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KING: An efficient optimization approach

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ABSTRACT

Real-world engineering optimization problems are often highly challenging due to narrow feasible regions, numerous local optima, and intricate constraints. Metaheuristic algorithms (MAs) have shown promise in addressing these issues owing to their global search capability, flexibility, and adaptability. However, a critical challenge with MAs is effectively balancing the global search (exploration) and local search (exploitation) phases, which significantly influences the efficiency and precision of convergence. Many MAs require problem-specific adjustments to control convergence behavior, thereby increasing computational cost and implementation effort. Moreover, existing improvements are often tailored to specific problems, lacking comprehensive validation in terms of generality, robustness, and scalability. To overcome these limitations, this paper proposes a novel high-performance optimization algorithm with enhanced adaptability, named the Three Kingdoms Optimization Algorithm (KING), inspired by historical dynamics of the Three Kingdoms period in China. We establish an analogy between key components of MAs—such as population initialization, exploration, and exploitation—and four historical phases: the ascent of the might, joint confrontation, three-legged tripod, and whole country united. KING incorporates a new reinforcement convergence mechanism to systematically guide the search process while maintaining an effective balance between exploration and exploitation, enabling rapid and efficient convergence. Additionally, a dynamic, tolerance-based constraint-handling technique is introduced to strengthen its capability in solving complex constrained problems. The performance of KING is extensively evaluated on the IEEE CEC 2017 and IEEE CEC 2022 benchmark test suites, comparing it with classical algorithms, high-performance variants, and state-of-the-art methods across problems of varying scales. Experimental results demonstrate that KING outperforms the compared algorithms in convergence speed, solution accuracy, and stability. Its superiority is further validated through applications to four real-world engineering problems. The proposed algorithm proves to be an effective and reliable tool for engineering optimization. Its source code will be made publicly available at https://aliasgharheidari.com/KING.html and other websites.

1. Introduction

Real-world engineering optimization problems are inherently challenging due to their high number of variables, complex constraints, and terrain with many peaks and valleys (multimodal landscapes) [1,2]. Traditional methods, such as gradient descent and linear programming, often struggle with these problems, particularly when the problems lack desirable mathematical properties like convexity or smoothness, causing them to get stuck in numerous local optima. In response, metaheuristic algorithms (MAs) have emerged as powerful alternatives. As stochastic search methods, MAs employ high-level strategies and adaptive rules to explore solution spaces effectively, obtaining near-optimal solutions within a practical amount of time. Unlike conventional approaches, MAs do not rely on simplifying assumptions about the problem's structure. This allows them to robustly handle nonlinear, non-differentiable, and discontinuous systems.

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Dhiman et al. [3] classify MAs into three primary categories: evolutionary algorithms, swarm intelligence algorithms, and physics-inspired algorithms. Evolutionary algorithms, drawing inspiration from biological evolution, conceptualize decision variables as genetic components and simulate processes such as crossover, mutation, and selection to iteratively refine populations. Notable representatives include the genetic algorithm (GA) [4] and differential evolution (DE) [5], etc. Physics-inspired algorithms derive their mechanisms from fundamental physical phenomena, such as gravitational forces, electromagnetic interactions, and thermodynamic principles, exemplified by the multi-verse optimizer (MVO) [6], fata morgana algorithm (FATA) [7], gravitational search algorithm (GSA) [8], polar lights optimization (PLO) [9], and rime optimization algorithm (RIME) [10], etc.

Swarm intelligence algorithms, simulating collective behaviors observed in biological systems, leverage cooperative interactions and information exchange among agents to drive optimization. Prominent examples include particle swarm optimization (PSO) [11], grey wolf optimization (GWO) [12], whale optimizer (WOA) [13], ant colony optimization for continuous domains (ACOR) [14], Harris hawks optimization (HHO) [15], slime mould algorithm (SMA) [16], moth-flame optimization (MFO) [17], red fox optimization algorithm (RFO) [18], colony predation algorithm (CPA) [19], and honey badger algorithm (HBA) [20]. Additionally, in recent years, numerous algorithms based on human-related concepts have emerged, such as teaching-learning-based optimization (TLBO) [21], status-based optimization (SBO) [22], imperialist competitive algorithm (ICA) [23], educational competition optimizer (ECO) [24], growth optimizer (GO) [25], escape or escape algorithm (ESC) [26], political optimizer (PO) [27], and election algorithm (EA) [28], etc.

Although a large number of MAs have been proposed based on different design principles and research backgrounds, their optimization efficiency in practical applications relies on the balance of two important determinants during the search process: global exploration (broad search for undiscovered solution regions) and local exploitation (refined search within identified promising areas) [29,30]. This balance directly governs convergence speed, solution accuracy, and robustness against premature stagnation.

However, the specific nature of engineering problems makes this balance even harder to achieve. These problems often include discrete variables, tight constraints, and complex rules that worsen the imbalance between exploration and exploitation. This often leads to wasted computational effort or premature convergence, where the algorithm gets stuck on a suboptimal solution. To mitigate these issues, advanced strategies, particularly reinforcement convergence mechanisms, are essential. These mechanisms dynamically adjust the algorithm's search behavior, to ensure a more effective and harmonious interaction between global exploration and local refinement. Recent advancements include the WOA based on the Lévy initialization strategy, the directional crossover mechanism, and the directional mutation mechanism (LXMWOA) [31], GWO combines with an improved spread strategy and a chaotic local search mechanism (SCGWO) [32], random spare and chaotic intensification improved ACOR (RCACO) [33], the opposition learning based GWO (IGWO) [34], SCA with differential evolution (SCADE) [35], FOA hybrid SMA combined with Lévy flight, oppositional learning (LSEOFOA) [36], adaptive sine cosine optimization algorithm integrated with particle swarm optimization (ASCA_PSO) [37]. To enhance the robustness in solving practical dynamic multi-objective optimization problems, Li et al. [38] proposed a label-free adaptive transfer framework, reducing the need for human intervention effort. In subsequent work, they innovatively introduced soft labels and fuzzy systems [39] to achieve more objective and flexible knowledge transfer, thereby advancing both the practicality and reliability of evolutionary transfer optimization algorithms for addressing dynamic complex problems. Despite these innovations, MA enhancements remain constrained by two critical issues: (1) heavy reliance on empirical tuning and computationally intensive validation, which escalates deployment costs, and (2) insufficient evaluation of generalizability and robustness, raising concerns about performance consistency across diverse problem scales and constraint configurations.

To address these gaps, this paper proposes the Three Kingdoms Optimization Algorithm (KING), an efficient metaheuristic algorithm inspired by the historical dynamics of the Three Kingdoms period in China. KING draws analogies between MA's population initialization, global exploration, local exploitation, and reinforcement convergence strategies with the historical phases of ascent of the might, joint confrontation, three-legged tripod, and whole country united. Furthermore, KING integrates a dynamic equality tolerance-based constraint-handling technique [40] to enhance adaptability in complex constrained optimization scenarios.

The efficacy of KING is rigorously validated through comprehensive comparisons with classical, high-performance, and state-of-the-art algorithms on the IEEE CEC 2017 [41] and IEEE CEC 2022 [42] benchmark suites across multiple dimensions. Empirical results demonstrate KING's superior convergence speed, solution precision, and dimensional scalability. In four practical engineering design problems, KING outperforms competitors, achieving higher accuracy and reliability. The principal contributions of this work are summarized as follows:

- An innovative algorithm, the three kingdoms optimization algorithm (KING), inspired by the historical evolution process of the three kingdoms, is proposed.
- Development of a reinforcement convergence mechanism to balance exploration-exploitation dynamics, ensuring efficient convergence.
- Extensive benchmarking against classical, high-performance, and state-of-the-art algorithms on standardized test suites.
- Demonstrated excellence in real-world engineering optimization tasks, underscoring KING's industrial applicability.

Paper Organization: Section 2 elucidates the historical inspiration underpinning KING. Section 3 details KING's architectural components and implementation. In Section 4, a comparative analysis with classical algorithms was conducted to examine the convergence equation design and time complexity of KING. Section 5 presents comparative analyses on benchmark functions and engineering case studies. Section 6 concludes with insights and future research directions.

2. Inspiration

The cyclical paradigm of geopolitical integration and fragmentation is profoundly encapsulated in the aphorism from *Romance of the Three Kingdoms* — a canonical masterpiece among China's Four Great Classical Novels—"The empire, long divided, must unite; long united, must divide." This foundational masterpiece chronicles the transformative century spanning the fall of the Eastern Han dynasty (25–220 CE) to the rise of the Western Jin dynasty (266–316 CE), a period defined by tripartite confrontation and strategic shifts. This era's history has exerted a lasting impact on China's political structures and social models, leading to ongoing academic study and reflection. The intricate interplay of military strategies, diplomatic maneuvers, and the struggle for power renders it one of the most richly studied epochs in Chinese history.

The Three Kingdoms era (220–280 CE), a defining period of disunity and transformation in Chinese history, originated from the collapse of the Eastern Han Dynasty. The dynasty's decline, driven by internal corruption and external pressures, culminated in the Yellow Turban Rebellion of 184 CE. This large-scale uprising crippled the central government and created a power vacuum, allowing local military leaders to carve out independent states.

By 190 CE, the Han imperial court had effectively collapsed, plunging the empire into internecine warfare among regional warlords. The Battle of Red Cliffs (208 CE) marked a decisive turning point, where the alliance of Sun Quan and Liu Bei halted Cao Cao's southern

campaign, establishing the geopolitical preconditions for tripartite division. The formalization of this trisection occurred through successive imperial proclamations: Cao Pi's abdication of Emperor Xian in 220 CE established Wei state (capital: Luoyang), followed by Liu Bei's declaration of Shu Han in 221 CE and Sun Quan's foundation of Eastern Wu in 229 CE (see Fig. 1).

The land was finally brought together in three main steps:

1. In 263 CE, a general named Sima Zhao led an army that defeated the kingdom of Shu Han.
2. In 266 CE, Sima Zhao's son, Sima Yan, took power from the Wei kingdom. He started a new ruling family called the Western Jin.
3. In 280 CE, Sima Yan's armies attacked and took over the last kingdom, Eastern Wu. This joined all the land under one rule again.

This historical trajectory can be systematically categorized into four evolutionary phases (illustrated in Fig. 2):

Ascent of the might (184–190 CE): Decentralization following Han decline
Joint confrontation (190–208 CE): Warlord alliances against hegemonic forces
Three-legged tripod (208–263 CE): Stabilized tripartite balance of power among the Wei, Shu Han, and Eastern Wu
Whole country united (263–280 CE): Progressive absorption of states into Western Jin

The historical evolution of the Three Kingdoms period presents many interesting analogies with the optimization process of MAs, as shown in Table 1. Clearly, the historical phases of ascent of the might, joint confrontation, three-legged tripod, and whole country united during the three kingdoms correspond to the population initialization, exploration capability, exploitation capability, and reinforcement convergence strategy in the optimization process of MAs. These complex similarities between the historical evolution of the Three Kingdoms era and the optimization process of MAs pave the way for an efficient metaheuristic algorithm that uses the historical evolution of the three kingdoms as a metaphor, known as the Three Kingdoms Optimization Algorithm (KING). We will explain the proposed algorithm in detail in the next section.

3. Three-kingdom optimization algorithm

The core optimization process of KING comprises four distinct phases: Ascent of the might (AOM), Joint confrontation (JC), Three-legged tripod (TLT), and Whole country united (WCU). In the AOM phase, diverse factions with varying levels of influence emerge. Among these, the three most powerful factions solidify into distinct states. During the JC phase, the two weaker states ally to counter the dominant state. The TLT phase is characterized by a relative equilibrium in power among the three states. They engage in mutual checks and balances while independently developing their capabilities, attracting surrounding factions, and enhancing their individual strength. In the later stages of evolution, the process transitions to the WCU phase. The three states are gradually annexed by a single, prevailing state, forming a unified entity. This consolidated sovereignty exerts centralized governance over all factions.

3.1. Population initialization method: ascent of the might (AOM)

In the AOM, KING randomly generates N entities with distinct positions and varying strengths. Each entity comprises D distinct elements influencing national strength, such as economy, military, politics, science and technology, and natural resources. The three most powerful entities are then identified through evaluation, corresponding to the states of Wei, Shu Han, and Eastern Wu. For initialization, KING employs a random initialization method, as given by Eq. (1):

$$X = L + \theta \circ (U - L)$$

Fig. 1. Map of territorial distribution during the three kingdoms period.

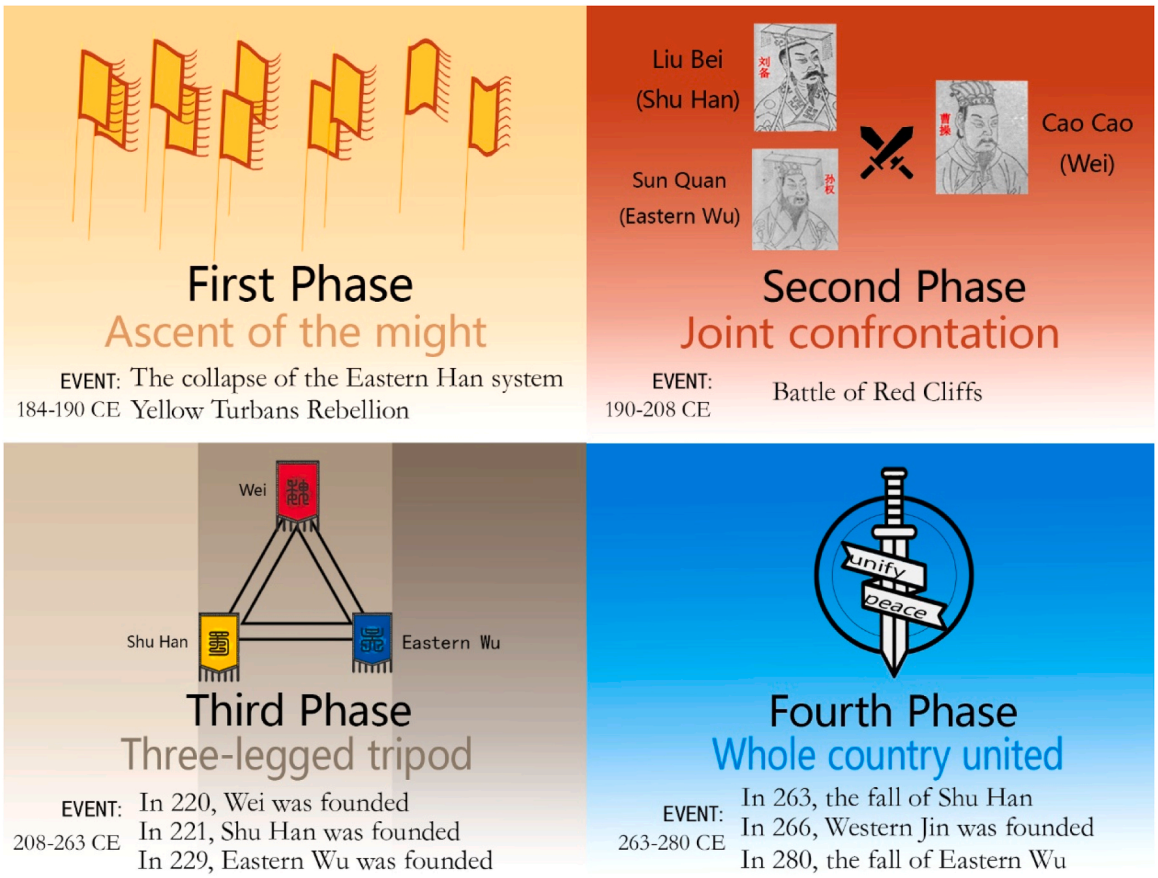

Fig. 2. Timeline of major events during the three kingdoms period.

Table 1
Similarities between the historical evolution of the Three kingdoms period and the optimization process of Mas.

The historical evolution of the Three Kingdoms period	The optimization process of metaheuristic algorithms
Ascent of the might	Population initialization
Joint confrontation	Global exploration
Three-legged tripod	Local exploitation
Whole country united	Reinforced convergence

$$= \begin{bmatrix} x_{1,1} & x_{1,2} & & x_{1,D-1} & x_{1,D} \\ & & \cdots & & \\ x_{2,1} & x_{2,2} & & x_{2,D-1} & x_{2,D} \\ \vdots & & \ddots & \vdots & \\ x_{N-1,1} & x_{N-1,2} & & x_{N-1,D-1} & x_{N-1,D} \\ & & \cdots & & \\ x_{N,1} & x_{N,2} & & x_{N,D-1} & x_{N,D} \end{bmatrix} \tag{1}$$

Where X represents the initial population. L and U denote the lower and upper bounds of the problem's solution space, respectively, defining the feasible range for all decision variables: $L = [L_1, L_2, \ldots, L_{D-1}, L_D]$, $U = [U_1, U_2, \ldots, U_{D-1}, U_D]$. θ is a D-dimensional random vector where each component θ_D $(d = 1, 2, \ldots, D)$ is independently sampled from a uniform distribution $U(0, 1)$. $\circ$ signifies the Hadamard product (element-wise multiplication).

Following initial population creation, the objective function $f(\bullet)$ evaluates the fitness of the population. The three individuals exhibiting the highest fitness values are then selected and denoted as k_1, k_2, and k_3.

3.2. Design of convergence equations

After the AOM, three of the most powerful forces emerge among the various factions, forming the states of Wei, Shu Han, and Eastern Wu. These three nations are not entirely opposed to each other. There exists a degree of cooperation as well. When one of the nations becomes sufficiently strong and poses a threat to the other two, the weaker nations unite to confront the strongest nation, entering the JC phase. When the strengths of the three nations reach a balanced state where no single nation can eliminate the others, they tend to develop independently, attracting additional forces to enhance their strength, thereby entering the TLT phase. Over time, as the strengths of the three nations gradually increase, the likelihood of joint resistance decreases, leading each nation to prefer independent development.

This process analogizes the historical periods of joint resistance and balance of power during the Three Kingdoms era. In the optimization process of MAs, the algorithm's global exploration capability and local exploitation capability exhibit a conflicting yet complementary relationship. The search process in MAs commences with extensive exploration of the entire solution space to identify potential areas for finding the global optimum, then intensively exploit these areas to refine solution quality. The balance between global exploration and local exploitation is crucial to algorithm performance. Crucially, while engaging in local exploitation, it remains necessary to maintain a certain probability of global exploration to avoid getting trapped in local optima. This exploration probability is dynamically decayed throughout the process, progressively reallocating computational resources on refining the optimal solution, thus enhancing overall optimization effectiveness.

In the KING, the JC and TLT phases primarily fulfill the core functions of global exploration and local exploitation, respectively. A dynamic Trade-off Factor (TF) adaptively directs each search agent to the

solution vector generated by either the exploration or exploitation phase, thereby achieving a balance between exploration and exploitation. This pivotal selection mechanism is governed by Eq. (2):

$$x'_{i,t} = \begin{cases} jx_{i,t}, & \text{If } r_1 > TF \\ tx_{i,t}, & \text{Otherwise} \end{cases} \tag{2}$$

Specifically, $x'_{i,t}$ represents the agent individual corresponding to the i-th individual x_i in the population during the t-th iteration. The selection of $x'_{i,t}$ is determined by comparing the TF value with a random number r_1, uniformly distributed between 0 and 1. jx_i and tx_i denote the solution vectors calculated through the global exploration (JC) and local exploitation (TLT) phases, respectively. TF is computed as shown in Eq. (3):

$$TF = h^{\left(\frac{1-\tan(\pi\times(r_2-0.5))}{MaxFEs}\right)} \tag{3}$$

The $\tan(\cdot)$ function is symmetric around $r_2 = 0.5$, enabling a smooth transition between exploration and exploitation probabilities. The uniformly distributed random number r_2 within $(0,1)$ introduces uncertainty into individual selection. When $r_2 > 0.5$, $\tan(\pi \times (r_2 - 0.5)) > 0$, causing the exponent term to decrease and the TF value to increase, thereby enhancing the tendency towards local exploitation. When $r_2 < 0.5$, the exponent term increases and the TF value decreases, strengthening the tendency towards global exploration. $MaxFEs$ denotes the maximum number of function evaluations. Its inclusion in the denominator constrains the magnitude of the exponent, preventing excessive sensitivity of TF to random perturbations during the later stages of optimization. The parameter h models the progression of both the optimization process and the historical evolutionary analogy, as defined in Eq. (4):

$$h = \sqrt{\frac{FEs - 1}{MaxFEs}} \tag{4}$$

The square root function ensures that the exploration rate in the early optimization phase is significantly faster than the exploitation rate in the later phase, aligning with the exponential decay pattern observed in natural optimization processes. FEs represents the current number of function evaluations. Initial Stage $(FEs \approx 1): h \approx 0 \rightarrow TF \approx 0$, global exploration dominates the early optimization phase. Intermediate Stage $(FEs = 0.5 \times MaxFEs): h \approx 0.707 \rightarrow TF$ gradually increases, signifying a transition towards local exploitation. Convergence Stage $(FEs \rightarrow MaxFEs): h \rightarrow 1 \rightarrow TF \rightarrow 1$, local exploitation dominates the final convergence phase.

Through the synergistic design of the TF and the historical progression parameter h, the KING algorithm dynamically modulates the activation probabilities of the JC and TLT phases based on the optimization progress. This achieves an adaptive balance between global exploration and local exploitation without requiring predefined phase-switching thresholds.

3.2.1. Global exploration: joint confrontation (JC)

The JC phase models the historical scenario from the Three Kingdoms period, where weaker states formed alliances to counter a dominant power. When one of the three states becomes sufficiently powerful, posing a threat to the other two, the weaker states unite to confront the currently strongest state, initiating the JC phase. During this phase, the two weaker states, k_2 and k_3, share specific strength components, forming a joint force $jx_{i,j}$ to oppose the dominant state k_1. The j-th component of the JC solution vector, $jx_{i,j}$, is defined by Eq. (5):

$$jx_{i,j} = w \times Tk_{2,j} + (1 - w) \times Tk_{3,j} \tag{5}$$

w is a uniformly distributed random number within $(0,1)$, $w \sim U(0,1)$, controlling the blending ratio between the correction terms $Tk_{2,j}$ and $Tk_{3,j}$ from the two sub-optimal individuals. By blending $Tk_{2,j}$ and $Tk_{3,j}$, $jx_{i,j} \in [\min(Tk_{2,j}, Tk_{3,j}), \max(Tk_{2,j}, Tk_{3,j})]$. This guarantees that $jx_{i,j}$ resides within the high-quality region defined by the two sub-optimal correction terms, thereby facilitating the inheritance of beneficial historical optimization experience. The correction terms $Tk_{2,j}$ and $Tk_{3,j}$ are calculated via Eq. (6) and Eq. (7):

$$Tk_{2,j} = w_1 \times k_{2,j} + (1 - w_1) \times x_{i,j} + r_3 \times (r_4 \times (U_j - L_j) + L_j) \tag{6}$$

$$Tk_{3,j} = w_2 \times k_{3,j} + (1 - w_2) \times x_{i,j} + r_5 \times (r_6 \times (U_j - L_j) + L_j) \tag{7}$$

$Tk_{2,j}$ and $Tk_{3,j}$ blend the current individual with a sub-optimal elite individual and incorporate a global random perturbation. $w_1, w_2, r_3, r_4, r_5, r_6 \sim U(0,1)$ are generated independently. w_1 and w_2 regulate the retention strength of the elite individual components. $k_{2,j}$ and $k_{3,j}$ represent the j-th component of the two sub-optimal individuals k_2 and k_3, respectively. $x_{i,j}$ represents the j-th component of the current individual x_i. The perturbation term generates a step uniformly distributed across the entire feasible range $[L_j, U_j]$ for dimension j. This imbues $jx_{i,j}$ with the capability for random jumps spanning the entire solution space.

The JC serves as a global exploration strategy. It operates by blending the current individual with sub-optimal elites individuals, it leverages information pertinent to promising convergence directions. Concurrently, it introduces exploration steps of random magnitude bounded by the solution space limits. This mechanism significantly mitigates the risk of the algorithm becoming trapped in local optima and facilitates comprehensive global search across the solution space.

3.2.2. Local exploitation: three-legged tripod (TLT)

The TLT phase models the historical period of the Three Kingdoms where the three states pursued independent development. When their strengths reach a state of equilibrium such that no single state can eliminate the others, they tend to focus on autonomous growth, attracting surrounding factions to bolster their individual power. During this development, each state k_1, k_2, k_3 enhances its strength by compensating for weaknesses Pt_1 and amplifying strengths Pt_2. The TLT solution vector tx_i for an individual x_i is defined by Eq. (8):

$$tx_i = bx + (Pt_1 + Pt_2) \circ L(D)$$

Where:

$$bx = \begin{cases} x_{n1}, & \text{If } (x_{n1}) < f(x_i) \\ x_i, & \text{Otherwise} \end{cases}$$

$$n1 \in \{1, 2, \ldots, N\}, \quad n1 \neq i \tag{8}$$

bx represents either the current individual x_i or a randomly selected individual x_{n1} from the population exhibiting a superior fitness value. The index $n1$ is chosen randomly from the population indices excluding i. If $f(x_{n1}) < f(x_i)$, the random elite x_{n1} is selected to enhance exploitation quality. If $f(x_{n1}) \geq f(x_i)$, the current solution x_i is retained to maintain population diversity. This randomized elite selection fosters diverse exploitation trajectories, mitigating the risk of premature convergence associated with a single elite guidance strategy. The exploitation enhancement terms Pt_1 and Pt_2 are calculated via Eqs. (9) and (10). $L(D)$ is a D-dimensional vector where each component follows a Lévy distribution [43]. Compared to a uniform random distribution, the Lévy distribution primarily generates small step sizes, ensuring high-precision local exploitation, while also possessing a heavy-tailed property that occasionally produces large steps, assisting the algorithm in escaping local optima.

$$Pt_1 = \theta_1 \circ (k_{n2} - bx) \tag{9}$$

$$Pt_2 = \theta_2 \circ (bx - x_i) \tag{10}$$

θ_1 and θ_2 are D-dimensional random vectors with components uniformly distributed, $\theta_1, \theta_2 \sim U_D(0,1)$. $n2$ is a randomly selected elite index, $n2 \sim U\{1,2,3\}$. Pt_1 constructs an exploration step guided by a randomly chosen elite individual k_{n2}, facilitating elite-directed

exploitation. Pt_2 is only active when $bx = x_{n1}$ (i.e., a random elite was selected). It filters out information from potentially inferior solutions x_i, aiding in accelerated convergence.

TLT employs a base individual bx chosen as either the current solution or a randomly selected solution with better fitness. This strategy enhances population quality while preserving diversity. The introduction of random steps based on the Lévy distribution and information from relatively superior solutions allows the algorithm to refine solution accuracy around promising regions identified by the base individual bx, concurrently providing opportunities to escape local optima through the inherent long jumps of the Lévy flights.

3.2.3. Enhanced convergence: whole country united (WCU)

The WCU phase models the process where the most powerful state gradually assimilates the others. During WCU, the increasing disparity in strength development among the three states renders the alliance of the two weaker states k_2 and k_3 progressively less effective in countering the dominant state k_1. Consequently, the strongest state gradually annexes the remaining entities $x_{i,j}$, establishing a unified sovereignty. This sovereignty orchestrates global coordination by evaluating the strength components of all factions to promote balanced development. The j-th component of the WCU solution vector, $wx_{i,j}$, is constructed via Eq. (11):

$$wx_{i,j} = \begin{cases} cx_{i,j}, & \text{If} \quad r_7 > p_i \\ x_{i,j}, & \text{Otherwise} \end{cases} \tag{11}$$

The value of $wx_{i,j}$ is determined by the coordination scheduling parameter p_i, selecting either to retain the original individual $x_{i,j}$ or to construct the corresponding solution vector $cx_{i,j}$. Here, $r_7 \sim U(0,1)$ is a uniformly distributed random number. The parameter p_i is an individual evaluation metric derived from the normalized fitness values of all individuals in the population, calculated using Eqs. (12)-(13):

$$p_i = v \cdot \text{sech}(m_i) = v \cdot \frac{2}{e^{m_i} + e^{-m_i}} \tag{12}$$

$$m_i = \begin{cases} 0.5 & \text{If} \quad d_{\max} = d_{\min} \\ \dfrac{d_i - d_{\min}}{d_{\max} - d_{\min}} & \text{Otherwise} \end{cases} \tag{13}$$

$v = 2$ is a scaling factor controlling the range of the probability distribution p. The sensitivity of this parameter is analyzed in Section 5.3. sech(•) denotes the hyperbolic secant function, performing a nonlinear transformation of the normalized deviation. This even function exhibits symmetric, monotonically decreasing behavior over the entire real domain. It attains its maximum value of 1 at $m = 0$ and asymptotically approaches 0 as $m \to \pm\infty$. m_i represents the normalized fitness deviation within the population, quantifying the quality gap for individual i. $d_i = |f_i - f_{best}|$ is the absolute difference between the fitness of the current individual f_i and the current best individual f_{best}. $d_{\max}$ and $d_{\min}$ are the maximum and minimum values of d_i across the entire population, respectively.

Through normalization, fitness deviations are mapped onto the interval $[0,1]$. Individuals with poorer fitness exhibit larger m_i values. After the nonlinear smoothing by sech(•), these individuals yield smaller p_i values, consequently granting a higher probability for constructing $cx_{i,j}$. The component $cx_{i,j}$ enhances solution accuracy by incorporating the current best individual and is computed via Eq. (14):

$$cx_{i,j} = h \times best_j + (1-h) \times x_{i,j} + r_8 \times (best_j - x_{i,j}) \tag{14}$$

$cx_{i,j}$ blends the current individual $x_{i,j}$ with the current best individual $best_j$ corresponding dimensional components and incorporates a random perturbation. h is the historical progression parameter modeling both the optimization process and the Three Kingdoms historical evolution, defined previously in Eq. (4). Within WCU, h controls the mixing ratio between the current individual and the best individual. As optimization progresses, h increases, progressively amplifying the influence of the best individual to accelerate convergence. $r_8 \sim U(0,1)$ is a random number controlling the magnitude of the local exploration step.

During population update, the next-generation individual $x_{i,t+1}$ is determined by greedily selecting the best solution among the original individual $x_{i,t}$ and the WCU solution vector $wx_{i,t}$. For minimization problems, KING's population update is defined by Eq. (15):

$$x_{i,t+1} = \begin{cases} wx_{i,t}, & \text{If} \quad (wx_{i,t}) < f(x_{i,t}) \\ x_{i,t}, & \text{Otherwise} \end{cases} \tag{15}$$

The WCU phase selects target individuals of lower quality via normalized fitness evaluation. It enhances solution accuracy by hybridizing these target individuals with the current best solution. Furthermore, the progressively enhanced influence of the best solution throughout the optimization process ensures efficient algorithmic convergence.

3.3. Constraint-handling method: dynamic tolerance for equality constraints

Solution feasibility is evaluated through aggregate constraint violation metrics encompassing both equality and inequality constraints, as formalized in Eqs. (16)-(18). For an optimization problem with p inequality constraints $g(x)$ and m equality constraints $h(x)$. Let $svc\ (x, \epsilon_t)$ represents the total constraint violation of the solution x under the equality tolerance ϵ_t. $\mathscr{I}(x)$ represents cumulative inequality constraint violation. $\mathscr{E}(x, \epsilon_t)$ represents the cumulative equality constraint violation under tolerance ϵ_t. The violation metrics are computed as:

$$svc\ (x, \epsilon_t) = \mathscr{I}(x) + \mathscr{E}(x, \epsilon_t) \tag{16}$$

$$\mathscr{I}(x) = \sum_{i=1}^{p} \max\{g_i(x), 0\} \tag{17}$$

$$\mathscr{E}(x, \epsilon_t) = \sum_{j=p+1}^{m} \max\{|h_j(x)| - \epsilon_{j,t}, 0\} \tag{18}$$

The tolerance parameter $\epsilon_{j,t}$ for each equality constraint $h_j(x)$ is dynamically adjusted through Eq. (19).

$$\epsilon_{j,t+1} = \begin{cases} \epsilon_{j,t} \times \left(\dfrac{\epsilon_f}{\epsilon_{j,t}}\right)^{\frac{1}{FEs_\epsilon - FEs}} & \text{If } FEs < FEs_\epsilon \text{ and } x_{i,t} \text{ are } \epsilon - \text{feasible} \\ \epsilon_{j,t} & \text{Other case} \end{cases} \tag{19}$$

where ϵ_f denotes the final tolerance threshold. The ϵ −feasible condition requires zero equality constraint violations ($\mathscr{E}(x_{i,t}, \epsilon_t) = 0$) with $\epsilon_{j,t} > \epsilon_f$, Tolerance adjustment occurs within a predefined maximum evaluation budget FEs_ϵ.

For minimization problems, the update between candidate solution u_i and parent $x_{i,t}$ follows the hierarchical selection rule in Eq. (20). The priority of selection first considers lower constraint violation amplitudes. When both solutions are feasible, choose individuals with superior fitness values. This dual-phase mechanism ensures strict feasibility enforcement through constraint violation prioritization and optimal solution refinement under feasible conditions.

$$x_{i,t+1} = \begin{cases} u_i & svc\ (u_i; \epsilon_t) < svc\ (x_{i,t}; \epsilon_t) \\ u_i & svc\ (u_i; \epsilon_t) = svc\ (x_{i,t}; \epsilon_t) = 0 \\ & \wedge f(u_i) < f(x_{i,t}) \\ x_{i,t} & svc\ (u_i; \epsilon_t) = svc\ (x_{i,t}; \epsilon_t) = 0 \\ & \wedge f(x_{i,t}) < f(u_i) \\ x_{i,t} & \text{Other case} \end{cases} \tag{20}$$

Out-of-bound solutions are reconfigured via Eq. (21).

$$u_{i,j,t} = \begin{cases} (1-r) \cdot U_j + r \cdot x_{i,j,t} & \text{If } u_{i,j,t} > U_j \\ (1-r) \cdot L_j + r \cdot x_{i,j,t} & \text{If } u_{i,j,t} < L_j \end{cases} \tag{21}$$

where U_j and L_j denote the upper/lower bounds of the j-th decision

variable, with $r \in (0, 0.1)$ as a stochastic scaling factor.

3.4. Implementation of KING for constrained optimization

After AOM initializes the population and its objective function values for KING. Firstly, under the conditions of $FEs < FEs_\epsilon$ and $\epsilon -$ feasible, dynamically adjust the individual's tolerance for equality constraints. Subsequently, a trade-off factor TF is used to determine whether to use JC or TLT for updating the solution vectors of the population. During this process, there is a risk of the solution vectors going out of bounds, therefore, boundary handling must be performed on the population before calculating the objective function values. Next, the population is updated using a greedy selection method. Finally, WCU is used to guide algorithm convergence and achieve a balance between exploration strategy and development strategy. The WCU encompasses the complete process of solution vector updates, boundary handling, objective function value evaluation, and population updates. In summary, the flowchart of KING is shown in Fig. 3.

4. Theoretical analysis of the algorithms

In this section, the efficacy of KING's formula design and its time complexity are analyzed through comparative evaluations against four classical algorithms: genetic algorithm (GA) [4], differential evolution (DE) [5], particle swarm optimization (PSO) [11], and ant colony optimization for continuous domains (ACOR) [14].

4.1. Comparative analysis of formula design

To evaluate the efficacy and innovation of KING's formula design, this section compares its convergence equations with GA, DE, PSO, and ACOR. GA and DE belong to the evolutionary algorithms category, solving optimization problems by simulating biological processes of crossover, mutation, and selection, though they exhibit significant differences in operational mechanisms and performance characteristics. PSO updates particle positions by adjusting velocity vectors based on individual historical best positions and the global historical best position. ACOR maintains an 'archive' storing high-quality solutions and their objective function values, generating new solutions by sampling from a probability density function constructed from this archive. Table 2 summarizes the core operations and convergence equations of these algorithms.

In the crossover operation of GA, parental genes are exchanged to

Table 2
Convergence equation designs of classical algorithms.

Algorithms	Operations	Formulas
GA	Crossover	$c_1 = 0.5[(1+\beta)p_1 + (1-\beta)p_2]c_2 = 0.5[(1-\beta)p_1 + (1+\beta)p_2]$
	Mutation	$x_i' = x_i + \delta \cdot \mathcal{N}(0,1)$
DE	Crossover	$v_{i,t} = x_{n0,t} + F_i \bullet (x_{n1,t} - x_{n2,t})$
	Mutation	$u_{i,j,t} = \begin{cases} v_{i,j,t}, & \text{If } r \le CR_i \text{ or } j = j_{rand} \\ x_{i,j,t}, & \text{Otherwise} \end{cases}$
PSO	Speed vector update	$v_{i,t+1} = w \times v_{i,t} + c_1 \times r_1 \times \left(pbest_{i,t} - x_{i,t}\right) + c_2 \times r_2 \times (gbest_t - x_{i,t})$
	Individual update	$x_{i,t+1} = x_{i,t} + v_{i,t+1}$
ACOR	Wight update	$w_l = \frac{1}{qk\sqrt{2\pi}} \exp\left(-\frac{(l-1)^2}{2q^2k^2}\right) p_l = \frac{w_l}{\sum_{j=1}^{k} w_j}$
	Individual update	$\sigma_l^d = \xi \sum_{j=1}^{k} \frac{\lvert s_{jd} - s_{ld} \rvert}{k-1} s_{new,d} \sim \mathcal{N}\left(s_{ld}, \left(\sigma_l^d\right)^2\right)$

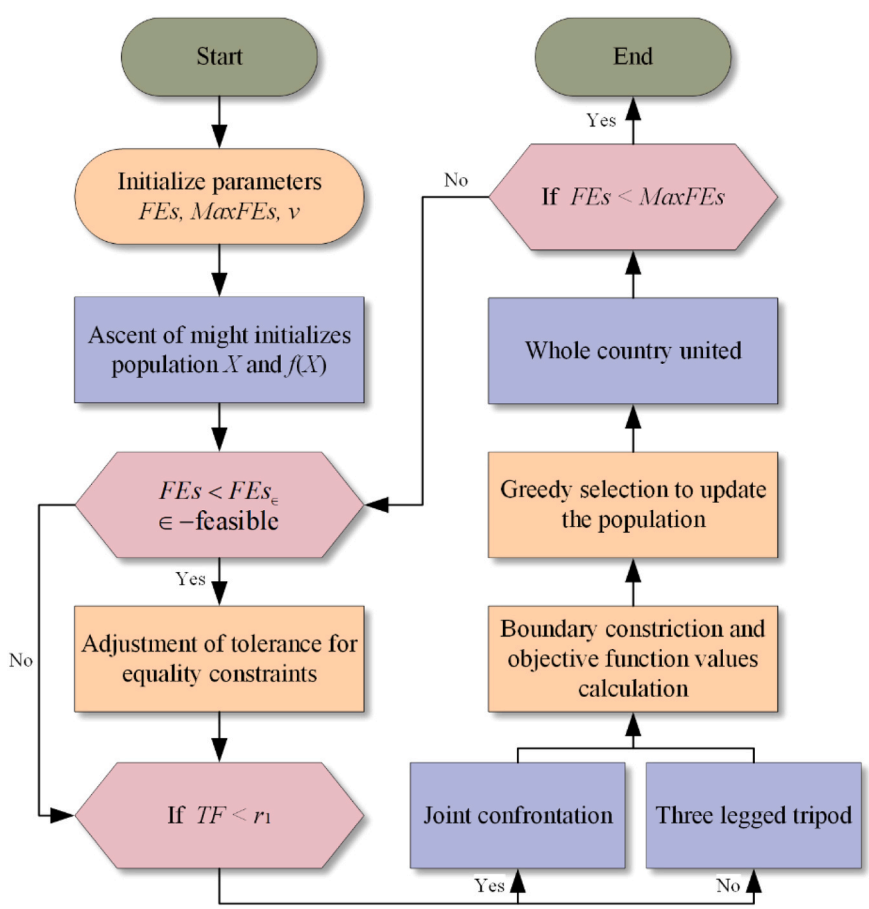

Fig. 3. Flowchart of the KING algorithm.

generate offspring individuals. p_1 and p_2 represent parent individuals selected via roulette wheel or tournament methods. c_1 and c_2 denote the offspring individuals generated by exchanging parental genes. β controls the degree of crossover. In the mutation operation of GA, individuals are randomly perturbed to maintain population diversity. x_i' represents the mutated individual corresponding to x_i. δ denotes a random perturbation, typically sampled from a distribution with mean 0 and small variance (e.g., uniform distribution $U(-a, a)$ or Gaussian distribution $N(0,\ \sigma)$). $\mathcal{N}(0,1)$ indicates a standard normally distributed random number. Subsequently, offspring individuals are added to the new population, replacing the old population through elite preservation.

In the crossover operation of DE, a mutant vector $v_{i,t}$ is generated for each target individual x_i. $x_{n0,t}$, $x_{n1,t}$, and $x_{n2,t}$ are three distinct individuals randomly selected from the population ($n0 \neq n1 \neq n2 \neq$ i). F_i is the scaling factor for the individual x_i, controlling the amplification ratio of the differential vector. In the mutation operation of DE, the mutant vector $v_{i,t}$ is combined with the target vector $x_{i,t}$ to generate a trial vector $u_{i,t}$. Here, r is a uniform random number in $[0, 1)$. Crossover probability CR_i controls the probability of inheriting genes from the mutant vector. j_{rand} is a randomly selected dimension index ensuring at least one dimension of the trial vector originates from the mutant vector. Subsequently, a greedy strategy selects individuals with superior fitness for the next generation.

The core of PSO lies in velocity vector update. Here, w controls the proportion of the original velocity retained by the particle. c_1 and c_2 are constants controlling the weighting of individual and population experience, respectively. Random numbers r_1 and r_2 within $(0, 1)$ introduce stochastic perturbations to avoid premature convergence. $pbest_{i,t}$ and $gbest_t$ represent the historical best position of particle i and the current global best position, respectively. PSO's individual update is computed by superimposing the individual position $x_{i,t}$ and the velocity vector $v_{i,t+1}$.

In ACOR's individual weight update, w_l denotes the individual weight, and p_l is the normalized result of individual weights. k is the archive size. q is the pressure parameter controlling weight distribution. In ACOR's individual position update, reference individuals are selected via weight probability, and solution vectors are sampled according to a Gaussian distribution. Here, σ_l^d is the standard deviation controlled by the perturbation factor ξ which scales the standard deviation. s_{jd} and s_{ld} represent solutions selected from the archive with probability p_l. Finally, the new population and archive are merged, retaining the top k optimal solutions to update the archive.

Compared with the above classical algorithms, in the population initialization phase, KING adopts the same pseudo-random sequence-based sampling method and selects the top three solutions as reference individuals. In the global exploration phase, GA generates offspring solutions by blending two candidate parent solutions. DE generates exploration steps by differencing two reference individuals based on one candidate solution. The global exploration efficiency of GA and DE highly depends on candidate solution selection and mutation coefficient values. PSO and ACOR lack independent global exploration phases. In contrast, KING's formula design in the global exploration phase blends proxies constructed from two sub-optimal individuals and incorporates boundary-designed random steps for perturbation. This mitigates performance variations caused by candidate solution selection and parameter design.

In the local exploitation phase, both GA and DE employ mutation strategies. GA adds exploration steps based on a normal distribution to target individuals, where exploitation precision depends on sampling results. DE retains mutant vectors via mutation probability, where exploitation precision depends on the mutation probability value. In the formula designs of PSO and ACOR, PSO's step size is derived from velocity vectors. The exploration step integrates individual historical best and global best solutions, but weight coefficients critically impact exploitation precision. ACOR selects reference individuals from the archive and samples solution vectors via a Gaussian distribution, where exploitation precision relies on sampling results. KING, building upon either the current individual or a random individual with higher fitness from the population, selects one of the three optimal individuals and employs the Lévy distribution as the convergence coefficient. Compared to fixed-value designs or single sampling methods, the Lévy distribution provides the algorithm with a certain possibility to escape local optima. Furthermore, compared to other classical algorithms, KING incorporates an enhanced convergence phase. It controls convergence behavior via a coordination scheduling parameter to improve KING's performance in real-world constrained optimization problems. Similar to DE's crossover operation, it hybridizes offspring individuals with a proxy vector designed based on the global best solution, further amplifying the guiding effect of the global optimum on the population and accelerating convergence.

4.2. Time complexity analysis

To evaluate the computational complexity of the algorithms, this section calculates and comparatively analyzes the time complexity of KING and the classical algorithms. Assuming the complexity of computing the objective function is O(F), the population size is N, and the problem dimension is D. Complexity calculations for constant-level operations such as algorithm parameter initialization, parameter updates, and global best solution recording are omitted. Uncontrollable computational overhead, like population boundary adjustment, is also neglected.

The time complexity for the first iteration of KING is: O(KING) = O(AOM) + $N\times$ ($TF\times$ O(JC) + (1 − TF) × O(TLT) + O(WCU) + O(Individual evaluation)) + O(Population update). Where: O(AOM) = O($N \times D + N \times F$). O(JC) = O(D). O(TLT) = O(D). O(WCU) = O($D + F$). O(Individual evaluation) = O(F). O(Population update) = O(N). Therefore, the time complexity of KING is: O(KING) = O($3 \times N \times (D + F) + N$).

The composition of the time complexity for the first iteration of GA and DE is identical: O(GA) = O(GA) = O(Population initialization) + $N\times$ (O(Selection) + O(Crossover) + O(Mutation) + O(Individual evaluation)) + O(Population update). Where: O(Population initialization) = O($N \times D + N \times F$)。 O(Selection) = O(D). O(Crossover) = O(D). O(Mutation) = O(D). O(Individual evaluation) = O(F). O(Population update) = O(N). Therefore, the time complexity of GA and DE is: O(GA) = O(GA) = O($N \times (4 \times D + 2 \times F + 1)$).

The time complexity for the first iteration of PSO is: O(PSO) = O(Population initialization) + O(Population velocity vector initialization) + $N\times$ (O(Individual velocity vector update) + O(Individual update) + O(Individual evaluation)) + O(Individual historical optimal update). Where: O(Population initialization) = O($N \times D + N \times F$). O(Population velocity vector initialization) = O($N \times D$). O(Individual velocity vector update) = O(D). O(Individual update) = O(D). O(Individual evaluation) = O(F). O(Individual historical optimal update) = O(N). Therefore, the time complexity of PSO is: O(PSO) = O($N \times (4 \times D + 2 \times F + 1)$).

The time complexity for the first iteration of ACOR is: O(ACOR) = O(Archive initialization) + O(Weight calculation) + $N\times$ (O(Probability distribution) + O(Individual update) + O(Individual evaluation)) + O(Archive update). Where: O(Archive initialization) = O($k \times D + k \times F$). O(Weight calculation) = O(k). O(Probability distribution) = O(k). O(Individual update) = O($k\times D$). O(Individual evaluation) = O(F). In archive update, the archive and new population need to be merged and sorted, therefore O(Archive update) = O($(k + N)\log(k + N)$). In summary, the time complexity of ACOR is: O(ACOR) = O($k \times (N \times D + D + F + N + 1) + N \times F + (k + N)\log(k + N)$).

By comparing the time complexities of the above algorithms, it can be concluded that the time complexities of GA, DE, and PSO are all O($N\times (4\times D + 2\times F + 1)$). The time complexity of ACOR is O($k \times (N \times D + D + F + N + 1) + N \times F + (k + N)\log(k + N)$). Here, the value of k is a key factor affecting the computational efficiency of the

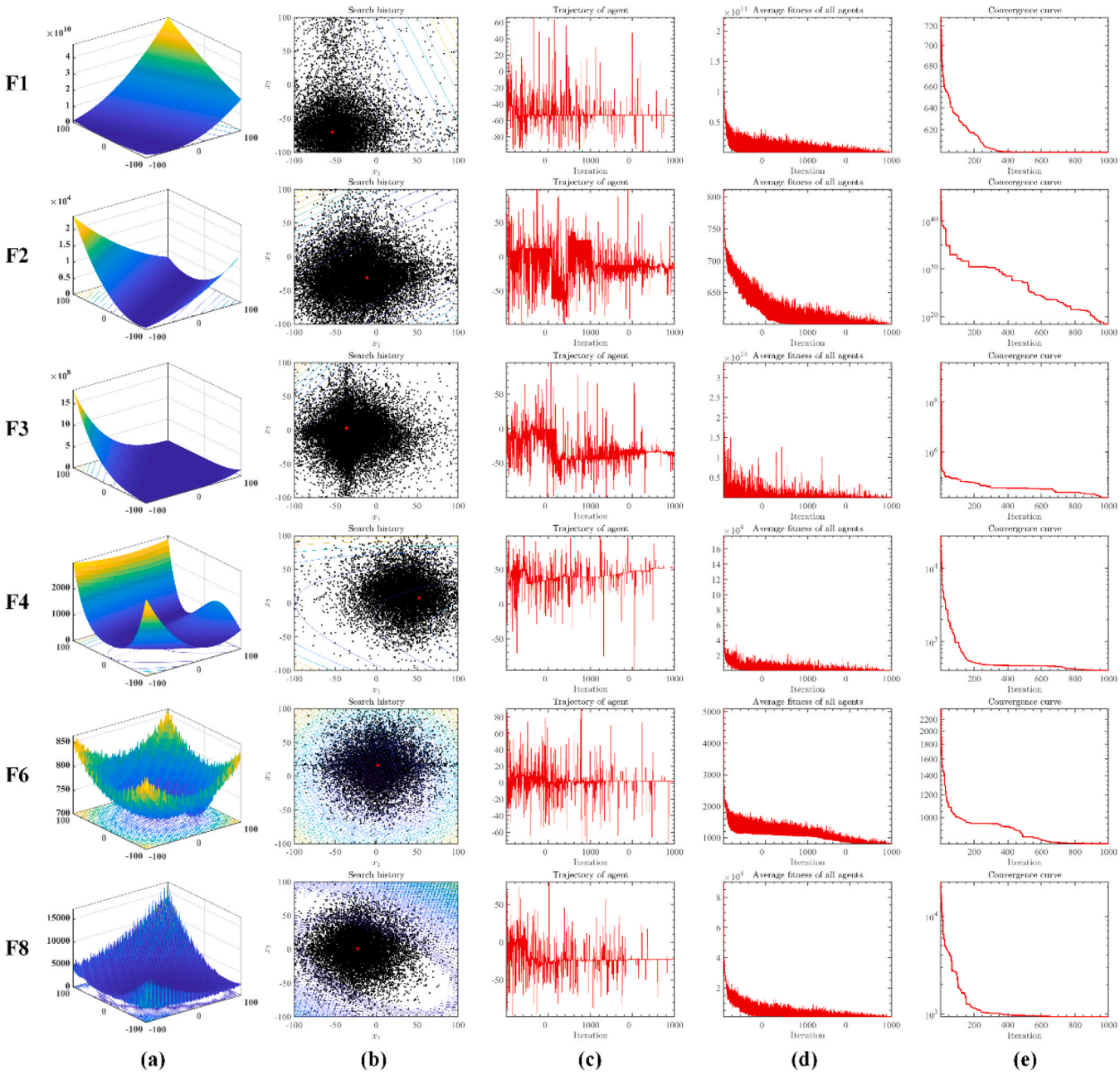

Fig. 4. Qualitative analysis experiment of KING.

algorithm. In the general parameter design of the ACOR algorithm [44], k is typically set to $k = 5 \times N$. The time complexity of ACOR is one order of magnitude higher than that of the other algorithms. The time complexity of KING is $O(3 \times N \times (D + F) + N)$. Compared to GA, DE, and PSO, the difference in KING's time complexity is $O(N \times (F - D))$. The increase in KING's complexity primarily stems from solution vector evaluation computation. When the problem scale is large or a more computationally efficient processor is employed, the increase in KING's complexity is not significant.

5. Experiments and results analysis

In this section, a comprehensive analysis of the algorithmic performance of KING is conducted. First, we perform a qualitative analysis of KING's search characteristics and algorithm properties. Then, a detailed qualitative assessment of each phase of the KING algorithm is carried out. Next, the sensitivity of the key parameter settings in KING is analyzed. To validate the superiority of KING over similar algorithms, a comparative analysis is performed against the original algorithm and improved algorithms with superior performance, along with verification on more complex and challenging functions from IEEE CEC 2022. Finally, the optimization capability of KING is validated across five practical engineering design problems.

5.1. Experimental setup

In this section, we describe the research conditions and parameter settings for the experiments conducted in this paper. The experiments are mainly divided into two categories: benchmark function experiments and engineering design problem experiments.

(1) In the benchmark function experiments, KING is compared with other algorithms using the IEEE CEC 2017 [41] benchmark test set and the more complex and challenging IEEE CEC 2022 [42] function test set. Appendix Tables A.1 and A.2 provide additional information about the test functions from IEEE CEC 2017 and IEEE CEC 2022, respectively. To ensure the validity and fairness of the experiments, all competing algorithms retain their original parameter settings. The experiments employ a maximum evaluation limit to assess the fitness values of the comparison algorithms, with the maximum evaluations set to 300,000. To reduce the impact of algorithm randomness on the experimental results, all algorithms are run independently in parallel 30 times. To test the adaptability of the algorithms to optimization problems of varying scales, experiments are conducted independently at four different dimensions: 10, 30, 50, and 100, with the population size set to 30. The experimental results will be analyzed using the mean (AVG), standard deviation (STD), and two non-parametric tests: Wilcoxon Signed-Rank Test (WSRT) [45] and Friedman (FT) [46].

(2) To evaluate the optimization capability of KING in practical applications, the algorithm is compared with other algorithms on four real-world engineering design optimization problems, which include welded beam design, speed reducer design, cantilever beam design, and multiple disk clutch brake design. The experiments are limited to a maximum of 2000 iterations, with a population size of 50, and all comparison algorithms are run independently in parallel 50 times. According to the experimental setup in reference [40], in the constraint handling method of KING and KING3, set the maximum number of evaluations allowed for updating equation tolerance ϵ_G to $FEs_\epsilon = 0.6 \times MaxFEs$. and the final equation constraint tolerance $\epsilon_f = 10^{-4}$. The comparison algorithms all adopt the constraint processing method of penalty function.

Table 3
Versions of KING.

The value of v	2	4	6	8	10
KING versions	KING_2	KING_4	KING_6	KING_8	KING_10

All experiments are conducted in the same testing environment. The experiments are performed on Windows Server 11, coded in MATLAB 2021b, with hardware configured as an Intel i5–12500H processor (12 cores) and 16GB of memory.

5.2. Qualitative analysis

In this section, we select six functions from IEEE CEC 2017 to conduct a qualitative analysis of KING's search trajectory and convergence process. These functions include single-modal functions F1, F2, and F3, as well as simple multimodal functions F4, F6, and F8. The single-modal functions contain only one minimum value to test the algorithm's exploitation capability, while the simple multimodal functions contain one minimum and several local minima to evaluate the algorithm's exploration capability and its ability to escape local optima. For the experiments in this section, the number of iterations is set to 2000, with a population size of 30.

The results of the qualitative analysis are shown in Fig. 4. Fig. 4a displays the distribution of the test functions in the three-dimensional solution space. Fig. 4b records the two-dimensional distribution of the search history of all individuals on the first dimension. Whether with single-modal functions or simple multimodal functions that have multiple local optima, KING's historical search trajectories consistently cover the global optimum and are more concentrated around the near-optimal regions. This reflects KING's stable optimization capability and its ability to escape local optima across different functions. Fig. 4c records the average value of the first-dimension variable for all solutions in the population over the iterations. In the early stages of iteration, the average dimensional variable values of the KING population fluctuate significantly and with high frequency, indicating extensive exploration of the solution space, which aids in escaping local optima. In the later stages of iteration, the frequency and amplitude of the fluctuations in the average dimensional variable values gradually decrease, indicating that the KING population is converging towards the global optimum, thus ensuring the accuracy of the convergence results. Fig. 4d records the average fitness values of the population throughout the iterations, confirming the analysis presented in Fig. 4c. After the average fitness value of the KING population drops to a lower level at the initial convergence stage, its range of fluctuation decreases, demonstrating that KING effectively achieves population convergence and avoids meaningless searches in the late iterations. Fig. 4e shows the fitness values of the optimal solution during the iterations, illustrating that KING exhibits stable exploitation capability, with fitness values converging steadily. Moreover, in the case of the simple multimodal function F6, KING effectively avoids getting trapped in local optima, maintaining stable convergence throughout the iterations without experiencing stagnation in convergence.

In summary, KING has the following advantages: 1) Strong global exploration capability, consistently finding global optima across different types of functions; 2) Stable convergence ability, enabling the KING population to achieve stable convergence in near-optimal regions, ensuring thorough exploitation of these areas; 3) Effective ability to escape local optima, allowing KING to avoid local optima during the convergence process, which guarantees the precision of the solutions.

5.3. Parameter sensitivity analysis

In the design of the KING, the scaling factor v is a critical hyperparameter. It directly controls the WCU execution probability p by regulating the range of the probability distribution, thereby influencing

the mixing with the optimal individual and the algorithm's convergence. When $v \to 0^+$, the WCU probability approaches 1, potentially causing premature convergence and trapping in local optima. When $v \to +\infty, p$ approaches 0, rendering WCU ineffective. Preliminary experiments revealed a systematic performance degradation when $v > 10$, with the magnitude of decline exceeding variations observed within the interval $(0, 10]$. Consequently, an upper limit of $v = 10$ was selected to capture potential performance inflection points. To effectively discern performance trends while controlling experimental computational cost, the interval $(0, 10]$ was sampled with a step size $\Delta v = 2$ to distinguish the impact of adjacent v values.

To systematically evaluate the sensitivity of v to algorithm performance, a controlled variable experiment was designed: Maintaining strictly identical values for other parameters (e.g., population size, iteration count), five v values incrementing by 2 within $(0, 10]$ were tested ($v = 2, 4, 6, 8, 10$). This corresponds to five algorithm variants (KING_2, KING_4, KING_6, KING_8, KING_10), as shown in Table 3.

All five KING variants were rigorously evaluated on a benchmark test suite comprising 30 diverse functions (covering unimodal, multimodal, composite, and hybrid types). Appendix Table A.3 details the AVG and STD values for each variant on each function. As indicated by the bolded data in Table A.3, no single variant performed optimally across all functions. Different variants demonstrated advantages on different function types, indicating adaptive differences in the v-regulated WCU mechanism to varying problem characteristics. Despite this function-specificity, statistical results showed that KING_2 simultaneously achieved the smallest AVG and STD values on a significantly larger number of functions. This indicates that KING_2 not only exhibited superior convergence accuracy but also generally outperformed other variants in solution stability, making it the most balanced choice for overall performance.

To provide a global performance ranking and overcome the limitations of single-function evaluation, the FT was employed for non-parametric statistical assessment. Table 4 presents the analysis results based on rankings of convergence outcomes across all 30 functions: the rank of each variant on every function was calculated and then averaged. KING_2 achieved the lowest mean rank, signifying its best overall performance. The direct ranking based on mean ranks confirmed the leading position of KING_2, followed sequentially by KING_4, KING_6, KING_8, and KING_10.

Based on the experimental results above, although the numerical differences in mean ranks between different v values appear relatively small, the consistent lead of KING_2 is statistically significant. This relatively modest difference precisely illustrates that the KING algorithm exhibits a degree of robustness to the value of v, particularly within the interval $v \in [2, 6]$. However, given the statistically significant ranking advantage of KING_2 and its attainment of the best convergence accuracy and result stability on the majority of test functions, $v = 2$ was selected as the default configuration for the KING algorithm in this work.

5.4. Ablation experiment

To compare and validate the impact of different stages of KING on algorithm performance and to assess the effectiveness of WCU in improving convergence speed, we conducted an ablation experiment in this section. Table 5 presents variations of KING with different stage combinations. For instance, KING3 includes only the global exploration and local exploitation phases (JC and TLT) from KING, without incorporating WCU, which guides the algorithm's convergence behavior.

Table 4
Results of FT's evaluation of different KING versions.

KING versions	KING_2	KING_4	KING_6	KING_8	KING_10
Mean rank	2.6956	2.7222	2.9211	3.2744	3.3867
Final rank	1	2	3	4	5

Table 5
KING variants.

	JC	TLT	WCU
KING	1	1	1
KING1	0	1	1
KING2	1	0	1
KING3	1	1	0

Appendix Tables A.4-A.7 show the AVG and STD of the results from the KING ablation experiments across four different dimensions. KING performs optimally on most functions. Specifically, in the cases of 10-dimensional and 100-dimensional problems, KING demonstrates superior precision in convergence results and greater stability compared to other algorithms.

Table 6 presents the analysis results of the ablation experiments conducted by WSRT. The ranking results indicate that KING outperforms other KING variants across different dimensions, securing the first place, while KING3, which lacks the reinforcement convergence phase, ranks second. KING1, missing the exploration phase, and KING2, lacking the exploitation phase, rank third and fourth, respectively, across various dimensions. The symbols '+/-/=' represent the pairwise comparison results among KING variants on 30 benchmark functions. KING shows significant advantages over KING1 and KING2, particularly in the 50-dimensional case, KING yields better optimization results on 24 test functions compared to KING1. In the 100-dimensional case, KING's convergence results outperform those of KING2 across all 30 test functions. Furthermore, KING demonstrates superior performance compared to KING3 in both 10-dimensional and 100-dimensional scenarios. This indicates that WCU effectively enhances the convergence accuracy of KING3 in both small-scale and large-scale optimization problems.

Fig. 5 presents the analysis results of the ablation experiments for KING using FT across different dimensions. KING consistently ranks first in all dimensions, and its ranking improves as the problem size increases. This indicates that KING, which integrates exploration strategies, exploitation strategies, and reinforcement convergence mechanisms, outperforms other KING variants and demonstrates some adaptability to different dimensional settings.

Using single-modal function F1, simple multimodal function F7, mixed function F12, and composite function F21 as examples, Fig. 6 illustrates the convergence curves of different variants in the KING ablation experiments. While KING3 demonstrates certain advantages in exploitation capability on the 100-dimensional single-modal function F1, KING exhibits stronger exploitation ability compared to other KING variants in the 10, 30, and 50 dimensions. As other algorithms gradually be trapped in local optima and experience convergence stagnation, KING converges to solutions with higher precision at a faster rate. On different dimensions of the simple multimodal function F7 and the mixed function F12, KING shows stable advantages compared to other algorithms. In the case of composite function F21, KING has lower convergence precision at 10 dimensions compared to KING1 and KING3. However, as the problem size increases, KING's advantages become increasingly apparent, not only improving convergence precision but also accelerating the convergence speed. This indicates that the reinforcement convergence mechanism WCU effectively enhances KING3's convergence precision and speed in larger-scale and more complex optimization problems.

5.5. Comparative experiments on benchmark functions

To validate the performance of KING, we conducted comparative experiments between KING and 10 classical algorithms as well as 10 high-performance improved algorithms across four dimensions of the IEEE CEC 2017 benchmark function set. Furthermore, to assess KING's performance on more complex and challenging function problems, we compared it with 8 state-of-the-art algorithms on the IEEE CEC 2022

Table 6
The WSRT results of KING's ablation experiment.

	10			30			50			100		
	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank
KING	~	**1.40**	**1**	~	**1.43**	**1**	~	**1.57**	**1**	~	**1.50**	**1**
KING1	14/0/16	3.13	3	22/0/8	3.40	4	24/0/6	3.50	4	22/2/6	3.47	4
KING2	25/1/4	3.20	4	29/0/1	3.37	3	29/0/1	3.20	3	30/0/0	3.1	3
KING3	15/1/14	2.27	2	7/5/18	1.80	2	7/4/19	1.73	2	12/6/12	1.93	2

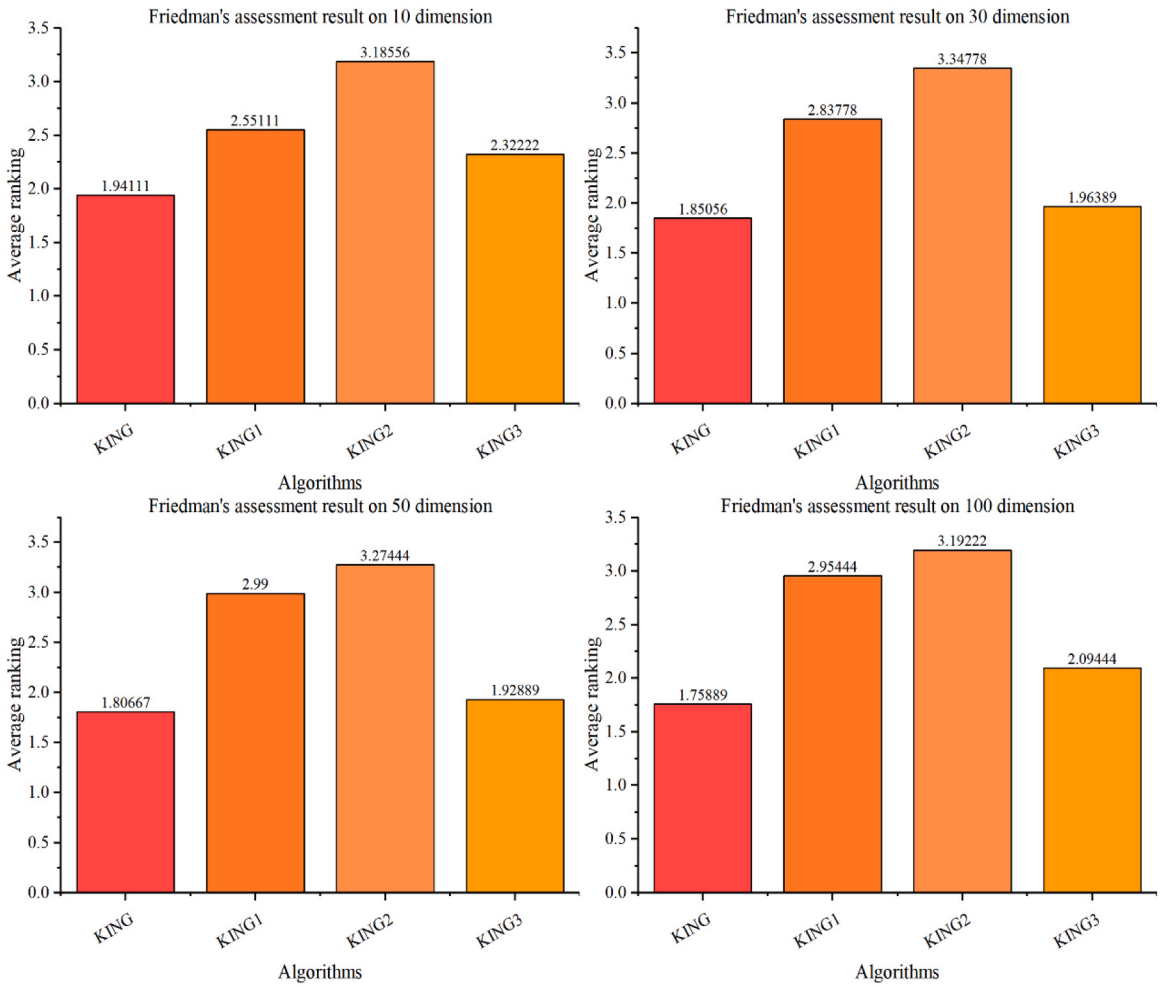

Fig. 5. The FT results of KING's ablation experiment.

benchmark function set.

5.5.1. *Comparative with classical algorithms*

In this section, we compare KING with classical algorithms to assess the differences in performance. Considering the impact of problem scale on algorithm performance, experiments were conducted independently across four dimensions: 10, 30, 50, and 100. Appendix Tables A.8-A.11 present the AVG and STD of the comparative experimental results between KING and classical algorithms at different dimensions. In all four dimensions, KING achieved higher precision in average convergence results across more functions compared to classical algorithms, with smaller standard deviations among parallel results. This indicates that KING exhibits stronger precision and stability compared to classical algorithms.

Table 7 shows the analysis results by WSRT for the experiments. Although KING's average ranking increased with the problem size, it ranked first across all four dimensions. This indicates that KING has a stable performance advantage over classical algorithms in different dimensions. The symbols '+/-/=' represent the pairwise comparison results of KING against classical algorithms on 30 benchmark functions from WSRT. Among these, RIME ranks second in 10, 30, and 50 dimensions, while KING has better convergence results than RIME on 20 out of 30 functions. SMA ranks second in the 100-dimensional case, just behind KING. However, KING demonstrates significant advantages in 17 test functions and achieves comparable convergence results in 9 functions.

Fig. 7 presents the analysis results of the experiments using FT across different dimensions. Although KING's ranking improves with increasing problem size, it consistently outperforms the comparison algorithms in the 10, 30, 50, and 100-dimensional cases, ranking first overall. The evaluation results from FT corroborate KING's performance advantages over classical algorithms, particularly in the 10-dimensional case where the objective function has fewer decision variables.

In Fig. 8, we use single-modal function F1, simple multimodal function F5, mixed function F12, and composite function F30 as examples to illustrate the convergence curves of KING compared to classical

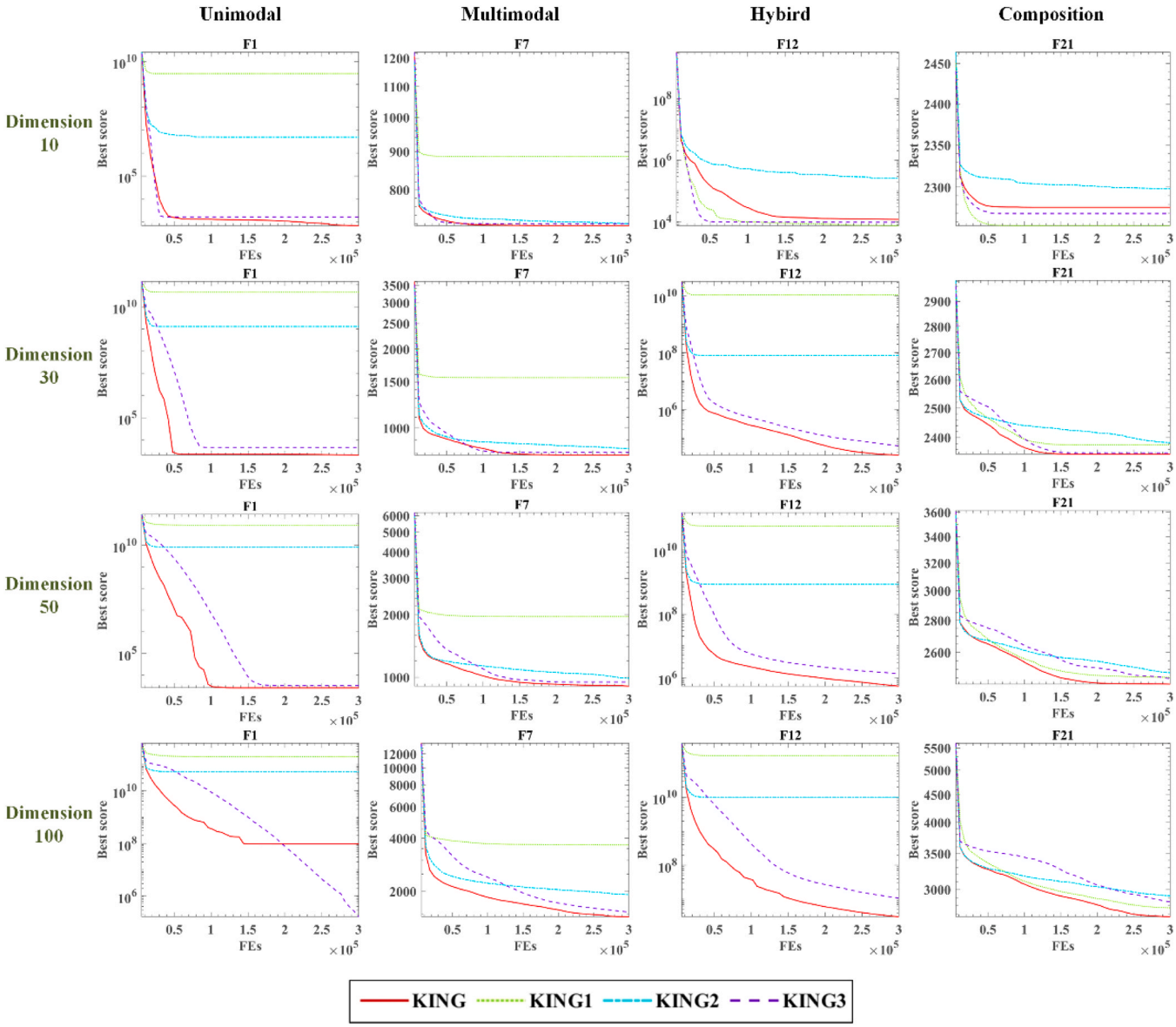

Fig. 6. The convergence curve of KING's ablation experiment.

algorithms across different dimensions in four categories of functions. Although KING exhibits weaker exploitation capability on the 100-dimensional single-modal function F1, it demonstrates strong exploration ability on the simple multimodal function F5, remaining unaffected by local optima during the convergence process. Furthermore, on the mixed function F12 and composite function F30, KING

Table 7
The WSRT results of KING with classic algorithms.

	10			30			50			100		
	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank
KING	~	**1.73**	**1**	~	**1.77**	**1**	~	**2.40**	**1**	~	**3.00**	**1**
GWO	27/0/3	8.37	8	29/0/1	8.10	8	29/0/1	8.37	8	26/1/3	8.80	8
WOA	28/1/1	11.27	12	30/0/0	12.53	14	30/0/0	11.80	13	29/0/1	11.30	13
SCA	28/1/5	9.43	10	30/0/0	13.03	15	30/0/0	13.80	15	29/0/1	14.40	15
PSO	30/0/0	9.30	9	27/1/2	9.53	9	24/3/3	9.43	10	25/3/2	9.60	10
MFO	29/0/1	11.33	13	30/0/0	11.83	13	30/0/0	12.23	14	29/0/1	12.43	14
MVO	26/1/3	5.77	4	25/3/2	4.73	3	21/5/4	4.73	4	16/8/6	3.87	3
ACOR	22/2/6	7.60	7	27/0/3	6.50	7	28/0/2	7.77	7	28/1/1	9.43	9
HHO	30/0/0	11.37	14	30/0/0	10.63	10	28/0/2	10.17	12	26/2/2	10.10	12
RFO	30/0/0	11.90	15	27/1/2	10.63	10	26/2/2	9.97	11	23/3/4	8.47	7
RIME	23/1/6	3.67	2	21/2/7	3.83	2	20/2/8	3.80	2	20/4/6	4.60	4
SMA	23/2/5	5.00	3	26/1/3	5.27	4	22/3/5	4.57	3	17/4/9	3.77	2
RUN	26/1/3	5.93	5	22/3/5	5.70	6	24/4/2	6.17	6	22/5/3	5.90	6
HBA	24/1/5	6.53	6	20/3/7	5.27	4	22/4/4	5.50	5	17/5/8	4.70	5
PO	28/0/2	10.70	11	27/0/3	10.63	10	27/1/2	9.30	9	26/1/3	9.63	11

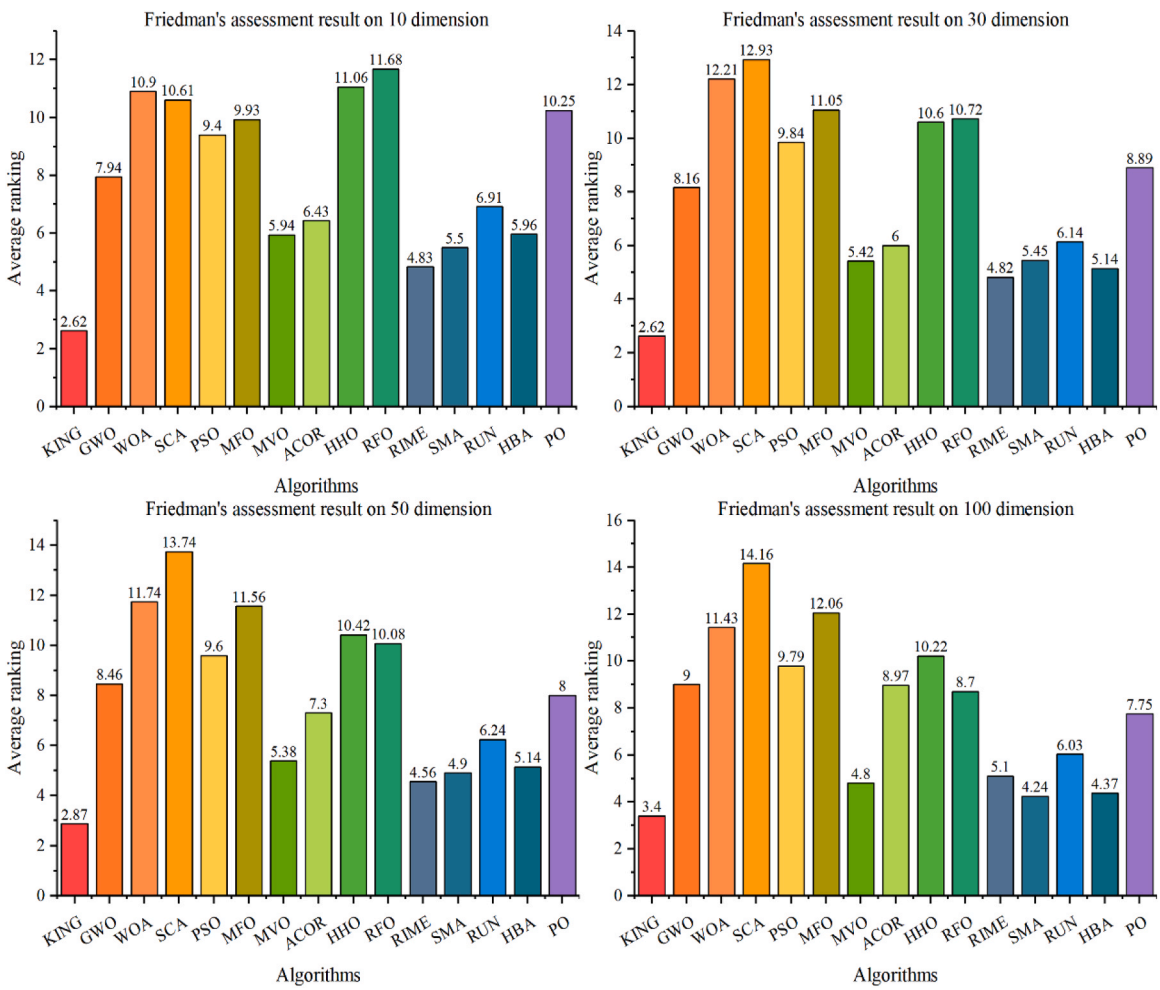

Fig. 7. The FT results of KING with classic algorithms.

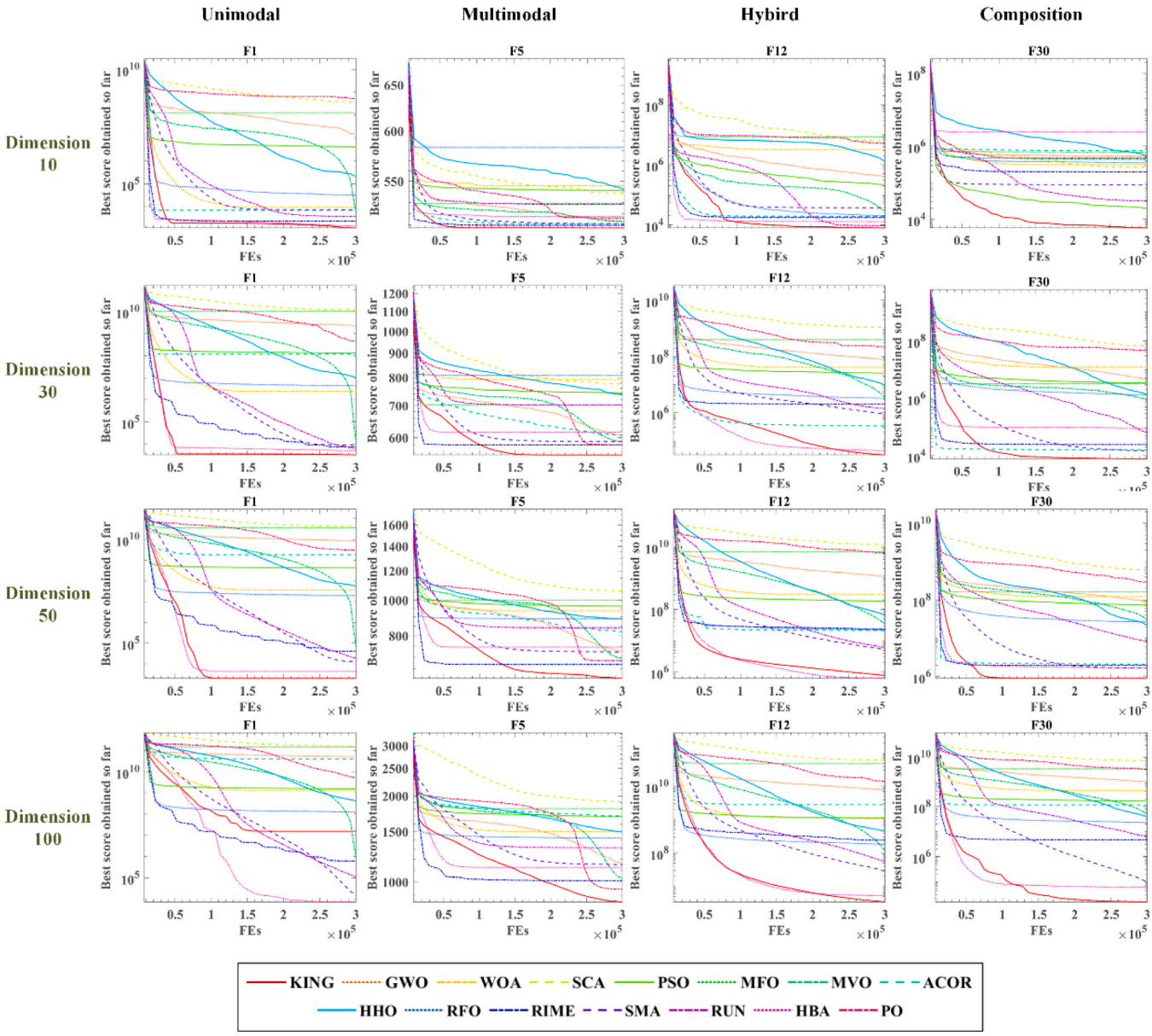

Fig. 8. The convergence curve of KING with classic algorithms.

Table 8
The WSRT results of KING with high-performance algorithms.

	10			30			50			100		
	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank	+/-/=	Mean	Rank
KING	~	**2.07**	**1**	~	**1.67**	**1**	~	**1.77**	**1**	~	**2.53**	**1**
LXMWOA	22/2/6	6.90	6	19/3/8	4.60	3	22/3/5	4.17	2	20/4/6	4.10	3
SCGWO	29/0/1	10.97	12	29/0/1	10.90	13	29/0/1	10.93	12	29/0/1	11.37	13
RCACO	19/2/9	5.80	4	21/1/8	4.27	2	22/2/6	4.57	3	21/4/5	5.70	5
LSEOFOA	27/2/1	8.87	11	28/0/2	8.10	8	29/0/1	8.67	8	27/1/2	8.17	9
IGWO	22/5/3	4.53	2	30/0/0	6.07	6	29/1/0	6.40	6	27/1/2	7.50	7
EESHHO	28/0/2	6.53	5	24/1/5	5.90	5	23/2/5	4.77	4	24/3/3	4.03	2
ASCA_PSO	27/1/2	8.20	10	30/0/0	10.67	12	29/0/1	11.07	13	29/0/1	11.13	12
RDWOA	29/0/1	7.43	8	27/0/3	8.67	10	29/0/1	8.93	10	26/1/3	9.50	11
SCADE	28/2/0	11.90	14	30/0/0	13.50	14	30/0/0	13.80	14	30/0/0	13.83	14
GCHHO	25/2/3	7.67	9	25/0/5	7.37	7	24/2/4	6.87	7	23/3/4	6.03	6
MOFOA	29/0/1	14.70	15	30/0/0	14.97	15	30/0/0	14.97	15	30/0/0	14.93	15
RCBA	30/0/0	11.63	13	28/1/1	10.00	11	25/3/2	9.47	11	21/5/4	7.77	8
LGCMFO	21/0/9	5.53	3	25/0/5	5.00	4	27/2/1	4.90	5	26/2/2	5.20	4
OBLGWO	27/1/2	7.07	7	30/0/0	8.33	9	30/0/0	8.73	9	27/2/1	8.20	10

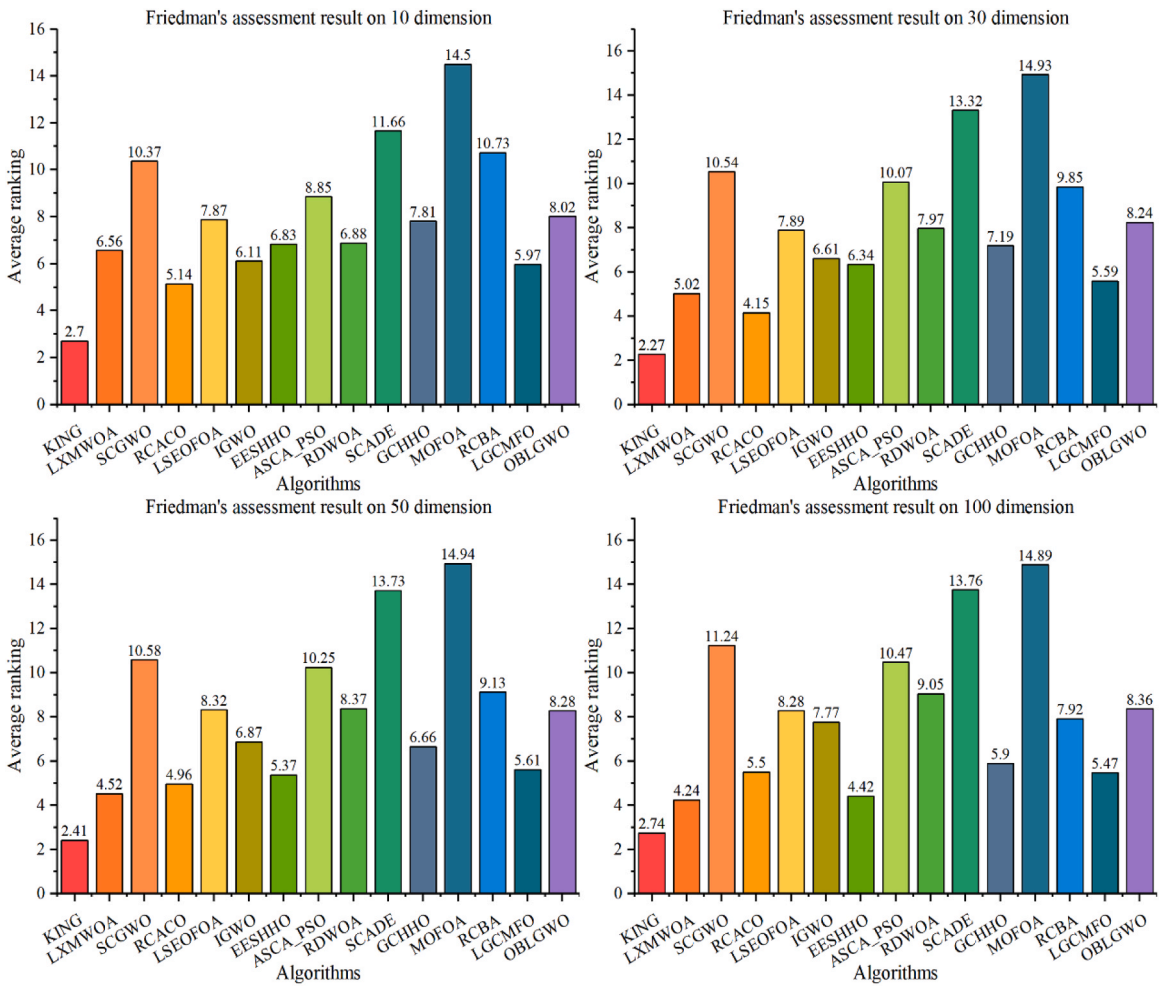

Fig. 9. The FT results of KING with high-performance algorithms.

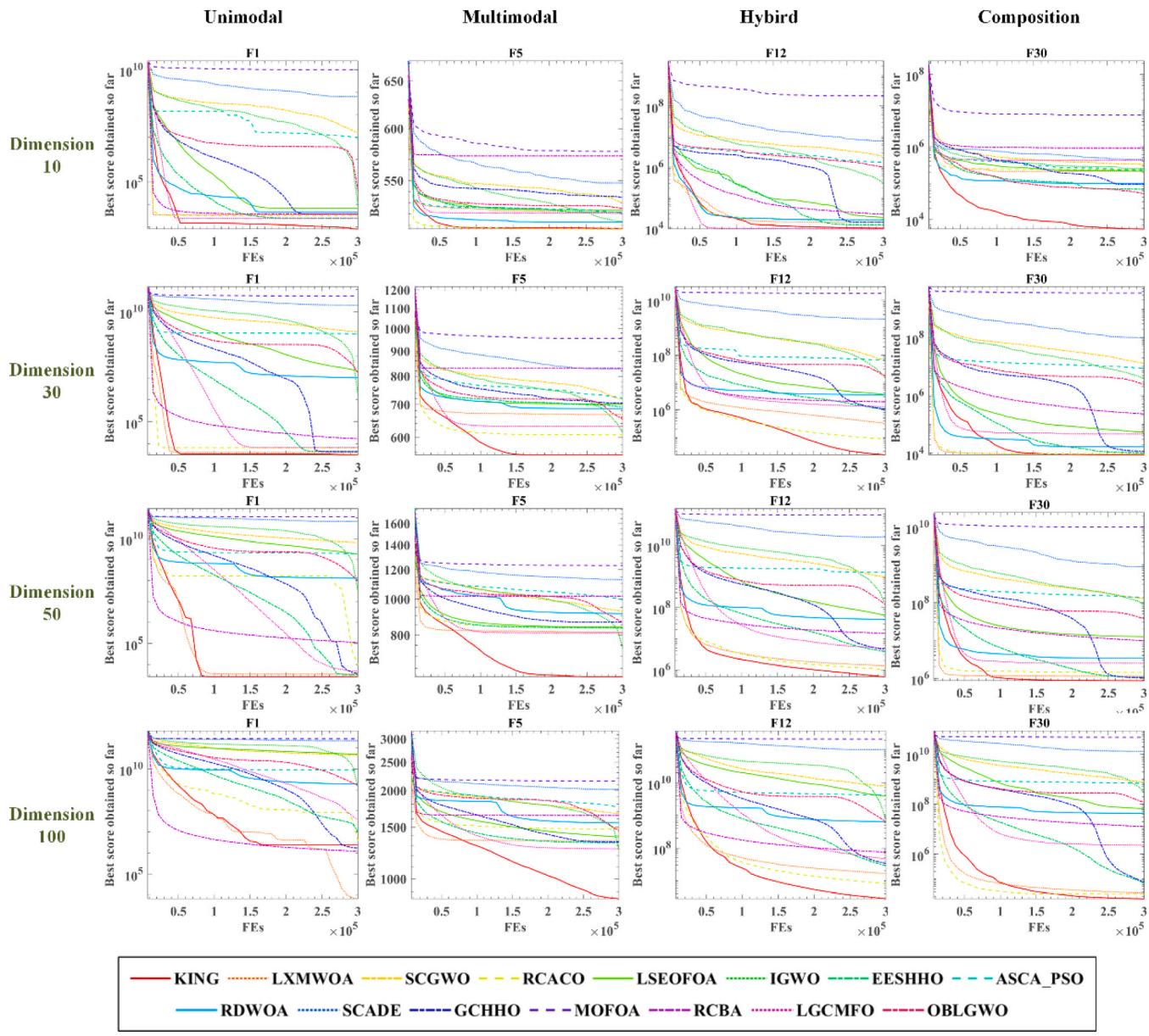

Fig. 10. The convergence curve of KING with high-performance algorithms.

Table 9
The WSRT and FT results of KING with state-of-the-art algorithms.

	WSRT			FT	
	+/-/=	Mean	Rank	Mean	Rank
KING	~	**2.67**	**1**	**3.12**	**1**
AO	8/1/3	4.08	5	4.19	5
HOA	11/1/0	8.08	9	8.14	9
RBMO	8/3/1	3.5	3	3.29	3
SBOA	8/1/3	3.25	2	3.29	2
WO	10/2/0	6.75	8	6.99	8
BKA	10/2/0	6.67	7	6.44	7
IVY	9/1/2	6.08	6	5.74	6
BEO	7/4/1	3.75	4	3.80	4

shows superior overall optimization performance compared to other classical algorithms, with both faster convergence speed and improved exploitation accuracy. Its advantages significantly increase with the dimensionality.

5.5.2. *Comparison with high-performance algorithms*

In this section, we conduct comparative experiments to comprehensively assess the performance of KING against high-performance algorithms. Tables A.12 to A.15 in the appendix present the average values (AVG) and standard deviations (STD) of the experimental results comparing KING with high-performance algorithms. Across four different dimensions, KING achieves smaller AVG and STD values on most test functions compared to the high-performance algorithms, indicating higher stability and algorithm precision.

Table 8 shows the statistical analysis results from WSRT comparing KING with high-performance algorithms. KING ranks first in all four dimensions, with the highest average ranking in the 30-dimensional case, where its advantages are most pronounced. Specifically, different comparative algorithms excel at varying problem scales. IGWO, RCACO, LXMWOA, and EESHHO rank second in the 10, 30, 50, and 100 dimensions, respectively. However, in all four dimensions, KING demonstrates higher convergence precision than the second-ranking algorithms on over 20 out of 30 test functions.

Fig. 9 presents the analysis results of the comparative experiments

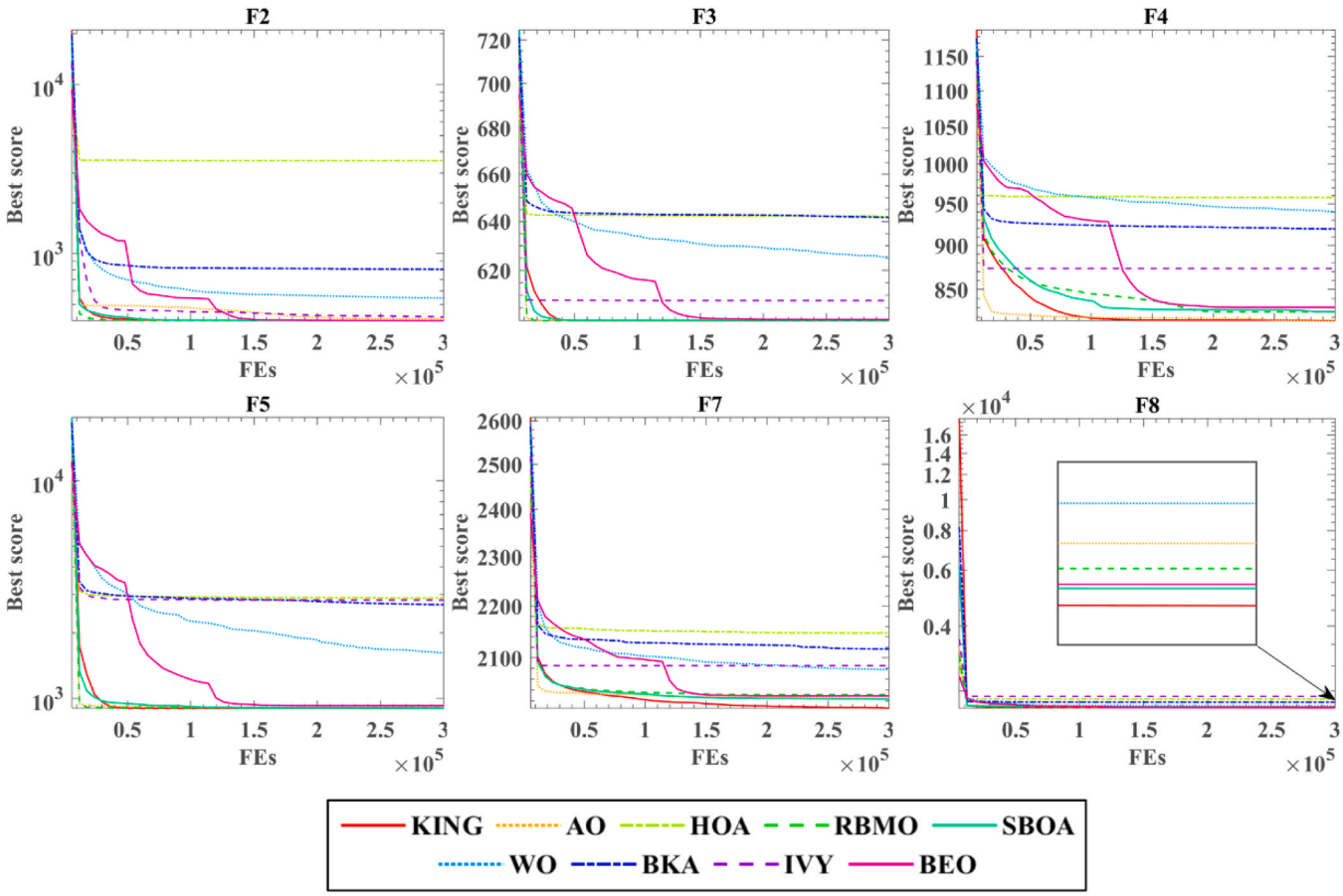

Fig. 11. The convergence curve of KING with state-of-art algorithms.

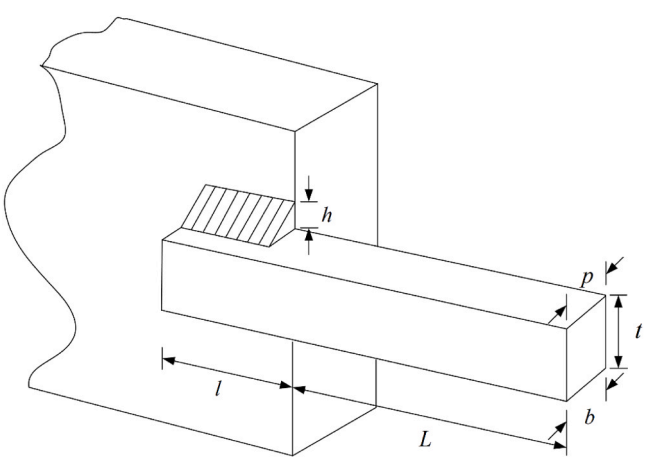

Fig. 12. WBD problem diagram.

between KING and high-performance algorithms using FT across different dimensions. In all four-dimension settings, KING consistently ranks above the comparison algorithms, securing the top position. Furthermore, in the 30-dimensional case, KING's ranking is even more prominent, highlighting its performance advantage.

Fig. 10 illustrates the convergence curves of KING compared to high-performance algorithms across different dimensions in four categories of functions. Compared to high-performance algorithms, KING demonstrates a stronger exploitation capability in small to medium-scale optimization problems. As the problem size increases, the advantages of KING's exploration capabilities become even more pronounced. On mixed and composite functions, KING exhibits excellent overall performance, outperforming comparison algorithms in both convergence speed and convergence accuracy across different problem scales.

5.5.3. *Comparison with state-of-the-art algorithms on IEEE CEC 2022*

To evaluate the performance of KING in more complex and challenging optimization problems, this section compares KING with eight state-of-the-art algorithms introduced in 2024, tested on twelve complex benchmark functions from IEEE CEC 2022. The comparison algorithms include: artemisinin optimization (AO) [47], hiking optimizer algorithm (HOA) [48], red-billed blue magpie optimizer (RBMO) [49], secretary bird optimization algorithm (SBOA) [50], walrus optimizer (WO) [51], black-winged kite algorithm (BKA) [52], Ivy algorithm (IVY) [53], black eagle optimizer (BEO) [54]. Table A.16 in the appendix presents the average values (AVG) and standard deviations (STD) of the experimental results. Among the twelve test functions, KING achieves the smallest AVG and STD values in most cases, indicating that KING demonstrates better optimization accuracy and algorithm stability compared to other state-of-the-art algorithms in more complex and challenging test functions.

Table 9 shows the evaluation results of the comparative experiments between KING and state-of-the-art algorithms based on WSRT and FT. The results indicate that KING ranks first according to both WSRT and FT evaluations. Compared to SBOA, which ranks second in WSRT, KING shows significant advantages in 8 out of 12 test functions and achieves comparable optimization results in 3 functions. The FT statistical results further corroborate KING's superiority, with an average ranking of 3.29 for SBOA, which is higher than KING's average ranking of 3.12.

Fig. 11 illustrates the convergence curves of KING compared to state-of-the-art algorithms on some benchmark functions from IEEE CEC 2022. In contrast to algorithms like EBO, WO, and HOA, which converge

Table 10
The problem definition of WBD.

Consider $X = \{x_1, x_2, \quad x_3, \quad x_4\} = \{h, l, t, b\}$Minimize $f(x) = (1 + c_3)x_1^2 x_2 + c_4 x_3 x_4 (L + x_2)$Where:$c_3$ (specific cost of weld material, 1972) = \$/volume of weld material= (0.37) (0.283) (\$/in.) = 0.10471c_4 (specific cost of bar stock, 1972) = \$/volume of bar stock= (0.17) (0.283) (\$/in.) = 0.04811L = 14.0 inMinimize $f(x) = 1.10471 x_1^2 x_2 + 0.04811 x_3 x_4 (14.0 + x_2)$

Subject to:$g_1(x) = \tau_d - \tau(x) \geq 0 \rightarrow g_1(x) = \tau_{\max} - \tau(x) \geq 0 g_2(x) = \sigma_d - \sigma(x) \geq 0 \rightarrow g_2(x) = \sigma_{\max} - \sigma(x) \geq 0 g_3(x) = x_4 - x_1 \geq 0 g_4(x) = 0.25 - DEL(x) \geq 0 \rightarrow g_4(x) = \delta_{\max} - \delta(x) \geq 0 g_5(x) = P_c(x) - F \geq 0 \rightarrow g_5(x) = P_c(x) - P \geq 0$

Where: $\tau(x) = \sqrt{(\tau')^2 + 2\tau'\tau''\frac{x_2}{2R} + (\tau'')^2}\tau' = \frac{P}{\sqrt{2}x_1 x_2}\tau'' = \frac{MR}{J}M = P\left(L + \frac{x_2}{2}\right)R = \sqrt{\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2}J = 2\left\{0.707 x_1 x_2 \left[\frac{x_2^2}{12} + \left(\frac{x_1 + x_3}{2}\right)^2\right]\right\}$, where $0.707 = \frac{1}{\sqrt{2}} \rightarrow J = 2\left\{\frac{x_1 x_2}{\sqrt{2}}\left[\frac{x_2^2}{12} + \left(\frac{x_1 + x_3}{2}\right)^2\right]\right\}\sigma(x) = \frac{6PL}{x_4 x_3^2}\delta(x) = \frac{4PL^3}{E x_3^3 x_4}P_C(x) = \frac{4.013\sqrt{Ela}}{L^2}\left(1 - \frac{x_3\sqrt{\frac{El}{a}}}{2L}\right)$, where: $I = \frac{x_3 x_4^3}{12}$ and $a = \frac{G x_3 x_4^3}{3} \rightarrow P_C(x) = \frac{4.013\sqrt{\frac{E G x_3^2 x_4^6}{36}}}{L^2}\left(1 - \frac{x_3\sqrt{\frac{E}{4G}}}{2L}\right)$

In which:$P = 6000lb$, $L = 14$in, $E = 30 \times 10^6 psi$, $G = 12 \times 10^6 psi$, $\tau_{\max} = 13600psi$, $\sigma_{\max} = 30000psi$, $\delta_{\max} = 0.25$ inRange: $(0.125 \leq x_1, x_4)$, and $(0 \leq x_2, x_3)$

Table 11
Comparison results of WBD between KING and other approaches.

Algorithms	Optimal values for variables				Optimum cost
	h	*l*	*t*	*b*	
KING	**0.201500**	**3.211000**	**9.147808**	**0.208064**	**1.720023**
KING3	0.182000	3.731000	9.036560	0.205733	1.722428
RIME [10]	0.208000	3.250000	9.053702	0.208620	1.722821
HGA [55]	0.205700	3.470500	9.036600	0.205700	1.724852
CBO [56]	0.243400	6.255200	8.291500	0.244400	2.384110
CDE [57]	0.203137	3.542998	9.033498	0.206179	1.733462
GWO [12]	0.205700	3.478400	9.036800	0.205800	1.726240
GSA [8]	0.182129	3.856979	10.00000	0.202376	1.879950
NDE [58]	0.205729	3.470488	9.903662	0.205729	1.724852

slowly in the early iterations, KING can quickly identify the region near the approximate optimal solution. During the iteration process, when algorithms such as IVY and BKA experience stagnation in convergence and gradually fall into local optima traps, KING maintains a stable exploitation capability and converges to solutions with higher precision.

5.6. Experiments on engineering design problems

To validate the optimization performance of KING in real-world optimization problems, this section compares KING with KING3. KING3 includes only the global exploration and local exploitation phases of the JC and TLT algorithms from KING, without the guiding WCU for convergence behavior. We apply both algorithms to four real-world engineering design optimization problems. In these engineering design optimization problems, some decision variables are subject to complex constraint relationships, often resulting in multiple feasible solutions. Therefore, researchers typically need to identify one effective, approximate optimal solution while satisfying the constraints.

5.6.1. Welded beam design

The welded beam design (WBD) optimization problem seeks to determine an optimal structural configuration that simultaneously satisfies mechanical performance requirements (e.g., strength, stiffness, and stability) and minimizes manufacturing costs under predefined load and constraint conditions. Specifically, the problem involves a 1010-grade steel beam with a fixed length $L = 14in$, engineered to sustain a static load of 6000 lb. The objective function formalizes cost minimization while adhering to constraints on four critical mechanical parameters: Shear stress (τ), Bending stress (σ), Buckling load (P_c), End deflection (δ). The optimization is governed by four design variables x_1, x_2, x_3 and x_4, denotes weld thickness (h), weld length (l), beam thickness (t), and beam width (b). A schematic representation of the WBD problem is depicted in Fig. 12, while the complete mathematical formulation, including constraint boundaries and variable ranges, is

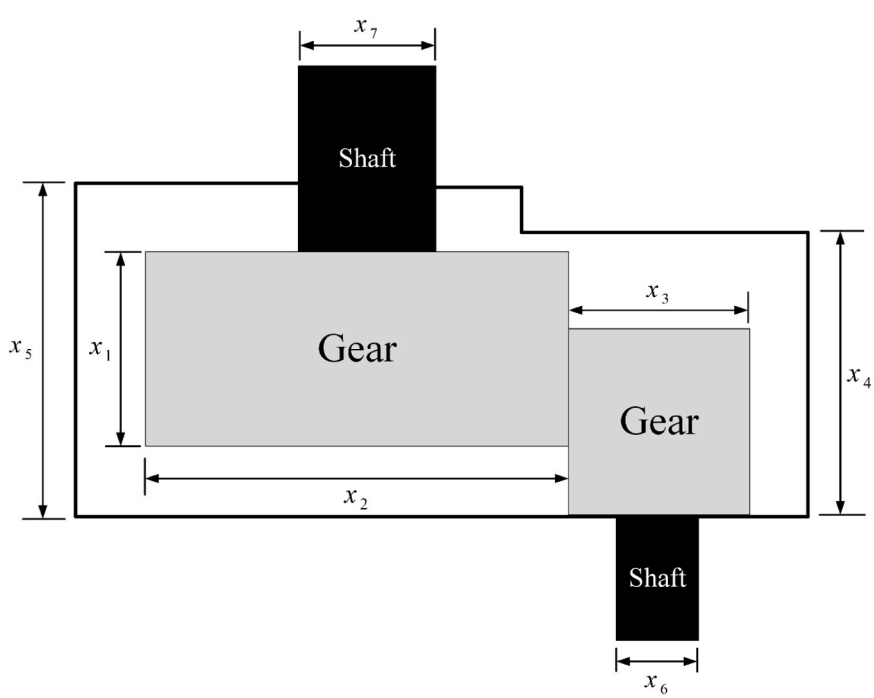

Fig. 13. SRD problem diagram.

Table 12
The problem definition of SRD.

Consider $X = \{x_1, x_2, \quad x_3, \quad x_4, \quad x_5, \quad x_6, \quad x_7\} = \{b, m, \quad z, \quad l_1, \quad l_2, \quad d_1, \quad d_2\}$ Minimize $f(x) = 0.7854x_1x_2^2(3.3333x_3^2 + 14.9334x_3 - 43.0932) - 1.5079x_1(x_6^2 + x_7^2) + 7.4769(x_6^3 + x_7^3) \quad + 0.7854(x_4x_6^2 + x_5x_7^2)$
Subject to: $g_1(x) = \frac{27}{x_1x_2^2x_3} - 1 \le 0$ $g_2(x) = \frac{397.5}{x_1x_2^2x_3^2} - 1 \le 0$ $g_3(x) = \frac{1.93x_4^3}{x_2x_3x_6^4} - 1 \le 0$ $g_4(x) = \frac{1.93x_5^3}{x_2x_3x_7^4} - 1 \le 0$ $g_5(x) = \frac{\left[(745(x_4/x_2x_3))^2 + 16.9 \times 10^6\right]^{1/2}}{110x_6^3} - 1 \le 0$ $g_6(x) = \frac{\left[(745(x_5/x_2x_3))^2 + 157.5 \times 10^6\right]^{1/2}}{85x_7^3} - 1 \le 0$ $g_7(x) = \frac{x_2x_3}{40} - 1 \le 0$ $g_8(x) = \frac{5x_2}{x_1} - 1 \le 0$ $g_9(x) = \frac{x_1}{12x_2} - 1 \le 0$ $g_{10}(x) = \frac{1.5x_6 + 1.9}{x_4} - 1 \le 0$ $g_{11}(x) = \frac{1.1x_7 + 1.9}{x_5} - 1 \le 0$
Range: $2.6 \le x_1 \le 3.6, \quad 0.7 \le x_2 \le 0.8, \quad 17 \le x_3 \le 28, \quad 7.3 \le x_4 \le 8.3, 7.3 \le x_5 \le 8.3, \quad 2.9 \le x_6 \le 3.9, \quad 5.0 \le x_7 \le 5.5$

Table 13
Comparison results of SRD between KING and other methods.

Algorithms	Optimum variables							Optimum cost
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	
KING	**3.50006**	**0.7**	**17**	**7.301600**	**7.716086**	**3.350034**	**5.286596**	**2994.4407**
KING3	3.50000	0.7	17	7.300000	7.715320	3.350215	5.286654	2994.4711
RIME[10]	3.50357	0.7	17	7.300000	7.800000	3.350230	5.287497	2997.6982
AGOA [59]	3.50000	0.7	17	7.310097	7.737602	3.350234	5.287056	2995.3092
GWO[12]	3.50669	0.7	17	7.380933	7.815726	3.357847	5.286768	3001.2880
PSO[60]	3.50001	0.7	17	8.300000	7.800000	3.352412	5.286715	3005.7630
SCA[61]	3.50875	0.7	17	7.300000	7.800000	3.461020	5.289213	3030.5630
GSA[8]	3.60000	0.7	17	8.300000	7.800000	3.369658	5.289224	3051.1200

tabulated in Table 10.

Table 11 shows the optimization results of KING and other algorithms on the WBD problem. Among them, the optimization cost of KING is 1.720023, which has the smallest value among all algorithms. This indicates that KING can solve the welded beam design problem better compared to other algorithms under the constraints of limited shear stress, bending stress, buckling load, and deflection.

5.6.2. Speed reducer design

The Speed Reducer Design (SRD) constitutes a critical component in mechanical drive systems, engineered to reduce output rotational speed while augmenting output torque. The SRD optimization problem aims to minimize the total weight of the gearbox under constraints governing the bending stress of gear teeth and surface stress of shafts. This problem is parameterized by seven design variables $(x_1, x_2, \quad x_3, \quad x_4, \quad x_5, \quad x_6, \quad x_7)$ denotes face width (b), module of teeth (m), number of teeth in the pinion (z), length of the first shaft between bearings (l_1), length of the second shaft between bearings (l_2), diameter of the first shaft (d_1), and diameter of the second shaft (d_2). The primary objective is to minimize the reducer's weight while satisfying constraints on: shaft bending and surface stresses, transverse deflection of shafts, bending stress of gear teeth, and surface contact stress. A schematic representation of the SRD problem is illustrated in Fig. 13, with the complete mathematical formulation and constraint specifications provided in Table 12.

Table 13 shows the experimental results of KING and other algorithms in the SRD problem. From the experimental results in the table, it can be seen that the optimization cost of KING is 2994.4407, which is the lowest of all the compared algorithms. This reflects the excellent performance of KING in the speed reducer design optimization problem, which has significant advantages over other algorithms.

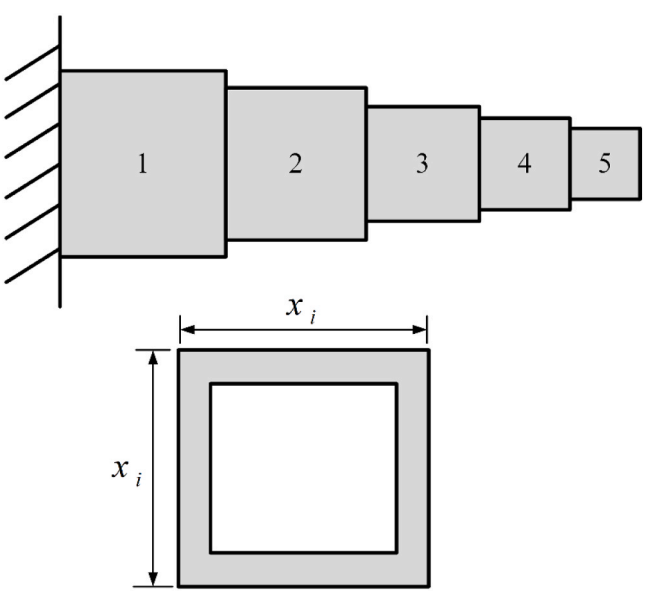

Fig. 14. CBD problem diagram.

Table 14
The problem definition of CBD.

Consider $X = \{x_1, x_2, \quad x_3, \quad x_4, \quad x_5\}$ Minimize $f(x) = 0.0624(x_1 + x_2 + x_3 + x_4 + x_5)$
Subject to: $g(x) = \frac{61}{x_1^3} + \frac{37}{x_2^3} + \frac{19}{x_3^3} + \frac{7}{x_4^3} + \frac{1}{x_5^3} \le 1$ Where: $x_i > 0, i = 1, 2, \ldots, 5$

5.6.3. Cantilever beam design

The Cantilever Beam Design (CBD) problem involves a structural configuration comprising five hollow elements, each characterized by a uniform-thickness cross-section. The objective of this optimization task is to minimize the total mass of the cantilever beam while ensuring compliance with load-bearing capacity requirements. The CBD problem is governed by five design variables $(x_1, x_2, \quad x_3, \quad x_4, \quad x_5)$, which correspond to the geometric parameters of the hollow elements, and a single vertical displacement constraint. Each variable maintains a constant thickness value, and the optimization aims to achieve weight reduction under the prescribed mechanical constraints. A schematic representation of the CBD problem is illustrated in Fig. 14, while the complete mathematical formulation, including variable definitions and constraint specifications, is detailed in Table 14.

Table 15 shows the experimental results of KING and other algorithms in CBD problem. From the experimental results in the table, it can be seen that the optimization cost of KING is 1.339956, which is the lowest of all the compared algorithms. This reflects the excellent performance of KING in the CBD problem, which has significant advantages over other algorithms.

Table 15
Comparison results of CBD between KING and other approaches.

Algorithms	Optimum variables					Optimum cost
	x_1	x_2	x_3	x_4	x_5	
KING	**6.0160**	**5.3092**	**4.4942**	**3.5015**	**2.1527**	**1.339956**
KING3	6.0153	5.3124	4.4923	3.4996	2.1542	1.339957
SMA [16]	6.0178	5.3109	4.4938	3.5011	2.1502	1.339957
MFO [17]	5.9830	5.3167	4.4973	3.5136	2.1616	1.33998
SOS [62]	6.0188	5.3034	4.4959	3.4990	2.1556	1.33996
CS [63]	6.0089	5.3049	4.5023	3.5077	2.1504	1.33999
GSA [8]	6.0100	5.3000	4.4900	3.4900	2.1500	1.34000

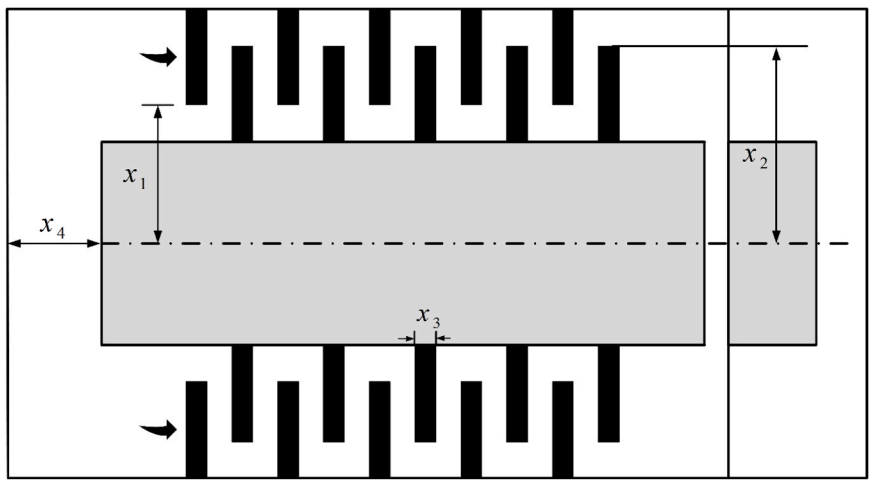

Fig. 15. MDCBD problem diagram.

5.6.4. Multiple disk clutch brake design

The Multiple Disk Clutch Brake Design (MDCBD) problem addresses the optimization of a critical mechanical transmission component widely employed in automotive systems and heavy machinery. The objective is to identify an optimal multi-disc clutch brake configuration that maximizes clutching/braking efficacy while minimizing mass under predefined operational conditions and constraints. This discrete optimization problem is governed by five integer variables (x_1,x_2, x_3, x_4, x_5), denotes inner radius (r_i), outer radius (r_0), disk thickness (t), actuating force (F) and number of friction surfaces (Z). The optimization aims to minimize the total mass of the MDCBD assembly while satisfying constraints related to thermal performance, wear resistance, and mechanical durability. A schematic representation of the MDCBD problem is depicted in Fig. 15, with the complete mathematical formulation, including variable bounds and constraint equations, provided in Table 16.

Table 17 shows the optimization results of KING and other comparative algorithms on the MDCBD problem. Among them, KING has the smallest cost among all the algorithms. Compared to the second-ranked KING3, KING achieves a lower cost by reducing the internal

Table 16
The problem definition of MDCBD.

Consider $X = \{r_i, \quad r_0, \quad t, \quad F, \quad Z\} = \{x_1, x_2, \quad x_3, \quad x_4, \quad x_5\}$Minimize $f(x) = \pi(r_0^2 - r_1^2)t(Z+1)\rho$

Subject to:$g_1(x) = r_0 - r_1 - \Delta r > 0 g_2(x) = l_{\max} - (Z+1)(t+\delta) \geq 0 g_3(x) = p_{\max} - p_{rz} \geq 0 g_4(x) = p_{\max} v_{srmax} - p_{rz} v_{sr} \geq 0 g_5(x) = v_{srmax} - v_{sr} \geq 0 g_6(x) = T_{\max} - T \geq 0 g_7(x) = M_h - sM_s \geq 0 g_8(x) = T \geq 0$

Where:$M_h = \frac{2}{3}\mu F Z \frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}$ N mm, $\omega = \frac{\pi n}{30} rad/s$, A $= \pi(r_0^2 - r_i^2) \quad mm^2, p_{rz} = \frac{F}{A} N/mm^2, v_{sr} = \frac{\pi R_{sr} n}{30} mm/s, R_{sr} = \frac{2(r_0^3 - r_i^3)}{3(r_0^2 - r_i^2)} mm, T = \frac{I_z \omega}{(M_h + M_f)}$

In which:$\Delta r = 20mm, l_{\max} = 30mm, \mu = 0.5, p_{\max} = 1MPa, \rho = 0.0000078 \frac{kg}{mm^3}, v_{srmax} = 10 \frac{m}{s}, s = 1.5, T_{\max} = 15s, n = 250rpm, M_s = 40N\ m, M_f = 3N\ m, I_z = 55kgm^2, \delta = 0.5mm$

$r_i = \{60, 61, \ldots, 80\} in\ mm, r_0 = \{91, 92, \ldots, 110\} in\ mm, t = \{1, 1.5, 2, 2.5, 3\} in\ mm, F = \{600, 610, \ldots, 1000\} in\ N, Z = \{2, 3, \ldots, 10\}$ *is number of disks*

Table 17
Comparison results of MDCBD between KING and other approaches.

Algorithms	Optimum variables					Optimum cost
	r_i	r_0	t	F	Z	
KING	**71.0000**	**91.0000**	**1.0000**	**940.0000**	**2.0000**	**0.238183**
KING3	72.0000	92.0000	1.0000	980.0000	2.0000	0.241124
RIME [10]	75.0000	95.0000	1.0000	1000.0000	2.0000	0.249945
TLBO [64]	74.0000	94.0000	1.0000	940.0000	2.0000	0.247005
PVS [65]	74.0000	94.0000	1.0000	920.0000	2.0000	0.247005
WCA [66]	74.0000	94.0000	1.0000	970.0000	2.0000	0.247005
CBA [67]	74.0000	94.0000	1.0000	980.0000	2.0000	0.247005

radius, external radius, and drive force with the same number of friction surfaces and disc thickness. The experimental results of TLBO, PVS, and WCA only differ in parameter *F*, and the final optimized results show a significant gap compared to KING.

6. Conclusion and future works

To address the pervasive challenge of balancing exploration and exploitation in metaheuristic optimization, this paper proposes a novel, efficient algorithm inspired by the Three Kingdoms period in Chinese history. It is called the Three Kingdoms Optimization Algorithm (KING). In KING, the population initialization, algorithm exploration phase, algorithm exploitation phase, and enhanced convergence mechanism are analogized to the historical stages of ascent of the might, joint confrontation, three-legged tripod, and whole country united (WCU) in the Three Kingdoms era. KING innovatively introduces the WCU as a reinforcement convergence mechanism that systematically guides the search process toward rapid and effective convergence while enhancing performance across different scales of optimization problems. By using a constraint handling method based on dynamic equality constraint tolerance, KING is forced to improve its adaptability to constrained optimization problems. The effectiveness of WCU has been validated through ablation experiments, significantly improving the convergence speed and accuracy of the algorithm for larger-scale and more complex optimization objectives.

This study verifies the performance advantages of KING through experiments on benchmark function test sets from IEEE CEC 2017 and IEEE CEC 2022, comparing it with multiple classical algorithms, high-performance improved algorithms, and state-of-the-art algorithms. Moreover, KING's optimization performance has been validated across four real-world engineering design optimization problems, demonstrating significant advantages over other algorithms.

In future work, we plan to develop binary and multi-objective versions of KING to address different types of optimization problems, further enhancing KING's optimization capabilities and expanding its applicability to more engineering design domain challenges.

CRediT authorship contribution statement

Zongda Wu: Investigation. **Ali Asghar Heidari:** Writing – review & editing. **Yupeng Li:** Conceptualization. **Zhen Wang:** Methodology. **Dong Zhao:** Writing – original draft. **chen huiling:** Funding acquisition. **Yi Chen:** Resources.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT to improve and proofread the English of the paper. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A1
Details of the IEEE CEC 2017

		Functions	f_{min}
Unimodal Functions	F1	Shifted and Rotated Bent Cigar Function	100
	F2	Shifted and Rotated Sum of Different Power Function	200
	F3	Shifted and Rotated Zakharov Function	300
Multimodal Functions	F4	Shifted and Rotated Rosenbrocks Function	400
	F5	Shifted and Rotated Rastrigins Function	500
	F6	Shifted and Rotated Expanded Scaffers F6 Function	600
	F7	Shifted and Rotated Lunacek Bi_Rastrigin Function	700
	F8	Shifted and Rotated Non-Continuous Rastrigins Function	800
	F9	Shifted and Rotated Levy Function	900
	F10	Shifted and Rotated Schwefels Function	1000
Hybrid Functions	F11	Hybrid Function 1 (N = 3)	1100
	F12	Hybrid Function 2 (N = 3)	1200
	F13	Hybrid Function 3 (N = 3)	1300
	F14	Hybrid Function 4 (N = 4)	1400
	F15	Hybrid Function 5 (N = 4)	1500
	F16	Hybrid Function 6 (N = 4)	1600
	F17	Hybrid Function 6 (N = 5)	1700
	F18	Hybrid Function 6 (N = 5)	1800
	F19	Hybrid Function 6 (N = 5)	1900
	F20	Hybrid Function 6 (N = 6)	2000
Composition Functions	F21	Composition Function 1 (N = 3)	2100
	F22	Composition Function 2 (N = 3)	2200
	F23	Composition Function 3 (N = 4)	2300
	F24	Composition Function 4 (N = 4)	2400
	F25	Composition Function 5 (N = 5)	2500
	F26	Composition Function 6 (N = 5)	2600
	F27	Composition Function 7 (N = 6)	2700
	F28	Composition Function 8 (N = 6)	2800

(*continued on next page*)

Table A1 (*continued*)

	Functions	f_{min}
F29	Composition Function 9 (N = 3)	2900
F30	Composition Function 10 (N = 3)	3000

Table A2
Details of the IEEE CEC 2022

	No.	Functions	Fi*
Unimodal Function	1	Shifted and full Rotated Zakharov Function	300
Basic Functions	2	Shifted and full Rotated Rosenbrock's Function	400
	3	Shifted and full Rotated Expanded Schaffer's f6 Function	600
	4	Shifted and full Rotated Non-Continuous Rastrigin's Function	800
	5	Shifted and full Rotated Levy Function	900
Hybrid Functions	6	Hybrid Function 1 (N = 3)	1800
	7	Hybrid Function 2 (N = 6)	2000
	8	Hybrid Function 3 (N = 5)	2200
Composition Functions	9	Composition Function 1 (N = 5)	2300
	10	Composition Function 2 (N = 4)	2400
	11	Composition Function 3 (N = 5)	2600
	12	Composition Function 4 (N = 6)	2700
Search range: [−100,100]			

Table A3
AVG and STD values of parameter sensitivity analysis experiment

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**2.1264E+03**	**2.3270E+03**	4.2873E+13	2.1516E+14	4.1788E+03	2.5234E+03
KING_4	2.3866E+03	2.8661E+03	2.8988E+02	4.9229E+02	**3.0193E+02**	**8.0807E+00**
KING_6	3.3987E+03	4.1183E+03	**2.0000E+02**	**2.1297E−03**	3.0822E+02	4.1646E+01
KING_8	3.1670E+03	3.8999E+03	8.8460E+06	4.8450E+07	3.0660E+02	2.1129E+01
KING_10	4.2752E+03	6.7268E+03	4.0066E+09	2.1945E+10	5.7755E+02	1.0893E+03
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**4.3519E+02**	3.8551E+01	**5.4947E+02**	1.3782E+01	**6.0000E+02**	**8.6833E−04**
KING_4	4.3563E+02	3.5820E+01	5.5406E+02	1.6266E+01	6.0009E+02	1.6600E−01
KING_6	4.4423E+02	3.6421E+01	5.5058E+02	**1.1073E+01**	6.0048E+02	3.9482E−01
KING_8	4.5182E+02	3.9594E+01	5.6008E+02	1.5329E+01	6.0114E+02	8.2954E−01
KING_10	4.4948E+02	**3.4763E+01**	5.5552E+02	1.6602E+01	6.0180E+02	1.8255E+00
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**7.8985E+02**	2.7465E+01	8.5520E+02	2.5907E+01	**9.0512E+02**	**7.9065E+00**
KING_4	7.9702E+02	1.6335E+01	**8.5263E+02**	**1.2616E+01**	9.2618E+02	3.2380E+01
KING_6	7.9270E+02	**1.6189E+01**	8.5343E+02	1.2812E+01	9.3868E+02	2.4448E+01
KING_8	8.0046E+02	1.8987E+01	8.5638E+02	1.5256E+01	9.4834E+02	3.8835E+01
KING_10	8.0364E+02	1.8191E+01	8.6033E+02	1.6131E+01	9.9907E+02	7.2504E+01
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING_2	4.3020E+03	1.1086E+03	**1.1391E+03**	**2.6890E+01**	5.5701E+04	7.6052E+04
KING_4	3.9883E+03	**5.6985E+02**	1.1463E+03	2.8664E+01	**2.8866E+04**	1.8873E+04
KING_6	4.1807E+03	9.5957E+02	1.1704E+03	2.7394E+01	3.1482E+04	**1.7132E+04**
KING_8	4.0778E+03	1.0915E+03	1.1934E+03	3.7727E+01	3.8959E+04	3.1238E+04
KING_10	**3.9842E+03**	6.9383E+02	1.1900E+03	3.9247E+01	6.1563E+04	9.1775E+04
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING_2	1.6812E+04	1.4158E+04	4.7221E+03	4.2553E+03	**6.1880E+03**	**5.4253E+03**
KING_4	**1.1948E+04**	1.2809E+04	4.4948E+03	3.1922E+03	9.0954E+03	7.8105E+03
KING_6	1.3296E+04	**1.2623E+04**	**3.9890E+03**	3.1538E+03	1.0707E+04	8.8790E+03

(*continued on next page*)

Table A3 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING_8	1.3410E+04	1.4259E+04	4.4793E+03	**2.9656E+03**	9.4674E+03	9.9200E+03
KING_10	1.5697E+04	1.4463E+04	6.1425E+03	5.3201E+03	1.0706E+04	9.8972E+03
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**2.1118E+03**	**1.9462E+02**	1.7953E+03	7.4307E+01	2.3636E+05	**1.2483E+05**
KING_4	2.1171E+03	2.2778E+02	**1.7837E+03**	**6.0555E+01**	2.0530E+05	1.8714E+05
KING_6	2.1635E+03	1.9737E+02	1.8413E+03	7.7228E+01	1.6395E+05	1.9828E+05
KING_8	2.2104E+03	2.6849E+02	1.8148E+03	9.7476E+01	1.4411E+05	1.2486E+05
KING_10	2.2761E+03	2.6620E+02	1.8578E+03	1.1349E+02	**1.3074E+05**	1.5767E+05
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING_2	1.0158E+04	1.0234E+04	2.1479E+03	**7.7847E+01**	**2.3519E+03**	2.1095E+01
KING_4	9.6292E+03	1.0553E+04	2.1235E+03	8.3438E+01	2.3533E+03	1.4302E+01
KING_6	1.0110E+04	1.0174E+04	**2.1182E+03**	8.1912E+01	2.3545E+03	**1.3958E+01**
KING_8	1.3628E+04	1.3387E+04	2.1377E+03	8.5835E+01	2.3528E+03	1.4805E+01
KING_10	**8.9079E+03**	**9.9268E+03**	2.1476E+03	1.0360E+02	2.3567E+03	1.4063E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**2.3007E+03**	**1.4086E+00**	2.7078E+03	1.4630E+01	2.8984E+03	3.9591E+01
KING_4	2.3028E+03	3.3195E+00	**2.7045E+03**	1.7199E+01	**2.8778E+03**	1.7760E+01
KING_6	2.3035E+03	3.8912E+00	2.7135E+03	2.0618E+01	2.8793E+03	2.0235E+01
KING_8	2.4028E+03	5.2774E+02	2.7137E+03	**1.4304E+01**	2.8853E+03	**1.6616E+01**
KING_10	2.3873E+03	4.5368E+02	2.7156E+03	2.1924E+01	2.8857E+03	1.9442E+01
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING_2	**2.8898E+03**	7.9725E+00	3.9105E+03	**5.6466E+02**	**3.2130E+03**	**9.8384E+00**
KING_4	2.8940E+03	1.2482E+01	**3.7100E+03**	6.4649E+02	3.2189E+03	1.2554E+01
KING_6	2.8906E+03	**5.7773E+00**	3.8749E+03	7.0015E+02	3.2291E+03	1.3315E+01
KING_8	2.8982E+03	1.7066E+01	3.9789E+03	7.0681E+02	3.2404E+03	1.6335E+01
KING_10	2.8996E+03	1.8979E+01	4.1676E+03	6.4519E+02	3.2516E+03	1.4037E+01
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING_2	3.1493E+03	5.8695E+01	3.4689E+03	9.1984E+01	9.7603E+03	9.2409E+03
KING_4	3.1450E+03	5.6944E+01	3.4332E+03	1.0869E+02	8.3939E+03	2.5681E+03
KING_6	**3.1357E+03**	**5.1428E+01**	**3.3931E+03**	**6.3212E+01**	**8.0396E+03**	2.1250E+03
KING_8	3.1506E+03	5.6826E+01	3.4856E+03	9.5995E+01	8.4276E+03	2.8995E+03
KING_10	3.1534E+03	5.2033E+01	3.4662E+03	1.4742E+02	8.1270E+03	**1.7719E+03**

Ablation experiment results

Table A4
AVG and STD values of ablation experiment on dimension 10

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**6.6483E+02**	**6.6797E+02**	2.0000E+02	7.7893E−04	3.0000E+02	3.2603E−13
KING1	2.9975E+09	9.1464E+09	2.0000E+02	1.7276E−03	2.6888E+05	5.4635E+05
KING2	4.9946E+06	5.3369E+06	1.0749E+05	2.9189E+05	3.8454E+02	8.5041E+01
KING3	1.5972E+03	1.6466E+03	**2.0000E+02**	**4.7837E−05**	**3.0000E+02**	**0.0000E+00**
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.0003E+02**	**6.4129E−03**	5.0793E+02	3.3409E+00	**6.0000E+02**	**3.6984E−04**
KING1	1.1336E+03	1.9022E+03	5.2202E+02	2.0875E+01	6.0139E+02	4.9962E+00
KING2	4.0600E+02	2.9847E+00	5.0966E+02	3.6364E+00	6.0005E+02	6.2088E−02
KING3	4.0005E+02	6.7681E−03	**5.0789E+02**	**2.9322E+00**	6.0000E+02	5.1871E−04
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.1630E+02**	**2.9575E+00**	**8.0710E+02**	**2.7619E+00**	**9.0008E+02**	**3.2311E−01**
KING1	8.8714E+02	7.7333E+01	8.7012E+02	5.9543E+01	3.0272E+03	1.6000E+03
KING2	7.2131E+02	5.7240E+00	8.0992E+02	4.2206E+00	9.0036E+02	4.0622E−01
KING3	7.2049E+02	4.4947E+00	8.0750E+02	3.1651E+00	9.0025E+02	8.2684E−01

(*continued on next page*)

Table A4 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.1844E+03**	1.5170E+02	**1.1018E+03**	**1.4256E+00**	1.1874E+04	1.1691E+04
KING1	1.2100E+03	**1.4883E+02**	1.1026E+03	1.6702E+00	**7.4385E+03**	**4.7721E+03**
KING2	1.2525E+03	1.9371E+02	1.1077E+03	5.1375E+00	2.5355E+05	4.6360E+05
KING3	1.2383E+03	1.7766E+02	1.1050E+03	4.8924E+00	9.6353E+03	7.4631E+03
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.4660E+03**	**1.6813E+02**	**1.4090E+03**	**1.0920E+01**	**1.5047E+03**	**3.8896E+00**
KING1	1.5099E+03	2.1794E+02	1.4523E+03	1.4789E+02	1.5111E+03	1.3495E+01
KING2	3.1818E+03	4.1279E+03	1.4294E+03	1.5702E+01	1.5350E+03	3.3419E+01
KING3	7.7735E+03	4.3499E+03	1.4176E+03	1.7218E+01	1.5289E+03	3.5905E+01
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.6007E+03**	**3.0471E−01**	**1.7040E+03**	**4.9511E+00**	**2.5369E+03**	**1.3721E+03**
KING1	1.7760E+03	3.3702E+02	1.7216E+03	1.7788E+01	3.0398E+03	3.2207E+03
KING2	1.6093E+03	2.2617E+01	1.7132E+03	1.1858E+01	4.4316E+03	5.0060E+03
KING3	1.6097E+03	3.1582E+01	1.7073E+03	7.5479E+00	5.2910E+03	4.0301E+03
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.9033E+03**	**2.9290E+00**	**2.0014E+03**	**8.0334E−01**	2.2766E+03	5.1045E+01
KING1	1.9048E+03	5.9201E+00	2.0065E+03	2.1781E+01	**2.2552E+03**	5.6220E+01
KING2	1.9155E+03	1.1454E+01	2.0059E+03	5.9045E+00	2.2980E+03	**3.8899E+01**
KING3	1.9098E+03	9.8456E+00	2.0050E+03	6.2051E+00	2.2692E+03	5.3445E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.2996E+03**	1.5254E+01	**2.5982E+03**	5.6447E+01	2.6963E+03	8.9364E+01
KING1	2.5031E+03	7.6097E+02	2.6107E+03	**4.2190E+00**	**2.6773E+03**	1.0901E+02
KING2	2.3026E+03	1.5212E+01	2.6127E+03	4.4870E+00	2.7409E+03	9.3348E+00
KING3	2.3011E+03	**7.3934E−01**	2.6107E+03	4.7481E+00	2.7387E+03	**3.8389E+00**
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.9139E+03**	2.2035E+01	**2.8916E+03**	3.6578E+01	3.0939E+03	2.4349E+00
KING1	3.7527E+03	9.5015E+02	3.1244E+03	7.5741E+02	3.0944E+03	3.6213E+00
KING2	2.9302E+03	**1.9995E+01**	2.9190E+03	**2.3154E+01**	**3.0933E+03**	2.1932E+00
KING3	2.9225E+03	2.4283E+01	2.8956E+03	2.8761E+01	3.0953E+03	**2.1668E+00**
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.1696E+03	1.1854E+02	**3.1438E+03**	**9.0376E+00**	3.2644E+04	1.4883E+05
KING1	3.3701E+03	3.3940E+02	3.1515E+03	1.6198E+01	1.6929E+07	9.2386E+07
KING2	3.1877E+03	**1.0880E+02**	3.1607E+03	1.1612E+01	1.7324E+04	1.7885E+04
KING3	**3.1357E+03**	1.1453E+02	3.1549E+03	1.4908E+01	**5.1599E+03**	**1.2212E+03**

Table A5
AVG and STD values of ablation experiment on dimension 30

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.0492E+03**	**2.5869E+03**	2.9262E+10	1.6028E+11	**3.1217E+02**	**4.2158E+01**
KING1	4.5220E+10	4.3022E+10	**2.6203E+06**	**1.4351E+07**	2.5395E+08	4.6820E+08
KING2	1.2860E+09	6.4113E+08	1.1925E+27	6.3946E+27	1.2427E+04	9.0937E+03
KING3	4.4665E+03	4.7140E+03	5.9991E+06	3.2019E+07	5.8540E+03	3.8981E+03
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.3735E+02**	3.5062E+01	**5.5104E+02**	**1.5062E+01**	6.0007E+02	6.5977E−02
KING1	1.4387E+04	1.7383E+04	9.5499E+02	2.1855E+02	6.7131E+02	6.5001E+01
KING2	6.5511E+02	8.6557E+01	5.8591E+02	3.6562E+01	6.0089E+02	6.3845E−01
KING3	4.6794E+02	**3.0434E+01**	5.5202E+02	1.8849E+01	**6.0000E+02**	**8.1681E−03**

(*continued on next page*)

Table A5 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.8892E+02**	**1.6467E+01**	**8.5068E+02**	**1.3704E+01**	**9.2141E+02**	**1.8400E+01**
KING1	1.5550E+03	1.8573E+02	1.1840E+03	1.8494E+02	2.0474E+04	1.5263E+04
KING2	8.3474E+02	3.4552E+01	8.8465E+02	4.0660E+01	1.0402E+03	9.6360E+01
KING3	8.0779E+02	2.5418E+01	8.5321E+02	1.6236E+01	9.3518E+02	5.6521E+01
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.0889E+03**	**9.2108E+02**	1.1570E+03	3.2455E+01	**2.4424E+04**	**1.5688E+04**
KING1	5.5452E+03	2.9694E+03	1.1622E+03	3.2212E+01	1.0812E+10	1.4453E+10
KING2	4.7368E+03	1.1818E+03	1.2867E+03	1.0911E+02	8.0317E+07	6.4710E+07
KING3	4.2146E+03	1.2842E+03	**1.1392E+03**	**2.8675E+01**	5.2210E+04	3.0460E+04
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	1.4885E+04	1.4437E+04	**3.4450E+03**	**1.6586E+03**	7.8522E+03	7.8469E+03
KING1	5.8917E+09	1.5278E+10	5.2171E+03	3.6275E+03	2.3891E+09	3.1935E+09
KING2	3.1761E+06	5.0937E+06	2.5008E+04	2.6141E+04	9.9795E+05	2.2631E+06
KING3	**1.1346E+04**	**1.0471E+04**	1.0465E+04	9.3256E+03	**5.9534E+03**	**5.6526E+03**
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.1179E+03**	2.3075E+02	**1.7880E+03**	**5.7414E+01**	1.8886E+05	**1.6043E+05**
KING1	2.1396E+03	**2.1658E+02**	1.1302E+04	5.1802E+04	**1.4392E+05**	2.1275E+05
KING2	2.5371E+03	3.3047E+02	1.9529E+03	1.1810E+02	4.2656E+05	3.3148E+05
KING3	2.2038E+03	2.8900E+02	1.8251E+03	1.2786E+02	1.9644E+05	1.9265E+05
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	9.9713E+03	1.0557E+04	**2.1104E+03**	**6.9532E+01**	**2.3453E+03**	1.2709E+01
KING1	3.1024E+09	3.3733E+09	2.1604E+03	8.3871E+01	2.3757E+03	3.6284E+01
KING2	6.9989E+05	1.5988E+06	2.2619E+03	7.4777E+01	2.3830E+03	4.0867E+01
KING3	**8.7178E+03**	**8.6554E+03**	2.1631E+03	9.2502E+01	2.3492E+03	**8.5700E+00**
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	2.3019E+03	2.2299E+00	**2.7049E+03**	**1.3516E+01**	2.8802E+03	1.9241E+01
KING1	3.9074E+03	3.5370E+03	2.7177E+03	2.0062E+01	2.9216E+03	4.7205E+01
KING2	2.8705E+03	1.2029E+03	2.7436E+03	3.5614E+01	2.9292E+03	5.3654E+01
KING3	**2.3003E+03**	**8.5653E−01**	2.7059E+03	1.3892E+01	**2.8735E+03**	**1.4943E+01**
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	2.8976E+03	1.6254E+01	**3.9085E+03**	6.6827E+02	3.2228E+03	1.7034E+01
KING1	7.5543E+03	2.8526E+03	1.0385E+04	6.1610E+03	3.2298E+03	1.3264E+01
KING2	3.0160E+03	5.3013E+01	4.2420E+03	**5.2823E+02**	3.2491E+03	1.6083E+01
KING3	**2.8899E+03**	**9.2798E+00**	3.9955E+03	5.9262E+02	**3.2226E+03**	**1.2797E+01**
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.1350E+03**	**5.5515E+01**	**3.4176E+03**	**7.1841E+01**	7.8024E+03	1.7068E+03
KING1	7.6503E+03	3.4730E+03	2.7029E+04	7.1836E+04	8.2875E+03	2.8239E+03
KING2	3.4530E+03	8.0858E+01	3.7076E+03	1.2412E+02	1.4595E+06	1.7964E+06
KING3	3.1772E+03	6.0331E+01	3.4556E+03	1.1456E+02	**7.1647E+03**	**1.4978E+03**

Table A6
AVG and STD values of ablation experiment on dimension 50

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.5620E+03**	**2.8479E+03**	2.0650E+40	1.1310E+41	4.1250E+04	1.8975E+04
KING1	8.5942E+10	6.6510E+10	1.3593E+88	1.3825E+88	**4.0276E+04**	1.8081E+04
KING2	8.2334E+09	3.7091E+09	1.5828E+58	5.2158E+58	6.1509E+04	2.2664E+04
KING3	3.3205E+03	5.6011E+03	**1.2972E+28**	**4.2286E+28**	6.6286E+04	**8.9888E+03**

(*continued on next page*)

Table A6 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.9896E+02**	**4.5689E+01**	**6.1253E+02**	2.9328E+01	6.0100E+02	6.2399E−01
KING1	3.0790E+04	2.8832E+04	1.2128E+03	2.4993E+02	6.9336E+02	6.0690E+01
KING2	1.5571E+03	4.7451E+02	7.1336E+02	8.3746E+01	6.0263E+02	1.7375E+00
KING3	5.3040E+02	5.2946E+01	6.2299E+02	**2.0289E+01**	**6.0003E+02**	**5.1206E−02**
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**9.0669E+02**	**2.9350E+01**	9.1848E+02	4.9758E+01	1.5715E+03	4.4691E+02
KING1	1.9610E+03	3.5356E+02	1.5127E+03	2.6959E+02	5.3023E+04	3.4967E+04
KING2	9.8868E+02	7.7430E+01	9.6537E+02	6.3143E+01	2.5591E+03	6.2716E+02
KING3	9.4810E+02	5.6173E+01	**9.1144E+02**	**2.3762E+01**	**1.3109E+03**	**3.4399E+02**
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	6.9540E+03	2.1516E+03	1.2091E+03	3.5067E+01	**5.4222E+05**	**2.8020E+05**
KING1	**6.5045E+03**	**1.1077E+03**	4.1396E+05	8.3960E+05	5.7315E+10	7.1395E+10
KING2	8.1381E+03	1.5887E+03	2.3019E+03	9.7759E+02	8.5150E+08	5.3590E+08
KING3	9.1668E+03	3.3617E+03	**1.1781E+03**	**2.7411E+01**	1.3466E+06	8.0707E+05
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.3952E+03**	**3.5348E+03**	**4.3649E+04**	4.5288E+04	**5.3931E+03**	4.4232E+03
KING1	1.5180E+10	3.9363E+10	4.4037E+04	3.8754E+04	1.1181E+10	1.2157E+10
KING2	8.9867E+07	7.8220E+07	3.4822E+05	3.6304E+05	1.3828E+07	2.9690E+07
KING3	4.7960E+03	5.2828E+03	4.5212E+04	**2.5426E+04**	5.9727E+03	**4.2365E+03**
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	2.8046E+03	4.5884E+02	**2.5815E+03**	**2.6675E+02**	8.2450E+05	6.8524E+05
KING1	2.7339E+03	**3.0756E+02**	9.6672E+04	8.9405E+04	3.5555E+08	8.0820E+08
KING2	3.5145E+03	4.9753E+02	3.1332E+03	3.9081E+02	3.0961E+06	2.1570E+06
KING3	**2.7195E+03**	3.7286E+02	2.6627E+03	2.9763E+02	**6.5609E+05**	**5.3273E+05**
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.4422E+04**	1.1230E+04	**2.4717E+03**	1.8850E+02	**2.4154E+03**	4.8644E+01
KING1	5.1452E+09	6.8777E+09	4.3992E+03	1.1929E+03	2.4528E+03	**3.5108E+01**
KING2	4.1171E+06	4.5585E+06	2.9942E+03	3.4452E+02	2.4802E+03	8.1732E+01
KING3	1.5945E+04	**8.3781E+03**	2.4935E+03	**1.8577E+02**	2.4468E+03	9.2312E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	8.2123E+03	**3.6174E+03**	**2.8603E+03**	**2.7956E+01**	3.0327E+03	**2.7279E+01**
KING1	7.6762E+03	3.6534E+03	2.9003E+03	3.9647E+01	3.1518E+03	8.5206E+01
KING2	8.8882E+03	4.0915E+03	2.9435E+03	8.6589E+01	3.1426E+03	1.0005E+02
KING3	**6.7996E+03**	4.8644E+03	2.8682E+03	3.0540E+01	**3.0279E+03**	3.0882E+01
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	3.0454E+03	3.5186E+01	5.1989E+03	5.2805E+02	3.4047E+03	6.7144E+01
KING1	1.3822E+04	8.3281E+03	1.6322E+04	6.5802E+03	3.4456E+03	7.2119E+01
KING2	4.0004E+03	5.1472E+02	5.9483E+03	7.1794E+02	3.5492E+03	7.6699E+01
KING3	**3.0325E+03**	**3.4641E+01**	**5.1985E+03**	**5.2676E+02**	**3.3214E+03**	**3.3831E+01**
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.2906E+03	**1.9012E+01**	**3.6110E+03**	**1.6845E+02**	**9.1596E+05**	2.5700E+05
KING1	1.2950E+04	8.5901E+03	2.3008E+05	1.2390E+06	9.1941E+09	1.2289E+10
KING2	4.8044E+03	4.5046E+02	4.1854E+03	3.6567E+02	7.2200E+07	6.3154E+07
KING3	**3.2874E+03**	2.1584E+01	3.7629E+03	2.4647E+02	9.3659E+05	**1.3805E+05**

Table A7
AVG and STD values of ablation experiment on dimension 100

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	9.5585E+07	2.4898E+08	2.6362E+126	1.4439E+127	3.1284E+05	4.5019E+04
KING1	1.9857E+11	1.4278E+11	1.1690E+191	**6.5535E+04**	**2.5145E+05**	3.7695E+04
KING2	5.3791E+10	2.4481E+10	1.0161E+142	3.8799E+142	3.3125E+05	3.5709E+04
KING3	**1.6333E+05**	**1.5562E+05**	**1.2852E+111**	7.0396E+111	3.2054E+05	**3.0107E+04**
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**6.9111E+02**	6.2010E+01	**8.2180E+02**	**5.3317E+01**	6.0836E+02	3.2395E+00
KING1	1.0710E+05	7.6525E+04	2.0579E+03	5.0718E+02	6.9583E+02	4.8714E+01
KING2	6.3579E+03	2.3392E+03	1.0872E+03	2.1471E+02	6.0994E+02	2.9753E+00
KING3	7.0070E+02	**5.2931E+01**	1.1437E+03	3.6147E+02	**6.0770E+02**	**2.1346E+00**
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.4384E+03**	**1.1277E+02**	**1.1716E+03**	**8.0457E+01**	1.2019E+04	7.7821E+03
KING1	3.6635E+03	8.3831E+02	2.5117E+03	5.1294E+02	8.6575E+04	4.4672E+04
KING2	1.9197E+03	2.9682E+02	1.4198E+03	2.0039E+02	1.6779E+04	6.3875E+03
KING3	1.5308E+03	1.8382E+02	1.3082E+03	3.1474E+02	**9.6430E+03**	**3.9198E+03**
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.7647E+04**	6.8137E+03	**1.9514E+03**	**2.3713E+02**	**3.0516E+06**	**1.3320E+06**
KING1	2.1133E+04	1.0478E+04	2.1766E+03	1.3471E+03	1.6530E+11	1.2792E+11
KING2	2.0692E+04	5.2969E+03	2.5635E+04	1.8584E+04	9.9179E+09	4.5211E+09
KING3	2.8274E+04	**4.1379E+03**	9.4018E+03	6.6038E+03	1.0911E+07	5.5572E+06
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	6.1930E+03	**3.7808E+03**	4.8373E+05	3.9457E+05	3.7285E+03	2.8268E+03
KING1	4.8231E+10	2.9582E+10	9.9382E+07	3.7715E+08	2.4885E+10	2.0666E+10
KING2	8.6019E+08	4.2728E+08	6.6781E+06	4.7730E+06	1.4230E+08	8.2426E+07
KING3	**5.8093E+03**	4.2285E+03	**4.5367E+05**	**2.0732E+05**	**3.3291E+03**	**1.8337E+03**
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**5.2475E+03**	**1.1896E+03**	**4.4914E+03**	8.7392E+02	**2.2616E+06**	2.5093E+06
KING1	2.2256E+04	1.7542E+04	4.2330E+07	7.8034E+07	5.0134E+08	7.2002E+08
KING2	7.8380E+03	1.5601E+03	5.9604E+03	**8.1841E+02**	6.8270E+06	3.2797E+06
KING3	6.7992E+03	2.4374E+03	5.5224E+03	1.4328E+03	3.4425E+06	**2.0212E+06**
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	5.3727E+03	6.3895E+03	4.9187E+03	1.0298E+03	**2.6708E+03**	**5.8971E+01**
KING1	2.5129E+10	2.0868E+10	**4.4742E+03**	**6.5816E+02**	2.7746E+03	8.7449E+01
KING2	2.2103E+08	1.6108E+08	5.6776E+03	8.1093E+02	2.9229E+03	1.7602E+02
KING3	**3.3869E+03**	**2.0398E+03**	6.2844E+03	1.0649E+03	2.8478E+03	2.7860E+02
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	2.0563E+04	6.7799E+03	3.2053E+03	6.3711E+01	**3.7763E+03**	**8.8342E+01**
KING1	**1.8228E+04**	**3.5236E+03**	3.2404E+03	7.3403E+01	5.4220E+03	3.8525E+03
KING2	2.4942E+04	5.4799E+03	3.3049E+03	8.6324E+01	4.0626E+03	1.4979E+02
KING3	2.9845E+04	8.3616E+03	**3.1548E+03**	**6.1638E+01**	3.8235E+03	1.2718E+02
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.3401E+03**	**5.7590E+01**	1.1942E+04	**1.0468E+03**	3.7679E+03	1.0725E+02
KING1	2.5065E+04	1.5591E+04	5.1337E+04	2.0155E+04	3.8515E+03	1.0428E+02
KING2	8.1628E+03	1.6965E+03	1.4612E+04	1.8684E+03	4.1529E+03	1.5117E+02
KING3	3.3480E+03	5.9680E+01	**1.0967E+04**	1.7179E+03	**3.5175E+03**	**5.1234E+01**
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.4421E+03**	**3.8110E+01**	6.3523E+03	6.1796E+02	**1.4669E+04**	1.0893E+04
KING1	3.5615E+04	1.6349E+04	4.1874E+06	4.5460E+06	2.8569E+10	3.1063E+10
KING2	1.1764E+04	2.0995E+03	7.9520E+03	8.7659E+02	9.3072E+08	3.7752E+08
KING3	3.4832E+03	4.1815E+01	**5.9362E+03**	**5.6524E+02**	1.7564E+04	**8.5528E+03**

Comparison results with basic algorithms

Table A8
AVG and STD values of comparative with classical algorithms on dimension 10

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.16415E+03**	**1.30493E+03**	2.00001E+02	1.13774E−03	3.00000E+02	7.89906E−14
GWO	1.49518E+07	6.37175E+07	4.10438E+06	1.20967E+07	2.26546E+03	3.22105E+03
WOA	9.70258E+03	1.85399E+04	1.19821E+03	2.41982E+03	3.48767E+02	6.59910E+01
SCA	3.63802E+08	1.23719E+08	1.78678E+06	5.97284E+06	9.08089E+02	5.41916E+02
PSO	4.08588E+06	1.40338E+06	2.59939E+02	3.48363E+01	3.11333E+02	3.15138E+00
MFO	1.25402E+08	4.31227E+08	1.17674E+09	3.79968E+09	1.18557E+04	1.42362E+04
MVO	5.24927E+03	4.24334E+03	2.00001E+02	4.21117E−04	3.00001E+02	3.87317E−04
ACOR	6.90068E+03	4.10170E+03	2.00000E+02	2.22319E−05	**3.00000E+02**	**2.79274E−14**
HHO	2.05044E+05	7.50134E+04	2.03731E+02	1.13544E+01	3.00591E+02	2.65315E−01
RFO	3.18814E+04	1.13695E+04	2.00003E+02	1.30360E−03	3.00085E+02	2.41390E−02
RIME	2.35218E+03	2.02213E+03	2.00000E+02	2.37347E−04	3.00000E+02	1.86968E−04
SMA	7.37807E+03	4.27430E+03	2.00000E+02	5.59732E−05	3.00000E+02	1.02091E−05
RUN	3.75949E+03	1.83422E+03	2.00001E+02	5.57450E−04	3.00000E+02	9.37568E−05
HBA	1.43275E+03	1.65550E+03	**2.00000E+02**	**3.42500E−06**	3.00000E+02	5.17115E−14
PO	5.41628E+08	7.06668E+08	6.62623E+07	1.28091E+08	3.00000E+02	6.15490E−14

	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	4.00038E+02	**7.61335E−03**	**5.07055E+02**	**2.47433E+00**	**6.00000E+02**	**6.79138E−05**
GWO	4.19232E+02	2.67248E+01	5.13170E+02	6.88372E+00	6.00764E+02	1.25139E+00
WOA	4.17015E+02	2.62585E+01	5.45854E+02	1.67693E+01	6.23538E+02	1.26678E+01
SCA	4.25754E+02	6.76661E+00	5.38785E+02	5.09183E+00	6.13737E+02	2.54432E+00
PSO	4.07112E+02	1.23262E+01	5.41228E+02	1.51180E+01	6.08174E+02	6.78505E+00
MFO	4.21551E+02	3.81655E+01	5.29294E+02	1.13990E+01	6.04761E+02	5.82034E+00
MVO	4.02147E+02	1.01000E+01	5.12823E+02	5.76891E+00	6.00097E+02	1.53083E−01
ACOR	**4.00009E+02**	2.85456E−02	5.10755E+02	6.53166E+00	6.00337E+02	1.46418E+00
HHO	4.07105E+02	1.25299E+01	5.42212E+02	1.57294E+01	6.23979E+02	1.07533E+01
RFO	4.00143E+02	1.48398E−01	5.83377E+02	3.26294E+01	6.55618E+02	7.59288E+00
RIME	4.00977E+02	6.03094E−01	5.09485E+02	3.89954E+00	6.00005E+02	3.57402E−03
SMA	4.01345E+02	3.98932E−01	5.11089E+02	4.85617E+00	6.00013E+02	6.55943E−03
RUN	4.00102E+02	3.31949E−02	5.28522E+02	6.02851E+00	6.11556E+02	7.57651E+00
HBA	4.01964E+02	1.01344E+01	5.17134E+02	6.48948E+00	6.00319E+02	8.13894E−01
PO	4.07018E+02	3.12238E+00	5.15770E+02	1.02131E+01	6.20895E+02	1.33780E+01

	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.18467E+02**	3.88730E+00	**8.06268E+02**	**2.77938E+00**	9.00018E+02	8.39882E−02
GWO	7.26057E+02	8.60728E+00	8.13638E+02	6.58770E+00	9.11187E+02	2.12205E+01
WOA	7.75613E+02	2.49962E+01	8.38801E+02	1.42572E+01	1.16170E+03	1.97993E+02
SCA	7.61299E+02	7.42303E+00	8.29020E+02	5.40308E+00	9.48281E+02	2.14070E+01
PSO	7.31293E+02	3.89338E+00	8.21358E+02	8.28814E+00	9.01472E+02	3.37835E−01
MFO	7.40237E+02	1.33029E+01	8.31013E+02	1.32518E+01	1.01695E+03	1.64868E+02
MVO	7.24154E+02	7.29807E+00	8.13866E+02	6.53951E+00	9.00030E+02	1.15267E−01
ACOR	7.21280E+02	8.74549E+00	8.07934E+02	4.95059E+00	9.01307E+02	2.77464E+00
HHO	7.74288E+02	1.98347E+01	8.27899E+02	7.44727E+00	1.26750E+03	2.56294E+02
RFO	8.14958E+02	6.19433E+00	8.42045E+02	1.15633E+01	1.74168E+03	1.06326E+02
RIME	7.20077E+02	**3.40854E+00**	8.08623E+02	4.13409E+00	9.00000E+02	6.87441E−05
SMA	7.18507E+02	4.16214E+00	8.10314E+02	3.98396E+00	**9.00000E+02**	**2.16392E−05**
RUN	7.59690E+02	1.45797E+01	8.24774E+02	4.82039E+00	9.79608E+02	6.12871E+01
HBA	7.28416E+02	1.11430E+01	8.16118E+02	5.64891E+00	9.00351E+02	8.43811E−01
PO	7.44554E+02	3.10675E+01	8.31342E+02	6.79350E+00	1.64644E+03	2.51788E+02

	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.21751E+03**	**1.38677E+02**	**1.10248E+03**	**2.18705E+00**	**7.78861E+03**	6.94272E+03
GWO	1.48669E+03	2.46591E+02	1.13426E+03	5.02197E+01	4.07666E+05	5.91075E+05
WOA	1.85308E+03	3.35715E+02	1.19681E+03	9.06669E+01	3.13662E+06	4.14150E+06
SCA	2.04283E+03	1.93285E+02	1.16557E+03	2.72843E+01	6.10199E+06	5.70967E+06
PSO	1.95369E+03	2.82396E+02	1.13829E+03	1.49185E+01	2.19803E+05	1.63363E+05
MFO	2.00304E+03	3.54477E+02	1.27690E+03	5.31980E+02	8.47807E+06	3.93266E+07
MVO	1.51630E+03	1.83288E+02	1.11005E+03	5.11731E+00	2.80088E+04	1.84856E+04
ACOR	1.47567E+03	3.15132E+02	1.12576E+03	3.82539E+01	1.90367E+04	1.83088E+04
HHO	1.90699E+03	2.70193E+02	1.14255E+03	1.97706E+01	1.27712E+06	1.02768E+06
RFO	2.53062E+03	3.37948E+02	1.19307E+03	4.90257E+01	2.00785E+04	1.30893E+04
RIME	1.36060E+03	1.49932E+02	1.10597E+03	3.08669E+00	1.74626E+04	1.71749E+04
SMA	1.46421E+03	2.10400E+02	1.10755E+03	3.75476E+00	3.69278E+04	2.24334E+04
RUN	1.48902E+03	1.48638E+02	1.12348E+03	6.06003E+00	9.48278E+03	**5.78906E+03**
HBA	1.93877E+03	6.00758E+02	1.11171E+03	9.26951E+00	1.27080E+04	1.40082E+04

(*continued on next page*)

Table A8 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
PO	1.78922E+03	3.08595E+02	1.36253E+03	3.45230E+02	5.36279E+06	8.44236E+06
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.40035E+03**	**1.75621E+02**	**1.40569E+03**	**4.42032E+00**	1.50825E+03	1.25007E+01
GWO	7.28088E+03	3.40348E+03	2.07362E+03	1.37578E+03	2.70501E+03	1.75625E+03
WOA	2.26146E+04	1.42875E+04	1.50591E+03	3.62193E+01	2.51567E+03	1.16756E+03
SCA	1.20163E+04	9.27583E+03	1.51463E+03	3.51226E+01	1.68935E+03	9.41492E+01
PSO	1.17218E+04	8.77640E+03	1.45772E+03	1.51925E+01	1.59660E+03	4.04383E+01
MFO	1.22305E+04	1.06337E+04	5.68192E+03	7.01473E+03	1.34669E+04	1.56243E+04
MVO	1.15735E+04	9.29017E+03	1.42160E+03	7.93312E+00	1.50740E+03	3.56423E+00
ACOR	1.20618E+04	1.07082E+04	5.12078E+03	6.80648E+03	4.73895E+03	5.96849E+03
HHO	1.72127E+04	1.13824E+04	1.50235E+03	2.46917E+01	1.92388E+03	3.59559E+02
RFO	1.01167E+04	6.99279E+03	1.90723E+03	2.52545E+02	1.74790E+03	1.31743E+02
RIME	1.32495E+04	9.96631E+03	1.40930E+03	7.16637E+00	**1.50459E+03**	**3.30981E+00**
SMA	7.91228E+03	8.34913E+03	1.42891E+03	1.23397E+01	1.50768E+03	5.55822E+00
RUN	5.43321E+03	2.59342E+03	1.44064E+03	1.24151E+01	1.52570E+03	4.63707E+00
HBA	1.87682E+03	4.20952E+02	1.47780E+03	5.16874E+01	1.54721E+03	5.63965E+01
PO	5.65358E+04	1.46332E+05	1.56217E+03	5.08060E+01	3.81863E+03	1.64419E+03
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.60065E+03**	**2.81700E−01**	**1.70581E+03**	1.19116E+01	2.90307E+03	3.95266E+03
GWO	1.70999E+03	1.13763E+02	1.74939E+03	1.78178E+01	2.52504E+04	1.35233E+04
WOA	1.76666E+03	1.16667E+02	1.78628E+03	4.26893E+01	1.92481E+04	1.38035E+04
SCA	1.66581E+03	2.54047E+01	1.76149E+03	**8.70515E+00**	4.65765E+04	2.13169E+04
PSO	1.81740E+03	1.39751E+02	1.78142E+03	3.99069E+01	1.40679E+04	1.66264E+04
MFO	1.78660E+03	1.16707E+02	1.77768E+03	5.46540E+01	1.80849E+04	1.66780E+04
MVO	1.73052E+03	1.20881E+02	1.75779E+03	5.76782E+01	5.61144E+03	3.52830E+03
ACOR	1.70900E+03	1.15595E+02	1.75410E+03	4.54526E+01	2.40314E+04	1.37571E+04
HHO	1.91486E+03	1.12331E+02	1.77978E+03	2.99598E+01	1.54384E+04	1.26940E+04
RFO	2.13266E+03	2.54004E+02	1.98643E+03	1.76265E+02	1.23153E+04	1.00153E+04
RIME	1.72263E+03	1.14007E+02	1.72958E+03	3.27264E+01	**2.53178E+03**	**1.26569E+03**
SMA	1.71240E+03	8.63125E+01	1.72812E+03	1.71972E+01	1.63442E+04	9.23360E+03
RUN	1.70747E+03	9.06828E+01	1.75530E+03	1.69869E+01	1.50952E+04	1.09526E+04
HBA	1.71484E+03	1.15858E+02	1.74217E+03	1.90071E+01	2.93580E+03	2.60980E+03
PO	1.71879E+03	1.33007E+02	1.96503E+03	5.22541E+01	4.82796E+04	1.89196E+05
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	1.90323E+03	4.82076E+00	**2.00167E+03**	**1.26738E+00**	2.28290E+03	4.66189E+01
GWO	3.33789E+03	3.69055E+03	2.06197E+03	4.68035E+01	2.31040E+03	2.00650E+01
WOA	1.70739E+04	1.28306E+04	2.12321E+03	6.09473E+01	2.29648E+03	7.15462E+01
SCA	2.11330E+03	2.54301E+02	2.07073E+03	1.18040E+01	2.20757E+03	**2.84614E+00**
PSO	1.92452E+03	1.41721E+01	2.11912E+03	7.05204E+01	2.32981E+03	4.60821E+01
MFO	1.41986E+04	1.77851E+04	2.11094E+03	7.51956E+01	2.32302E+03	4.25707E+01
MVO	1.90514E+03	1.69771E+00	2.07480E+03	8.57123E+01	2.29728E+03	4.48215E+01
ACOR	9.27022E+03	1.07132E+04	2.07907E+03	8.51746E+01	2.31283E+03	5.83180E+00
HHO	6.76116E+03	5.28577E+03	2.13292E+03	5.83712E+01	2.32484E+03	5.86182E+01
RFO	1.95270E+03	3.64695E+01	2.34235E+03	1.49428E+02	2.35968E+03	5.97021E+01
RIME	**1.90200E+03**	**1.18105E+00**	2.00870E+03	2.26070E+01	2.28722E+03	4.87453E+01
SMA	1.90402E+03	5.69275E+00	2.01426E+03	9.58697E+00	2.29404E+03	4.74782E+01
RUN	4.04248E+03	4.34205E+03	2.07658E+03	5.42554E+01	**2.20413E+03**	2.15186E+01
HBA	1.97927E+03	1.91176E+02	2.04898E+03	5.95572E+01	2.29239E+03	5.19765E+01
PO	3.07906E+03	4.49178E+02	2.16774E+03	9.53743E+01	2.33424E+03	3.35195E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.29821E+03**	1.85548E+01	**2.60855E+03**	**3.23367E+00**	**2.70548E+03**	8.20671E+01
GWO	2.30921E+03	9.77216E+00	2.61461E+03	8.10308E+00	2.73072E+03	4.13240E+01
WOA	2.38762E+03	3.24136E+02	2.64380E+03	1.78460E+01	2.76661E+03	5.44114E+01
SCA	2.33803E+03	1.92987E+01	2.64493E+03	6.67132E+00	2.72809E+03	9.03787E+01
PSO	2.34545E+03	2.27283E+02	2.69921E+03	3.45841E+01	2.77173E+03	7.45289E+01
MFO	2.31184E+03	2.26459E+01	2.62770E+03	1.11516E+01	2.76601E+03	1.17991E+01
MVO	2.31917E+03	1.06116E+02	2.61458E+03	5.93648E+00	2.73854E+03	4.56935E+01
ACOR	2.34068E+03	1.48297E+02	2.61828E+03	8.18268E+00	2.74535E+03	**6.34127E+00**
HHO	2.35155E+03	1.67236E+02	2.66002E+03	2.19485E+01	2.80345E+03	9.13331E+01
RFO	2.56357E+03	5.66212E+02	2.77141E+03	7.37083E+01	2.89884E+03	6.41810E+01
RIME	2.31036E+03	4.00724E+01	2.61386E+03	5.87634E+00	2.72443E+03	7.64439E+01
SMA	2.35863E+03	2.26609E+02	2.61774E+03	6.18961E+00	2.74774E+03	4.75660E+01
RUN	2.30403E+03	**2.95990E+00**	2.62201E+03	8.75938E+00	2.72860E+03	6.23483E+01
HBA	2.29903E+03	1.41892E+01	2.62335E+03	1.20010E+01	2.74616E+03	4.82319E+01

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Table A8 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
PO	2.41654E+03	1.34286E+02	2.63290E+03	1.23218E+01	2.78307E+03	1.42162E+01
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	2.91535E+03	2.25463E+01	**2.89518E+03**	2.77755E+01	3.09401E+03	2.36255E+00
GWO	2.92578E+03	1.87601E+01	3.08524E+03	3.77816E+02	3.09843E+03	1.37527E+01
WOA	2.91506E+03	7.70012E+01	3.23701E+03	4.81623E+02	3.11758E+03	3.44175E+01
SCA	2.94516E+03	**1.75392E+01**	3.02986E+03	**2.21759E+01**	3.09965E+03	**1.64035E+00**
PSO	2.92654E+03	2.24880E+01	3.06182E+03	3.89582E+02	3.14331E+03	5.24026E+01
MFO	2.94031E+03	3.26576E+01	3.04296E+03	7.00268E+01	3.09509E+03	3.27808E+00
MVO	2.91983E+03	2.37123E+01	2.97199E+03	2.62006E+02	3.09197E+03	9.30421E+00
ACOR	2.94204E+03	2.10191E+01	3.26334E+03	4.31771E+02	3.10153E+03	2.14741E+01
HHO	2.92095E+03	4.31234E+01	3.41859E+03	5.81340E+02	3.14884E+03	3.73723E+01
RFO	2.94465E+03	2.14082E+01	4.00801E+03	6.86754E+02	3.23292E+03	6.08869E+01
RIME	2.92050E+03	6.50913E+01	2.96744E+03	2.72400E+02	3.09427E+03	3.98254E+00
SMA	2.93642E+03	2.45450E+01	3.14157E+03	3.97324E+02	**3.09193E+03**	9.25260E+00
RUN	2.92131E+03	2.36227E+01	2.93699E+03	1.49706E+02	3.09348E+03	2.25243E+00
HBA	2.93424E+03	1.97778E+01	3.07818E+03	3.86538E+02	3.12558E+03	4.96080E+01
PO	**2.91312E+03**	2.03038E+01	2.93683E+03	6.43031E+01	3.10120E+03	2.98680E+00
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.13877E+03**	1.00632E+02	**3.14985E+03**	**1.28973E+01**	**5.76524E+03**	**1.61069E+03**
GWO	3.36958E+03	8.11101E+01	3.18288E+03	4.83446E+01	5.37425E+05	9.34918E+05
WOA	3.34465E+03	1.52100E+02	3.32340E+03	8.14704E+01	3.07684E+05	4.05874E+05
SCA	3.21986E+03	**2.03655E+01**	3.19072E+03	1.78357E+01	2.63287E+05	2.35721E+05
PSO	3.15732E+03	3.80968E+01	3.23429E+03	5.46980E+01	1.96156E+04	1.70356E+04
MFO	3.31645E+03	9.55094E+01	3.24335E+03	7.64945E+01	6.87643E+05	5.62456E+05
MVO	3.27920E+03	1.47316E+02	3.21226E+03	7.24288E+01	4.39148E+05	5.52373E+05
ACOR	3.40130E+03	1.55285E+02	3.16721E+03	4.97488E+01	7.55915E+05	7.56205E+05
HHO	3.35891E+03	1.25585E+02	3.29688E+03	7.52418E+01	5.11243E+05	7.46861E+05
RFO	3.33930E+03	1.45263E+02	3.55406E+03	2.38708E+02	3.48308E+05	6.03573E+05
RIME	3.24479E+03	1.63171E+02	3.16985E+03	3.01114E+01	1.99685E+05	3.97549E+05
SMA	3.25287E+03	1.74953E+02	3.16123E+03	2.91542E+01	8.79481E+04	2.48462E+05
RUN	3.30159E+03	1.39941E+02	3.19178E+03	3.33697E+01	3.20512E+04	1.49085E+05
HBA	3.42873E+03	2.27634E+02	3.22754E+03	6.44622E+01	2.49562E+06	4.53769E+06
PO	3.38580E+03	1.26084E+02	3.17742E+03	3.08308E+01	4.78218E+05	3.05129E+05

Table A9
AVG and STD values of comparative with classical algorithms on dimension 30

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.17946E+03**	**3.08103E+03**	2.00001E+02	2.48388E−03	3.02108E+02	1.11281E+01
GWO	2.20981E+09	1.50823E+09	1.58733E+31	6.55653E+31	3.16441E+04	1.01677E+04
WOA	2.43476E+06	1.79472E+06	8.81075E+20	3.60949E+21	1.49127E+05	6.27146E+04
SCA	1.23737E+10	1.63208E+09	4.74353E+34	1.91894E+35	3.55678E+04	6.91080E+03
PSO	1.32723E+08	1.05939E+07	3.21158E+13	2.58033E+13	6.18254E+02	3.79475E+01
MFO	1.03328E+10	7.77682E+09	1.50715E+37	7.42725E+37	9.81398E+04	5.79710E+04
MVO	1.14208E+04	6.54150E+03	9.25512E+02	1.50245E+03	3.00344E+02	1.18372E−01
ACOR	1.16148E+08	6.36103E+08	3.13923E+27	1.44289E+28	8.41349E+03	9.15488E+03
HHO	1.03263E+07	1.96373E+06	2.25919E+12	3.71147E+12	4.89373E+03	2.31733E+03
RFO	4.30740E+06	5.98167E+05	2.84628E+02	1.78515E+02	3.10379E+02	1.86562E+00
RIME	7.28893E+03	5.09463E+03	1.04840E+03	1.68030E+03	3.01899E+02	8.77840E−01
SMA	8.88106E+03	7.17508E+03	**2.00001E+02**	1.87756E−03	3.00006E+02	3.21292E−03
RUN	5.92921E+03	5.66142E+03	2.00002E+02	**1.75348E−03**	3.00158E+02	1.18607E−01
HBA	4.96459E+03	5.23056E+03	2.60329E+03	1.05433E+04	**3.00000E+02**	**4.16246E−05**
PO	4.55050E+08	2.14347E+09	1.64175E+39	8.76707E+39	5.22488E+04	9.12793E+03
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.45657E+02**	3.81493E+01	**5.52235E+02**	1.46874E+01	**6.00081E+02**	**9.60942E−02**
GWO	5.68496E+02	5.73224E+01	6.05500E+02	2.30962E+01	6.06728E+02	4.25558E+00
WOA	5.52511E+02	4.23651E+01	7.93458E+02	6.28744E+01	6.68062E+02	9.97294E+00
SCA	1.48624E+03	4.38147E+02	7.77844E+02	2.20861E+01	6.49271E+02	4.80084E+00
PSO	4.73841E+02	2.89407E+01	7.43312E+02	2.49555E+01	6.52408E+02	1.54893E+01
MFO	1.54726E+03	1.16648E+03	7.02583E+02	4.87185E+01	6.38904E+02	1.24915E+01
MVO	4.88826E+02	**5.31680E+00**	5.88543E+02	2.94711E+01	6.09475E+02	1.04017E+01
ACOR	4.92269E+02	6.07344E+01	6.07029E+02	6.28353E+01	6.04274E+02	4.13880E+00

(*continued on next page*)

Table A9 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
HHO	5.37750E+02	4.04940E+01	7.36763E+02	2.58378E+01	6.60488E+02	6.24977E+00
RFO	4.96840E+02	1.95643E+01	8.08427E+02	**1.15776E+01**	6.74653E+02	8.41116E+00
RIME	4.87492E+02	2.60993E+01	5.79335E+02	2.07524E+01	6.00381E+02	5.38415E−01
SMA	4.88658E+02	1.36807E+01	5.88709E+02	2.34966E+01	6.00958E+02	8.46400E−01
RUN	4.96720E+02	1.91801E+01	7.02159E+02	4.08375E+01	6.42614E+02	9.71882E+00
HBA	4.56426E+02	3.64136E+01	6.16075E+02	3.05013E+01	6.03910E+02	3.12634E+00
PO	6.02065E+02	3.52101E+02	5.79450E+02	2.77413E+01	6.11237E+02	1.84490E+01

	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.92987E+02**	2.07003E+01	**8.51074E+02**	1.42715E+01	**9.19751E+02**	**2.13642E+01**
GWO	8.65287E+02	4.01306E+01	8.87631E+02	1.74628E+01	1.74159E+03	5.14355E+02
WOA	1.23101E+03	7.39205E+01	1.01583E+03	5.08032E+01	8.58557E+03	3.86525E+03
SCA	1.11526E+03	3.61162E+01	1.05299E+03	1.49624E+01	5.54383E+03	9.85775E+02
PSO	9.17293E+02	**1.56452E+01**	9.87360E+02	2.82145E+01	6.05036E+03	2.20029E+03
MFO	1.13335E+03	1.63572E+02	1.00807E+03	6.21992E+01	7.21651E+03	2.32554E+03
MVO	8.22529E+02	2.66368E+01	8.95243E+02	2.55495E+01	2.16939E+03	2.33278E+03
ACOR	9.26794E+02	6.95956E+01	8.86448E+02	4.69900E+01	1.55593E+03	6.65472E+02
HHO	1.24178E+03	8.09356E+01	9.58050E+02	2.83778E+01	6.49843E+03	6.23099E+02
RFO	1.35058E+03	2.40656E+01	9.97806E+02	**7.66982E+00**	7.43276E+03	6.50001E+02
RIME	8.15094E+02	2.55650E+01	8.79787E+02	1.75951E+01	1.22462E+03	4.82600E+02
SMA	8.36965E+02	2.13243E+01	9.05648E+02	2.40203E+01	2.21042E+03	1.27974E+03
RUN	1.01084E+03	6.98685E+01	9.49376E+02	1.74740E+01	3.55418E+03	7.10859E+02
HBA	8.73230E+02	3.64280E+01	9.05050E+02	2.27171E+01	1.95394E+03	7.92263E+02
PO	8.16476E+02	1.61170E+01	8.99269E+02	5.85941E+01	3.38319E+03	1.42744E+03

	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	3.80059E+03	5.77856E+02	**1.16132E+03**	2.96322E+01	**3.16632E+04**	**1.25467E+04**
GWO	4.00785E+03	5.55671E+02	1.86733E+03	8.61468E+02	7.77393E+07	8.97696E+07
WOA	6.09817E+03	9.98245E+02	1.57984E+03	4.55245E+02	4.13110E+07	2.69278E+07
SCA	8.15775E+03	**2.41472E+02**	2.23858E+03	6.82315E+02	1.11032E+09	3.04836E+08
PSO	5.92139E+03	5.64702E+02	1.29131E+03	4.67978E+01	2.55524E+07	1.03771E+07
MFO	5.14711E+03	8.62315E+02	5.62912E+03	5.19158E+03	4.00557E+08	7.18761E+08
MVO	4.11682E+03	5.55138E+02	1.23963E+03	5.31780E+01	3.54242E+06	3.09124E+06
ACOR	4.62950E+03	2.01663E+03	1.31652E+03	7.51633E+01	3.39552E+05	6.44176E+05
HHO	5.50675E+03	6.64534E+02	1.25008E+03	4.06081E+01	9.59803E+06	6.10438E+06
RFO	5.77815E+03	7.26757E+02	1.29542E+03	6.42270E+01	3.28397E+06	1.51125E+06
RIME	**3.66500E+03**	5.24774E+02	1.18112E+03	3.36523E+01	2.00556E+06	1.83888E+06
SMA	4.30327E+03	6.03377E+02	1.23090E+03	4.65231E+01	8.69974E+05	7.86159E+05
RUN	4.49517E+03	8.21162E+02	1.19206E+03	**2.58815E+01**	1.42162E+06	6.76169E+05
HBA	4.85317E+03	1.12298E+03	1.21011E+03	5.14328E+01	4.55110E+04	4.80149E+04
PO	4.61464E+03	1.00845E+03	1.41929E+03	6.07402E+02	2.22970E+08	5.61119E+08

	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	1.62429E+04	1.57211E+04	4.77803E+03	3.56740E+03	**8.61064E+03**	6.52650E+03
GWO	1.00830E+07	5.01844E+07	1.50246E+05	2.80597E+05	2.68827E+05	7.54872E+05
WOA	1.32388E+05	6.06962E+04	8.77048E+05	9.02895E+05	6.68741E+04	5.14648E+04
SCA	3.53052E+08	1.14558E+08	1.74844E+05	1.16049E+05	1.55614E+07	1.07012E+07
PSO	4.44403E+06	1.43851E+06	8.40246E+03	4.91104E+03	4.69148E+05	1.86370E+05
MFO	3.42589E+06	1.30179E+07	2.00181E+05	4.16622E+05	6.64389E+04	5.10656E+04
MVO	8.00461E+04	5.39178E+04	6.30954E+03	5.03752E+03	1.86560E+04	1.36557E+04
ACOR	2.30368E+04	2.32492E+04	1.91774E+04	1.11596E+04	2.05502E+04	1.44629E+04
HHO	4.13437E+05	3.66674E+05	4.05500E+04	4.80165E+04	5.22522E+04	3.16762E+04
RFO	2.42492E+05	8.59882E+04	5.92114E+03	3.81054E+03	4.55288E+04	2.78480E+04
RIME	**1.44080E+04**	1.83656E+04	1.22056E+04	8.14463E+03	1.03317E+04	1.01885E+04
SMA	3.47151E+04	2.68442E+04	2.60047E+04	1.50455E+04	1.93576E+04	1.59191E+04
RUN	2.91327E+04	**1.26050E+04**	**2.59791E+03**	**8.60356E+02**	1.61231E+04	**2.57866E+03**
HBA	3.12124E+04	2.26919E+04	1.63165E+04	6.89237E+04	1.03535E+04	1.09847E+04
PO	3.01588E+08	4.63408E+08	2.91958E+05	3.17905E+05	3.16883E+05	1.65379E+06

	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.09680E+03**	**2.00074E+02**	**1.78110E+03**	**7.56663E+01**	1.61005E+05	1.14940E+05
GWO	2.38400E+03	3.19492E+02	1.99280E+03	1.44604E+02	1.09842E+06	2.14517E+06
WOA	3.70635E+03	4.99144E+02	2.65267E+03	3.22827E+02	2.27123E+06	2.03080E+06
SCA	3.58235E+03	2.09411E+02	2.37613E+03	1.90477E+02	2.93217E+06	1.83993E+06
PSO	2.95154E+03	3.27161E+02	2.40306E+03	1.91974E+02	1.76170E+05	8.21741E+04
MFO	3.20633E+03	4.53164E+02	2.49067E+03	2.67389E+02	5.72150E+06	1.25929E+07
MVO	2.37002E+03	2.93328E+02	2.02209E+03	1.50642E+02	2.41101E+05	2.51338E+05
ACOR	2.23601E+03	3.61495E+02	2.03125E+03	1.99244E+02	6.61734E+05	7.80366E+05

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Table A9 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
HHO	3.25670E+03	3.30773E+02	2.52544E+03	2.72293E+02	6.84714E+05	6.47642E+05
RFO	3.57966E+03	4.38358E+02	2.85519E+03	3.09535E+02	1.49959E+05	8.77987E+04
RIME	2.46216E+03	2.25232E+02	2.08087E+03	1.82790E+02	2.67362E+05	2.73779E+05
SMA	2.39156E+03	2.73957E+02	2.22030E+03	2.12374E+02	3.83908E+05	3.29898E+05
RUN	2.62060E+03	2.09464E+02	2.19456E+03	2.13772E+02	**4.18439E+04**	**1.59324E+04**
HBA	2.54159E+03	4.02655E+02	2.19541E+03	2.26971E+02	9.35889E+04	5.65201E+04
PO	3.25960E+03	6.40840E+02	2.80701E+03	3.24995E+02	4.78485E+06	3.73515E+06
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	7.72399E+03	7.04607E+03	**2.12986E+03**	**7.87434E+01**	**2.35077E+03**	2.02517E+01
GWO	7.04629E+05	1.55466E+06	2.37541E+03	1.33627E+02	2.38172E+03	1.76131E+01
WOA	2.69264E+06	2.00778E+06	2.73640E+03	1.72982E+02	2.56715E+03	6.19412E+01
SCA	1.92291E+07	1.16219E+07	2.56054E+03	1.03029E+02	2.55640E+03	**1.57995E+01**
PSO	1.40001E+06	6.51111E+05	2.62450E+03	1.86925E+02	2.52257E+03	7.16715E+01
MFO	1.87651E+07	4.76571E+07	2.71409E+03	2.83411E+02	2.50810E+03	4.49711E+01
MVO	2.58561E+04	2.31597E+04	2.27650E+03	1.26149E+02	2.38711E+03	2.31434E+01
ACOR	3.31746E+04	2.27418E+04	2.26820E+03	1.93054E+02	2.42438E+03	6.65296E+01
HHO	2.63303E+05	1.87211E+05	2.78703E+03	2.14913E+02	2.54113E+03	4.11847E+01
RFO	3.84621E+05	1.72391E+05	3.08909E+03	2.62203E+02	2.68071E+03	6.80733E+01
RIME	1.25769E+04	1.37840E+04	2.33078E+03	1.43861E+02	2.38980E+03	1.72965E+01
SMA	2.35791E+04	2.13975E+04	2.48910E+03	1.94573E+02	2.40501E+03	2.72453E+01
RUN	7.89582E+03	**4.54169E+03**	2.41420E+03	1.28242E+02	2.45063E+03	4.45058E+01
HBA	**7.58784E+03**	8.59577E+03	2.47404E+03	2.32917E+02	2.39624E+03	2.74647E+01
PO	1.28158E+07	1.86074E+07	2.71561E+03	1.68586E+02	2.36617E+03	1.61516E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.30200E+03**	**2.85882E+00**	**2.70737E+03**	2.13702E+01	**2.87736E+03**	**1.84250E+01**
GWO	4.43381E+03	1.40190E+03	2.75131E+03	3.34831E+01	2.92351E+03	5.57374E+01
WOA	6.96381E+03	1.74696E+03	3.03600E+03	9.86368E+01	3.17495E+03	8.31666E+01
SCA	7.26886E+03	2.88303E+03	2.98278E+03	2.86725E+01	3.16016E+03	2.37535E+01
PSO	5.37970E+03	2.54045E+03	3.06962E+03	1.08991E+02	3.25774E+03	1.06928E+02
MFO	6.47743E+03	1.09302E+03	2.84024E+03	3.89092E+01	2.98293E+03	3.27158E+01
MVO	5.37657E+03	8.04756E+02	2.73122E+03	3.25521E+01	2.89961E+03	2.38303E+01
ACOR	5.86733E+03	1.89734E+03	2.74358E+03	3.33319E+01	2.93412E+03	5.92460E+01
HHO	6.26702E+03	2.09924E+03	3.16816E+03	9.04566E+01	3.41451E+03	1.35834E+02
RFO	7.32943E+03	1.54150E+03	3.55808E+03	1.99915E+02	3.66369E+03	1.22606E+02
RIME	4.48453E+03	1.41391E+03	2.74086E+03	1.94255E+01	2.93792E+03	3.71433E+01
SMA	5.23725E+03	1.16416E+03	2.74264E+03	**1.88908E+01**	2.92396E+03	2.72371E+01
RUN	2.71570E+03	1.10875E+03	2.77306E+03	3.22299E+01	2.91697E+03	2.78449E+01
HBA	3.70196E+03	2.47230E+03	2.76503E+03	3.76564E+01	3.01348E+03	2.13853E+02
PO	5.27411E+03	1.83072E+03	2.83229E+03	7.24672E+01	3.30400E+03	1.02959E+02
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	2.89841E+03	1.72855E+01	**3.84269E+03**	6.30277E+02	3.22112E+03	1.42342E+01
GWO	2.98204E+03	4.93379E+01	4.51789E+03	4.49530E+02	3.25342E+03	3.13403E+01
WOA	2.96021E+03	3.57057E+01	7.93818E+03	1.05138E+03	3.37722E+03	1.14943E+02
SCA	3.21750E+03	1.11584E+02	6.85905E+03	3.27362E+02	3.39232E+03	3.49474E+01
PSO	2.90811E+03	3.02897E+01	5.81022E+03	1.77119E+03	**3.17860E+03**	4.55551E+01
MFO	3.35092E+03	5.25057E+02	5.91730E+03	4.44049E+02	3.25016E+03	2.52536E+01
MVO	2.88850E+03	7.33328E+00	4.49242E+03	**2.30846E+02**	3.21235E+03	**1.02892E+01**
ACOR	2.90178E+03	4.32869E+01	4.66074E+03	4.41454E+02	3.23632E+03	2.38665E+01
HHO	2.91224E+03	2.08512E+01	5.95204E+03	2.10311E+03	3.34469E+03	9.39177E+01
RFO	**2.88560E+03**	3.47221E+00	7.80473E+03	2.90265E+03	4.06267E+03	4.47623E+02
RIME	2.88832E+03	3.90373E+00	4.42356E+03	7.51849E+02	3.22452E+03	1.15043E+01
SMA	2.88700E+03	**1.20874E+00**	4.58072E+03	4.08653E+02	3.21573E+03	1.23660E+01
RUN	2.90375E+03	1.56580E+01	4.95924E+03	1.70050E+03	3.24646E+03	1.92709E+01
HBA	2.89158E+03	1.41011E+01	4.50674E+03	8.94513E+02	3.36273E+03	1.93009E+02
PO	2.89762E+03	1.63252E+01	6.21014E+03	1.40262E+03	3.38989E+03	6.57807E+01
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.12980E+03	5.10180E+01	**3.42899E+03**	**6.40612E+01**	**7.67981E+03**	**1.95683E+03**
GWO	3.41272E+03	1.16885E+02	3.77176E+03	1.94059E+02	4.56180E+06	4.05750E+06
WOA	3.30017E+03	2.97750E+01	4.78105E+03	4.10259E+02	1.21543E+07	1.29748E+07
SCA	3.79863E+03	9.56290E+01	4.64976E+03	2.33024E+02	6.75163E+07	3.12938E+07
PSO	3.24626E+03	**2.19043E+01**	4.26955E+03	2.66936E+02	3.45236E+06	1.65778E+06
MFO	4.59870E+03	1.00461E+03	4.10449E+03	2.30211E+02	3.20749E+06	1.36200E+07
MVO	3.21051E+03	4.17709E+01	3.72776E+03	1.18944E+02	8.52203E+05	7.57705E+05
ACOR	3.28736E+03	8.71020E+01	3.75776E+03	1.69530E+02	1.61247E+04	1.81056E+04

(*continued on next page*)

Table A9 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
HHO	3.25681E+03	4.26199E+01	4.31854E+03	5.21555E+02	1.34405E+06	6.84412E+05
RFO	3.15994E+03	5.14386E+01	4.83611E+03	3.25552E+02	1.29456E+06	7.59908E+05
RIME	3.21292E+03	2.45707E+01	3.69170E+03	1.82451E+02	2.43590E+04	2.69832E+04
SMA	3.23172E+03	4.85341E+01	3.78461E+03	2.12776E+02	1.46631E+04	3.92317E+03
RUN	**3.11466E+03**	3.85265E+01	4.10271E+03	2.41368E+02	6.66814E+04	3.19523E+04
HBA	3.14871E+03	6.57615E+01	4.06782E+03	4.42129E+02	8.90278E+04	2.50154E+05
PO	3.79135E+03	6.11432E+02	4.59567E+03	4.34201E+02	4.68261E+07	6.30219E+07

Table A10
AVG and STD values of comparative with classical algorithms on dimension 50

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.97953E+03**	**2.08167E+03**	1.26183E+43	6.74171E+43	3.37242E+04	1.74300E+04
GWO	8.64223E+09	3.70947E+09	1.67733E+49	5.49643E+49	8.04169E+04	1.64159E+04
WOA	3.73241E+07	2.85948E+07	8.43426E+60	4.61527E+61	1.14318E+05	5.21877E+04
SCA	4.31883E+10	6.77617E+09	1.85475E+63	8.06215E+63	1.11083E+05	1.06129E+04
PSO	4.20552E+08	3.99805E+07	1.42975E+28	4.76781E+28	1.57774E+03	1.71764E+02
MFO	3.72122E+10	2.00092E+10	5.88296E+74	2.84655E+75	1.90355E+05	1.25113E+05
MVO	5.90736E+04	1.74658E+04	1.24977E+13	3.60450E+13	3.10456E+02	3.36609E+00
ACOR	1.88570E+09	3.83039E+09	1.65481E+56	9.06045E+56	1.04067E+05	3.16334E+04
HHO	5.53260E+07	1.13614E+07	1.57875E+27	6.73558E+27	3.05205E+04	7.27641E+03
RFO	1.97981E+07	2.18045E+06	1.32506E+09	3.25959E+09	3.64415E+02	1.05668E+01
RIME	4.06090E+04	1.74779E+04	1.91531E+12	6.48030E+12	6.76118E+02	1.55297E+02
SMA	1.29506E+04	1.02677E+04	1.66450E+06	9.11138E+06	3.03435E+02	2.99969E+00
RUN	1.84825E+04	6.47539E+03	**3.48378E+04**	**1.66239E+05**	**3.00875E+02**	**3.78483E−01**
HBA	4.41099E+03	4.16062E+03	2.06915E+11	8.35890E+11	2.51299E+03	2.22942E+03
PO	3.03462E+09	1.74969E+09	1.73987E+64	5.15260E+64	1.85912E+05	1.62699E+04
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	5.18604E+02	4.09197E+01	**6.12975E+02**	3.29300E+01	**6.01109E+02**	**6.98711E−01**
GWO	1.27304E+03	4.88991E+02	7.24275E+02	6.26048E+01	6.18079E+02	4.75929E+00
WOA	7.30888E+02	5.73392E+01	9.35616E+02	7.42208E+01	6.80235E+02	1.04031E+01
SCA	6.65586E+03	1.45250E+03	1.06018E+03	2.71598E+01	6.69954E+02	3.88541E+00
PSO	5.70126E+02	7.04789E+01	9.62944E+02	4.07209E+01	6.71609E+02	1.18229E+01
MFO	5.23586E+03	2.65728E+03	9.97840E+02	6.99396E+01	6.57590E+02	1.27030E+01
MVO	5.33860E+02	4.03942E+01	6.94710E+02	4.87330E+01	6.26240E+02	1.04568E+01
ACOR	7.17048E+02	2.22222E+02	8.21214E+02	1.26285E+02	6.08925E+02	4.71177E+00
HHO	6.37665E+02	4.35605E+01	8.88012E+02	2.24207E+01	6.70100E+02	4.49377E+00
RFO	5.70807E+02	**3.87168E+01**	8.89086E+02	**1.09717E+01**	6.76545E+02	5.72337E+00
RIME	5.43655E+02	7.00582E+01	6.68709E+02	3.88536E+01	6.03260E+02	2.44347E+00
SMA	5.47280E+02	4.64359E+01	7.22725E+02	4.84968E+01	6.10310E+02	9.38399E+00
RUN	5.18077E+02	6.49364E+01	8.41694E+02	2.29618E+01	6.55830E+02	5.23036E+00
HBA	**4.89338E+02**	4.79124E+01	7.45829E+02	4.10571E+01	6.16657E+02	8.90512E+00
PO	1.21339E+03	2.18049E+03	6.84894E+02	5.43308E+01	6.07948E+02	5.60519E+00
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**9.10107E+02**	3.39101E+01	**9.19322E+02**	2.07896E+01	**1.54002E+03**	**4.88124E+02**
GWO	1.07087E+03	8.66587E+01	1.02876E+03	3.33092E+01	7.20886E+03	2.99221E+03
WOA	1.75199E+03	1.38804E+02	1.21957E+03	5.80178E+01	2.11746E+04	5.61554E+03
SCA	1.62407E+03	7.15270E+01	1.36407E+03	3.25853E+01	2.24387E+04	3.02625E+03
PSO	1.15331E+03	2.68771E+01	1.26778E+03	4.56002E+01	2.54443E+04	4.55715E+03
MFO	1.88892E+03	2.86719E+02	1.28046E+03	9.85729E+01	1.96611E+04	4.24062E+03
MVO	9.80081E+02	3.92821E+01	9.88019E+02	4.18367E+01	9.75166E+03	7.09670E+03
ACOR	1.28629E+03	1.57978E+02	1.16089E+03	1.14071E+02	8.82382E+03	5.46540E+03
HHO	1.80114E+03	9.24482E+01	1.17161E+03	3.34085E+01	2.10602E+04	2.16842E+03
RFO	1.87681E+03	4.53381E+01	1.23196E+03	**8.77081E+00**	2.82044E+04	1.53907E+03
RIME	9.25011E+02	3.99348E+01	9.83248E+02	3.37597E+01	4.24606E+03	2.73525E+03
SMA	1.00572E+03	4.64375E+01	1.00580E+03	4.31975E+01	9.55407E+03	4.43469E+03
RUN	1.42481E+03	1.14151E+02	1.12985E+03	3.46597E+01	1.08311E+04	1.43487E+03
HBA	1.09927E+03	9.90683E+01	1.04365E+03	3.83166E+01	5.68739E+03	1.73196E+03
PO	9.39426E+02	**2.44276E+01**	9.69731E+02	3.23103E+01	5.64182E+03	4.74670E+03
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	7.03512E+03	1.63666E+03	**1.22052E+03**	3.82570E+01	7.79919E+05	**4.09247E+05**
GWO	6.84080E+03	1.50416E+03	5.19233E+03	2.47069E+03	1.13928E+09	9.85672E+08

(*continued on next page*)

Table A10 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
WOA	1.02900E+04	1.28704E+03	1.72436E+03	1.20234E+02	3.05636E+08	1.85630E+08
SCA	1.44941E+04	**4.19457E+02**	6.57309E+03	9.82164E+02	1.21840E+10	2.80551E+09
PSO	1.09996E+04	7.72793E+02	1.49777E+03	6.28244E+01	1.86169E+08	4.86125E+07
MFO	8.39022E+03	9.85310E+02	1.26011E+04	1.16681E+04	6.88360E+09	5.27500E+09
MVO	6.51644E+03	9.12188E+02	1.42223E+03	7.63948E+01	3.37649E+07	1.78897E+07
ACOR	1.23669E+04	3.12754E+03	3.21456E+03	5.38028E+03	2.14620E+07	4.88324E+07
HHO	8.54424E+03	1.01097E+03	1.46810E+03	8.83114E+01	6.56731E+07	3.17511E+07
RFO	9.12277E+03	9.20660E+02	1.42249E+03	8.28141E+01	2.21105E+07	1.50095E+07
RIME	6.90895E+03	6.29751E+02	1.36077E+03	8.28281E+01	2.41639E+07	1.43362E+07
SMA	6.93173E+03	6.21012E+02	1.38484E+03	5.48761E+01	5.12937E+06	2.54695E+06
RUN	7.24105E+03	1.19864E+03	1.24275E+03	**2.45572E+01**	6.05859E+06	2.23121E+06
HBA	7.82760E+03	1.34272E+03	1.30454E+03	6.91795E+01	**6.24635E+05**	4.32615E+05
PO	**6.37602E+03**	1.07570E+03	1.40452E+03	2.69882E+02	6.47614E+09	8.39640E+09

	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.41779E+03**	**3.37671E+03**	3.44721E+04	2.72669E+04	**6.10495E+03**	6.13308E+03
GWO	1.41112E+08	1.72156E+08	5.95842E+05	5.27198E+05	4.67427E+07	1.77555E+08
WOA	4.71134E+05	6.48551E+05	1.18242E+06	6.88412E+05	8.76096E+04	5.90229E+04
SCA	2.68572E+09	6.55394E+08	2.71252E+06	1.63977E+06	3.68935E+08	1.54575E+08
PSO	3.45736E+07	6.56544E+06	8.48056E+04	3.98285E+04	7.82490E+06	1.84797E+06
MFO	1.17309E+09	1.53589E+09	1.74402E+06	2.61863E+06	1.12712E+08	3.35582E+08
MVO	2.17111E+05	1.54102E+05	5.86119E+04	3.21721E+04	8.39480E+04	4.78510E+04
ACOR	2.28929E+04	1.36295E+04	1.51940E+05	2.26777E+05	1.35742E+04	9.48007E+03
HHO	2.45199E+06	2.48847E+06	5.66732E+05	2.99335E+05	3.59714E+05	1.53925E+05
RFO	1.50523E+06	2.94362E+05	5.63097E+04	3.52074E+04	3.38125E+05	8.03161E+04
RIME	2.00357E+04	1.29896E+04	8.54349E+04	5.03599E+04	1.04859E+04	8.34749E+03
SMA	3.04311E+04	1.10687E+04	1.36919E+05	8.87007E+04	2.15873E+04	1.19530E+04
RUN	3.59079E+04	8.22429E+03	**1.75673E+04**	**1.00697E+04**	2.64793E+04	**5.77639E+03**
HBA	2.24335E+04	1.52687E+04	8.46994E+06	4.61444E+07	1.60476E+04	8.77628E+03
PO	1.85350E+08	5.25437E+08	4.15785E+06	2.92203E+06	4.76062E+08	4.91385E+08

	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.66717E+03**	3.30073E+02	**2.55777E+03**	2.69115E+02	6.74537E+05	6.66819E+05
GWO	2.97316E+03	3.55931E+02	2.74225E+03	**2.43715E+02**	2.79382E+06	3.27291E+06
WOA	4.79561E+03	5.87697E+02	4.02520E+03	4.67238E+02	7.12935E+06	8.41181E+06
SCA	5.42424E+03	**3.16492E+02**	4.24343E+03	3.01910E+02	1.49143E+07	9.20733E+06
PSO	3.92128E+03	4.51996E+02	3.22614E+03	2.95081E+02	1.18669E+06	6.13423E+05
MFO	4.41818E+03	5.86222E+02	4.09180E+03	5.43036E+02	9.11397E+06	1.55450E+07
MVO	2.97262E+03	5.02963E+02	2.99442E+03	3.13757E+02	5.77362E+05	2.72161E+05
ACOR	3.03537E+03	7.51288E+02	2.85949E+03	4.48401E+02	1.54344E+06	2.12866E+06
HHO	4.22327E+03	4.82165E+02	3.71746E+03	3.75402E+02	2.63391E+06	2.16312E+06
RFO	4.47733E+03	5.49588E+02	3.59230E+03	2.95083E+02	3.79634E+05	1.72173E+05
RIME	3.38226E+03	3.62555E+02	2.78821E+03	2.71416E+02	7.73576E+05	6.56049E+05
SMA	3.27632E+03	3.22032E+02	3.11750E+03	3.17799E+02	7.05000E+05	3.54124E+05
RUN	3.16118E+03	3.53194E+02	3.18408E+03	3.48922E+02	**9.06056E+04**	**4.44793E+04**
HBA	3.36711E+03	4.11487E+02	2.89094E+03	3.67138E+02	1.91665E+05	1.27961E+05
PO	5.43198E+03	8.99550E+02	2.93594E+03	5.21673E+02	1.05334E+07	9.49568E+06

	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	1.57446E+04	**7.66081E+03**	**2.43710E+03**	2.84680E+02	**2.41132E+03**	**2.56769E+01**
GWO	5.23738E+06	1.04464E+07	2.90647E+03	3.05263E+02	2.50891E+03	2.74839E+01
WOA	2.77161E+06	2.65212E+06	3.65031E+03	2.95496E+02	2.85888E+03	9.50358E+01
SCA	2.94167E+08	1.17468E+08	3.86347E+03	**1.68803E+02**	2.87207E+03	3.75003E+01
PSO	5.80115E+06	2.35868E+06	3.33068E+03	3.32711E+02	2.78854E+03	5.12391E+01
MFO	8.06528E+07	2.63009E+08	3.64075E+03	3.54108E+02	2.75050E+03	6.24084E+01
MVO	1.34403E+06	1.07925E+06	2.93457E+03	2.11739E+02	2.48237E+03	5.04879E+01
ACOR	2.12955E+04	1.48689E+04	3.10525E+03	5.23277E+02	2.60424E+03	1.39068E+02
HHO	7.73315E+05	4.53062E+05	3.36073E+03	3.37933E+02	2.83832E+03	6.02449E+01
RFO	1.07641E+06	7.38732E+05	3.93408E+03	2.29592E+02	3.13288E+03	1.00937E+02
RIME	**1.47734E+04**	1.15714E+04	2.85179E+03	2.89671E+02	2.47268E+03	3.66909E+01
SMA	2.29466E+04	1.83433E+04	3.05367E+03	2.08768E+02	2.50032E+03	4.37858E+01
RUN	9.41934E+04	3.79862E+04	3.09175E+03	2.30245E+02	2.61630E+03	6.15814E+01
HBA	2.38146E+04	1.43515E+04	3.09555E+03	4.31941E+02	2.49607E+03	3.53579E+01
PO	2.11677E+06	1.03390E+07	3.25292E+03	1.75059E+02	2.59286E+03	1.61540E+02

	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	**6.42118E+03**	2.98916E+03	**2.86023E+03**	2.97973E+01	**3.03938E+03**	**3.06452E+01**
GWO	9.29399E+03	1.74482E+03	2.97827E+03	7.73535E+01	3.14668E+03	8.90620E+01

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Table A10 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
WOA	1.16498E+04	1.13869E+03	3.60046E+03	1.68354E+02	3.72924E+03	1.68869E+02
SCA	1.62140E+04	**3.24332E+02**	3.50996E+03	5.05976E+01	3.70898E+03	5.81465E+01
PSO	1.22373E+04	1.95516E+03	3.61313E+03	2.03168E+02	3.68612E+03	1.87601E+02
MFO	1.07456E+04	9.59675E+02	3.18378E+03	9.29286E+01	3.24692E+03	5.48683E+01
MVO	8.40325E+03	9.17620E+02	2.90637E+03	**2.89260E+01**	3.05953E+03	4.56903E+01
ACOR	1.30964E+04	3.48305E+03	2.96752E+03	9.40206E+01	3.27134E+03	9.13293E+01
HHO	1.07482E+04	9.71159E+02	3.72670E+03	2.01436E+02	4.22279E+03	2.25634E+02
RFO	1.06812E+04	1.09415E+03	4.33959E+03	3.01541E+02	4.28354E+03	1.64603E+02
RIME	8.41385E+03	9.78413E+02	2.93555E+03	4.49946E+01	3.11861E+03	4.68089E+01
SMA	8.53437E+03	9.19283E+02	2.95373E+03	4.61911E+01	3.11773E+03	5.71785E+01
RUN	9.14278E+03	1.63998E+03	3.11784E+03	8.16627E+01	3.10150E+03	4.95722E+01
HBA	1.01168E+04	2.28483E+03	2.98542E+03	7.79611E+01	3.42094E+03	5.74644E+02
PO	7.89178E+03	1.60122E+03	3.23711E+03	2.05896E+02	3.94184E+03	1.43040E+02
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	3.05148E+03	3.40923E+01	**5.16290E+03**	4.99746E+02	3.40780E+03	5.39514E+01
GWO	3.64991E+03	2.71373E+02	6.50664E+03	6.46062E+02	3.62035E+03	1.15076E+02
WOA	3.19173E+03	4.16994E+01	1.29457E+04	1.65836E+03	4.40061E+03	4.49409E+02
SCA	6.07009E+03	6.61327E+02	1.17846E+04	4.47127E+02	4.39915E+03	1.25199E+02
PSO	3.02091E+03	3.65207E+01	5.96986E+03	3.62107E+03	**3.20635E+03**	1.77621E+02
MFO	6.45582E+03	2.86840E+03	8.95110E+03	7.63424E+02	3.61412E+03	1.10111E+02
MVO	**3.01697E+03**	2.85127E+01	5.74406E+03	4.88487E+02	3.28435E+03	**4.34046E+01**
ACOR	3.15950E+03	2.12469E+02	6.14766E+03	6.15303E+02	3.50392E+03	1.06142E+02
HHO	3.14124E+03	2.76953E+01	9.10899E+03	2.67507E+03	4.16057E+03	3.65732E+02
RFO	3.07592E+03	**2.43583E+01**	9.56029E+03	3.80376E+03	5.79298E+03	8.47261E+02
RIME	3.04978E+03	3.53441E+01	5.73650E+03	**3.82433E+02**	3.38169E+03	6.93959E+01
SMA	3.02254E+03	3.61104E+01	5.21830E+03	1.35277E+03	3.43426E+03	9.03227E+01
RUN	3.08969E+03	3.44880E+01	1.05042E+04	1.49861E+03	3.64162E+03	1.05097E+02
HBA	3.06035E+03	3.10775E+01	5.94111E+03	1.51353E+03	4.00064E+03	3.88450E+02
PO	3.03251E+03	3.55707E+01	6.29120E+03	2.25218E+03	4.17859E+03	2.91227E+02
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.30493E+03	2.87182E+01	**3.67590E+03**	**2.64433E+02**	**8.94399E+05**	**1.48008E+05**
GWO	4.33464E+03	4.79234E+02	4.32329E+03	2.92363E+02	9.22670E+07	3.87399E+07
WOA	3.52884E+03	8.01458E+01	7.25568E+03	7.29006E+02	1.21430E+08	3.97837E+07
SCA	6.57735E+03	6.03135E+02	7.39440E+03	6.32122E+02	6.19426E+08	2.14746E+08
PSO	3.30357E+03	1.94591E+01	5.52172E+03	3.81421E+02	7.32800E+07	1.07854E+07
MFO	8.18011E+03	1.24036E+03	5.38693E+03	4.70799E+02	1.64469E+08	5.08426E+08
MVO	**3.28257E+03**	2.09627E+01	4.53043E+03	3.88555E+02	3.16502E+07	8.40537E+06
ACOR	5.00746E+03	1.34930E+03	4.26724E+03	3.73102E+02	2.09258E+06	8.89355E+05
HHO	3.37984E+03	2.93812E+01	5.40959E+03	4.14974E+02	2.17713E+07	4.70211E+06
RFO	3.30706E+03	**1.41561E+01**	6.01680E+03	6.21748E+02	2.68379E+07	5.08668E+06
RIME	3.30589E+03	2.25931E+01	4.07279E+03	2.80119E+02	1.99530E+06	7.20624E+05
SMA	3.29783E+03	2.67762E+01	4.41705E+03	3.30248E+02	1.65868E+06	4.58572E+05
RUN	3.32070E+03	2.28238E+01	4.92180E+03	4.77034E+02	8.35541E+06	2.98578E+06
HBA	3.30178E+03	1.87854E+01	4.29335E+03	3.80795E+02	1.68145E+06	1.01459E+06
PO	4.44250E+03	1.98813E+03	7.88829E+03	1.63313E+03	2.91098E+08	4.69995E+08

Table A11
AVG and STD values of comparative with classical algorithms on dimension 100

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	1.56871E+07	6.42024E+07	7.86909E+119	3.59630E+120	3.20394E+05	4.32075E+04
GWO	4.98805E+10	9.27424E+09	9.15312E+146	5.01337E+147	2.30375E+05	2.28787E+04
WOA	1.32559E+09	4.92425E+08	3.40535E+148	1.47946E+149	7.56360E+05	1.91755E+05
SCA	1.68377E+11	9.81056E+09	2.60605E+155	**6.55350E+04**	3.21865E+05	3.28318E+04
PSO	1.57009E+09	1.04207E+08	1.32611E+75	5.20679E+75	8.19636E+04	2.03215E+04
MFO	1.46602E+11	5.20732E+10	4.06232E+167	6.55350E+04	7.36234E+05	2.17354E+05
MVO	8.21460E+05	1.49138E+05	2.63684E+53	1.44267E+54	1.51028E+04	**4.84804E+03**
ACOR	3.85066E+10	1.78099E+10	1.71877E+137	9.34991E+137	6.23006E+05	1.02208E+05
HHO	4.18050E+08	4.58185E+07	1.94377E+100	1.05464E+101	1.97950E+05	2.16339E+04
RFO	1.27174E+08	1.03755E+07	5.48638E+48	3.00500E+49	4.30130E+04	1.30144E+04
RIME	6.21320E+05	1.70906E+05	3.24626E+65	1.77694E+66	9.54503E+04	1.73577E+04
SMA	1.63807E+04	1.70680E+04	**7.99856E+40**	4.23977E+41	**1.26088E+04**	5.29975E+03
RUN	1.07073E+05	3.00925E+04	4.85231E+58	2.34422E+59	3.75600E+04	5.80678E+03
HBA	**7.16942E+03**	**9.66336E+03**	6.28690E+61	3.44348E+62	1.17851E+05	1.79221E+04

(*continued on next page*)

Table A11 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
PO	5.06739E+09	1.84552E+09	1.52827E+154	6.55350E+04	3.27642E+05	1.01898E+04
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	6.69849E+02	4.74508E+01	**8.50659E+02**	7.16671E+01	**6.08577E+02**	2.76637E+00
GWO	4.70197E+03	1.08257E+03	1.15836E+03	5.96492E+01	6.36889E+02	4.83161E+00
WOA	1.55097E+03	1.95193E+02	1.50386E+03	1.20679E+02	6.83862E+02	8.82667E+00
SCA	2.92280E+04	4.36689E+03	1.91175E+03	5.99849E+01	6.92190E+02	4.80639E+00
PSO	7.75110E+02	1.01168E+02	1.69506E+03	7.18809E+01	6.90480E+02	5.71996E+00
MFO	2.49586E+04	1.39956E+04	1.80641E+03	1.26776E+02	6.73970E+02	6.34491E+00
MVO	**6.68117E+02**	**3.69544E+01**	1.02784E+03	9.14427E+01	6.51449E+02	8.44550E+00
ACOR	4.07155E+03	2.69726E+03	1.70256E+03	1.16300E+02	6.27237E+02	5.16959E+00
HHO	9.75296E+02	7.43348E+01	1.49662E+03	4.49729E+01	6.81874E+02	3.19285E+00
RFO	7.06624E+02	3.89446E+01	1.42419E+03	**2.35618E+01**	6.77024E+02	1.98836E+00
RIME	7.11182E+02	4.89517E+01	1.01008E+03	9.12459E+01	6.16031E+02	4.59755E+00
SMA	6.77706E+02	4.53747E+01	1.14985E+03	1.00617E+02	6.37881E+02	8.31676E+00
RUN	7.16081E+02	5.08019E+01	1.31801E+03	3.83655E+01	6.62412E+02	**1.96067E+00**
HBA	6.84146E+02	4.33398E+01	1.12541E+03	7.97102E+01	6.32298E+02	5.77224E+00
PO	2.11578E+03	6.19819E+03	9.42990E+02	5.85659E+01	6.24260E+02	6.64923E+00
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	1.45253E+03	1.12360E+02	**1.13946E+03**	6.47431E+01	**1.35100E+04**	6.81934E+03
GWO	1.98816E+03	9.84722E+01	1.46694E+03	8.47742E+01	3.30068E+04	1.24544E+04
WOA	3.32368E+03	1.65196E+02	1.97885E+03	1.03750E+02	4.32367E+04	9.22546E+03
SCA	3.54340E+03	1.25574E+02	2.26853E+03	5.62868E+01	7.17975E+04	6.74859E+03
PSO	1.82546E+03	**6.41862E+01**	2.10032E+03	7.52900E+01	6.66200E+04	7.09916E+03
MFO	5.04699E+03	1.10269E+03	2.17760E+03	1.89774E+02	4.68006E+04	7.29754E+03
MVO	1.51048E+03	1.59448E+02	1.31482E+03	1.12037E+02	3.90604E+04	1.18139E+04
ACOR	3.22842E+03	5.90139E+02	1.89368E+03	2.93580E+02	6.52623E+04	1.42166E+04
HHO	3.64360E+03	1.88358E+02	1.90852E+03	6.23353E+01	4.63348E+04	5.12909E+03
RFO	3.60349E+03	8.16402E+01	1.94016E+03	**2.12631E+01**	6.62758E+04	2.08394E+03
RIME	**1.29513E+03**	1.13423E+02	1.30459E+03	7.13680E+01	1.91496E+04	8.44823E+03
SMA	1.73292E+03	1.34368E+02	1.37626E+03	7.35467E+01	2.46261E+04	3.26032E+03
RUN	2.80871E+03	2.38945E+02	1.74032E+03	6.73098E+01	2.28816E+04	**1.08747E+03**
HBA	2.07685E+03	2.41072E+02	1.40851E+03	7.89867E+01	1.93403E+04	3.65275E+03
PO	1.52929E+03	8.44118E+01	1.23520E+03	8.65436E+01	1.99901E+04	3.84036E+03
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	1.56740E+04	5.27830E+03	**2.07153E+03**	5.56516E+02	**3.41774E+06**	**1.32099E+06**
GWO	1.53386E+04	3.40200E+03	4.99008E+04	1.16555E+04	8.02022E+09	3.18958E+09
WOA	2.25313E+04	1.84170E+03	4.32482E+04	2.85352E+04	1.16287E+09	3.21331E+08
SCA	3.16311E+04	**5.89215E+02**	8.93982E+04	1.28399E+04	6.17576E+10	7.80377E+09
PSO	2.47921E+04	1.05460E+03	3.53891E+03	2.35433E+02	1.09159E+09	2.02918E+08
MFO	1.75844E+04	2.09394E+03	1.58137E+05	1.09407E+05	4.86383E+10	1.81812E+10
MVO	**1.40070E+04**	1.29505E+03	2.70491E+03	2.31053E+02	1.17537E+08	4.12819E+07
ACOR	3.06563E+04	3.60265E+03	3.05797E+04	2.72961E+04	2.81265E+09	4.53935E+09
HHO	2.00219E+04	1.48868E+03	4.51363E+03	7.22852E+02	4.39238E+08	1.16083E+08
RFO	1.81378E+04	1.63929E+03	2.97377E+03	2.33887E+02	1.83512E+08	3.91126E+07
RIME	1.49819E+04	1.35477E+03	2.98523E+03	3.69811E+02	2.44056E+08	7.92255E+07
SMA	1.47678E+04	1.17770E+03	2.47976E+03	2.16874E+02	2.85730E+07	1.17171E+07
RUN	1.53645E+04	2.08725E+03	2.10865E+03	**1.07930E+02**	5.47130E+07	1.85140E+07
HBA	1.55558E+04	1.66261E+03	4.66122E+04	2.41106E+05	5.35730E+06	2.25625E+06
PO	1.44964E+04	1.28538E+03	5.23200E+04	1.59037E+04	1.42312E+10	2.89832E+10
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**5.52800E+03**	**3.39370E+03**	4.54541E+05	2.76901E+05	**3.77730E+03**	**3.83408E+03**
GWO	9.81890E+08	1.09878E+09	5.14839E+06	2.63462E+06	1.25543E+08	1.87361E+08
WOA	1.03055E+06	1.03114E+06	4.07037E+06	2.29503E+06	4.65762E+05	9.28376E+05
SCA	9.78909E+09	1.61557E+09	2.36345E+07	1.07400E+07	3.52829E+09	9.71211E+08
PSO	9.30992E+07	9.48296E+06	1.46128E+06	3.47289E+05	3.28517E+07	5.11576E+06
MFO	9.02099E+09	5.24654E+09	1.53154E+07	1.95486E+07	2.28557E+09	1.67442E+09
MVO	1.06574E+05	3.36376E+04	8.78639E+05	4.97281E+05	9.24361E+04	3.31507E+04
ACOR	3.08053E+07	7.79698E+07	8.86303E+05	8.24256E+05	6.20709E+05	2.26959E+06
HHO	8.00821E+06	5.11551E+06	1.82358E+06	5.12514E+05	1.80229E+06	4.31161E+05
RFO	5.13068E+06	8.78436E+05	6.55292E+05	3.65270E+05	1.86154E+06	2.71920E+05
RIME	9.10113E+04	3.91820E+04	1.25928E+06	5.77115E+05	4.68399E+04	5.99072E+04
SMA	4.47197E+04	1.23729E+04	6.41932E+05	2.74617E+05	2.47827E+04	1.09218E+04
RUN	3.05433E+04	9.67851E+03	**1.44354E+05**	**4.03173E+04**	2.07170E+04	4.52295E+03
HBA	1.24734E+04	6.31382E+03	2.17282E+05	1.04869E+05	7.37005E+03	6.16662E+03

(*continued on next page*)

Table A11 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
PO	2.70036E+09	5.60519E+09	4.80618E+06	8.02559E+06	1.10201E+09	1.86863E+09
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**5.11910E+03**	1.02059E+03	**4.26050E+03**	8.30244E+02	3.02625E+06	2.86064E+06
GWO	6.06265E+03	6.25388E+02	4.84867E+03	7.39419E+02	5.77998E+06	3.75376E+06
WOA	1.21045E+04	2.17675E+03	7.44484E+03	9.06789E+02	3.69738E+06	1.64355E+06
SCA	1.28238E+04	6.63817E+02	1.44416E+04	6.41008E+03	4.39857E+07	1.46066E+07
PSO	7.91690E+03	5.56643E+02	6.23183E+03	5.10391E+02	2.72281E+06	9.11128E+05
MFO	8.44162E+03	7.57105E+02	2.10734E+04	3.13557E+04	1.19183E+07	1.53838E+07
MVO	5.39267E+03	7.61972E+02	4.87793E+03	5.47829E+02	1.42452E+06	5.64936E+05
ACOR	6.49607E+03	2.24230E+03	5.77880E+03	1.27459E+03	3.05240E+06	1.48254E+06
HHO	7.33534E+03	1.00770E+03	6.35047E+03	6.65358E+02	3.07217E+06	1.31428E+06
RFO	7.39120E+03	7.42048E+02	6.26981E+03	7.38820E+02	1.04091E+06	3.82110E+05
RIME	6.34296E+03	7.37025E+02	5.25086E+03	4.76833E+02	2.50670E+06	1.06104E+06
SMA	5.68199E+03	6.60794E+02	5.32030E+03	6.71274E+02	1.80486E+06	8.89655E+05
RUN	6.14551E+03	5.79357E+02	5.46884E+03	**4.52100E+02**	**1.86632E+05**	**4.94047E+04**
HBA	5.38538E+03	**5.12631E+02**	5.00962E+03	5.73564E+02	6.39912E+05	2.91045E+05
PO	7.67662E+03	3.61600E+03	9.35546E+03	1.21491E+04	7.85738E+06	9.59315E+06
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.85568E+03**	**2.12065E+03**	4.59451E+03	9.38651E+02	**2.67115E+03**	1.35116E+02
GWO	2.63962E+08	5.61679E+08	**4.50112E+03**	6.40437E+02	2.98715E+03	1.12807E+02
WOA	1.71337E+07	1.04149E+07	6.22949E+03	6.95967E+02	4.04580E+03	2.38272E+02
SCA	2.75587E+09	6.92993E+08	7.47652E+03	**2.41474E+02**	3.97983E+03	9.00581E+01
PSO	4.92695E+07	1.04441E+07	5.92431E+03	4.92208E+02	3.82875E+03	1.63221E+02
MFO	1.92052E+09	2.35700E+09	5.91655E+03	5.26438E+02	3.75851E+03	1.39624E+02
MVO	7.62174E+06	2.31550E+06	4.97723E+03	4.87570E+02	2.83362E+03	**6.93104E+01**
ACOR	1.35703E+07	7.36441E+07	6.48271E+03	1.35899E+03	3.49311E+03	2.56945E+02
HHO	8.85988E+06	3.32743E+06	5.94772E+03	6.46789E+02	4.02666E+03	2.23224E+02
RFO	4.52443E+06	2.55255E+06	6.53248E+03	5.29149E+02	4.51495E+03	2.26052E+02
RIME	3.81052E+04	2.45875E+04	5.19506E+03	4.94410E+02	2.84767E+03	7.76478E+01
SMA	2.18567E+04	1.45364E+04	4.88297E+03	6.41044E+02	2.89935E+03	8.19414E+01
RUN	1.02803E+06	4.00949E+05	5.03294E+03	4.48831E+02	3.04315E+03	1.00501E+02
HBA	6.13806E+03	5.38277E+03	4.82949E+03	4.44908E+02	2.87175E+03	1.11131E+02
PO	9.90752E+08	1.60488E+09	5.75181E+03	1.25105E+03	2.88038E+03	3.15122E+02
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	2.02296E+04	7.61224E+03	**3.20499E+03**	**6.29020E+01**	3.80599E+03	**7.81746E+01**
GWO	1.81161E+04	1.51442E+03	3.52331E+03	7.62312E+01	4.19597E+03	1.15487E+02
WOA	2.57313E+04	2.53557E+03	4.82054E+03	2.43006E+02	6.12743E+03	4.24189E+02
SCA	3.40385E+04	**4.47272E+02**	4.89491E+03	6.92587E+01	6.56304E+03	2.37870E+02
PSO	2.81109E+04	1.05850E+03	4.96790E+03	2.82438E+02	5.88761E+03	4.32984E+02
MFO	2.03097E+04	1.81148E+03	3.86123E+03	1.43638E+02	4.57373E+03	1.93965E+02
MVO	1.62485E+04	1.25523E+03	3.39065E+03	1.03074E+02	3.80365E+03	9.29165E+01
ACOR	3.28937E+04	7.48155E+02	3.46056E+03	1.46079E+02	4.00189E+03	2.00770E+02
HHO	2.34374E+04	1.18050E+03	5.12623E+03	2.86132E+02	6.33865E+03	5.30355E+02
RFO	2.09349E+04	1.54662E+03	5.94443E+03	4.05556E+02	6.10790E+03	6.25286E+02
RIME	1.72595E+04	1.54461E+03	3.29598E+03	7.77186E+01	**3.77827E+03**	1.13289E+02
SMA	1.73678E+04	1.30111E+03	3.27390E+03	6.56549E+01	3.84751E+03	9.54772E+01
RUN	2.03680E+04	3.57372E+03	3.41273E+03	9.03738E+01	4.15778E+03	1.19076E+02
HBA	1.86036E+04	3.98565E+03	3.47375E+03	3.02866E+02	4.64467E+03	1.44311E+03
PO	**7.51245E+03**	6.74551E+03	5.40304E+03	2.68593E+02	7.65517E+03	6.78711E+02
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	3.32251E+03	**3.76177E+01**	1.18832E+04	9.17759E+02	3.75139E+03	1.16461E+02
GWO	6.49468E+03	9.85034E+02	1.54119E+04	1.62013E+03	4.04552E+03	1.42873E+02
WOA	4.01625E+03	1.07026E+02	3.14741E+04	3.01349E+03	5.21878E+03	5.90193E+02
SCA	1.57900E+04	1.86233E+03	3.40696E+04	1.69518E+03	7.17988E+03	4.55843E+02
PSO	3.44879E+03	5.06979E+01	1.71149E+04	7.76869E+03	**3.27228E+03**	**2.97273E+01**
MFO	1.29364E+04	5.53731E+03	1.92413E+04	1.57489E+03	4.16289E+03	3.73486E+02
MVO	**3.27787E+03**	6.80547E+01	**1.09911E+04**	**7.36274E+02**	3.44910E+03	4.76097E+01
ACOR	5.65392E+03	1.89518E+03	1.37582E+04	2.10723E+03	3.55338E+03	7.67616E+01
HHO	3.68734E+03	7.49042E+01	2.54898E+04	1.92559E+03	4.38203E+03	2.91980E+02
RFO	3.32864E+03	4.69488E+01	1.30744E+04	8.58499E+03	5.55555E+03	1.00477E+03
RIME	3.36812E+03	7.12161E+01	1.14281E+04	8.92941E+02	3.59742E+03	6.35106E+01
SMA	3.30350E+03	5.88474E+01	1.24437E+04	1.15198E+03	3.53126E+03	7.86663E+01
RUN	3.39421E+03	4.92117E+01	2.65989E+04	2.42581E+03	4.30786E+03	3.56165E+02
HBA	3.32862E+03	5.13304E+01	1.37102E+04	3.04725E+03	4.43801E+03	1.29534E+03

(*continued on next page*)

Table A11 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
PO	3.40573E+03	9.02864E+01	2.24815E+04	9.66682E+03	5.88684E+03	9.99580E+02
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.42077E+03	3.77697E+01	**6.09217E+03**	7.16234E+02	**1.47371E+04**	**1.15875E+04**
GWO	8.51111E+03	1.40234E+03	8.26567E+03	7.94432E+02	9.95126E+08	1.07105E+09
WOA	4.35916E+03	2.11241E+02	1.50751E+04	2.13021E+03	4.50008E+08	2.20580E+08
SCA	1.99423E+04	1.42157E+03	1.74172E+04	2.28228E+03	7.16102E+09	1.43254E+09
PSO	3.43595E+03	6.01213E+01	9.62945E+03	6.25008E+02	1.68472E+08	4.32652E+07
MFO	1.97664E+04	3.57824E+03	1.25563E+04	1.05715E+04	3.32305E+09	2.52643E+09
MVO	**3.39373E+03**	**3.76917E+01**	7.29273E+03	6.52484E+02	4.85389E+07	2.21329E+07
ACOR	1.57614E+04	1.42684E+03	6.98099E+03	5.48622E+02	1.16615E+08	4.99909E+08
HHO	3.66129E+03	4.89324E+01	9.72101E+03	7.86463E+02	3.89347E+07	1.31529E+07
RFO	3.42935E+03	3.77447E+01	9.45733E+03	**5.01930E+02**	2.30025E+07	5.53621E+06
RIME	3.47147E+03	3.85194E+01	7.48577E+03	5.73409E+02	4.65725E+06	2.16085E+06
SMA	3.41948E+03	4.13368E+01	7.12922E+03	5.50429E+02	9.79198E+04	3.64928E+04
RUN	3.43502E+03	5.04134E+01	9.66634E+03	8.61036E+02	6.28351E+06	2.28177E+06
HBA	3.43680E+03	3.93214E+01	6.60206E+03	5.54193E+02	5.85831E+04	5.40936E+04
PO	3.47718E+03	5.31621E+01	1.49135E+04	9.12228E+03	3.21808E+09	4.15355E+09

Comparison results with improved algorithms

Table A12
AVG and STD values of comparative with high-performance algorithms on dimension 10

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.95955E+02**	**7.89403E+02**	2.00000E+02	6.82155E−04	**3.00000E+02**	8.24415E−14
LXMWOA	3.40933E+03	3.26834E+03	**2.00000E+02**	**3.84034E−05**	3.00000E+02	6.06371E−14
SCGWO	1.52349E+07	8.23125E+06	2.74744E+05	3.52791E+05	8.33706E+02	1.09216E+03
RCACO	3.21313E+03	3.14721E+03	2.00000E+02	2.46732E−04	3.00000E+02	**1.82828E−14**
LSEOFOA	6.73914E+03	4.31729E+03	2.04934E+02	1.87720E+01	3.00004E+02	4.38339E−03
IGWO	8.38946E+03	4.46630E+03	2.23461E+02	2.72412E+01	3.00006E+02	3.22114E−03
EESHHO	2.44522E+03	1.75776E+03	2.00001E+02	8.91090E−04	3.00000E+02	3.24732E−10
ASCA_PSO	9.31397E+06	1.29894E+07	2.74098E+03	8.14601E+03	3.19554E+02	4.25352E+00
RDWOA	4.61205E+03	5.15823E+03	2.00004E+02	3.44835E−03	3.00012E+02	6.54997E−02
SCADE	6.29965E+08	2.53450E+08	1.65319E+07	4.29210E+07	2.20226E+03	6.73115E+02
GCHHO	3.71488E+03	3.96503E+03	2.00001E+02	5.76371E−04	3.00000E+02	2.65571E−08
MOFOA	9.71746E+09	1.74854E+09	3.40110E+10	2.22749E+10	7.78644E+03	7.64562E+02
RCBA	3.69313E+03	3.73754E+03	2.00001E+02	3.08025E−04	3.00001E+02	2.91804E−04
LGCMFO	2.34827E+03	1.99054E+03	2.00000E+02	1.12756E−04	3.00000E+02	6.92174E−14
OBLGWO	3.81425E+04	4.82321E+04	4.43763E+02	5.58369E+02	3.12830E+02	1.44027E+01
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.00039E+02**	**8.03328E−03**	5.07429E+02	2.91818E+00	**6.00000E+02**	**7.20525E−06**
LXMWOA	4.00300E+02	1.78340E−01	5.21922E+02	1.07111E+01	6.00959E+02	1.75572E+00
SCGWO	4.12617E+02	1.23957E+01	5.30201E+02	1.05257E+01	6.03349E+02	2.16174E+00
RCACO	4.02298E+02	1.22362E+01	**5.06884E+02**	**2.60923E+00**	6.00092E+02	3.52598E−01
LSEOFOA	4.06786E+02	4.71972E+00	5.23414E+02	1.23742E+01	6.05197E+02	6.54459E+00
IGWO	4.04004E+02	1.22020E+00	5.13227E+02	5.88757E+00	6.00351E+02	6.27749E−01
EESHHO	4.03385E+02	1.24347E+01	5.21557E+02	7.13814E+00	6.00498E+02	8.28270E−01
ASCA_PSO	4.14559E+02	2.31591E+01	5.20917E+02	6.44262E+00	6.03205E+02	1.58843E+00
RDWOA	4.10189E+02	2.18214E+01	5.12772E+02	4.23006E+00	6.00007E+02	1.71547E−02
SCADE	4.31729E+02	6.69171E+00	5.47800E+02	6.90649E+00	6.15613E+02	3.01106E+00
GCHHO	4.03254E+02	1.12776E+00	5.34579E+02	1.33015E+01	6.05884E+02	4.82510E+00
MOFOA	9.53230E+02	1.26998E+02	5.77541E+02	9.09879E+00	6.52259E+02	3.57803E+00
RCBA	4.00359E+02	1.19068E−01	5.73140E+02	2.91314E+01	6.53586E+02	1.68306E+01
LGCMFO	4.02716E+02	1.52962E+00	5.20499E+02	6.78485E+00	6.00033E+02	1.39491E−01
OBLGWO	4.08091E+02	1.28401E+01	5.24784E+02	8.33790E+00	6.00721E+02	8.08853E−01
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	7.17661E+02	3.21190E+00	8.06535E+02	**2.64802E+00**	9.00147E+02	3.72035E−01
LXMWOA	7.42416E+02	1.22021E+01	8.20927E+02	6.30070E+00	9.14256E+02	3.98285E+01
SCGWO	7.51013E+02	1.00444E+01	8.24007E+02	5.66404E+00	9.24051E+02	4.99087E+01
RCACO	**7.14988E+02**	**2.40859E+00**	**8.06271E+02**	4.68013E+00	9.00240E+02	5.63994E−01
LSEOFOA	7.72317E+02	2.53642E+01	8.23348E+02	7.12571E+00	1.50198E+03	2.86027E+02
IGWO	7.27355E+02	8.00667E+00	8.13598E+02	5.50785E+00	**9.00067E+02**	**1.56384E−01**
EESHHO	7.43263E+02	1.28042E+01	8.19402E+02	7.62116E+00	9.01966E+02	5.42306E+00

(*continued on next page*)

Table A12 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
ASCA_PSO	7.45204E+02	8.40489E+00	8.22531E+02	8.86553E+00	9.02244E+02	5.52071E−01
RDWOA	7.25152E+02	6.96142E+00	8.12537E+02	4.70030E+00	9.00767E+02	1.72363E+00
SCADE	7.67557E+02	7.79183E+00	8.39270E+02	5.47524E+00	9.97492E+02	3.25809E+01
GCHHO	7.56432E+02	1.84559E+01	8.24576E+02	8.04982E+00	9.15674E+02	3.36277E+01
MOFOA	8.15220E+02	8.43829E+00	8.60972E+02	6.00443E+00	1.26546E+03	6.98597E+01
RCBA	8.77014E+02	7.91540E+01	8.54503E+02	2.41460E+01	2.22192E+03	8.25814E+02
LGCMFO	7.30563E+02	1.05876E+01	8.20994E+02	7.29434E+00	9.01129E+02	4.65854E+00
OBLGWO	7.37864E+02	1.09019E+01	8.22963E+02	6.73309E+00	9.00495E+02	8.64944E−01
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	1.25519E+03	1.86273E+02	**1.10250E+03**	**2.55345E+00**	1.00332E+04	7.25251E+03
LXMWOA	1.66303E+03	2.31505E+02	1.11131E+03	5.87365E+00	1.55982E+04	1.60280E+04
SCGWO	1.75747E+03	4.03696E+02	1.13329E+03	2.04970E+01	2.23635E+06	1.88119E+06
RCACO	**1.17739E+03**	**1.30485E+02**	1.10380E+03	3.59961E+00	1.78869E+04	1.71759E+04
LSEOFOA	1.62239E+03	2.58054E+02	1.11832E+03	2.55056E+01	2.24124E+04	2.28127E+04
IGWO	1.46066E+03	2.02186E+02	1.11172E+03	5.93005E+00	2.98571E+05	3.79875E+05
EESHHO	1.51801E+03	2.31084E+02	1.11769E+03	7.23079E+00	1.28811E+04	8.70627E+03
ASCA_PSO	1.73090E+03	2.57675E+02	1.13288E+03	1.46119E+01	1.45162E+06	1.53389E+06
RDWOA	1.47087E+03	1.81476E+02	1.10981E+03	4.47632E+00	1.85967E+04	1.40387E+04
SCADE	2.14354E+03	1.67613E+02	1.22208E+03	3.26979E+01	7.14045E+06	5.83841E+06
GCHHO	1.84238E+03	2.58308E+02	1.13231E+03	1.78245E+01	1.54708E+04	1.25007E+04
MOFOA	2.75960E+03	1.57507E+02	2.95822E+03	8.57147E+02	2.17325E+08	1.73851E+08
RCBA	2.32640E+03	2.78179E+02	1.20559E+03	5.15522E+01	2.82901E+04	2.58054E+04
LGCMFO	1.64444E+03	3.07257E+02	1.10700E+03	4.23001E+00	**9.32527E+03**	**6.08381E+03**
OBLGWO	1.62911E+03	2.85304E+02	1.12330E+03	1.35699E+01	9.96951E+05	1.13594E+06
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.43143E+03**	**1.36168E+02**	**1.40815E+03**	**7.76334E+00**	**1.50737E+03**	6.33008E+00
LXMWOA	9.36800E+03	8.34299E+03	1.42182E+03	1.35965E+01	1.50742E+03	**5.11415E+00**
SCGWO	2.04596E+04	1.51946E+04	1.53747E+03	3.57899E+01	1.98292E+03	4.65443E+02
RCACO	1.16726E+04	1.04903E+04	1.43952E+03	4.66662E+01	3.54519E+03	2.10689E+03
LSEOFOA	1.47307E+04	1.09615E+04	1.71884E+03	8.18718E+02	2.14492E+03	9.14752E+02
IGWO	8.63724E+03	6.18837E+03	1.46204E+03	1.78030E+01	1.55385E+03	2.24089E+01
EESHHO	8.70325E+03	8.51633E+03	1.42708E+03	1.37714E+01	1.51538E+03	1.42071E+01
ASCA_PSO	1.13945E+04	8.14790E+03	1.48187E+03	2.71318E+01	1.65425E+03	6.70877E+01
RDWOA	9.87488E+03	9.29493E+03	1.56247E+03	6.36160E+02	1.88132E+03	9.44780E+02
SCADE	1.57248E+04	7.18938E+03	1.53197E+03	1.72176E+01	1.99139E+03	3.54550E+02
GCHHO	9.89074E+03	7.82103E+03	1.47692E+03	2.50159E+01	1.54315E+03	3.11688E+01
MOFOA	3.24419E+06	5.44189E+06	1.84809E+03	5.23798E+02	4.95022E+03	1.75615E+03
RCBA	1.18471E+04	9.00393E+03	1.47372E+03	3.14724E+01	1.69172E+03	1.17410E+02
LGCMFO	1.19677E+04	8.48213E+03	1.47416E+03	3.94542E+01	1.56021E+03	5.13022E+01
OBLGWO	1.35069E+04	9.48098E+03	1.47048E+03	1.93605E+01	1.58772E+03	4.34480E+01
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.60865E+03**	3.03106E+01	**1.70337E+03**	**3.90887E+00**	**2.43119E+03**	**1.35605E+03**
LXMWOA	1.80104E+03	1.35574E+02	1.72274E+03	1.03787E+01	7.97874E+03	9.59066E+03
SCGWO	1.77868E+03	1.17454E+02	1.76314E+03	1.99332E+01	3.87842E+04	3.14905E+04
RCACO	1.68432E+03	7.75872E+01	1.72605E+03	2.83345E+01	1.39595E+04	1.18485E+04
LSEOFOA	1.74519E+03	1.27027E+02	1.73371E+03	1.89734E+01	1.66636E+04	1.39811E+04
IGWO	1.62523E+03	**2.63364E+01**	1.73489E+03	1.26686E+01	2.12619E+04	1.58275E+04
EESHHO	1.72947E+03	1.03201E+02	1.73475E+03	1.66139E+01	1.34881E+04	8.19776E+03
ASCA_PSO	1.65797E+03	4.58808E+01	1.75531E+03	8.98074E+00	1.98961E+04	1.24443E+04
RDWOA	1.73251E+03	9.89149E+01	1.72567E+03	2.69525E+01	1.10869E+04	7.91926E+03
SCADE	1.73041E+03	5.90669E+01	1.77142E+03	1.06778E+01	5.00670E+04	3.06279E+04
GCHHO	1.69406E+03	8.09691E+01	1.75193E+03	1.93721E+01	1.65656E+04	1.28152E+04
MOFOA	2.08260E+03	7.46601E+01	1.82676E+03	8.87863E+00	2.34180E+06	4.60588E+06
RCBA	1.94582E+03	1.84322E+02	1.89812E+03	1.25255E+02	2.04285E+04	1.26917E+04
LGCMFO	1.71531E+03	1.35882E+02	1.73909E+03	1.22201E+01	5.38588E+03	3.46836E+03
OBLGWO	1.64982E+03	4.57371E+01	1.74834E+03	1.11417E+01	1.88702E+04	1.32629E+04
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.90437E+03**	**4.10975E+00**	**2.00149E+03**	**1.17627E+00**	2.26902E+03	5.34587E+01
LXMWOA	8.02289E+03	8.64875E+03	2.10903E+03	5.65780E+01	2.30721E+03	4.32489E+01
SCGWO	3.26830E+03	2.32067E+03	2.07396E+03	3.60527E+01	2.26536E+03	6.13485E+01
RCACO	3.29108E+03	1.51614E+03	2.02236E+03	3.81837E+01	2.30367E+03	2.80049E+01
LSEOFOA	5.36299E+03	5.02208E+03	2.04856E+03	4.31740E+01	2.21446E+03	3.76180E+01
IGWO	1.94015E+03	2.46206E+01	2.03019E+03	1.34827E+01	**2.19739E+03**	1.84276E+01
EESHHO	3.00636E+03	2.02608E+03	2.04202E+03	4.85569E+01	2.24693E+03	6.21020E+01

(*continued on next page*)

Table A12 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
ASCA_PSO	1.96906E+03	3.75899E+01	2.05858E+03	1.51893E+01	2.22471E+03	4.81246E+01
RDWOA	6.74500E+03	4.16182E+03	2.00544E+03	6.85550E+00	2.27966E+03	5.87570E+01
SCADE	2.59935E+03	5.39054E+02	2.09895E+03	1.67356E+01	2.22550E+03	7.65781E+00
GCHHO	2.41423E+03	1.64039E+03	2.06707E+03	4.21718E+01	2.20829E+03	2.92266E+01
MOFOA	1.78448E+04	2.53455E+04	2.27457E+03	4.92118E+01	2.27048E+03	2.96551E+01
RCBA	1.94994E+03	3.39427E+01	2.21290E+03	9.06079E+01	2.34927E+03	6.66001E+01
LGCMFO	2.08593E+03	4.08623E+02	2.02532E+03	1.33911E+01	2.25195E+03	5.92709E+01
OBLGWO	1.97788E+03	5.19592E+01	2.04471E+03	1.66669E+01	2.20203E+03	**1.93975E+00**
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	2.30167E+03	**6.68792E−01**	2.60847E+03	**3.45482E+00**	2.72164E+03	6.04188E+01
LXMWOA	2.30051E+03	1.75171E+01	2.63019E+03	1.39272E+01	2.71183E+03	1.09640E+02
SCGWO	2.31184E+03	4.09797E+00	2.63322E+03	9.02038E+00	2.73170E+03	7.55013E+01
RCACO	2.30070E+03	2.88354E+01	2.61275E+03	5.08594E+00	2.74300E+03	**4.84687E+00**
LSEOFOA	2.30520E+03	1.27496E+01	2.62699E+03	1.09860E+01	2.52865E+03	8.64976E+01
IGWO	**2.29521E+03**	2.84039E+01	**2.60833E+03**	5.86646E+01	**2.49361E+03**	3.69342E+01
EESHHO	2.30301E+03	1.62815E+01	2.63734E+03	1.34616E+01	2.73473E+03	9.57667E+01
ASCA_PSO	2.31030E+03	1.01234E+00	2.62149E+03	9.52698E+00	2.71319E+03	9.37003E+01
RDWOA	2.32408E+03	1.33371E+02	2.62711E+03	9.76214E+00	2.73096E+03	1.06596E+02
SCADE	2.34020E+03	2.17172E+01	2.64214E+03	6.37705E+00	2.57566E+03	5.73953E+01
GCHHO	2.32240E+03	8.39914E+01	2.63756E+03	1.45235E+01	2.70943E+03	1.07222E+02
MOFOA	2.94563E+03	1.23343E+02	2.75122E+03	2.71966E+01	2.82791E+03	4.96103E+01
RCBA	2.40206E+03	3.84603E+02	2.69589E+03	4.63384E+01	2.79142E+03	1.23267E+02
LGCMFO	2.30170E+03	9.44599E−01	2.61922E+03	7.34223E+00	2.72439E+03	7.65659E+01
OBLGWO	2.30539E+03	3.29150E+00	2.62042E+03	7.10870E+00	2.72205E+03	8.86553E+01
	F25		F26		F27	
	AVG	STD	AVG	STD	AVG	STD
KING	2.92163E+03	2.34520E+01	**2.89198E+03**	5.61988E+01	3.09323E+03	2.48827E+00
LXMWOA	2.92777E+03	2.33135E+01	3.05724E+03	3.78973E+02	3.10197E+03	2.21437E+01
SCGWO	2.93399E+03	1.74512E+01	2.91479E+03	6.07181E+01	3.09756E+03	6.61739E+00
RCACO	2.93080E+03	2.28372E+01	3.11896E+03	3.29378E+02	3.09997E+03	1.24943E+01
LSEOFOA	2.93341E+03	3.02631E+01	2.95084E+03	1.52682E+02	3.09998E+03	1.65365E+01
IGWO	2.92163E+03	2.39505E+01	2.90008E+03	**1.55435E−02**	**3.09059E+03**	**1.55309E+00**
EESHHO	2.92924E+03	2.31008E+01	3.04628E+03	2.79906E+02	3.10505E+03	2.06104E+01
ASCA_PSO	2.92750E+03	2.19495E+01	2.95608E+03	5.77053E+01	3.09774E+03	3.58429E+00
RDWOA	2.92176E+03	6.47259E+01	3.22956E+03	4.22362E+02	3.11044E+03	2.53050E+01
SCADE	2.94511E+03	**1.45177E+01**	3.11801E+03	3.45459E+01	3.10185E+03	1.79436E+00
GCHHO	2.91496E+03	6.33947E+01	2.95613E+03	1.01437E+02	3.09717E+03	4.18535E+00
MOFOA	3.30566E+03	6.77725E+01	4.03353E+03	2.56690E+02	3.17790E+03	1.86247E+01
RCBA	2.93173E+03	3.05859E+01	3.84040E+03	6.04101E+02	3.12272E+03	3.53013E+01
LGCMFO	2.92824E+03	2.23255E+01	2.91464E+03	6.90753E+01	3.09337E+03	2.70953E+00
OBLGWO	2.92771E+03	2.45598E+01	2.94476E+03	7.59771E+01	3.09329E+03	2.86961E+00
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.17941E+03	1.34139E+02	**3.14549E+03**	**1.24514E+01**	**5.31529E+03**	**1.33020E+03**
LXMWOA	3.32129E+03	1.76463E+02	3.25140E+03	5.98513E+01	2.09969E+05	3.84405E+05
SCGWO	3.35744E+03	1.04832E+02	3.21240E+03	2.53912E+01	3.25425E+05	6.94077E+05
RCACO	3.38918E+03	6.80494E+01	3.15932E+03	2.52042E+01	2.35399E+05	4.20758E+05
LSEOFOA	3.29155E+03	1.24599E+02	3.19836E+03	4.69394E+01	2.12948E+05	3.98512E+05
IGWO	**3.17062E+03**	1.03957E+02	3.15697E+03	1.74964E+01	2.46580E+05	4.07672E+05
EESHHO	3.27225E+03	1.36616E+02	3.21253E+03	3.99807E+01	6.65976E+04	2.05046E+05
ASCA_PSO	3.19653E+03	**2.74594E+01**	3.17226E+03	2.07647E+01	2.27300E+05	3.23734E+05
RDWOA	3.28081E+03	1.37382E+02	3.21979E+03	6.13809E+01	9.60646E+04	2.47586E+05
SCADE	3.30246E+03	4.90494E+01	3.23985E+03	2.73959E+01	4.52269E+05	2.24778E+05
GCHHO	3.19408E+03	1.20258E+02	3.22596E+03	3.96772E+01	9.12455E+04	2.49353E+05
MOFOA	3.75333E+03	5.21445E+01	3.38557E+03	6.16379E+01	7.57839E+06	3.00733E+06
RCBA	3.37090E+03	2.05021E+02	3.34445E+03	1.00694E+02	9.26344E+05	1.38790E+06
LGCMFO	3.27757E+03	1.54281E+02	3.20549E+03	3.69757E+01	4.24561E+05	4.78001E+05
OBLGWO	3.25518E+03	1.15902E+02	3.18475E+03	3.77829E+01	5.07228E+04	1.45937E+05

Table A13
AVG and STD values of comparative with high-performance algorithms on dimension 30

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.16658E+03**	**3.55445E+03**	2.03955E+02	2.16600E+01	3.00784E+02	2.78146E+00
LXMWOA	4.00224E+03	4.32022E+03	4.63598E+02	1.41529E+03	**3.00008E+02**	**2.57300E−02**
SCGWO	1.22439E+09	7.61829E+08	6.35288E+30	3.47110E+31	4.13836E+04	8.67887E+03
RCACO	6.54075E+03	5.79483E+03	1.66923E+23	9.14277E+23	5.84744E+02	4.89500E+02
LSEOFOA	2.02481E+07	4.81466E+07	8.00793E+16	1.68799E+17	6.29214E+03	2.98128E+03
IGWO	1.61002E+06	8.21272E+05	1.67516E+14	8.43547E+14	1.31025E+03	5.30180E+02
EESHHO	4.52774E+03	5.05539E+03	6.17029E+07	2.76766E+08	2.39081E+03	1.41074E+03
ASCA_PSO	9.91547E+08	1.79156E+09	2.79814E+30	9.44786E+30	1.31453E+03	6.09929E+02
RDWOA	1.01039E+07	1.80491E+07	4.67036E+16	1.10414E+17	1.93734E+04	8.04475E+03
SCADE	1.97901E+10	2.99135E+09	4.20297E+36	1.75897E+37	6.03785E+04	8.22102E+03
GCHHO	4.42614E+03	5.94032E+03	1.21689E+06	3.72061E+06	6.11158E+02	2.50663E+02
MOFOA	5.15409E+10	2.32401E+09	7.59902E+46	2.75471E+47	7.94575E+04	2.98105E+03
RCBA	1.69328E+04	6.17558E+03	**2.00003E+02**	**2.42493E−03**	3.01055E+02	3.57926E−01
LGCMFO	6.74439E+03	6.79782E+03	3.08998E+12	8.03633E+12	6.40733E+03	3.06902E+03
OBLGWO	1.58455E+07	1.06463E+07	7.23946E+16	1.68237E+17	1.89776E+04	6.46532E+03
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**4.28913E+02**	3.31696E+01	**5.52268E+02**	**1.34322E+01**	**6.00071E+02**	**5.53933E−02**
LXMWOA	4.60285E+02	2.83150E+01	6.67451E+02	3.15152E+01	6.08131E+02	5.28655E+00
SCGWO	6.38871E+02	8.90816E+01	7.18310E+02	4.57066E+01	6.19973E+02	7.31470E+00
RCACO	4.56416E+02	2.42796E+01	6.06587E+02	2.37344E+01	6.00160E+02	3.98411E−01
LSEOFOA	5.08838E+02	3.32187E+01	7.01993E+02	4.50896E+01	6.34348E+02	1.67088E+01
IGWO	5.06112E+02	2.46029E+01	6.13680E+02	1.87474E+01	6.22700E+02	4.42328E+00
EESHHO	4.98951E+02	**1.89548E+01**	6.93032E+02	3.92989E+01	6.18491E+02	1.23321E+01
ASCA_PSO	5.78726E+02	1.53869E+02	7.20424E+02	3.69324E+01	6.37349E+02	9.02616E+00
RDWOA	5.19402E+02	2.93959E+01	6.86911E+02	4.10423E+01	6.13511E+02	5.65902E+00
SCADE	3.39063E+03	9.08160E+02	8.28138E+02	1.90837E+01	6.61102E+02	6.17125E+00
GCHHO	4.91940E+02	2.30624E+01	7.04522E+02	4.02430E+01	6.50384E+02	7.79066E+00
MOFOA	1.32842E+04	1.29158E+03	9.55522E+02	1.41998E+01	7.04761E+02	6.25869E+00
RCBA	4.92882E+02	2.63368E+01	8.29802E+02	6.41235E+01	6.70744E+02	1.06842E+01
LGCMFO	4.84506E+02	2.50516E+01	6.32166E+02	3.60839E+01	6.16415E+02	9.29895E+00
OBLGWO	5.21481E+02	3.15445E+01	6.53772E+02	3.27305E+01	6.15150E+02	1.25977E+01
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**7.92003E+02**	2.32779E+01	**8.51937E+02**	1.62491E+01	**9.21371E+02**	**1.87612E+01**
LXMWOA	8.85028E+02	4.04703E+01	9.21106E+02	1.45018E+01	3.55191E+03	1.01410E+03
SCGWO	1.03254E+03	5.83034E+01	9.75786E+02	2.79081E+01	6.76834E+03	2.18150E+03
RCACO	8.57646E+02	**1.56783E+01**	9.13646E+02	1.79375E+01	9.46775E+02	9.78451E+01
LSEOFOA	1.10422E+03	9.37349E+01	9.51861E+02	3.08565E+01	4.77438E+03	5.57479E+02
IGWO	8.95737E+02	4.34875E+01	8.94810E+02	2.41962E+01	3.01091E+03	6.57546E+02
EESHHO	1.04987E+03	7.66582E+01	9.45263E+02	2.57337E+01	4.44702E+03	6.23090E+02
ASCA_PSO	9.79615E+02	3.22714E+01	1.00207E+03	3.19743E+01	4.42551E+03	1.55112E+03
RDWOA	9.76477E+02	5.77476E+01	9.77842E+02	3.86965E+01	4.92703E+03	2.59139E+03
SCADE	1.16429E+03	2.17020E+01	1.07889E+03	1.70356E+01	8.18312E+03	9.97141E+02
GCHHO	1.08881E+03	8.88617E+01	9.50304E+02	2.34790E+01	4.74820E+03	8.24012E+02
MOFOA	1.39190E+03	2.46763E+01	1.15505E+03	**1.22003E+01**	1.32793E+04	1.59598E+03
RCBA	1.90492E+03	3.20937E+02	1.05811E+03	4.60554E+01	7.47788E+03	2.19074E+03
LGCMFO	8.76810E+02	4.10491E+01	9.28571E+02	2.78617E+01	3.28127E+03	1.11239E+03
OBLGWO	9.28080E+02	8.16878E+01	9.48389E+02	3.05149E+01	2.52635E+03	1.50396E+03
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.76909E+03**	8.19110E+02	**1.15676E+03**	2.62069E+01	**2.23151E+04**	**1.08053E+04**
LXMWOA	4.70182E+03	5.79206E+02	1.20006E+03	4.21804E+01	3.17599E+05	3.38276E+05
SCGWO	6.26528E+03	1.20302E+03	1.62940E+03	3.76331E+02	6.54303E+07	3.68023E+07
RCACO	5.56751E+03	6.26979E+02	1.18911E+03	3.89867E+01	8.42378E+04	4.23078E+04
LSEOFOA	4.56268E+03	6.33654E+02	1.24214E+03	2.87021E+01	3.48928E+06	3.02728E+06
IGWO	4.53172E+03	7.13647E+02	1.24492E+03	**2.14726E+01**	1.39595E+07	1.12228E+07
EESHHO	4.18530E+03	5.87556E+02	1.18018E+03	2.54181E+01	1.02955E+06	6.87016E+05
ASCA_PSO	6.16662E+03	7.25353E+02	1.31043E+03	3.59002E+01	6.39988E+07	9.61139E+07
RDWOA	4.85922E+03	5.83999E+02	1.25027E+03	3.60843E+01	3.51304E+06	2.35623E+06
SCADE	8.14198E+03	2.64500E+02	3.30393E+03	4.81311E+02	2.08304E+09	4.84855E+08
GCHHO	5.28165E+03	5.86636E+02	1.23649E+03	8.03898E+01	1.07281E+06	9.37102E+05
MOFOA	8.77304E+03	**1.86313E+02**	8.58495E+03	6.66186E+02	1.80239E+10	1.80857E+09
RCBA	5.87236E+03	5.45011E+02	1.32356E+03	7.24278E+01	1.92557E+06	1.13095E+06
LGCMFO	4.98226E+03	5.64328E+02	1.24574E+03	7.77155E+01	1.29316E+06	3.01179E+06
OBLGWO	5.36491E+03	7.46838E+02	1.27791E+03	5.36411E+01	1.66626E+07	1.58060E+07
	F13		F14		F15	

(*continued on next page*)

Table A13 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	AVG	STD	AVG	STD	AVG	STD
KING	1.48010E+04	1.50678E+04	**3.79415E+03**	**3.03896E+03**	7.93774E+03	7.62863E+03
LXMWOA	1.65057E+04	1.64001E+04	1.43389E+04	1.16536E+04	**4.40788E+03**	7.44484E+03
SCGWO	1.47975E+07	1.07780E+07	4.57273E+05	3.40238E+05	1.06049E+06	1.00789E+06
RCACO	2.12278E+04	1.96146E+04	3.83844E+04	2.49698E+04	1.41799E+04	1.20454E+04
LSEOFOA	5.19530E+04	3.69598E+04	6.30675E+04	3.44215E+04	6.79909E+03	6.91100E+03
IGWO	2.26077E+05	3.11051E+05	5.23336E+04	3.37013E+04	5.77824E+04	3.36831E+04
EESHHO	**9.46831E+03**	**8.33555E+03**	3.06839E+04	2.17666E+04	8.01438E+03	8.19407E+03
ASCA_PSO	8.32809E+06	2.29597E+06	2.76591E+04	2.15841E+04	1.27251E+06	4.90703E+05
RDWOA	1.94528E+04	2.02649E+04	1.43689E+05	2.61409E+05	1.21991E+04	1.20622E+04
SCADE	6.54960E+08	2.91697E+08	2.87503E+05	1.56810E+05	1.10518E+07	1.36286E+07
GCHHO	1.58922E+04	1.63404E+04	4.26166E+04	3.94146E+04	5.04393E+03	5.59547E+03
MOFOA	1.61527E+10	4.67908E+09	3.93061E+06	2.77403E+06	5.41249E+08	1.90846E+08
RCBA	1.12710E+05	6.92679E+04	6.30789E+03	4.17188E+03	3.88754E+04	3.32675E+04
LGCMFO	4.56288E+04	3.51554E+04	3.65381E+04	2.87848E+04	6.64034E+03	**4.46902E+03**
OBLGWO	2.31674E+05	1.47112E+05	6.68378E+04	5.10709E+04	8.19560E+04	6.04710E+04
	F16		F17		F18	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.14957E+03**	2.59798E+02	**1.78321E+03**	**6.95101E+01**	1.30256E+05	**6.96735E+04**
LXMWOA	2.82462E+03	3.58257E+02	2.32423E+03	2.41703E+02	**7.35281E+04**	7.39334E+04
SCGWO	3.15706E+03	4.22260E+02	2.14423E+03	1.99851E+02	1.33661E+06	1.38415E+06
RCACO	2.35198E+03	2.99790E+02	1.96349E+03	1.58842E+02	7.72415E+05	6.95338E+05
LSEOFOA	2.71085E+03	2.93549E+02	2.23576E+03	1.92829E+02	1.19004E+06	1.08498E+06
IGWO	2.53497E+03	2.86474E+02	2.00122E+03	1.47536E+02	4.91491E+05	3.28029E+05
EESHHO	2.71684E+03	2.74447E+02	2.17405E+03	2.08754E+02	3.07814E+05	2.37841E+05
ASCA_PSO	3.06392E+03	2.59453E+02	2.22900E+03	1.89986E+02	4.36988E+05	3.29560E+05
RDWOA	2.84359E+03	3.35885E+02	2.19800E+03	1.67360E+02	3.35204E+05	3.02787E+05
SCADE	3.89611E+03	**2.11419E+02**	2.47504E+03	1.63079E+02	3.73293E+06	2.27473E+06
GCHHO	2.77764E+03	2.98530E+02	2.29779E+03	1.89197E+02	2.58780E+05	2.26722E+05
MOFOA	6.42482E+03	3.93429E+02	5.82099E+03	1.14710E+03	4.56475E+07	2.47743E+07
RCBA	3.37939E+03	4.90524E+02	2.66417E+03	2.88545E+02	2.20007E+05	1.70914E+05
LGCMFO	2.59788E+03	3.64239E+02	2.15428E+03	2.52786E+02	2.08750E+05	1.56115E+05
OBLGWO	2.78243E+03	3.21557E+02	2.22705E+03	2.35151E+02	1.31503E+06	9.24720E+05
	F19		F20		F21	
	AVG	STD	AVG	STD	AVG	STD
KING	9.53352E+03	7.13152E+03	**2.13736E+03**	**7.73923E+01**	**2.34856E+03**	**1.06792E+01**
LXMWOA	6.62148E+03	**3.75017E+03**	2.56753E+03	2.03595E+02	2.45639E+03	4.50737E+01
SCGWO	1.81288E+06	1.90904E+06	2.52042E+03	1.56325E+02	2.50631E+03	4.87799E+01
RCACO	8.20311E+03	9.80850E+03	2.20645E+03	1.40626E+02	2.40164E+03	1.99184E+01
LSEOFOA	7.64565E+03	9.56120E+03	2.42217E+03	1.28510E+02	2.45690E+03	4.78586E+01
IGWO	4.85409E+05	5.91605E+05	2.35957E+03	1.43127E+02	2.39595E+03	1.76105E+01
EESHHO	**5.71905E+03**	4.44171E+03	2.47878E+03	1.61979E+02	2.48214E+03	4.46628E+01
ASCA_PSO	3.53124E+06	2.33542E+06	2.54938E+03	1.42847E+02	2.49263E+03	2.90551E+01
RDWOA	1.02859E+04	1.12393E+04	2.49704E+03	1.71521E+02	2.49234E+03	4.63687E+01
SCADE	2.67095E+07	1.72162E+07	2.71842E+03	1.05720E+02	2.58351E+03	1.86237E+01
GCHHO	8.49356E+03	6.54380E+03	2.53141E+03	1.60923E+02	2.48708E+03	7.06880E+01
MOFOA	1.01366E+09	7.67729E+07	2.97469E+03	1.42065E+02	2.77640E+03	1.32313E+01
RCBA	2.20181E+04	1.91624E+04	2.89651E+03	3.06428E+02	2.61426E+03	6.87630E+01
LGCMFO	6.75119E+03	4.97517E+03	2.44104E+03	1.66046E+02	2.40281E+03	3.65995E+01
OBLGWO	3.86668E+05	3.52665E+05	2.48474E+03	2.03542E+02	2.44338E+03	3.88994E+01
	F22		F23		F24	
	AVG	STD	AVG	STD	AVG	STD
KING	2.30199E+03	2.64440E+00	**2.70673E+03**	**1.79267E+01**	**2.87442E+03**	**1.53860E+01**
LXMWOA	3.03234E+03	1.66971E+03	2.82434E+03	5.61307E+01	3.07753E+03	1.22513E+02
SCGWO	2.49644E+03	9.28581E+01	2.86322E+03	3.46088E+01	3.03903E+03	4.05595E+01
RCACO	5.74961E+03	2.14527E+03	2.74275E+03	2.79308E+01	2.94069E+03	2.58408E+01
LSEOFOA	4.65941E+03	2.00046E+03	2.83451E+03	4.82746E+01	3.04052E+03	5.38492E+01
IGWO	2.31116E+03	1.71701E+00	2.77601E+03	2.90461E+01	2.93291E+03	3.23937E+01
EESHHO	4.57560E+03	2.10901E+03	2.84738E+03	4.84353E+01	3.10540E+03	9.51460E+01
ASCA_PSO	5.57467E+03	2.18418E+03	2.87938E+03	4.29246E+01	3.03333E+03	4.06972E+01
RDWOA	6.32905E+03	1.03855E+03	2.85370E+03	4.89330E+01	3.11303E+03	7.45769E+01
SCADE	4.61591E+03	2.89446E+02	3.01081E+03	3.18262E+01	3.17449E+03	3.01979E+01
GCHHO	4.17132E+03	2.36304E+03	2.91302E+03	6.69028E+01	3.08529E+03	6.17814E+01
MOFOA	9.22812E+03	4.77996E+02	3.81052E+03	1.31986E+02	3.92215E+03	1.36208E+02
RCBA	7.42955E+03	9.09371E+02	3.31957E+03	1.49573E+02	3.39413E+03	1.85926E+02
LGCMFO	**2.30029E+03**	**9.10062E−01**	2.76739E+03	2.88417E+01	2.93707E+03	3.03915E+01
OBLGWO	2.75256E+03	1.32046E+03	2.81674E+03	3.56484E+01	2.97301E+03	4.35185E+01
	F25		F26		F27	

(*continued on next page*)

Table A13 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	AVG	STD	AVG	STD	AVG	STD
KING	2.90016E+03	1.90545E+01	**3.62774E+03**	6.63827E+02	**3.21966E+03**	**1.26978E+01**
LXMWOA	2.89727E+03	1.89776E+01	4.17026E+03	1.78406E+03	3.25417E+03	2.31616E+01
SCGWO	2.98346E+03	3.72172E+01	4.31911E+03	1.08479E+03	3.27223E+03	3.42589E+01
RCACO	**2.88895E+03**	**6.86987E+00**	4.49956E+03	4.04124E+02	3.22230E+03	1.44628E+01
LSEOFOA	2.91239E+03	2.56530E+01	5.02074E+03	1.68857E+03	3.25511E+03	2.57629E+01
IGWO	2.90738E+03	2.13014E+01	4.68902E+03	2.79313E+02	3.23523E+03	1.35544E+01
EESHHO	2.89990E+03	1.71489E+01	5.06104E+03	1.26375E+03	3.25694E+03	2.31779E+01
ASCA_PSO	2.93728E+03	5.42045E+01	6.29277E+03	6.53549E+02	3.29857E+03	3.99209E+01
RDWOA	2.91265E+03	2.16098E+01	5.75157E+03	5.44326E+02	3.25903E+03	2.65145E+01
SCADE	3.45352E+03	1.07113E+02	7.35395E+03	**2.69844E+02**	3.45160E+03	5.80794E+01
GCHHO	2.90249E+03	1.79941E+01	5.33388E+03	1.70053E+03	3.27046E+03	3.39483E+01
MOFOA	4.93939E+03	1.50446E+02	1.10096E+04	3.66156E+02	4.78656E+03	2.98709E+02
RCBA	2.89586E+03	1.88921E+01	8.87886E+03	2.37044E+03	3.43227E+03	1.23804E+02
LGCMFO	2.89598E+03	1.85714E+01	3.75695E+03	1.25889E+03	3.28354E+03	3.71716E+01
OBLGWO	2.92382E+03	2.82709E+01	5.34665E+03	4.85744E+02	3.24148E+03	1.76213E+01
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	**3.13115E+03**	5.34543E+01	**3.43140E+03**	**8.39693E+01**	**8.75335E+03**	**2.80121E+03**
LXMWOA	3.13861E+03	5.08355E+01	3.92264E+03	2.21307E+02	9.09048E+03	3.04917E+03
SCGWO	3.40326E+03	5.49401E+01	4.03675E+03	2.26670E+02	1.27733E+07	8.36995E+06
RCACO	3.17615E+03	6.99700E+01	3.55699E+03	1.57996E+02	9.25916E+03	3.48760E+03
LSEOFOA	3.26904E+03	3.25771E+01	3.96060E+03	1.75214E+02	5.39380E+04	4.70009E+04
IGWO	3.26150E+03	3.08209E+01	3.86244E+03	1.59144E+02	3.81223E+06	2.63404E+06
EESHHO	3.18657E+03	4.37305E+01	3.90106E+03	2.26817E+02	1.03018E+04	3.89217E+03
ASCA_PSO	3.32479E+03	1.39660E+02	4.34819E+03	2.60122E+02	8.61965E+06	4.81556E+06
RDWOA	3.25945E+03	**1.74152E+01**	3.91194E+03	1.80265E+02	1.66244E+04	7.88156E+03
SCADE	4.27403E+03	1.78769E+02	5.15226E+03	2.18778E+02	9.78304E+07	3.40435E+07
GCHHO	3.21645E+03	2.41368E+01	4.03628E+03	2.57123E+02	1.18592E+04	4.62052E+03
MOFOA	6.82630E+03	2.53558E+02	8.16816E+03	8.30369E+02	3.53501E+09	1.04476E+09
RCBA	3.16877E+03	7.38434E+01	4.94285E+03	4.78607E+02	2.26436E+05	1.72863E+05
LGCMFO	3.22647E+03	2.68576E+01	3.82177E+03	2.24199E+02	4.61270E+04	1.26773E+05
OBLGWO	3.27808E+03	4.17341E+01	3.98708E+03	2.04098E+02	2.38535E+06	1.76710E+06

Table A14
AVG and STD values of comparative with high-performance algorithms on dimension 50

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.55809E+03**	**2.63598E+03**	3.56419E+33	1.93674E+34	3.74598E+04	1.73603E+04
LXMWOA	3.40298E+03	2.96365E+03	6.89797E+12	3.57730E+13	1.02698E+03	1.58397E+03
SCGWO	6.64408E+09	2.97944E+09	9.11962E+51	4.73268E+52	1.32726E+05	1.16626E+04
RCACO	9.57631E+03	8.75565E+03	2.61754E+29	1.42258E+30	5.46538E+04	1.34240E+04
LSEOFOA	1.85692E+09	1.91178E+09	2.01241E+42	1.09738E+43	6.64903E+04	1.20050E+04
IGWO	2.93055E+07	9.76513E+06	7.69335E+40	3.71489E+41	1.96901E+04	4.23001E+03
EESHHO	3.21936E+03	4.69077E+03	4.96104E+17	1.79632E+18	1.79652E+04	4.63167E+03
ASCA_PSO	1.94968E+09	3.40680E+09	2.84173E+55	1.55600E+56	3.92724E+04	1.10756E+04
RDWOA	1.30330E+08	1.69593E+08	2.38898E+41	1.00472E+42	5.66443E+04	1.52067E+04
SCADE	6.66682E+10	7.51562E+09	2.63937E+72	1.43833E+73	1.53391E+05	1.06440E+04
GCHHO	3.59532E+03	3.87533E+03	3.72937E+21	1.79034E+22	1.04745E+04	3.04343E+03
MOFOA	1.10112E+11	1.87192E+09	3.86722E+81	4.43007E+81	1.67696E+05	6.70646E+03
RCBA	1.08219E+05	2.50098E+04	**2.06460E+03**	**2.96773E+03**	**3.09931E+02**	**2.31776E+00**
LGCMFO	4.66819E+03	4.57245E+03	1.13635E+28	5.41698E+28	5.29030E+04	1.28085E+04
OBLGWO	9.55843E+07	4.37080E+07	9.30052E+38	4.13295E+39	5.01995E+04	9.39747E+03
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	4.98480E+02	5.67558E+01	**6.16943E+02**	2.80002E+01	6.00910E+02	**4.26058E−01**
LXMWOA	**4.86731E+02**	5.02500E+01	8.14272E+02	3.13005E+01	6.16986E+02	6.63178E+00
SCGWO	1.23264E+03	4.01054E+02	9.28203E+02	4.21270E+01	6.37405E+02	9.14169E+00
RCACO	5.02831E+02	6.32230E+01	8.37684E+02	2.73769E+01	**6.00424E+02**	4.52635E−01
LSEOFOA	8.42316E+02	2.02359E+02	8.40219E+02	2.51884E+01	6.47125E+02	1.04329E+01
IGWO	6.29550E+02	**4.53764E+01**	7.36972E+02	3.06800E+01	6.41405E+02	6.62960E+00
EESHHO	5.33984E+02	6.39165E+01	8.34946E+02	3.63873E+01	6.27729E+02	1.04434E+01
ASCA_PSO	6.92802E+02	2.16232E+02	9.96277E+02	5.38563E+01	6.60170E+02	9.76528E+00
RDWOA	6.44589E+02	5.05959E+01	9.14256E+02	6.73110E+01	6.42775E+02	9.24618E+00
SCADE	1.32560E+04	1.87051E+03	1.13003E+03	2.15484E+01	6.87009E+02	8.00452E+00
GCHHO	5.48145E+02	5.10173E+01	8.66076E+02	2.97864E+01	6.59081E+02	3.40909E+00
MOFOA	3.13593E+04	2.74119E+03	1.23294E+03	**1.09943E+01**	7.06982E+02	1.75882E+00

(*continued on next page*)

Table A14 (*continued*)

	F1 AVG	STD	F2 AVG	STD	F3 AVG	STD
RCBA	5.47746E+02	5.34237E+01	1.01900E+03	9.03117E+01	6.76149E+02	7.84007E+00
LGCMFO	5.41869E+02	6.15798E+01	8.10632E+02	3.96685E+01	6.35548E+02	9.59742E+00
OBLGWO	6.34293E+02	5.09340E+01	8.64971E+02	6.29155E+01	6.42624E+02	1.91130E+01
	F7 AVG	**STD**	**F8 AVG**	**STD**	**F9 AVG**	**STD**
KING	**9.06411E+02**	3.30679E+01	**9.14471E+02**	2.63216E+01	**1.50491E+03**	**2.18778E+02**
LXMWOA	1.14823E+03	5.95618E+01	1.12185E+03	3.45819E+01	1.16029E+04	1.74372E+03
SCGWO	1.42977E+03	1.06087E+02	1.25072E+03	6.04822E+01	2.90559E+04	6.44749E+03
RCACO	1.10074E+03	2.68171E+01	1.12755E+03	3.39802E+01	1.76039E+03	1.43518E+03
LSEOFOA	1.56840E+03	1.42039E+02	1.17619E+03	3.25269E+01	1.33008E+04	5.80243E+02
IGWO	1.24421E+03	8.43349E+01	1.04903E+03	2.56351E+01	1.11628E+04	3.79181E+03
EESHHO	1.56373E+03	1.03796E+02	1.11740E+03	3.53580E+01	1.15525E+04	1.06780E+03
ASCA_PSO	1.30543E+03	7.15361E+01	1.28836E+03	5.93320E+01	2.02292E+04	6.05911E+03
RDWOA	1.37366E+03	9.17152E+01	1.20675E+03	9.16059E+01	1.64995E+04	4.79212E+03
SCADE	1.73118E+03	8.58629E+01	1.43053E+03	2.05523E+01	3.37394E+04	1.89288E+03
GCHHO	1.55753E+03	1.19967E+02	1.17009E+03	3.53879E+01	1.23438E+04	1.53508E+03
MOFOA	1.94750E+03	**2.40342E+01**	1.55777E+03	**1.15799E+01**	4.50714E+04	1.60809E+03
RCBA	2.92280E+03	5.67864E+02	1.32745E+03	6.32777E+01	1.99376E+04	4.70471E+03
LGCMFO	1.18216E+03	1.33870E+02	1.12294E+03	5.25178E+01	1.07017E+04	2.59157E+03
OBLGWO	1.15203E+03	1.20779E+02	1.16240E+03	5.85044E+01	1.21626E+04	7.80979E+03
	F10 AVG	**STD**	**F11 AVG**	**STD**	**F12 AVG**	**STD**
KING	**6.51425E+03**	2.08858E+03	**1.20654E+03**	3.37250E+01	**5.99270E+05**	**2.75161E+05**
LXMWOA	7.18883E+03	7.96940E+02	1.25791E+03	3.17772E+01	1.36186E+06	6.65839E+05
SCGWO	1.11920E+04	1.80473E+03	3.25988E+03	1.47535E+03	9.58315E+08	5.09825E+08
RCACO	1.25062E+04	6.48145E+02	1.37985E+03	7.82061E+01	1.03429E+06	6.22998E+05
LSEOFOA	7.72591E+03	9.93314E+02	1.47733E+03	2.79245E+02	5.61552E+07	6.52825E+07
IGWO	8.09179E+03	1.07391E+03	1.51212E+03	9.34772E+01	1.20217E+08	6.55913E+07
EESHHO	6.76739E+03	6.59006E+02	1.23747E+03	**2.28914E+01**	3.83959E+06	1.43898E+06
ASCA_PSO	1.07216E+04	1.44254E+03	1.54698E+03	6.38266E+01	1.34047E+09	1.97431E+09
RDWOA	8.84490E+03	7.64562E+02	1.43184E+03	1.03247E+02	4.20334E+07	3.35998E+07
SCADE	1.41864E+04	**3.98533E+02**	1.41280E+04	1.96513E+03	1.84417E+10	3.65889E+09
GCHHO	8.03782E+03	9.65889E+02	1.32962E+03	4.90935E+01	4.53397E+06	2.61957E+06
MOFOA	1.58925E+04	4.66204E+02	2.28859E+04	1.12653E+03	9.29708E+10	7.29405E+09
RCBA	8.90536E+03	8.92436E+02	1.40852E+03	7.46394E+01	1.49499E+07	6.16703E+06
LGCMFO	7.31059E+03	7.42739E+02	1.38737E+03	8.88275E+01	5.00576E+06	2.95448E+06
OBLGWO	8.61086E+03	1.33259E+03	1.57163E+03	9.45795E+01	1.23376E+08	8.15241E+07
	F13 AVG	**STD**	**F14 AVG**	**STD**	**F15 AVG**	**STD**
KING	**5.16860E+03**	**6.15729E+03**	5.43301E+04	4.08402E+04	**8.44955E+03**	**4.67583E+03**
LXMWOA	9.17974E+03	8.24166E+03	**4.35940E+04**	3.97066E+04	1.43617E+04	6.81250E+03
SCGWO	3.64316E+08	2.28800E+08	2.03485E+06	1.01849E+06	9.68355E+06	1.57958E+07
RCACO	2.20650E+04	5.98204E+04	7.78096E+04	5.06612E+04	1.39086E+04	9.02033E+03
LSEOFOA	9.75868E+04	1.14468E+05	4.12767E+05	2.60376E+05	2.36835E+04	4.95380E+03
IGWO	3.70369E+05	2.00174E+05	3.38736E+05	2.18616E+05	7.62900E+04	5.81654E+04
EESHHO	9.20155E+03	8.86803E+03	1.94971E+05	1.51356E+05	1.27800E+04	6.58500E+03
ASCA_PSO	1.97444E+08	6.16783E+08	4.35291E+05	4.38993E+05	2.98748E+07	7.57347E+07
RDWOA	5.30561E+04	1.00487E+05	4.88524E+05	4.11968E+05	1.50185E+04	1.11485E+04
SCADE	4.30234E+09	1.39529E+09	6.12081E+06	2.75314E+06	4.49637E+08	2.49584E+08
GCHHO	1.55612E+04	1.15056E+04	1.85821E+05	1.29933E+05	1.45886E+04	6.10139E+03
MOFOA	6.31315E+10	7.49746E+09	7.97115E+07	2.22198E+07	5.55476E+09	1.02942E+09
RCBA	1.79373E+05	1.41317E+05	5.65835E+04	**3.86455E+04**	7.33600E+04	5.44091E+04
LGCMFO	6.13644E+04	4.94943E+04	1.86062E+05	1.37804E+05	3.37575E+04	1.67553E+04
OBLGWO	2.05578E+06	1.41660E+06	5.62580E+05	3.24281E+05	3.52267E+05	6.68584E+05
	F16 AVG	**STD**	**F17 AVG**	**STD**	**F18 AVG**	**STD**
KING	**2.71874E+03**	**2.59200E+02**	**2.46043E+03**	2.83292E+02	1.01330E+06	9.33532E+05
LXMWOA	3.57580E+03	4.16073E+02	3.42957E+03	3.19578E+02	**1.91131E+05**	**1.41990E+05**
SCGWO	4.32407E+03	7.93021E+02	3.95926E+03	5.04150E+02	4.26225E+06	4.05626E+06
RCACO	3.65309E+03	4.69595E+02	3.03942E+03	3.28398E+02	2.79441E+06	2.53597E+06
LSEOFOA	3.83607E+03	4.46816E+02	3.34696E+03	4.13949E+02	2.79570E+06	3.38179E+06
IGWO	3.45431E+03	4.91666E+02	2.95997E+03	**2.48177E+02**	2.83438E+06	1.65394E+06
EESHHO	3.70613E+03	3.31857E+02	3.20231E+03	4.48225E+02	9.61387E+05	6.19490E+05
ASCA_PSO	4.04359E+03	4.42548E+02	3.55389E+03	3.37896E+02	3.22863E+06	2.54058E+06
RDWOA	3.89993E+03	4.10323E+02	3.23456E+03	3.51191E+02	1.87433E+06	1.29717E+06
SCADE	5.79220E+03	3.24258E+02	4.57843E+03	2.84480E+02	2.86634E+07	1.32413E+07
GCHHO	3.59899E+03	4.16517E+02	3.42908E+03	4.17233E+02	1.07400E+06	7.56538E+05
MOFOA	9.84054E+03	8.68686E+02	1.65110E+04	4.20337E+03	2.09695E+08	1.68850E+07
RCBA	4.33111E+03	6.24845E+02	3.89324E+03	4.87845E+02	4.51585E+05	2.40942E+05
LGCMFO	3.56410E+03	4.09548E+02	3.13071E+03	3.82666E+02	9.97467E+05	4.36286E+05

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Table A14 (*continued*)

	F1 AVG	STD	F2 AVG	STD	F3 AVG	STD
OBLGWO	3.89728E+03	3.69250E+02	3.47485E+03	3.86328E+02	3.26819E+06	2.90655E+06

	F19 AVG	STD	F20 AVG	STD	F21 AVG	STD
KING	1.86952E+04	1.03112E+04	**2.51697E+03**	1.99875E+02	**2.41307E+03**	**2.24879E+01**
LXMWOA	1.97039E+04	**9.74237E+03**	3.32348E+03	2.78616E+02	2.66802E+03	8.60660E+01
SCGWO	1.48293E+07	8.57080E+06	3.24456E+03	3.21136E+02	2.71468E+03	6.52794E+01
RCACO	**1.83176E+04**	1.38055E+04	3.19760E+03	3.14815E+02	2.63984E+03	3.17590E+01
LSEOFOA	2.52879E+04	1.74583E+04	3.52856E+03	2.70371E+02	2.64153E+03	5.89818E+01
IGWO	7.63554E+05	5.91708E+05	3.05987E+03	2.95404E+02	2.55884E+03	3.56466E+01
EESHHO	2.46967E+04	1.32270E+04	3.19886E+03	3.25457E+02	2.65725E+03	5.97649E+01
ASCA_PSO	1.06255E+07	5.58520E+06	3.29550E+03	2.62618E+02	2.75807E+03	4.98783E+01
RDWOA	1.85540E+04	1.48436E+04	3.22828E+03	3.34151E+02	2.74114E+03	1.03941E+02
SCADE	3.38075E+08	1.22110E+08	3.82623E+03	1.30757E+02	2.91379E+03	4.22507E+01
GCHHO	2.28620E+04	1.18522E+04	3.25529E+03	2.72353E+02	2.68935E+03	5.30001E+01
MOFOA	6.59246E+09	1.38277E+09	4.27892E+03	**1.10851E+02**	3.20981E+03	2.90297E+01
RCBA	5.76941E+04	2.87994E+04	4.00292E+03	4.56073E+02	3.01552E+03	1.17833E+02
LGCMFO	2.85941E+04	2.01410E+04	3.11776E+03	3.63883E+02	2.55609E+03	5.42921E+01
OBLGWO	1.32297E+06	9.66524E+05	3.31805E+03	2.67734E+02	2.62118E+03	4.97776E+01

	F22 AVG	STD	F23 AVG	STD	F24 AVG	STD
KING	**7.00172E+03**	2.96575E+03	**2.86811E+03**	**3.72635E+01**	**3.04298E+03**	**3.06706E+01**
LXMWOA	9.00565E+03	2.44596E+03	3.14792E+03	1.30368E+02	3.51916E+03	2.63293E+02
SCGWO	9.94978E+03	5.62154E+03	3.18892E+03	5.90417E+01	3.35380E+03	5.64875E+01
RCACO	1.39192E+04	7.32164E+02	3.03525E+03	5.10283E+01	3.23237E+03	4.06050E+01
LSEOFOA	9.73261E+03	8.78543E+02	3.15277E+03	7.19921E+01	3.33532E+03	6.73679E+01
IGWO	9.39820E+03	1.59576E+03	3.05227E+03	4.55555E+01	3.21982E+03	6.18539E+01
EESHHO	8.77645E+03	7.07712E+02	3.22047E+03	1.04669E+02	3.49519E+03	1.06224E+02
ASCA_PSO	1.24771E+04	1.47145E+03	3.30757E+03	6.81824E+01	3.43138E+03	9.36178E+01
RDWOA	1.03235E+04	9.98751E+02	3.35981E+03	1.18280E+02	3.56602E+03	1.46743E+02
SCADE	1.60411E+04	**3.98404E+02**	3.57964E+03	6.87181E+01	3.73923E+03	5.98744E+01
GCHHO	1.00983E+04	1.13955E+03	3.38856E+03	9.53701E+01	3.53508E+03	1.40046E+02
MOFOA	1.80882E+04	4.97047E+02	4.94229E+03	2.74750E+02	5.04823E+03	2.31156E+02
RCBA	1.09425E+04	9.77554E+02	4.21733E+03	2.82042E+02	4.00182E+03	1.98915E+02
LGCMFO	8.36002E+03	3.52190E+03	3.04764E+03	7.44296E+01	3.16972E+03	5.58900E+01
OBLGWO	1.01047E+04	2.10719E+03	3.11376E+03	8.87985E+01	3.26422E+03	6.13027E+01

	F25 AVG	STD	F26 AVG	STD	F27 AVG	STD
KING	3.05649E+03	3.65307E+01	5.18463E+03	7.45728E+02	**3.41455E+03**	**6.32464E+01**
LXMWOA	3.07523E+03	2.99508E+01	4.50956E+03	2.81712E+03	3.62666E+03	1.55452E+02
SCGWO	3.59546E+03	3.28464E+02	5.46670E+03	1.43474E+03	3.72368E+03	1.15964E+02
RCACO	**3.01083E+03**	4.21699E+01	6.70503E+03	5.37041E+02	3.42982E+03	8.01360E+01
LSEOFOA	3.26918E+03	1.00590E+02	7.08363E+03	2.81157E+03	3.67652E+03	2.73271E+02
IGWO	3.13783E+03	4.49604E+01	7.22497E+03	5.20612E+02	3.56375E+03	6.43509E+01
EESHHO	3.07064E+03	4.08814E+01	7.40388E+03	3.48263E+03	3.60874E+03	1.75599E+02
ASCA_PSO	3.13403E+03	9.20650E+01	1.02474E+04	9.60239E+02	3.81524E+03	2.14916E+02
RDWOA	3.16692E+03	5.06865E+01	1.00517E+04	1.21644E+03	3.68831E+03	1.56189E+02
SCADE	8.65910E+03	7.76041E+02	1.33288E+04	5.77562E+02	4.65662E+03	1.81178E+02
GCHHO	3.07153E+03	3.09513E+01	7.32028E+03	3.41616E+03	3.73405E+03	1.40347E+02
MOFOA	1.44821E+04	5.65367E+02	1.67945E+04	**2.38257E+02**	7.82500E+03	9.61943E+02
RCBA	3.07026E+03	3.02911E+01	1.54747E+04	3.31453E+03	4.24748E+03	3.65425E+02
LGCMFO	3.08014E+03	**2.64720E+01**	**3.55359E+03**	2.05651E+03	3.66404E+03	9.26328E+01
OBLGWO	3.15885E+03	4.08505E+01	7.40951E+03	2.12998E+03	3.59890E+03	1.52950E+02

	F28 AVG	STD	F29 AVG	STD	F30 AVG	STD
KING	**3.29260E+03**	2.69341E+01	**3.62065E+03**	**1.85513E+02**	**8.59985E+05**	**1.45229E+05**
LXMWOA	3.30582E+03	2.70412E+01	4.36725E+03	2.99431E+02	1.13149E+06	2.86630E+05
SCGWO	4.13227E+03	3.92970E+02	5.06990E+03	6.44827E+02	1.26999E+08	3.99492E+07
RCACO	3.30248E+03	2.83414E+01	3.81267E+03	2.83968E+02	1.41547E+06	5.42713E+05
LSEOFOA	3.76504E+03	1.47539E+02	4.73572E+03	2.69967E+02	1.25795E+07	7.23639E+06
IGWO	3.42297E+03	5.34420E+01	4.76795E+03	3.65246E+02	8.90666E+07	2.52625E+07
EESHHO	3.30614E+03	**1.27009E+01**	4.58854E+03	3.30938E+02	1.01949E+06	2.21214E+05
ASCA_PSO	3.72692E+03	5.69877E+02	6.06339E+03	6.31016E+02	1.35418E+08	8.43250E+07
RDWOA	3.50995E+03	8.72044E+01	5.03503E+03	4.08642E+02	3.43476E+06	1.10205E+06
SCADE	8.41378E+03	4.93206E+02	8.12724E+03	6.40719E+02	8.96114E+08	2.62087E+08
GCHHO	3.33306E+03	3.02317E+01	4.93197E+03	3.87679E+02	1.05661E+06	2.83449E+05
MOFOA	1.30333E+04	3.95253E+02	4.44360E+04	1.00122E+04	1.00184E+10	8.04187E+08
RCBA	3.30932E+03	1.98994E+01	6.49014E+03	8.87236E+02	9.75057E+06	2.67159E+06
LGCMFO	3.38263E+03	4.77815E+01	4.74882E+03	3.90939E+02	2.49720E+06	1.55481E+06
OBLGWO	3.43148E+03	6.58284E+01	5.20023E+03	4.86848E+02	3.74158E+07	1.16856E+07

Table A15
AVG and STD values of comparative with high-performance algorithms on dimension 100

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	2.50709E+06	1.14989E+07	3.90780E+125	1.56464E+126	3.01350E+05	4.58611E+04
LXMWOA	**6.50422E+03**	**8.66771E+03**	3.02986E+76	1.50662E+77	**4.56487E+04**	1.38232E+04
SCGWO	4.51111E+10	9.97799E+09	2.64558E+146	1.44903E+147	3.10109E+05	1.59009E+04
RCACO	3.59804E+06	1.40472E+07	4.37490E+104	2.39612E+105	3.46114E+05	2.28833E+04
LSEOFOA	4.90949E+10	1.40168E+10	7.64160E+119	4.14646E+120	2.36605E+05	1.91274E+04
IGWO	1.36963E+09	2.07353E+08	6.31251E+122	3.45030E+123	1.97798E+05	2.39811E+04
EESHHO	1.02172E+07	2.01477E+07	5.95763E+71	2.17234E+72	1.48875E+05	1.68317E+04
ASCA_PSO	8.51488E+09	7.23978E+09	2.82672E+146	1.54826E+147	3.26871E+05	4.68379E+04
RDWOA	1.90570E+09	1.36144E+09	2.87888E+129	1.57680E+130	2.41269E+05	2.77075E+04
SCADE	2.14552E+11	1.04616E+10	2.02699E+160	**6.55350E+04**	3.30065E+05	1.02610E+04
GCHHO	1.69899E+06	7.49588E+06	2.31408E+84	9.01767E+84	1.34338E+05	1.40561E+04
MOFOA	2.65464E+11	3.57009E+09	9.53416E+169	6.55350E+04	3.38840E+05	**3.93826E+03**
RCBA	1.17186E+06	2.23432E+05	**2.08334E+35**	9.24328E+35	1.36666E+05	3.61242E+04
LGCMFO	3.90140E+07	4.55898E+07	1.51327E+100	8.28562E+100	2.41329E+05	1.34787E+04
OBLGWO	1.61169E+09	5.42877E+08	3.67818E+114	1.95731E+115	2.65073E+05	2.52806E+04
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**6.64270E+02**	4.63095E+01	**8.53333E+02**	9.23480E+01	6.06827E+02	1.84886E+00
LXMWOA	6.94036E+02	5.51198E+01	1.34798E+03	5.67677E+01	6.47316E+02	5.43646E+00
SCGWO	5.63214E+03	1.29383E+03	1.66918E+03	9.45768E+01	6.71593E+02	8.03571E+00
RCACO	6.67840E+02	4.71679E+01	1.47708E+03	4.43237E+01	**6.01301E+02**	**1.09756E+00**
LSEOFOA	4.71140E+03	1.69748E+03	1.38758E+03	5.05138E+01	6.61070E+02	3.05176E+00
IGWO	1.32417E+03	1.16255E+02	1.25457E+03	5.13636E+01	6.62372E+02	3.74961E+00
EESHHO	7.43224E+02	5.81413E+01	1.32868E+03	6.41911E+01	6.45614E+02	8.40843E+00
ASCA_PSO	1.93148E+03	1.38194E+03	1.76193E+03	1.19667E+02	6.89245E+02	7.25048E+00
RDWOA	1.32621E+03	2.45683E+02	1.55111E+03	1.35659E+02	6.64563E+02	6.81446E+00
SCADE	5.02113E+04	8.33117E+03	2.01699E+03	3.63677E+01	7.06034E+02	2.90946E+00
GCHHO	7.71693E+02	**4.20667E+01**	1.33710E+03	4.86647E+01	6.61598E+02	2.47487E+00
MOFOA	9.92247E+04	3.58349E+03	2.15766E+03	**1.91963E+01**	7.19608E+02	1.68094E+00
RCBA	6.88960E+02	4.29753E+01	1.64355E+03	1.49308E+02	6.77369E+02	5.62781E+00
LGCMFO	8.37121E+02	7.13549E+01	1.26474E+03	6.59072E+01	6.54850E+02	5.27253E+00
OBLGWO	1.16791E+03	1.25405E+02	1.45805E+03	7.57368E+01	6.70253E+02	9.22264E+00
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**1.47615E+03**	1.58012E+02	**1.15325E+03**	6.52386E+01	1.31237E+04	5.52464E+03
LXMWOA	2.88649E+03	2.87925E+02	1.80988E+03	8.06306E+01	2.29263E+04	1.03432E+03
SCGWO	2.82205E+03	2.07884E+02	2.04642E+03	1.24456E+02	6.86965E+04	8.60149E+03
RCACO	1.85907E+03	7.11729E+01	1.77215E+03	3.51043E+01	**1.07679E+04**	4.64028E+03
LSEOFOA	2.91654E+03	1.66013E+02	1.87084E+03	7.55644E+01	2.54214E+04	8.02943E+02
IGWO	2.62683E+03	2.07580E+02	1.60743E+03	7.73436E+01	3.93200E+04	8.72990E+03
EESHHO	3.06334E+03	1.86467E+02	1.77317E+03	7.69404E+01	2.24504E+04	1.20880E+03
ASCA_PSO	2.19971E+03	1.41025E+02	2.14983E+03	1.08274E+02	7.18470E+04	1.17567E+04
RDWOA	2.97355E+03	2.40392E+02	1.94450E+03	1.33136E+02	3.36039E+04	1.21199E+04
SCADE	3.70266E+03	9.32455E+01	2.43996E+03	5.53481E+01	7.24910E+04	3.00139E+03
GCHHO	3.05762E+03	2.06794E+02	1.78686E+03	8.03689E+01	2.31385E+04	**6.76955E+02**
MOFOA	4.03338E+03	**3.17302E+01**	2.62079E+03	**2.30716E+01**	8.41585E+04	3.04779E+03
RCBA	5.99600E+03	1.21642E+03	2.09915E+03	1.39161E+02	4.01987E+04	8.46065E+03
LGCMFO	2.24584E+03	1.61515E+02	1.61237E+03	1.01593E+02	2.70250E+04	1.02706E+04
OBLGWO	2.07546E+03	2.28633E+02	1.79339E+03	1.33726E+02	6.23325E+04	1.50768E+04
	F10		F11		F12	
	AVG	STD	AVG	STD	AVG	STD
KING	1.84133E+04	7.07117E+03	**1.97913E+03**	2.53013E+02	**2.76564E+06**	**1.04661E+06**
LXMWOA	1.58523E+04	1.17576E+03	2.11960E+03	**1.49012E+02**	1.66760E+07	7.63315E+06
SCGWO	2.58722E+04	3.30250E+03	9.81114E+04	1.46712E+04	7.99392E+09	5.90477E+09
RCACO	3.09313E+04	7.08307E+02	3.96112E+03	7.47985E+02	8.23577E+06	3.27201E+06
LSEOFOA	1.74387E+04	9.93247E+02	2.02108E+04	4.93038E+03	3.92755E+09	2.88705E+09
IGWO	1.72009E+04	1.76881E+03	7.18143E+03	1.47702E+03	7.36965E+08	2.51791E+08
EESHHO	**1.48823E+04**	1.03525E+03	3.20473E+03	1.92067E+03	2.86712E+07	1.12055E+07
ASCA_PSO	2.46103E+04	2.61608E+03	4.65960E+03	5.07995E+02	4.14649E+09	3.62286E+09
RDWOA	1.92730E+04	1.60659E+03	1.62155E+04	6.06302E+03	6.44923E+08	4.12934E+08
SCADE	3.15131E+04	5.63629E+02	1.66552E+05	2.19688E+04	1.02637E+11	1.30906E+10
GCHHO	1.61828E+04	1.43842E+03	2.69878E+03	2.91553E+02	3.41674E+07	1.55759E+07
MOFOA	3.19758E+04	**4.69104E+02**	2.09674E+05	2.15704E+04	2.16044E+11	5.50348E+09
RCBA	1.68398E+04	1.18768E+03	2.92828E+03	3.01969E+02	7.47061E+07	1.66665E+07
LGCMFO	1.51699E+04	1.22352E+03	1.07283E+04	4.04755E+03	4.60041E+07	2.10109E+07
OBLGWO	2.02802E+04	3.32402E+03	9.95651E+03	1.93201E+03	6.35133E+08	2.35930E+08
	F13		F14		F15	
	AVG	STD	AVG	STD	AVG	STD
KING	7.87052E+03	5.15510E+03	6.49385E+05	9.17582E+05	3.55061E+03	1.95973E+03

(*continued on next page*)

Table A15 (*continued*)

	F1 AVG	STD	F2 AVG	STD	F3 AVG	STD
LXMWOA	**7.41309E+03**	**4.34155E+03**	**3.33464E+05**	**1.80050E+05**	**3.13482E+03**	**1.52188E+03**
SCGWO	8.86229E+08	8.69350E+08	9.96177E+06	3.87633E+06	1.96901E+08	1.43546E+08
RCACO	1.41490E+04	1.11578E+04	1.81933E+06	3.71294E+06	7.46077E+03	7.39329E+03
LSEOFOA	8.87876E+06	2.34086E+07	4.23085E+06	3.80246E+06	4.31941E+04	7.75848E+04
IGWO	8.43945E+06	1.46899E+07	4.71114E+06	2.03296E+06	8.23535E+05	1.49119E+06
EESHHO	1.25841E+04	9.30521E+03	6.12761E+05	1.82130E+05	5.35507E+03	4.13251E+03
ASCA_PSO	4.48464E+08	9.65556E+08	3.68065E+06	3.20564E+06	2.66314E+08	3.95508E+08
RDWOA	5.01804E+06	9.68491E+06	1.79347E+06	1.12736E+06	9.06993E+04	2.60787E+05
SCADE	1.78568E+10	2.78592E+09	2.66476E+07	5.42367E+06	4.90207E+09	1.13869E+09
GCHHO	1.44216E+04	7.02687E+03	6.75549E+05	2.44266E+05	7.78877E+03	1.03009E+04
MOFOA	5.28696E+10	2.21979E+09	1.26693E+08	5.94376E+07	3.11748E+10	1.33824E+09
RCBA	8.22258E+04	3.21629E+04	5.11000E+05	2.28289E+05	6.39406E+04	4.30122E+04
LGCMFO	7.48204E+04	3.70570E+04	1.03988E+06	3.81693E+05	5.75283E+04	3.69654E+04
OBLGWO	7.67868E+06	4.73817E+06	4.04932E+06	2.01467E+06	2.03017E+06	1.80094E+06

	F16 AVG	STD	F17 AVG	STD	F18 AVG	STD
KING	**5.11399E+03**	1.23285E+03	**4.44600E+03**	9.59859E+02	2.95699E+06	3.53277E+06
LXMWOA	5.65343E+03	7.55164E+02	5.49753E+03	5.61423E+02	**4.51248E+05**	**1.97593E+05**
SCGWO	9.87313E+03	1.66183E+03	7.57857E+03	8.97866E+02	9.49964E+06	5.33086E+06
RCACO	8.59651E+03	9.21440E+02	6.35496E+03	4.62266E+02	1.16221E+07	9.76966E+06
LSEOFOA	7.10235E+03	8.27244E+02	5.39568E+03	**4.25115E+02**	4.73941E+06	3.77821E+06
IGWO	6.92986E+03	8.11161E+02	5.27765E+03	7.34813E+02	5.14158E+06	2.14506E+06
EESHHO	6.05071E+03	7.09225E+02	5.29765E+03	5.63055E+02	9.61819E+05	2.97877E+05
ASCA_PSO	7.93146E+03	8.93761E+02	6.57884E+03	5.56658E+02	6.82412E+06	4.81681E+06
RDWOA	8.32212E+03	1.10324E+03	6.22442E+03	6.49071E+02	2.50857E+06	1.18336E+06
SCADE	1.44825E+04	**6.86686E+02**	2.95876E+04	1.37356E+04	4.49709E+07	1.52820E+07
GCHHO	6.02380E+03	7.22186E+02	5.90916E+03	5.28393E+02	1.14257E+06	3.97722E+05
MOFOA	2.36374E+04	1.08866E+03	1.72919E+07	6.42641E+06	3.09905E+08	5.78303E+07
RCBA	7.22975E+03	7.43170E+02	6.17836E+03	6.92870E+02	9.04861E+05	3.06618E+05
LGCMFO	6.16855E+03	7.26966E+02	5.76923E+03	8.95094E+02	1.81267E+06	6.24235E+05
OBLGWO	7.93065E+03	1.06962E+03	6.04480E+03	7.88121E+02	6.01087E+06	2.65701E+06

	F19 AVG	STD	F20 AVG	STD	F21 AVG	STD
KING	4.54960E+03	2.82989E+03	**4.42460E+03**	9.42917E+02	**2.66925E+03**	7.13963E+01
LXMWOA	**3.92222E+03**	**2.00366E+03**	5.53117E+03	5.99950E+02	3.26627E+03	2.14434E+02
SCGWO	2.46957E+08	1.10228E+08	6.22733E+03	6.97270E+02	3.45961E+03	1.08235E+02
RCACO	8.20702E+03	8.85196E+03	6.19920E+03	4.97592E+02	3.34358E+03	**5.51728E+01**
LSEOFOA	1.53181E+06	5.96921E+06	5.37634E+03	6.40495E+02	3.28511E+03	9.44976E+01
IGWO	5.45686E+06	4.20078E+06	5.17042E+03	5.66663E+02	3.20990E+03	8.96147E+01
EESHHO	8.28875E+03	5.36954E+03	5.22509E+03	4.02334E+02	3.23540E+03	1.06856E+02
ASCA_PSO	1.47232E+08	2.06374E+08	6.07040E+03	5.83826E+02	3.72470E+03	1.50497E+02
RDWOA	2.81295E+05	5.15063E+05	5.91517E+03	5.08702E+02	3.68661E+03	2.43040E+02
SCADE	4.37186E+09	7.43870E+08	7.31996E+03	2.58932E+02	3.97494E+03	7.62314E+01
GCHHO	7.27170E+03	5.61456E+03	5.57158E+03	4.50486E+02	3.58467E+03	1.68866E+02
MOFOA	2.98229E+10	1.49793E+09	8.11768E+03	**2.15945E+02**	5.33188E+03	1.75743E+02
RCBA	1.80637E+06	8.79172E+05	6.01014E+03	5.46661E+02	4.43288E+03	2.63561E+02
LGCMFO	3.54762E+04	6.48374E+04	4.89514E+03	5.32143E+02	3.06665E+03	1.09556E+02
OBLGWO	1.44673E+07	5.82311E+06	5.45587E+03	4.83925E+02	3.29253E+03	1.75267E+02

	F22 AVG	STD	F23 AVG	STD	F24 AVG	STD
KING	**1.71123E+04**	2.97010E+03	**3.19958E+03**	**4.08094E+01**	**3.81092E+03**	**7.81730E+01**
LXMWOA	2.06643E+04	1.26048E+03	3.81310E+03	2.05939E+02	4.59613E+03	2.16338E+02
SCGWO	2.73209E+04	5.55390E+03	3.99970E+03	1.06829E+02	4.56448E+03	1.23242E+02
RCACO	3.25760E+04	8.42539E+02	3.45865E+03	2.01166E+02	4.18357E+03	9.96484E+01
LSEOFOA	2.02937E+04	1.54053E+03	3.67312E+03	1.01263E+02	4.59230E+03	1.80350E+02
IGWO	2.07938E+04	1.80101E+03	3.84954E+03	8.56477E+01	4.62740E+03	1.85325E+02
EESHHO	1.91058E+04	1.46552E+03	3.48030E+03	1.23342E+02	4.43767E+03	1.53508E+02
ASCA_PSO	2.73602E+04	3.03408E+03	4.25574E+03	1.24962E+02	5.07406E+03	2.21992E+02
RDWOA	2.28174E+04	2.14471E+03	4.06479E+03	2.37729E+02	4.95984E+03	2.80161E+02
SCADE	3.38463E+04	5.04813E+02	4.99790E+03	1.17135E+02	6.64566E+03	1.97958E+02
GCHHO	2.04709E+04	1.75922E+03	4.19286E+03	1.53749E+02	5.03845E+03	3.00536E+02
MOFOA	3.63583E+04	**4.01938E+02**	6.79098E+03	3.19931E+02	1.13939E+04	1.24956E+03
RCBA	2.02594E+04	1.45125E+03	5.57615E+03	2.86072E+02	6.76038E+03	5.98624E+02
LGCMFO	1.94707E+04	1.39564E+03	3.61539E+03	1.41310E+02	4.15624E+03	1.75878E+02
OBLGWO	2.19698E+04	1.79565E+03	3.87250E+03	1.38834E+02	4.39534E+03	2.80096E+02

	F25 AVG	STD	F26 AVG	STD	F27 AVG	STD
KING	3.32970E+03	5.71878E+01	**1.20699E+04**	1.80703E+03	3.75853E+03	1.11397E+02
LXMWOA	3.39037E+03	7.46591E+01	2.13354E+04	5.76902E+03	4.02123E+03	2.09356E+02
SCGWO	7.75223E+03	1.25055E+03	1.96495E+04	3.90502E+03	4.26928E+03	2.86309E+02
RCACO	**3.28175E+03**	5.84644E+01	1.54766E+04	**6.18839E+02**	**3.45698E+03**	**4.52604E+01**

(*continued on next page*)

Table A15 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
LSEOFOA	5.31338E+03	5.83925E+02	2.29936E+04	5.61725E+03	4.12298E+03	1.54167E+02
IGWO	3.87907E+03	9.28941E+01	2.03138E+04	1.58752E+03	4.46466E+03	2.33252E+02
EESHHO	3.40335E+03	6.95801E+01	1.93979E+04	8.45776E+03	3.88363E+03	1.69775E+02
ASCA_PSO	3.79289E+03	2.92619E+02	2.34507E+04	1.30453E+03	4.13114E+03	2.53568E+02
RDWOA	3.99139E+03	1.43187E+02	2.41606E+04	3.26584E+03	4.31118E+03	4.03481E+02
SCADE	1.94034E+04	1.05691E+03	3.70513E+04	2.12741E+03	8.02064E+03	4.80614E+02
GCHHO	3.41829E+03	5.17836E+01	2.32553E+04	5.08662E+03	4.19204E+03	2.72634E+02
MOFOA	2.65635E+04	9.46491E+02	5.64340E+04	1.25818E+03	1.65822E+04	1.68824E+03
RCBA	3.32399E+03	6.79441E+01	3.48569E+04	5.76353E+03	4.88143E+03	7.25777E+02
LGCMFO	3.48122E+03	**4.88214E+01**	1.72605E+04	7.12418E+03	3.98602E+03	1.80638E+02
OBLGWO	4.04570E+03	1.40608E+02	1.64512E+04	2.91228E+03	3.82760E+03	1.10407E+02
	F28		F29		F30	
	AVG	STD	AVG	STD	AVG	STD
KING	3.44079E+03	**3.78147E+01**	**6.10530E+03**	**4.64701E+02**	**1.56942E+04**	**1.32047E+04**
LXMWOA	3.48233E+03	4.48680E+01	7.56147E+03	5.03255E+02	2.70098E+04	1.61604E+04
SCGWO	8.83721E+03	1.04597E+03	1.00526E+04	8.52194E+02	7.87629E+08	6.02155E+08
RCACO	3.45758E+03	9.28675E+01	7.27726E+03	1.10358E+03	2.46364E+04	1.67495E+04
LSEOFOA	7.02445E+03	1.47575E+03	8.53539E+03	7.75758E+02	6.49373E+07	5.63272E+07
IGWO	3.94897E+03	9.89402E+01	9.08712E+03	6.96373E+02	2.86259E+08	1.16263E+08
EESHHO	3.47139E+03	5.12763E+01	7.28742E+03	5.24397E+02	6.85961E+04	3.85949E+04
ASCA_PSO	5.21426E+03	1.86249E+03	1.06490E+04	1.08341E+03	6.83070E+08	8.27530E+08
RDWOA	4.15693E+03	2.29797E+02	1.03245E+04	9.03594E+02	4.29330E+07	2.45318E+07
SCADE	2.36792E+04	9.77025E+02	2.80302E+04	6.59792E+03	1.33639E+10	2.89715E+09
GCHHO	3.52852E+03	3.92202E+01	7.81701E+03	5.69478E+02	7.72013E+04	4.39958E+04
MOFOA	3.33972E+04	2.68410E+02	9.90580E+05	2.21559E+05	4.87268E+10	2.59898E+09
RCBA	**3.40016E+03**	4.46867E+01	1.01970E+04	1.09941E+03	1.24438E+07	5.23324E+06
LGCMFO	3.99691E+03	1.55523E+02	7.35144E+03	6.44208E+02	2.27491E+06	3.20098E+06
OBLGWO	4.04040E+03	1.18660E+02	9.10365E+03	9.58821E+02	1.16721E+08	4.79756E+07

Table A16
AVG and STD values of comparative with state-of-art algorithms on IEEE CEC2022

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
KING	3.0000E+02	1.7972E−12	**4.0005E+02**	**6.6883E−02**	**6.0001E+02**	**2.6706E−02**
AO	3.2481E+02	1.4205E+01	4.1120E+02	2.0735E+01	6.0005E+02	1.5287E−01
HOA	4.9680E+04	1.2003E+04	3.5451E+03	1.0387E+03	6.4202E+02	6.3474E+00
RBMO	**3.0000E+02**	**0.0000E+00**	4.0024E+02	7.5563E−01	6.0002E+02	1.1238E−01
SBOA	3.0000E+02	2.4939E−08	4.0081E+02	1.0998E+00	6.0019E+02	5.9161E−01
WO	1.3124E+04	4.0531E+03	5.4553E+02	3.4552E+01	6.2549E+02	4.3062E+00
BKA	4.6667E+03	1.2616E+04	8.0762E+02	9.4192E+02	6.4167E+02	7.9934E+00
IVY	7.3430E+02	8.9912E+02	4.2017E+02	2.9426E+01	6.0796E+02	1.1253E+01
BEO	3.0000E+02	1.7118E−13	4.0055E+02	4.0531E−01	6.0052E+02	6.0121E−01
	F4		F5		F6	
	AVG	STD	AVG	STD	AVG	STD
KING	**8.1617E+02**	**4.5868E+00**	**9.0068E+02**	**1.4757E+00**	3.3098E+03	2.4690E+03
AO	8.1646E+02	8.1913E+00	9.0389E+02	9.5018E+00	6.5167E+04	1.1256E+05
HOA	9.5778E+02	2.1196E+01	2.8909E+03	4.8503E+02	1.6598E+09	1.0667E+09
RBMO	8.2572E+02	8.1007E+00	9.0536E+02	1.6877E+01	**1.8881E+03**	**4.1233E+01**
SBOA	8.2597E+02	7.9095E+00	9.0158E+02	4.2307E+00	4.4671E+03	2.1688E+03
WO	9.4005E+02	1.3482E+01	1.6169E+03	2.4831E+02	1.1950E+07	8.2767E+06
BKA	9.1948E+02	3.4216E+01	2.6963E+03	3.6278E+02	5.3420E+07	2.1067E+08
IVY	8.7349E+02	2.3204E+01	2.8307E+03	3.1371E+02	3.7719E+03	1.8737E+03
BEO	8.3057E+02	8.1044E+00	9.2619E+02	5.7273E+01	5.6591E+03	3.4634E+03
	F7		F8		F9	
	AVG	STD	AVG	STD	AVG	STD
KING	**2.0066E+03**	7.8225E+00	**2.2130E+03**	9.3276E+00	2.4000E+03	2.3380E−11
AO	2.0243E+03	5.0386E+01	2.2311E+03	4.2186E+01	2.4004E+03	8.5326E−01
HOA	2.1475E+03	6.5722E+01	2.3598E+03	1.0324E+02	2.4044E+03	1.4711E+00
RBMO	2.0310E+03	3.2240E+01	2.2249E+03	2.2449E+01	**2.4000E+03**	2.5333E−13
SBOA	2.0234E+03	**6.2466E+00**	2.2191E+03	7.2334E+00	2.4000E+03	**8.4444E−14**
WO	2.0779E+03	1.0150E+01	2.2417E+03	**5.5250E+00**	2.4547E+03	1.4632E+01
BKA	2.1167E+03	3.7907E+01	2.3078E+03	5.8083E+01	2.4286E+03	5.2988E+01
IVY	2.0850E+03	6.1438E+01	2.4048E+03	1.3255E+02	2.4067E+03	2.5371E+01
BEO	2.0292E+03	1.3302E+01	2.2207E+03	6.2083E+00	2.4000E+03	9.7019E−13
	F10		F11		F12	

(*continued on next page*)

Table A16 (*continued*)

	F1		F2		F3	
	AVG	STD	AVG	STD	AVG	STD
	AVG	STD	AVG	STD	AVG	STD
KING	2.5607E+03	4.9936E−01	2.7667E+03	7.5810E+01	2.9681E+03	9.6337E+00
AO	2.5001E+03	1.4148E−01	2.8002E+03	5.9930E−01	2.9436E+03	7.3911E+01
HOA	2.5083E+03	1.9553E+00	2.8006E+03	**2.9304E−01**	3.0782E+03	7.1536E+01
RBMO	2.6425E+03	2.7083E+02	2.7467E+03	8.9955E+01	2.9970E+03	1.2925E+01
SBOA	**2.5000E+03**	**8.4444E−14**	2.7667E+03	7.5810E+01	2.9808E+03	9.4806E+00
WO	2.5117E+03	3.1103E+00	2.8179E+03	6.8217E+00	2.8000E+03	5.6747E−02
BKA	2.5027E+03	9.9813E+00	2.8023E+03	4.6641E+01	**2.8000E+03**	**0.0000E+00**
IVY	2.5000E+03	1.3589E−03	2.8068E+03	2.5796E+01	2.9440E+03	8.8702E+01
BEO	2.5484E+03	2.4611E+01	**2.6733E+03**	9.8027E+01	2.9000E+03	0.0000E+00

Data Availability

Data will be made available on request.

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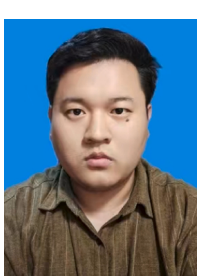

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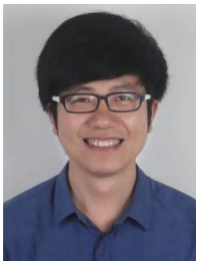

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