2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

Baghdad Science Journal

SBOA: A Novel Heuristic Optimization Algorithm

***Qi Diao**[1], **Apri Junaidi**[2], **WengHowe Chan** [2], **Azland Mohd Zain**[2], **Hao long Yang**[3]*

[1]Faculty of Artificial Intelligence, Zhejiang Dongfang Polytechnic, Wenzhou, 32500, China.
[2]Faculty of Computing, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia.
[3]Boston University, Massachusetts, 02215, America.
*Corresponding Author.
ICAC2023: The 4th International Conference on Applied Computing 2023.

Received 30/09/2023, Revised 10/02/2024, Accepted 12/02/2024, Published 25/02/2024

Abstract

A new human-based heuristic optimization method, named the Snooker-Based Optimization Algorithm (SBOA), is introduced in this study. The inspiration for this method is drawn from the traits of sales elites—those qualities every salesperson aspires to possess. Typically, salespersons strive to enhance their skills through autonomous learning or by seeking guidance from others. Furthermore, they engage in regular communication with customers to gain approval for their products or services. Building upon this concept, SBOA aims to find the optimal solution within a given search space, traversing all positions to obtain all possible values. To assesses the feasibility and effectiveness of SBOA in comparison to other algorithms, we conducted tests on ten single-objective functions from the 2019 benchmark functions of the Evolutionary Computation (CEC), as well as twenty-four single-objective functions from the 2022 CEC benchmark functions, in addition to four engineering problems. Seven comparative algorithms were utilized: the Differential Evolution Algorithm (DE), Sparrow Search Algorithm (SSA), Sine Cosine Algorithm (SCA), Whale Optimization Algorithm (WOA), Butterfly Optimization Algorithm (BOA), Lion Swarm Optimization (LSO), and Golden Jackal Optimization (GJO). The results of these diverse experiments were compared in terms of accuracy and convergence curve speed. The findings suggest that SBOA is a straightforward and viable approach that, overall, outperforms the aforementioned algorithms.

Keywords: autonomous learning, Evolutionary Computation, Heuristic optimization method, Single objective function, search space.

Introduction

In recent years, more and more researchers have focused on optimization problems, and proposed lots of algorithms. Their inspirations originate from different thoughts such as phenomenon, behaviors, simulation process, and so on. The structures of algorithms are simple and confirm that they are feasible and efficient to solve optimization problems. These optimization algorithms are divided into two categories: metaheuristic algorithms, heuristic algorithm.

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

Metaheuristic algorithms are divided into four categories: evolutionary algorithms, swarm algorithms, chemical & physical algorithms, and human-based algorithms[1,2] .The well-known algorithms are Genetic Algorithm (GA)[3], Differential Evolution Algorithm (DE)[4], Snake Optimizer (SO)[5], Sparrow Search Algorithm (SSA)[6], Golden jackal optimization (GJO)[7,] Pelican Optimization Algorithm (POA)[8],Sine cosine algorithm (SCA)[9], Whale Optimization Algorithm (WOA)[10], Grey Wolf Optimizer (GWO)[11], Thermal Exchange Optimization (TEO)[12], Teaching-learning-based optimization (TLBO)[13], Student psychology based optimization algorithm (SPBO)[14], Ant Colony Optimization (ACO)[15], Simulate Anneal Arithmetic[16] (SAA), Particle Swarm optimization (PSO)[17], Butterfly Optimization Algorithm(BOA)[18], and so on.

Heuristic algorithms provide footing stone for metaheuristic algorithms, and metaheuristic algorithms are included in heuristic algorithms. The commonness of metaheuristic algorithms and heuristic algorithms lies in obtaining the optimal solution, the difference is the degree of greed, namely heuristic algorithm is easy to fall into local solution.

SBOA

This section includes the inspiration and the mathematical model of SBOA.

Inspiration source

The layout of snooker is shown in **Error! Reference source not found.**. As everyone knows, if any player wants to win, he/she must make a good score. The highest score is 147, namely player must get 74 points at least. In a word, the number of cue balls contacting object balls must be more. It is said that one careless move loses the whole game. Therefore, players must maintain the initiative throughout the game. On one hand, players get score by offensive strategy. On the other hand, the player stops the opponent from scoring by defensive strategy, namely the cue ball is reasonably controlled by player, and create chances for score. can see from above; offensive strategy is an overall thinking and defensive strategy is a local thinking. The aim is to make a good score whether offensive strategy or defensive strategy. Thus, the play rules can be used to solve optimization problems.

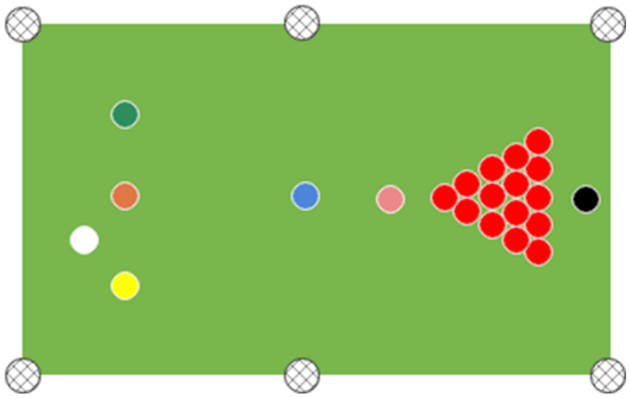


Figure 1. The layout of snooker.

Mathematical model

The thought about SBOA is simple, the structure is also simple. In the beginning of the search, the first kickoff result is produced by using Eq.1.

First, SBOA starts by generating a random population in uniform distribution to begin, including the cue ball and other balls. Based on this idea, the cue ball is considered as the best individual, its position that contacting object balls is very important. The initial population can be obtained using Eq.1.

$$X_i = X_{\min} + rand * (X_{\max} - X_{\min}) \quad 1$$

Where Xi is the position of all balls, rand is a random number between 0 and 1, and *Xmin*, *Xmax* are the lower and upper bounds of the problem respectively.

The best solution is shown using Eq.2.

$$BestX = \min(X_i), i = 1,2,\ldots,N \quad 2$$

Where N is the number of the first retrieval result.

Snooker as a sport with two players, is divided into two phases as follow:

(1) Attack phase

In the attack phase, the cue ball is contacted by other balls, a red ball then a colored ball. Alternating like this until a player wins. Therefore, the process is what the cue ball contacts other balls

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

so that has a good score. The process of Learning from colleagues is calculated using Eq. 3.

$$X_{i,new} = X_i + A \times rand(-1,1) \times (X_{best} - X_i)$$
$$A = \exp\left(\frac{t-10T}{T}\right)$$
3

Where X_{best} is the position of the cue ball, *rand* (0, 1) is random vectors in intervals [-1, 1]. A present's offensive ability that adapting to the game.

(2) Defensive phase

In defensive phase, the cue ball can be docked two balls, cushion, or around snookered ball/balls. The aim is to prevent the opponent from winning or scoring when a player has no scoring advantage. Thus, the process is simulated using Eq.4.

$$X_{i,new} = X_i + B \times rand(0,1) \times (X_{best} - X_i)$$
$$B = 2\sin(rand + \frac{\pi t}{4T}) \times e^{\frac{t-T}{T}}$$
4

Where *rand* (0, 1) is random vectors in intervals [0, 1], B presents defensive ability of players.

In the process, players usually have snooker according to the remaining balls on the billiard table. Therefore, searching for the best one (ball) using Eq.5.

$$X_{i,new} = \begin{cases} X_j + rand * (X_i - X_j), f(X_i) < f(X_j) \\ X_i + rand * (X_j - X_i), f(X_j) < f(X_i) \end{cases}$$
5

Where $f(X_i)$ is the fitness of position X_i, $f(X_j)$ is the fitness of position X_j.

The pseudo-code of SBOA is shown in **Error! Reference source not found.**.

Table 1. pseudo-code of SBOA

```
Algorithm: SBOA
Initialize Problem Setting
Initialize the population randomly
Calculate objective function using Eqs.2,
for t=1 to T
   phase1: Attack phase
     for i=1 to N
     Perform exploration phase using Eqs.3
     End
   phase2: Defensive phase
     for j=1 to N
     Perform exploration phase using Eqs.4, Eqs.5
     End
Return best solution
End
```

Experiment and Result

In this subsection, the performance of the SBOA Test is divided into three parts and has different benchmark functions obtained from CEC 2019 and CEC 2022. Each algorithm is performed 30 times, and parameter settings are shown in Table 2.

Table 2. Experiments parameters settings

Algorithm	Parameter name	Value
	Population size	30
Public	Dim	30
	Max number of iteration Scaling Factor	500
		0.5
DE	Crossover probability	0.5
SCA	a (constant)	2
	Convergence parameter (a)	
WOA	r is a random vector in the interval [0, 1]	
	l is a random number in [− 1, 1]	
LSO	β（Proportion of adult lions）	
SSA	ST (threshold)	0.6
	PD (Proportion of discoverers)	0.7
	SD (Aware of the proportion of dangerous sparrows)	0.2

GJO	c1(constant) r1(Random Number Based on Levy Distribution)	1.5 0.05.
BOA	p (Global flight probability) c (constant) a (Fragrance concentration index)	0.8 0.1 0.01

Result on CEC 2019

Table **1** shows the CEC 2019 summary of test functions include functions, opt, D, search range.

In this subsection, have used 10 objective functions obtained from CEC 2019.

Table 1. Benchmark functions of the CEC2019

No.	Functions	Opt	D	Search Range
1	Storn's Chebyshev Polynomial Fitting Problem	1	9	[-8192, 8192]
2	Inverse Hilbert Matrix Problem	1	16	[-16384, 16384]
3	Lennard-Jones Minimum Energy Cluster	1	18	[-4, 4]
4	Rastrigin's Function	1	10	[-100, 100]
5	Griewangk's Function	1	10	[-100, 100]
6	Weierstrass Function	1	10	[-100, 100]
7	Modified Schwefel's Function	1	10	[-100, 100]
8	Expanded Schaffer's F6 Function	1	10	[-100, 100]
9	Happy Cat Function	1	10	[-100, 100]
10	Ackley Function	1	10	[-100, 100]

Comparison Result

Table **2** shows the results of SBOA and other seven comparative algorithms (DE, SCA, WOA, LSO, SSA, GJO and BOA) in terms of mean (average), best (min), worst (max), median, and std. From **Error! Reference source not found.**, can see that SBOA outperforms other algorithms overall. SBOA has the best Mean results in 7 functions of all functions and ranked second in 1 function whereas it ranked fifth in other 2 functions.

Table 2. The comparison results 10 functions using CEC2019

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
F1	Min	6.62E+02	4.11E+04	1.00E+00	6.79E+04	1.00E+00	1.00E+00	1.00E+00	1.67E+00
	Mean	6.06E+05	1.91E+07	3.47E+02	1.49E+07	1.00E+00	1.00E+00	1.00E+00	2.54E+06
	Max	4.96E+06	2.08E+08	4.16E+03	5.35E+07	1.00E+00	1.00E+00	1.00E+00	2.01E+07
	Std	1.18E+06	4.96E+07	1.03E+03	1.29E+07	0.00E+00	1.00E+00	0.00E+00	5.01E+06
F2	Min	2.04E+02	2.86E+02	4.44E+00	3.85E+03	4.94E+00	4.97E+00	5.00E+00	9.78E+02
	Mean	1.63E+03	5.00E+03	1.17E+02	7.00E+03	5.00E+00	5.00E+00	5.00E+00	4.16E+03
	Max	3.64E+03	1.34E+04	5.58E+02	1.31E+04	5.00E+00	5.00E+00	5.00E+00	6.83E+03
	Std	9.54E+02	3.85E+03	1.65E+02	2.28E+03	1.48E-02	4.97E+00	0.00E+00	1.78E+03
F3	Min	1.00E+00	4.61E+00	1.39E+00	1.91E+00	5.08E+00	1.54E+00	4.23E+00	5.86E+00
	Mean	1.87E+00	9.01E+00	4.18E+00	5.59E+00	6.48E+00	4.99E+00	5.71E+00	9.12E+00
	Max	6.71E+00	1.23E+01	8.35E+00	9.71E+00	7.74E+00	8.05E+00	7.46E+00	1.12E+01
	Std	1.20E+00	2.10E+00	2.38E+00	2.29E+00	7.95E-01	1.54E+00	9.01E-01	1.61E+00
F4	Min	8.96E+00	1.39E+01	2.11E+01	2.98E+01	4.49E+01	9.56E+00	2.99E+01	3.65E+01
	Mean	2.95E+01	3.42E+01	3.29E+01	6.18E+01	8.95E+01	4.86E+01	7.43E+01	5.01E+01
	Max	4.78E+01	6.63E+01	4.61E+01	1.02E+02	1.10E+02	7.78E+01	1.30E+02	6.03E+01

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
	Std	1.20E+01	1.47E+01	8.80E+00	2.14E+01	1.46E+01	9.56E+00	2.55E+01	7.00E+00
F5	Min	1.07E+00	1.01E+00	1.65E+00	1.68E+00	7.22E+01	1.52E+00	3.27E+01	5.19E+00
	Mean	1.83E+00	3.87E+00	5.30E+00	2.32E+00	1.21E+02	1.93E+00	6.88E+01	9.93E+00
	Max	4.33E+00	3.51E+01	3.16E+01	3.49E+00	1.61E+02	2.63E+00	1.19E+02	1.94E+01
	Std	7.53E-01	7.75E+00	6.87E+00	4.76E-01	2.44E+01	1.52E+00	2.35E+01	4.05E+00
F6	Min	2.66E+00	1.74E+00	2.63E+00	4.66E+00	7.03E+00	3.54E+00	7.85E+00	5.98E+00
	Mean	5.70E+00	6.13E+00	4.38E+00	8.91E+00	9.01E+00	7.92E+00	9.69E+00	7.83E+00
	Max	9.18E+00	1.49E+01	7.62E+00	1.22E+01	1.09E+01	1.05E+01	1.21E+01	1.05E+01
	Std	1.54E+00	2.62E+00	1.29E+00	1.84E+00	9.36E-01	3.54E+00	9.94E-01	1.33E+00
F7	Min	4.31E+02	3.51E+02	2.66E+02	5.30E+02	1.51E+03	5.07E+02	1.31E+03	8.73E+02
	Mean	9.51E+02	1.53E+03	1.20E+03	1.34E+03	1.93E+03	1.10E+03	1.75E+03	1.64E+03
	Max	1.59E+03	2.58E+03	2.04E+03	2.24E+03	2.19E+03	1.59E+03	2.18E+03	2.02E+03
	Std	2.98E+02	4.95E+02	4.23E+02	3.95E+02	1.68E+02	5.07E+02	2.51E+02	2.25E+02
F8	Min	2.65E+00	4.10E+00	3.08E+00	4.20E+00	4.53E+00	4.34E+00	4.02E+00	3.60E+00
	Mean	3.96E+00	4.97E+00	4.14E+00	4.70E+00	4.88E+00	4.78E+00	4.76E+00	4.50E+00
	Max	4.53E+00	5.44E+00	5.00E+00	5.04E+00	5.15E+00	5.08E+00	5.36E+00	5.08E+00
	Std	4.45E-01	3.39E-01	4.30E-01	2.62E-01	1.71E-01	4.34E+00	3.23E-01	3.20E-01
F9	Min	1.09E+00	1.04E+00	1.10E+00	1.19E+00	3.12E+00	1.16E+00	1.59E+00	1.36E+00
	Mean	1.25E+00	1.42E+00	1.29E+00	1.45E+00	4.37E+00	1.48E+00	3.36E+00	1.62E+00
	Max	1.44E+00	3.32E+00	1.49E+00	1.81E+00	5.67E+00	2.03E+00	5.18E+00	2.00E+00
	Std	9.68E-02	4.13E-01	1.06E-01	1.44E-01	6.25E-01	1.16E+00	7.89E-01	1.63E-01
F10	Min	4.03E+00	2.13E+01	5.96E+00	2.11E+01	2.00E+01	2.11E+01	2.11E+01	2.13E+01
	Mean	2.01E+01	2.16E+01	2.05E+01	2.13E+01	2.14E+01	2.12E+01	2.15E+01	2.15E+01
	Max	2.16E+01	2.20E+01	2.16E+01	2.15E+01	2.16E+01	2.15E+01	2.17E+01	2.17E+01
	Std	3.92E+00	1.40E-01	3.76E+00	1.05E-01	2.80E-01	2.11E+01	1.51E-01	1.01E-01

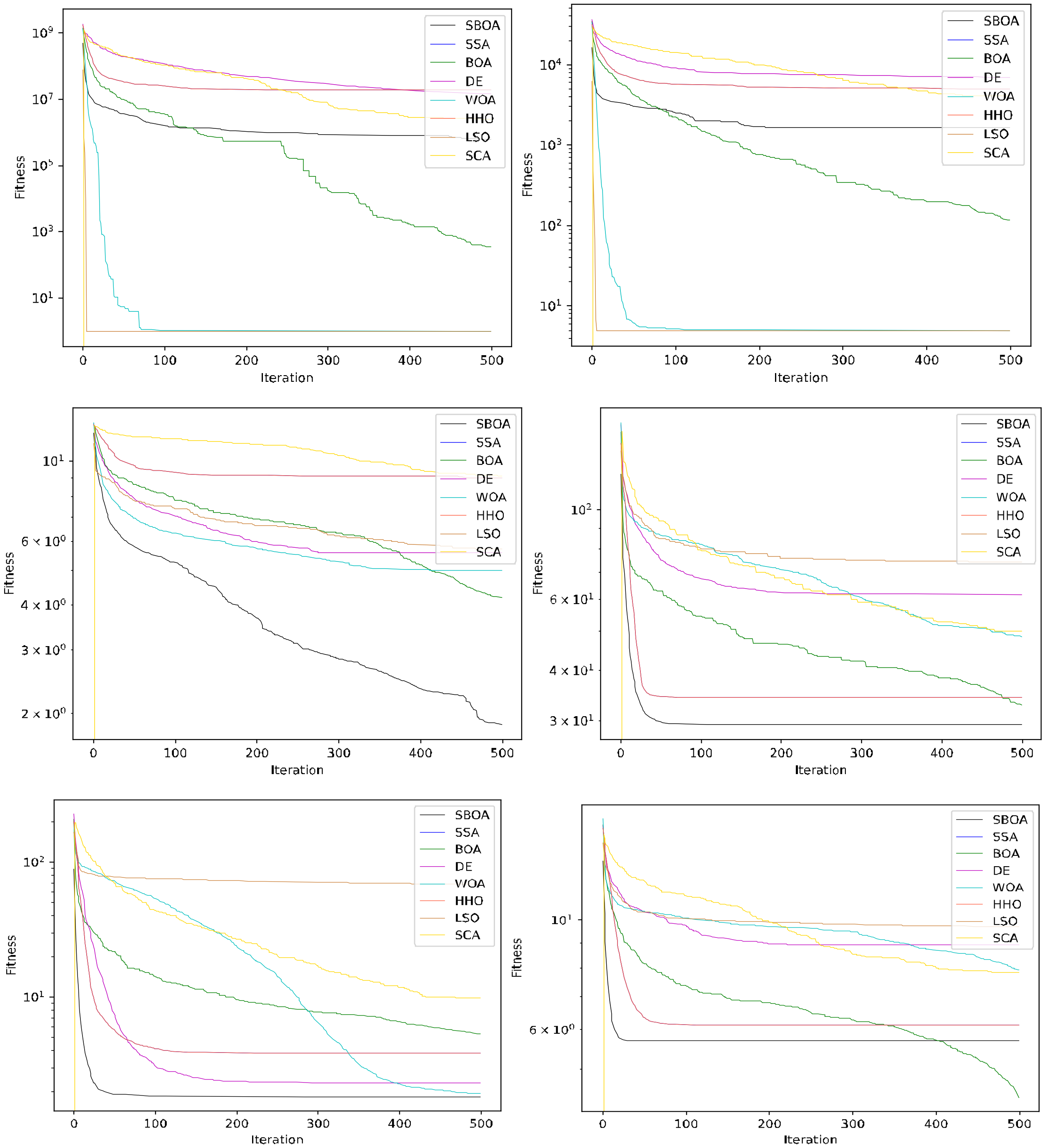
Table **3** shows the Wilcoxon rank sum test results for SBOA against other algorithms. From this table, can see that most P values are less than 0.05, and the smaller of the values, the better of these algorithms.

Table 3. Wilcoxon rank sum test results for SBOA against other algorithms CEC2019

Function	DE	SCA	WOA	LSO	SSA	GJO	BOA
F1	8.36E-04	9.17E-08	1.20E-06	8.01E-09	8.01E-09	8.01E-09	2.08E-01
F3	2.14E-03	1.43E-07	6.80E-08	1.13E-08	6.68E-08	8.01E-09	4.17E-05
F4	4.07E-11	6.52E-07	2.03E-09	4.57E-09	1.96E-10	4.61E-10	4.07E-11
F5	3.65E-01	4.90E-01	6.67E-06	2.22E-04	1.06E-07	6.92E-07	5.17E-06
F6	1.64E-01	5.25E-05	6.87E-04	2.23E-02	6.80E-08	6.80E-08	6.80E-08
F7	4.83E-01	9.52E-04	9.06E-08	5.46E-06	6.12E-10	9.92E-11	3.32E-06
F8	3.57E-06	1.22E-02	1.68E-04	3.51E-02	3.69E-11	2.15E-10	1.17E-09
F9	5.07E-10	1.86E-01	1.55E-09	1.61E-10	3.34E-11	3.50E-09	8.20E-07
F10	3.15E-02	1.33E-01	3.52E-07	2.28E-05	3.02E-11	3.02E-11	7.39E-11

Error! Reference source not found. show 10 convergence curves. From these convergence curves of all functions, it is seen that SBOA has obvious superiority than other algorithms in 7 functions, the second-best of 1 other function whereas it ranked fifth in other 2 functions.

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986



2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

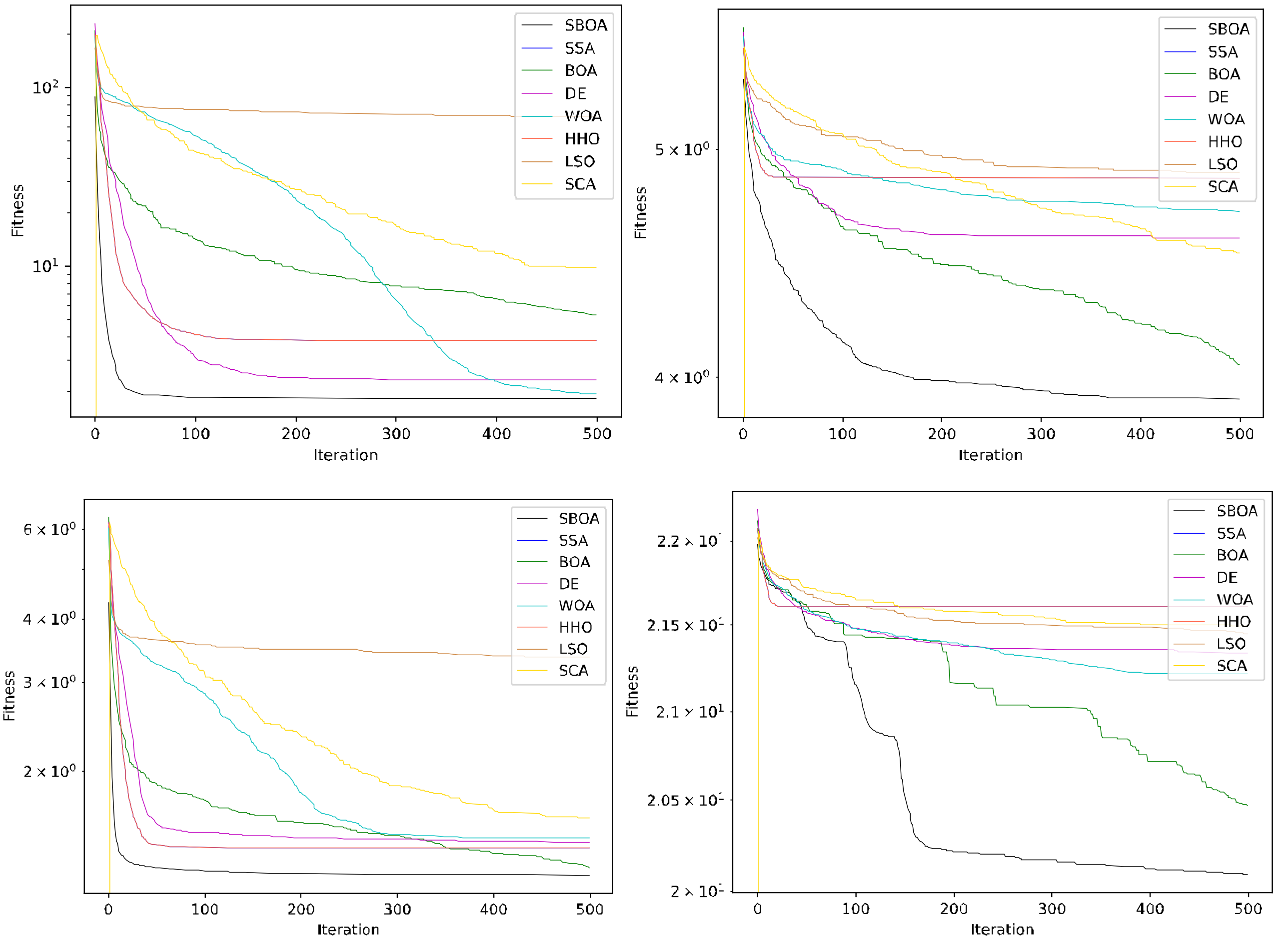


Figure 2. Convergence curve of some functions from F1–F10 for all algorithms CEC2019.

Result on CEC 2022

In this subsection, have used 12 objective benchmark functions obtained from CEC 2022. Table 4. Summary of the CEC 2022 test **functions** shows the CEC 2022 summary of test functions.

Table 4. Summary of the CEC 2022 test functions

Functions	No.	Functions	Opt
Unimodal Functions	1	Shifted and full Rotated Zakharov Function	300
	2	Shifted and full Rotated Rosenbrock's Function	400
Basis Functions	3	Shifted and full Rotated Expanded Scaffer'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: $[-100,100]^D$			

Comparison results

Table 5, **Error! Reference source not found.** show the results of SBOA and other seven comparative algorithms (DE, SCA, WOA, LSO, SSA, GJO and BOA) in terms of mean (average), best (min), worst (max), median, and std CEC 2022 and Dim=10. And Dim=20. It is seen that SBOA has the best Mean results in 11 functions from all functions at least. So it has obvious superiority to other algorithms.

Table 5. The comparison results 12 functions using CEC 2022 and Dim=10

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
F1	Min	3.35E+02	5.22E+02	6.44E+03	7.74E+02	8.49E+03	6.16E+03	5.08E+02	2.56E+03
	Mean	1.22E+03	1.22E+04	2.44E+04	2.47E+03	1.37E+04	8.76E+03	4.70E+03	6.58E+03
	Max	2.95E+03	7.43E+04	3.84E+04	5.74E+03	2.75E+04	1.05E+04	9.10E+03	9.08E+03
	Std	7.64E+02	2.23E+04	1.06E+04	1.39E+03	6.70E+03	6.16E+03	3.06E+03	2.16E+03
F2	Min	4.00E+02	4.01E+02	4.01E+02	4.37E+02	5.14E+02	4.03E+02	4.01E+02	1.01E+03
	Mean	4.17E+02	4.23E+02	4.71E+02	4.74E+02	1.36E+03	4.84E+02	4.53E+02	2.41E+03
	Max	4.74E+02	5.71E+02	7.32E+02	5.31E+02	3.92E+03	7.42E+02	5.24E+02	4.25E+03
	Std	2.46E+01	3.60E+01	8.89E+01	1.82E+01	7.66E+02	4.03E+02	2.78E+01	9.37E+02
F3	Min	6.00E+02	6.00E+02	6.18E+02	6.11E+02	6.26E+02	6.11E+02	6.01E+02	6.27E+02
	Mean	6.03E+02	6.10E+02	6.40E+02	6.21E+02	6.43E+02	6.46E+02	6.09E+02	6.45E+02
	Max	6.12E+02	6.30E+02	6.66E+02	6.30E+02	6.59E+02	6.65E+02	6.36E+02	6.57E+02
	Std	3.91E+00	7.77E+00	1.27E+01	4.83E+00	9.36E+00	6.11E+02	8.44E+00	7.76E+00
F4	Min	8.11E+02	8.09E+02	8.22E+02	8.28E+02	8.26E+02	8.18E+02	8.12E+02	8.34E+02
	Mean	8.19E+02	8.40E+02	8.44E+02	8.47E+02	8.49E+02	8.32E+02	8.27E+02	8.54E+02
	Max	8.30E+02	8.90E+02	9.01E+02	8.59E+02	8.63E+02	8.54E+02	8.46E+02	8.74E+02
	Std	4.27E+00	1.86E+01	1.78E+01	7.56E+00	8.22E+00	8.18E+02	9.44E+00	8.44E+00
F5	Min	9.00E+02	9.00E+02	1.01E+03	9.50E+02	1.02E+03	1.11E+03	9.02E+02	1.12E+03
	Mean	9.37E+02	1.40E+03	1.63E+03	1.07E+03	1.38E+03	1.41E+03	1.02E+03	1.40E+03
	Max	1.08E+03	3.27E+03	2.77E+03	1.36E+03	1.77E+03	1.49E+03	1.64E+03	1.79E+03
	Std	4.25E+01	5.98E+02	4.71E+02	1.05E+02	1.73E+02	1.11E+03	1.46E+02	1.64E+02
F6	Min	1.83E+03	1.97E+03	2.44E+03	2.46E+05	1.29E+06	1.88E+03	4.36E+03	2.82E+06
	Mean	2.21E+03	5.17E+05	6.53E+03	5.07E+06	7.26E+07	2.85E+03	1.29E+04	1.55E+08
	Max	4.54E+03	1.42E+07	2.50E+04	1.95E+07	3.64E+08	5.78E+03	5.59E+04	9.69E+08
	Std	5.96E+02	2.60E+06	4.22E+03	4.83E+06	9.15E+07	1.88E+03	1.02E+04	2.30E+08
F7	Min	3.10E+03	3.09E+03	3.11E+03	3.10E+03	3.12E+03	3.13E+03	3.09E+03	3.12E+03
	Mean	3.10E+03	3.11E+03	3.15E+03	3.11E+03	3.15E+03	3.22E+03	3.11E+03	3.19E+03
	Max	3.12E+03	3.17E+03	3.25E+03	3.11E+03	3.24E+03	3.33E+03	3.13E+03	3.30E+03
	Std	7.95E+00	2.41E+01	4.57E+01	2.82E+00	4.37E+01	3.13E+03	1.52E+01	5.95E+01
F8	Min	2.20E+03	2.22E+03	2.22E+03	2.23E+03	2.23E+03	2.23E+03	2.22E+03	2.23E+03
	Mean	2.22E+03	2.23E+03	2.24E+03	2.24E+03	2.27E+03	2.29E+03	2.23E+03	2.36E+03
	Max	2.23E+03	2.35E+03	2.27E+03	2.24E+03	2.45E+03	2.59E+03	2.24E+03	2.67E+03
	Std	5.39E+00	2.29E+01	1.10E+01	3.90E+00	6.00E+01	2.23E+03	3.54E+00	1.16E+02
F9	Min	2.53E+03	2.53E+03	2.56E+03	2.56E+03	2.65E+03	2.59E+03	2.53E+03	2.63E+03
	Mean	2.55E+03	2.54E+03	2.64E+03	2.59E+03	2.75E+03	2.67E+03	2.60E+03	2.78E+03
	Max	2.59E+03	2.59E+03	2.70E+03	2.63E+03	2.95E+03	2.74E+03	2.68E+03	2.99E+03
	Std	1.95E+01	2.51E+01	4.89E+01	2.35E+01	1.04E+02	2.59E+03	4.99E+01	1.09E+02
F10	Min	2.50E+03	2.50E+03	2.50E+03	2.50E+03	2.52E+03	2.50E+03	2.50E+03	2.50E+03
	Mean	2.55E+03	2.66E+03	2.65E+03	2.50E+03	2.66E+03	2.56E+03	2.59E+03	2.54E+03

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
	Max	2.64E+03	3.17E+03	3.69E+03	2.50E+03	2.96E+03	2.78E+03	2.65E+03	2.69E+03
	Std	6.51E+01	2.64E+02	3.71E+02	8.44E-01	1.27E+02	2.50E+03	6.27E+01	7.68E+01
F11	Min	2.61E+03	2.60E+03	2.72E+03	2.77E+03	2.90E+03	2.68E+03	2.73E+03	2.89E+03
	Mean	2.71E+03	2.96E+03	2.90E+03	2.79E+03	3.29E+03	3.04E+03	3.00E+03	3.41E+03
	Max	2.92E+03	3.41E+03	3.20E+03	2.82E+03	3.96E+03	3.94E+03	3.33E+03	4.54E+03
	Std	1.29E+02	2.77E+02	1.76E+02	1.43E+01	4.15E+02	2.68E+03	2.37E+02	5.40E+02
F12	Min	3.35E+02	5.22E+02	6.44E+03	7.74E+02	8.49E+03	6.16E+03	5.08E+02	2.56E+03
	Mean	1.22E+03	1.22E+04	2.44E+04	2.47E+03	1.37E+04	8.76E+03	4.70E+03	6.58E+03
	Max	2.95E+03	7.43E+04	3.84E+04	5.74E+03	2.75E+04	1.05E+04	9.10E+03	9.08E+03
	Std	7.64E+02	2.23E+04	1.06E+04	1.39E+03	6.70E+03	6.16E+03	3.06E+03	2.16E+03

Table 6. The comparison results 12 functions using CEC 2022 and Dim=20

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
F1	Min	8.64E+03	2.55E+04	2.59E+04	1.03E+04	2.79E+04	3.29E+04	7.23E+03	3.04E+04
	Mean	1.32E+04	6.56E+04	3.39E+04	1.91E+04	5.32E+04	4.80E+04	1.55E+04	6.09E+04
	Max	1.73E+04	1.50E+05	5.22E+04	3.02E+04	8.00E+04	6.27E+04	2.32E+04	1.02E+05
	Std	2.65E+03	3.59E+04	7.91E+03	5.60E+03	1.75E+04	3.29E+04	4.23E+03	2.17E+04
F2	Min	5.06E+02	4.31E+02	5.18E+02	6.27E+02	1.25E+03	6.81E+02	5.00E+02	1.59E+03
	Mean	6.07E+02	5.04E+02	6.32E+02	7.95E+02	2.75E+03	1.19E+03	6.33E+02	3.12E+03
	Max	6.85E+02	7.83E+02	7.87E+02	1.19E+03	4.50E+03	2.01E+03	8.33E+02	4.30E+03
	Std	4.21E+01	7.64E+01	6.54E+01	1.10E+02	7.40E+02	6.81E+02	9.06E+01	6.93E+02
F3	Min	6.16E+02	6.07E+02	6.54E+02	6.35E+02	6.52E+02	6.44E+02	6.13E+02	6.65E+02
	Mean	6.36E+02	6.21E+02	6.75E+02	6.52E+02	6.79E+02	6.67E+02	6.26E+02	6.81E+02
	Max	6.51E+02	6.32E+02	7.01E+02	6.66E+02	6.91E+02	6.82E+02	6.45E+02	6.96E+02
	Std	1.28E+01	7.73E+00	1.53E+01	1.01E+01	1.19E+01	6.44E+02	9.62E+00	9.29E+00
F4	Min	8.59E+02	8.66E+02	8.88E+02	9.16E+02	9.44E+02	9.10E+02	8.60E+02	9.64E+02
	Mean	8.75E+02	9.00E+02	9.31E+02	9.51E+02	9.67E+02	9.21E+02	8.93E+02	9.79E+02
	Max	9.03E+02	9.92E+02	9.66E+02	9.72E+02	9.90E+02	9.40E+02	9.24E+02	9.98E+02
	Std	1.19E+01	4.10E+01	2.86E+01	1.63E+01	1.66E+01	9.10E+02	1.92E+01	1.23E+01
F5	Min	1.39E+03	1.43E+03	2.53E+03	1.99E+03	2.95E+03	2.52E+03	1.57E+03	2.30E+03
	Mean	1.96E+03	3.19E+03	3.61E+03	2.91E+03	3.38E+03	2.58E+03	2.15E+03	3.48E+03
	Max	2.52E+03	7.53E+03	5.53E+03	4.02E+03	4.09E+03	2.64E+03	2.84E+03	4.22E+03
	Std	3.52E+02	1.92E+03	8.07E+02	7.62E+02	3.12E+02	2.52E+03	3.90E+02	5.94E+02
F6	Min	2.60E+03	7.35E+03	5.26E+05	4.35E+07	9.96E+08	1.11E+04	1.81E+04	5.78E+08
	Mean	5.03E+03	1.22E+07	3.73E+06	2.28E+08	1.92E+09	2.27E+08	1.61E+07	2.09E+09
	Max	1.07E+04	5.30E+07	2.21E+07	5.33E+08	3.34E+09	5.95E+08	6.11E+07	4.02E+09
	Std	2.40E+03	1.96E+07	6.52E+06	1.59E+08	8.08E+08	1.11E+04	2.06E+07	9.38E+08
F7	Min	2.04E+03	2.04E+03	2.10E+03	2.12E+03	2.11E+03	2.19E+03	2.05E+03	2.18E+03
	Mean	2.08E+03	2.23E+03	2.18E+03	2.14E+03	2.20E+03	2.31E+03	2.11E+03	2.22E+03
	Max	2.15E+03	2.49E+03	2.28E+03	2.24E+03	2.29E+03	2.46E+03	2.20E+03	2.29E+03
	Std	3.67E+01	1.60E+02	6.08E+01	3.84E+01	6.70E+01	2.19E+03	5.11E+01	3.40E+01
F8	Min	2.23E+03	2.23E+03	2.23E+03	2.25E+03	2.26E+03	2.26E+03	2.23E+03	2.39E+03
	Mean	2.27E+03	2.29E+03	2.29E+03	2.29E+03	2.81E+03	2.52E+03	2.27E+03	3.61E+03
	Max	2.45E+03	2.40E+03	2.50E+03	2.42E+03	6.31E+03	3.00E+03	2.36E+03	7.74E+03
	Std	6.40E+01	6.19E+01	7.48E+01	4.61E+01	9.32E+02	2.26E+03	5.14E+01	1.32E+03
F9	Min	2.48E+03	2.48E+03	2.53E+03	2.59E+03	2.87E+03	2.59E+03	2.53E+03	3.37E+03
	Mean	2.49E+03	2.50E+03	2.58E+03	2.65E+03	3.22E+03	2.72E+03	2.61E+03	4.02E+03
	Max	2.50E+03	2.55E+03	2.61E+03	2.75E+03	3.89E+03	2.85E+03	2.68E+03	4.59E+03
	Std	6.13E+00	2.93E+01	3.03E+01	5.37E+01	3.59E+02	2.59E+03	4.28E+01	4.22E+02

F		SBOA	DE	SCA	WOA	LSO	SSA	GJO	BOA
F10	Min	2.50E+03	2.50E+03	2.50E+03	2.52E+03	2.65E+03	2.77E+03	2.52E+03	2.54E+03
	Mean	2.66E+03	4.65E+03	5.16E+03	3.65E+03	5.75E+03	5.28E+03	4.26E+03	3.54E+03
	Max	4.66E+03	6.05E+03	6.97E+03	6.96E+03	7.38E+03	6.39E+03	7.09E+03	7.06E+03
	Std	4.35E+02	1.09E+03	1.11E+03	1.73E+03	1.53E+03	2.77E+03	1.71E+03	1.53E+03
F11	Min	3.32E+03	2.91E+03	3.99E+03	3.83E+03	7.84E+03	5.07E+03	4.02E+03	8.91E+03
	Mean	3.45E+03	4.66E+03	4.61E+03	5.08E+03	8.49E+03	6.72E+03	4.27E+03	9.33E+03
	Max	3.65E+03	8.15E+03	5.83E+03	5.87E+03	9.11E+03	8.41E+03	4.59E+03	9.90E+03
	Std	1.73E+02	3.02E+03	1.06E+03	1.09E+03	6.33E+02	5.07E+03	2.88E+02	5.06E+02
F12	Min	3.15E+03	3.17E+03	3.24E+03	3.26E+03	3.35E+03	3.43E+03	3.16E+03	3.30E+03
	Mean	3.20E+03	3.21E+03	3.31E+03	3.32E+03	3.69E+03	3.98E+03	3.22E+03	3.57E+03
	Max	3.25E+03	3.28E+03	3.50E+03	3.38E+03	4.06E+03	4.49E+03	3.34E+03	3.77E+03
	Std	3.55E+01	4.26E+01	8.42E+01	4.48E+01	2.47E+02	3.43E+03	5.04E+01	1.28E+02

Table **7**,
Table **8** show two the wilcoxon rank sum test results for SBOA against other algorithms CEC 2022 Dim = 10 and Dim=20. From these tables, the phenomenon that most values less than 0.05 is confirmed that SBOA is the best algorithm in all algorithms.

Table 7. Wilcoxon rank sum test results for SBOA against other algorithms CEC2022 Dim = 10

Function	DE	SCA	WOA	LSO	SSA	GJO	BOA
F1	3.76E-02	1.83E-04	1.73E-02	1.83E-04	1.83E-04	4.59E-03	2.46E-04
F3	8.77E-02	4.08E-05	7.12E-09	3.02E-11	1.86E-06	1.25E-05	3.02E-11
F4	1.17E-04	3.02E-11	3.34E-11	3.02E-11	3.34E-11	3.56E-04	3.02E-11
F5	1.47E-07	2.15E-10	3.34E-11	3.69E-11	1.56E-08	2.68E-04	3.02E-11
F6	2.77E-05	4.08E-11	3.20E-09	3.34E-11	3.02E-11	3.56E-04	3.02E-11
F7	3.82E-09	3.82E-10	3.02E-11	3.02E-11	5.87E-04	3.34E-11	3.02E-11
F8	3.15E-02	2.76E-03	1.65E-04	4.11E-05	4.11E-05	1.85E-03	4.11E-05
F9	2.15E-02	1.01E-08	3.82E-10	8.89E-10	1.29E-09	2.89E-03	3.34E-11
F10	4.35E-02	5.83E-04	3.61E-03	1.83E-04	2.46E-04	2.11E-02	1.83E-04
F11	6.40E-02	1.40E-02	6.40E-02	3.30E-04	1.40E-02	7.28E-03	3.30E-04
F12	3.45E-01	7.69E-04	2.41E-01	4.40E-04	1.83E-04	4.73E-01	2.46E-04

Table 8. Wilcoxon rank sum test results for SBOA against other algorithms CEC2022 Dim = 20

Function	DE	POA	WOA	LSO	SSA	GJO	GWO
F1	1.83E-04	1.83E-04	5.80E-03	1.83E-04	1.83E-04	5.39E-02	1.83E-04
F3	2.20E-07	1.22E-01	8.99E-11	3.02E-11	3.34E-11	4.46E-01	3.02E-11
F4	1.40E-02	1.83E-04	7.28E-03	1.83E-04	5.83E-04	1.04E-01	1.83E-04
F5	1.21E-01	2.46E-04	1.83E-04	1.83E-04	1.83E-04	3.12E-02	1.83E-04
F6	1.86E-01	1.83E-04	3.61E-03	1.83E-04	3.30E-04	3.45E-01	3.30E-04
F7	2.46E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04
F8	3.76E-02	7.69E-04	5.80E-03	7.69E-04	1.83E-04	1.04E-01	1.83E-04
F9	6.79E-02	2.56E-02	3.97E-03	5.23E-07	3.07E-06	4.73E-01	9.17E-08
F10	5.71E-01	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04
F11	5.46E-09	4.57E-09	3.59E-05	1.96E-10	5.49E-11	9.53E-07	1.87E-05
F12	8.35E-03	4.09E-01	1.79E-04	6.80E-08	1.23E-07	4.99E-02	6.80E-08

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

Engineering Problems

Engineering design optimization problems involve many inequalities constraints, are used to search maximum or minimum[19]. Their essences are known as mathematical problems, so many algorithms can be used to get the best value. To prove efficiency, SBOA is used solving 4 constrained problems in this subsection. Welded Beam Design[20], Pressure Vessel Design[21], Gear Train Design[22], and Three Bar Truss Design[23].

Pressure vessel design problem

Pressure vessel design problem has 4 design variables(x_1-x_4), the goal of this problem finds minimum. The equations as follow:

The objective function:

$$f(\vec{x}) = 0.6224x_1x_3x_4 + 1.7781x_2{x_3}^2 + 3.1661{x_1}^2x_4 + 19.84{x_1}^2x_3$$

Subject to:

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

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

$$g_3(\vec{x}) = -\pi {x_3}^2 x_4^2 - \frac{4}{3}\pi x_3^3 + 1{,}296{,}000 \leq 0$$

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

$$with 1 \times 0.0625 \leq x_1, x_2 \leq 99 \times 0.0625$$

$$10.0 \leq x_3, x_4 \leq 200.0$$

Results of SBOA and other algorithms are given in Table **9**, **Error! Reference source not found.**.

Table **9** shows the best solution x= [0.9559055314 0.4725024408 49.52835701 116.4764305] and where f(x)= 5920.777474. From **Error! Reference source not found.** and Figure 1 the SBOA outperform another algorithm.

Welded beam design problem

Welded beam design problem has 4 decision variables(x_1-x_4), the goal is to find the minimum because of cost savings. The equations of Welded beam design problem are shown below:

The objective function:

$$f(\vec{x}) = 1.10471x_1^2x_2 + 0.04811x_3\,x_4(14.0 + x_2)$$

$$g_1(\vec{x}) = \tau(\vec{x}) - 13{,}600 \leq 0$$

$$g_2(\vec{x}) = \sigma(\vec{x}) - 30{,}000 \leq 0$$

$$g_3(\vec{x}) = x_1 - x_4 \leq 0$$

$$g_4(\vec{x}) = 0.10471x_1^2 + 0.04811x_3\,x_4(14.0 + x_2) - 5.0 \leq 0$$

$$g_5(\vec{x}) = 0.125 - x_1 \leq 0$$

$$g_6(\vec{x}) = \sigma(\vec{x}) - 0.250$$

$$g_7(\vec{x}) = 6{,}000 - p_c(\vec{x}) \leq$$

Subject to:

$$\tau(\vec{x}) = \sqrt{(\tau')^2 + (2\tau'\tau'')\frac{x^2}{2R} + (\tau'')^2}$$

$$\tau' = \frac{6{,}000}{\sqrt{2}x_1x_2}, \tau'' = \frac{MR}{J}$$

$$M = 6{,}000\left(14 + \frac{x_2}{2}\right)$$

$$R = \sqrt{\frac{x_2^2}{4} + \left(\frac{x_1 + x_3}{2}\right)^2}$$

$$J = 2\left\{x_1x_2\sqrt{2}\left[\frac{x_2^2}{12} + \left(\frac{x_1 + x_3}{2}\right)^2\right]\right\}$$

$$\sigma(\vec{x}) = \frac{504{,}000}{x_4x_3^2}, \delta(\vec{x}) = \frac{65{,}856{,}000}{(30 \times 10^6)x_4x_3^2}$$

$$P_c(\vec{x}) = \frac{4.013(30 \times 10^6)\sqrt{\frac{x_3^2x_4}{36}}}{196}\left(1 - \frac{x_3\sqrt{\frac{30 \times 10^6}{4(12 \times 10^6)}}}{28}\right)$$

$$with 0.1 \leq x_1, x_4 \leq 2.0 \; and \; 0.1 \leq x_2, x_3 \leq 10.0$$

Results of SBOA and other algorithms are given in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error!**

Reference source not found.. **Error! Reference source not found.** shows the best solution *x*= [0.2057296398, 3.470488666, 9.03662391, 0.2057296398] and where *f(x)*= 1.724852309. From **Error! Reference source not found.** and **Error! Reference source not found.**, the SBOA algorithm is better than other algorithms, and convergence rate is best.

Gear train design problem

This problem has 2 design variables(x_1-x_4), the goal is to find minimum gear ratios. The equation of the problem is shown below:

The objective function:

$$f(\vec{x}) = \left(\frac{1}{6.931} - \frac{x_2 x_3}{x_1 x_4}\right)^2$$

$$12 \le x_1, x_2, x_3, x_4 \le 60$$

Results of SBOA and other algorithms are given in **Error! Reference source not found.**, **Error! Reference source not found.**6, and **Error! Reference source not found.**. **Error! Reference source not found.** shows the best solution *x*= [44.51174489, 14.4911759, 22.15518804, 45.55514392] and where *f(x)*=0. From **Error! Reference source not found.** and **Error! Reference source not found.**, the SBOA outperforms another algorithm.

Three Bar Truss Design problem

This problem has 2 design variables(x_1-x_2), the goal is to find minimum volume. The equation of the problem is shown below:

The objective function:

$$f(\vec{x}) = \left(\sqrt{2}x_1 + x_2\right) * 100$$

$$g_1(\vec{x}) = 2\frac{x_2}{\sqrt{2}x_1^2 + 2x_1x_2} - 2 \le 0$$

$$g_2(\vec{x}) = 2\frac{\sqrt{2}x_1 + x_2}{\sqrt{2}x_1^2 + 2x_1x_2} - 2 \le 0$$

$$g_3(\vec{x}) = \frac{2}{\sqrt{2}x_1^2 + 2x_1x_2} \le 0$$

$$with 0 \le x_1, x_2 \le 1$$

Results of SBOA and other algorithms are given in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**. **Error! Reference source not found.** shows the best solution *x*=[0.7886781057 0.4082398906, 10.06165022] and where *f(x)*= 263.8958437.From **Error! Reference source not found.** and **Error! Reference source not found.**, the SBOA outperform other algorithm.

Table 9. Comparison of optimum results for Pressure Vessel Design

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
X1	0.955905 5314	0.9630441 167	0.8342906 945	1.0327819 36	0.9559055 314	0.7781686 414	3.832522 915	0.8837330 516
X2	0.472502 4408	0.4760880 365	0.4124245 68	0.5041908 999	0.4725024 408	0.3846491 626	9.866387 089	0.5640434 348
X3	49.52835 701	49.894289 48	43.227437 64	51.256512 42	49.528357 01	40.319618 72	56.23997 968	44.804428 72
X4	116.4764 305	103.06116 95	166.13378 68	109.25068 45	116.47643 05	200.00000 000	59.23882 293	156.39804 03
cost	5920.777 474	5885.8260 56	6267.9908 16	6232.1187 71	6639.7536 12	82027.166 52	6089.760 092	6514.5341 63

Table 10. Statistical results for Pressure Vessel Design

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
Best	5920.7774 74	5885.8260 56	6267.9908 16	6232.1187 71	6639.7536 12	82027.166 52	6089.7600 92	6514.5341 63
Mean	6330.7994 18	5995.8313 66	6792.7834 66	6462.7782 94	5885.3327 74	82524.583 58	6171.6834 26	6954.5041 13
Worst	6740.8213 61	6105.8366 77	7317.5761 16	6693.4378 16	5885.3327 74	83022.000 64	6253.6067 61	7394.4740 64
Std	579.85859	155.57100	742.16888	326.20182	0	703.45395	115.85709	622.21147

36	18	31	49		25	07	1

Table 11. Comparison of optimum results for Welded beam design problem

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
X1	0.2057296398	0.2210538647	0.2057311878	0.2050539442	0.1564229738	0.2057296398	0.5163164759	0.2059869626
X2	3.470488666	3.289406174	3.470472596	3.69562116	5.259209356	3.470488666	2.331974532	3.746580124
X3	9.03662391	8.722957507	9.036579232	8.685785095	9.08891081	9.03662391	4.660468472	8.986799803
X4	0.2057296398	0.2212158756	0.2057316753	0.2287006703	0.2063213267	0.2057296398	0.8195458076	0.2146363308
cost	1.724852309	1.742159402	1.724853064	1.826945847	1.834899953	1.724852309	3.298087009	1.811390749

Table 12. Statistical results for Welded beam design problem

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
Best	1.724852309	1.742159402	1.724853064	1.826945847	1.834899953	1.724852309	3.298087009	1.811390749731
Mean	1.724852309	1.780303494	1.724860297	1.855640797	1.878859267	1.724852309	3.622747513	1.8223738619
Worst	1.724852309	1.818447586	1.724867529	1.884335747	1.922818582	1.724852309	3.947408017	1.8333569733
Std	3.140184917e-16	0.05394389176	1.022795925e-05	0.04058078767	0.06216785847	9.317242668e-12	0.4591392874	0.01553246557

Table 13. Comparison of optimum results for Three Bar Truss Design

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
x1	0.7886781057	0.7885912981	0.7895563504	0.7899812127	0.7885885394	0.7886751342	0.7749684666	0.7832913705
x2	0.4082398906	0.4084984596	0.4337208571	0.4056559916	0.408500096	0.4082482916	0.4536594544	0.4242569975
cost	263.8958437	263.8969781	264.905777	263.9872784	263.8964062	263.8958434	264.2747612	263.9365898

Table 14. Statistical results for Three Bar Truss Design

	SBOA	SSA	BOA	WOA	HHO	DE	LSO	SCA
Best	263.8958437	263.8969781	264.905777	263.9872784	263.8964062	263.8958434	264.2747612	263.9365898
Mean	263.8958437	263.8971478	266.6923455	264.0060282	263.8965311	263.8958434	264.5601286	263.9739556
Worst	263.8958438	263.8973174	268.478914	264.024778	263.896656	263.8958434	264.8454961	264.0113215
Std	1.37862016e-07	0.0002399571797	2.526589422	0.02651622575	0.0001766404548	0	0.4035705369	0.05284333457

Table 15. Comparison of optimum results for Gear train design

	SBOA	SSA	GWO	WOA	HHO	POA	LSO	SCA
x1	44.51174489	53.35576307	53.04977387	50.84889591	46.85152488	32.72524363	41.87283138	60
x2	14.4911759	28.381001	19.3136642	18.28141722	28.23560574	14.04978065	17.52778521	32.99962809
x3	22.15518804	16.59466426	20.10662087	20.58035155	14.20541526	12.40936158	15.73654678	17.43096945

x4	45.5551 4392	55.303 88372	35.2759503 9	46.507649 09	59.18020 488	39.562359 89	45.6736660 1	60
cost	0.00000 00000	5.6160 11718e -31	0.00027634 58932	0.0000000 000	0.000000 0000	3.7748226 91e-32	7.13756210 4e-11	1.604807594e-12

Table 16. Statistical results for Gear train design

	SBOA	SSA	GWO	WOA	HHO	POA	LSO	SCA
Best	0.0000000 000	5.61601171 8e-31	0.00027634 58932	0.0000000 000	0.0000000 000	3.77482269 1e-32	7.13756210 4e-11	1.6048075 94e-12
Mean	0.0000000 000	9.08754852 2e-15	0.00353192 6614	0.0000000 000	0.0000000 000	1.05540961 e-31	3.89309950 7e-09	2.3222941 68e-10
Worst	0.0000000 000	1.81750970 4e-14	0.00678750 7335	0.0000000 000	0.0000000 000	1.73333695 e-31	7.71482339 3e-09	4.6285402 59e-10
Std	0.0000000 000	1.28517343 7e-14	0.00460408 6409	0.0000000 000	0.0000000 000	9.58734039 1e-32	5.40473375 1e-09	3.2615245 01e-10

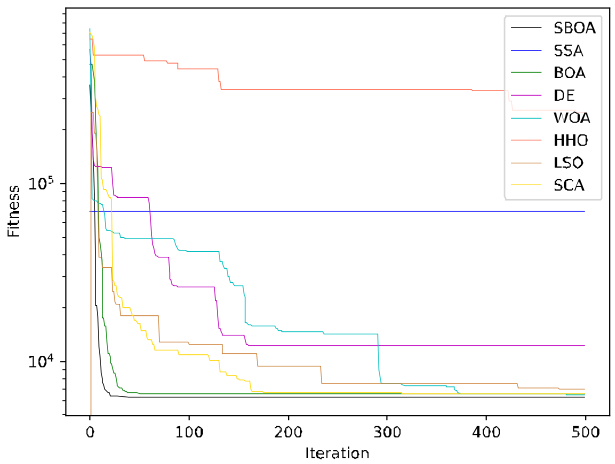


Figure 1. Pressure vessel design

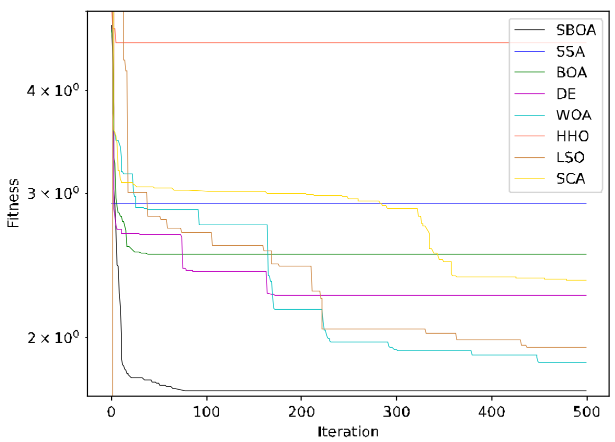


Figure 2. Welded beam design problem

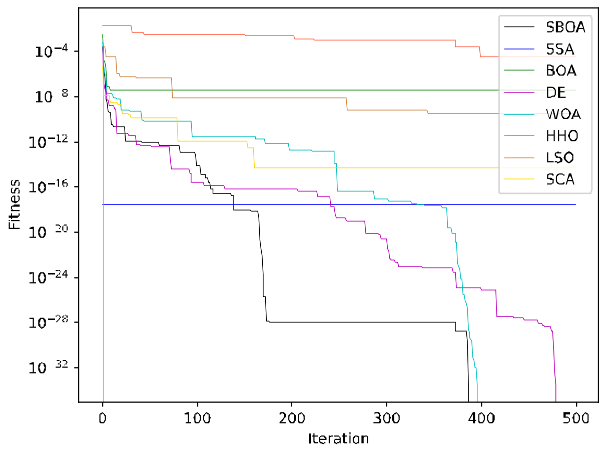


Figure 5. Gear train design problem

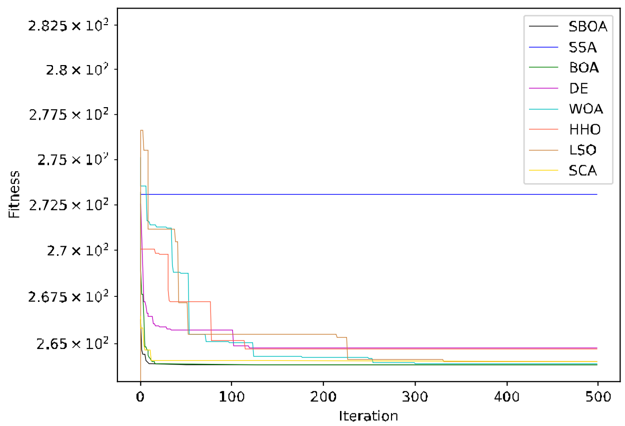


Figure 6. Three bar truss design

Conclusions

SBOA is proposed in this study and used 3 different benchmark functions to test performance and other well-known algorithms as DE, SSA, SCA, BOA, WOA, HHO, LSO, GJO. The results of these tables and figures show that SBOA is a feasible and simple algorithm, it is better than the above comparative algorithms.

Acknowledgment

The writer would like to express gratitude to Wenzhou Association for Science and Technology (grant No. jczc118), for their assistance with this project.

Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Universiti Teknologi Malaysia

Authors' Contribution Statement

D.Q wrote the manuscript with design and analysis, A.J edited the manuscript with revisions, C.W.H and A.M.Z. gave the idea of research and the tips of work. Y.H collected the literature. All authors read and approved the final manuscript.

References

1. 1.Almufti SM, Shaban AA, Ali ZA, Ali RI, Fuente JAD. Overview of Metaheuristic Algorithms. PGJSRT. 2023;2(2):10-32. https://doi.org/10.58429/pgjsrt.v2n2a144.
2. 2.Jassim OA, Abed MJ, Saied ZH. Indoor/Outdoor Deep Learning Based Image Classification for Object Recognition Applications. Baghdad Sci J. 2023;20(6(Suppl.)):2540. https://doi.org/10.21123/bsj.2023.8177.
3. 3.Gen M, Lin L. Genetic algorithms and their applications. Springer handbook of engineering statistics: Springer. 2023;p. 635-74.
4. 4.Song Y, Cai X, Zhou X, Zhang B, Chen H, Li Y, et al. Dynamic hybrid mechanism-based differential evolution algorithm and its application. Expert Syst Appl. 2023;213:118834. https://doi.org/10.1007/978-1-4471-7503-2_33.
5. 5.Khurma RA, Albashish D, Braik M, Alzaqebah A, Qasem A, Adwan O. An augmented Snake Optimizer for diseases and COVID-19 diagnosis. Biomed Signal Proces. 2023;84:104718. https://doi.org/10.1016/j.bspc.2023.104718.
6. 6.Gad AG, Sallam KM, Chakrabortty RK, Ryan MJ, Abohany AA. An improved binary sparrow search algorithm for feature selection in data classification. Neural Computing and Applications. 2022;34(18):15705-52. https://doi.org/10.1007/s00521-022-07203-7.
7. 7.Chopra N, Ansari MM. Golden jackal optimization: A novel nature-inspired optimizer for engineering applications. Expert Syst Appl. 2022;198:116924. https://doi.org/10.1016/j.eswa.2022.116924.
8. 8.Trojovský P, Dehghani M. Pelican optimization algorithm: A novel nature-inspired algorithm for engineering applications. Sensors-Basel. 2022;22(3):855. https://doi.org/10.3390/s22030855.
9. 9.Bacanin N, Zivkovic M, Al-Turjman F, Venkatachalam K, Trojovský P, Strumberger I, et al. Hybridized sine cosine algorithm with convolutional neural networks dropout regularization application. Sci Rep-Uk. 2022;12(1):6302. https://doi.org/10.1038/s41598-022-09744-2.
10. 10.Tang C, Sun W, Xue M, Zhang X, Tang H, Wu W. A hybrid whale optimization algorithm with artificial bee colony. Soft Comput. 2022;26(5):2075-97. https://doi.org/10.1007/s00500-021-06623-2.
11. 11.Meidani K, Hemmasian A, Mirjalili S, Barati Farimani A. Adaptive grey wolf optimizer. Neural Computing and Applications. 2022;34(10):7711-31. https://doi.org/10.1007/s00521-021-06885-9.
12. 12.Khodadadi N, Talatahari S, Dadras Eslamlou A. MOTEO: a novel multi-objective thermal exchange optimization algorithm for engineering problems. Soft Comput. 2022;26(14):6659-84. https://doi.org/10.1007/s00500-022-07050-7.
13. 13.Kommadath R, Maharana D, Sivadurgaprasad C, Kotecha P. Parallel computing strategies for sanitized teaching learning based optimization. J Comput Sci-Neth. 2022;63:101766. https://doi.org/10.1016/j.jocs.2022.101766.

2024, 21(2 Special Issue): 0764-0779
https://doi.org/10.21123/bsj.2024.9766
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

14. 14.Das B, Mukherjee V, Das D. Student psychology based optimization algorithm: A new population based optimization algorithm for solving optimization problems. Adv. Eng. Softw. . 2020;146:102804. https://doi.org/10.1016/j.advengsoft.2020.102804.
15. 15.Dorigo M, Stützle T. Ant colony optimization: overview and recent advances: Springer. 2019. https://doi.org/10.1007/978-3-319-91086-4_10.
16. 16.Ait-Saadi A, Meraihi Y, Soukane A, Ramdane-Cherif A, Gabis AB. A novel hybrid chaotic Aquila optimization algorithm with simulated annealing for unmanned aerial vehicles path planning. Comput. Electr. Eng. . 2022;104:108461. https://doi.org/10.1016/j.compeleceng.2022.108461.
17. 17.Abdulqader AW, Ali SM. Diversity Operators-based Artificial Fish Swarm Algorithm to Solve Flexible Job Shop Scheduling Problem. Baghdad Sci J. 2023;20(5(Suppl.)). https://dx.doi.org/10.21123/bsj.2023.6810.
18. 18.Sharma TK. Enhanced butterfly optimization algorithm for reliability optimization problems. J Ambient Intell Humaniz Comput. .2021;12(7):7595-619. https://doi.org/10.1007/s12652-020-02481-2.
19. 19.Mazher AN, Waleed J. Retina Based Glowworm Swarm Optimization for Random Cryptographic Key Generation. Baghdad Sci J. 2022;19(1):0179. https://doi.org/10.21123/bsj.2022.19.1.017920.
20. 20.Chugh T, Sindhya K, 20. Hakanen J, Miettinen K. A survey on handling computationally expensive multiobjective optimization problems with evolutionary algorithms. Soft Comput. 2019;23:3137-66. https://doi.org/10.1007/s00500-017-2965-0.
21. 21. Li X-D, Wang J-S, Hao W-K, Zhang M, Wang M. Chaotic arithmetic optimization algorithm. Appl. Intell. . 2022;52(14):16718-57. https://doi.org/10.1007/s10489-021-03037-3.
22. Nasr MF, Maalawi KY, Yihia K. Multi-Objective Optimization of Planetary Gear Train Using Genetic Algorithm. Journal of International Society for Science and Engineering. 2022;4(3):74-80. https://doi.org/10.21608/JISSE.2022.144284.1059.
23. Tao D, Wei X, Huang H, editors. Application of Improved Fruit Fly Optimization Algorithm in Three Bar Truss. International Conference on Intelligent Computing. 2022 Springer. https://doi.org/10.1007/978-3-031-13832-4_64.

SBOA: خوارزمية تحسين إرشادية جديدة

دياو كي[1]، آبري جنيدي[2]، جان وينك هو[2]،ازلاند موهد زين[2]، يانكهاولونك[3]

[1]كلية الذكاء الاصطناعي، تشجيانغ دونغفانغ بوليتكنيك، ونزهو، 32500، الصين.
[2]كلية الحاسبات، الجامعة التكنولوجية الماليزية، 81310، سكوداي، جوهور، ماليزيا.
[3]جامعة بوسطن، ماساتشوستس، 02215، أمريكا.

الخلاصة

تم تقديم طريقة تحسين إرشادية جديدة تعتمد على الإنسان، تسمى خوارزمية التحسين المستندة إلى السنوكر (SBOA)، في هذه الدراسة. الإلهام لهذه الطريقة مستوحى من سمات نخبة المبيعات - تلك الصفات التي يطمح كل مندوب مبيعات إلى امتلاكها. عادةً ما يسعى مندوبو المبيعات إلى تعزيز مهاراتهم من خلال التعلم الذاتي أو من خلال طلب التوجيه من الآخرين. علاوة على ذلك، فإنهم يشاركون في اتصالات منتظمة مع العملاء للحصول على الموافقة على منتجاتهم أو خدماتهم. بناءً على هذا المفهوم، تهدف SBOA إلى إيجاد الحل الأمثل ضمن مساحة بحث معينة، واجتياز جميع المواضع للحصول على جميع القيم الممكنة. لتقييم جدوى وفعالية SBOA مقارنة بالخوارزميات الأخرى، أجرينا اختبارات على عشر وظائف ذات هدف واحد من الوظائف المعيارية لعام 2019 للحساب التطوري (CEC)، بالإضافة إلى أربع وعشرين وظيفة ذات هدف واحد من CEC لعام 2022. وظائف مرجعية، بالإضافة إلى أربع مشاكل هندسية. تم استخدام سبع خوارزميات مقارنة: خوارزمية التطور التفاضلي (DE)، خوارزمية بحث العصفور (SSA)، خوارزمية جيب التمام (SCA)، خوارزمية تحسين الحيتان (WOA)، خوارزمية تحسين الفراشة (BOA)، تحسين سرب الأسد (LSO)، و تحسين ابن آوى الذهبي (GJO). وتمت مقارنة نتائج هذه التجارب المتنوعة من حيث الدقة وسرعة منحنى التقارب. تشير النتائج إلى أن SBOA هو نهج مباشر وقابل للتطبيق ويتفوق بشكل عام على الخوارزميات المذكورة أعلاه.

الكلمات المفتاحية: طريقة التحسين الإرشادية، الإحتساب التطوري، وظائف موضوعية واحدة، التعلم الذاتي، مساحة البحث.