{x_1 + \sqrt{2}x_2} - P - \sigma \leq 0 \tag{19}$$

$$0 \leq x_1, x_2 \leq 1 \tag{20}$$

$$l = 100 \text{ cm}; \quad P = 2 \text{ kN/cm}^2; \quad \sigma = 2 \text{ kN/cm}^2 \tag{21}$$

In order to analyze the application problem, we use the same comparison algorithm and parameter settings as in the Section 4.1. This is to maintain consistency of approach and to ensure comparable results. A detailed description of these algorithms and parameter settings has been given above.

The optimization results and their related data are shown in Table 11. By comparing and analyzing the results with other comparative algorithms, it is clear that DGSWOA achieves the best performance in solving the three-bar truss design problem. The optimized results not only show improvement in the mean values, but their reduced standard deviation also indicates the stability and reliability of the results. DGSWOA also performs well in both the best and worst performance metrics. The visual presentation of these data not only proves the theoretical superiority of DGSWOA, but also provides strong evidence for the optimization of truss design in practical engineering applications.

Table 11. Optimization results of three-bar truss design.

Algorithms	Statistical Results				Optimization Results	
	Mean	Std	Best	Worst	x_1	x_2
PSO	264.0102172	0.089045092	263.9064511	264.2583806	0.78925546	0.40775062
GA	264.7136911	0.487230295	263.9960005	265.4198156	0.787181601	0.420651119
GWO	269.9444207	4.131765734	264.4659362	278.160449	0.51189717	0.257295503
WOA	268.7030823	3.522943015	264.1199548	277.3260036	0.793886107	0.441581823
BOA	264.5959808	0.480966027	263.9142765	265.839117	0.778680571	0.443518559
SOA	265.4164476	1.998136218	263.903026	270.7246175	0.781988998	0.442365584
LWOA	264.0792459	0.129620357	263.9051139	264.3445435	0.787698749	0.412843951
MSWOA	263.9713221	0.090194172	263.8960647	264.2718789	0.785543396	0.417860973
DGSWOA	263.9446738	0.038407885	263.8967369	264.0726374	0.786838623	0.413931035

5.2. Pressure Vessel Design

Minimizing the total cost $f(x)$ whilst ensuring that production requirements are met is the core objective of pressure vessel design [37]. To achieve this goal, there are four main variables to consider in the design process: shell thickness T_s (denoted by x_3), head thickness T_h (denoted by x_4), inner radius R (denoted by x_1), and vessel length L (denoted by x_2 , excluding the head). The objective function and constraints of the problem are as follows:

$$\min f(x) = 0.6224x_1x_3x_4 + 1.7781x_2x_3^2 + 3.1661x_1^2x_4 + 19.84x_1^2x_3 \tag{22}$$

$$g_1(x) = -x_1 + 0.0193x_3 \leq 0 \tag{23}$$

$$g_2(x) = -x_2 + 0.00954x_3 \leq 0 \tag{24}$$

$$g_3(x) = -\pi x_3^2 x_4 - \frac{4}{3} \pi x_3^3 + 1296000 \leq 0 \tag{25}$$

$$g_4(x) = x_4 - 240 \leq 0 \tag{26}$$

$$0 \leq x_1 \leq 99, \quad 0 \leq x_2 \leq 99, \quad 10 \leq x_3 \leq 200, \quad 10 \leq x_4 \leq 200 \tag{27}$$

The optimization results and their related data are shown in Table 12. By comparing and analyzing the results with other comparative algorithms, the data clearly show that the DGSWOA algorithm performs consistently in second place on the pressure vessel design problem, behind the best performing LWOA algorithm. Although it has failed to maintain the top rank, the DGSWOA algorithm still demonstrates remarkable consistency and reliability. These findings suggest that the DGSWOA algorithm is a strong candidate and has the potential for further optimization.

Table 12. Optimization results of pressure vessel design.

Algorithms	Statistical Results				Optimization Results			
	Mean	Std	Best	Worst	T_s	T_h	R	L
PSO	30,390.520	8083.371	17,777.737	48,137.525	2.309	1.513	75.372	52.845
GA	120,763.889	56,080.125	30,688.705	231,074.092	4.381	5.577	81.543	54.552
GWO	10,700.645	1500.438	8398.811	15,708.056	1.512	0.775	69.265	12.478
WOA	31,526.721	66,876.075	8181.402	300,155.386	1.854	2.186	70.097	18.752
BOA	40,264.568	17,383.321	10,875.077	78,916.257	3.117	2.756	67.930	16.939
SOA	83,099.446	126,485.649	9439.262	54,0344.896	1.907	8.901	67.594	30.248
LWOA	8483.994	164.481	8164.971	8785.056	1.331	0.659	67.766	11.629
MSWOA	24,266.370	21,728.982	8732.646	111,624.903	1.364	2.449	67.386	31.039
DGSWOA	8949.740	827.810	8170.268	11,511.884	1.388	0.691	67.851	10.505

6. Conclusions

The proposed approach enhances the performance of the WOA algorithm in terms of solution quality and convergence speed by incorporating innovative strategies and efficient mechanisms. More specifically, the Sine–Tent–Cosine map helps the algorithm to initialize the population more uniformly and avoids premature convergence, which increases the search scope in the initial phase. Then, the application of the junior gaining–sharing knowledge phase of the GSK algorithm introduces a more purposeful and driven strategy, which further enhances the algorithm’s global search capability and avoids falling into a local optimum. Furthermore, Dynamic Opposition-Based Learning is intended to enhance solution diversity and increase the probability of discovering a globally optimal solution throughout the search process. To evaluate the performance of DGSWOA, optimization experiments were conducted based on BBOB and two engineering application problems. The experimental results demonstrate that our algorithm significantly improves the performance of the original WOA. Moreover, DGSWOA also outperforms the other eight well-known optimization algorithms in most cases with regard to the quality of the solution and convergence speed. Future research will investigate and improve the performance of the proposed algorithm for large-scale optimization problems with high dimensionality, a vast search space, and a multitude of variables.

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