Received: 29 September 2018 | Revised: 30 October 2018 | Accepted: 10 November 2018
DOI: 10.37917/ijeee.14.2.6 | Vol. 14| Issue 2 | December 2018
Open Access
Iraqi Journal for Electrical and Electronic Engineering
Original Article

Analysis of Scalability and Sensitivity for Chaotic Sine Cosine Algorithms

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Abstract *Chaotic Sine-Cosine Algorithms (CSCAs) are new metaheuristic optimization algorithms. However, Chaotic Sine-Cosine Algorithm (CSCAs) are able to manipulate the problems in the standard Sine-Cosine Algorithm (SCA) like, slow convergence rate and falling into local solutions. This manipulation is done by changing the random parameters in the standard Sine-Cosine Algorithm (SCA) with the chaotic sequences. To verify the ability of the Chaotic Sine-Cosine Algorithms (CSCAs) for solving problems with large scale problems. The behaviors of the Chaotic Sine-Cosine Algorithms (CSCAs) were studied under different dimensions 10, 30, 100, and 200. The results show the high quality solutions and the superiority of all Chaotic Sine-Cosine Algorithms (CSCAs) on the standard SCA algorithm for all selecting dimensions. Additionally, different initial values of the chaotic maps are used to study the sensitivity of Chaotic Sine-Cosine Algorithms (CSCAs). The sensitivity test reveals that the initial value 0.7 is the best option for all Chaotic Sine-Cosine Algorithms (CSCAs).*

Index Terms— **Chaos, Sine-Cosine Optimization Algorithm, Chaotic Sine-Cosine Optimization Algorithms, Scalability Analysis, Sensitivity Analysis.**

I. INTRODUCTION

Sine-Cosine Algorithm (SCA) is a new metaheuristic optimization algorithm [1]. The core inspection of the SCA algorithm is motivated from the sine and cosine mathematical functions. It is capable to demonstrate a superior performance compared to other well-established methods for solving different kinds of optimization problems. Similar to other metaheuristic optimization algorithms, it suffers from trapping into local optima and low convergence rate.

Recently, one of the mathematical methods that have been used to improve the performance of the metaheuristic algorithms is chaos. Chaos has several characteristics such as: sensitivity to initial values; quasi-stochastic, and ergodicity. Sensitivity to the initial value means, any alter in the initial values may lead to large alter in the output. Quasi-stochastic denotes to the capability of chaotic system to substitute random variables with chaotic maps values. Finally, ergodic characteristic indicates that the chaotic maps can investigate non-iteratively all cases within a certain bound. Integrating all these characteristics can vastly enhance the performance of the metaheuristic algorithms.

Many works have been embedded chaotic maps to improve the performance of the metaheuristic algorithms such as chaos-genetic algorithm [2], chaotic firefly algorithm [3], chaotic bat algorithm [4], chaotic cuckoo algorithm [5], chaotic crow search algorithm [6], chaotic whale optimization algorithm [7], chaotic jaya algorithm [8], grasshopper optimization algorithm [9], and chaotic salp swarm algorithm [10].

Dunia S. and Ramzy S. [11], presented new metaheuristic optimization algorithms, namely chaotic Sine-Cosine Algorithms (CSCAs) to overcome the drawbacks of the standard SCA algorithm. They are suggested four different Chaotic Sine-Cosine Algorithms. The random parameters in the standard Sine-Cosine Algorithm (SCA) are replaced with the chaotic sequences to improve the performance of the standard algorithm. As they stated, the statistical results showed that all Chaotic Sine-Cosine Algorithms can be outperformed the standard SCA. Different chaotic maps are used, the best chaotic maps for boosting the performance of the first CSCA-I and fourth CSCA-IV are Intermittency and Circle maps, respectively. While the Gauss map is the most suitable variant for the second CSCA-II and third CSCA-III methods [11].

One of a good characteristic of metaheuristic algorithms is the ability of solving the large scale optimization problems. The main aim of this paper is to investigate the scalability of the Chaotic Sine-Cosine Algorithms (CSCAs). Various dimensions have been used (10, 30, 100, and 200). Additionally, chaos is very sensitive to the initial values so the small changes of the initial value may cause of the large changes in output. Therefore, the sensitivity of the Chaotic Sine-Cosine Algorithms (CSCAs) to the initial values has been considered by using different values, and then the appropriate value is selected as the default value for all algorithms.

The rest of the paper is organized as follows. In Section-II, the standard Sine-Cosine Algorithm (SCA) and the Chaotic Sine-Cosine Algorithms are described. The performance analysis criteria presents in Section-III, .The simulation results are introduced in Section-IV. Section-V provides the conclusion of this study.

II. Chaotic Sine Cosine Algorithms

Sine-cosine algorithm (SCA) which was first proposed by Mirjalili S.in 2016, is inspired from the sine and cosine mathematical functions. Like other metaheuristic optimization algorithms, the optimization process of the SCA contains two mechanisms: exploitation versus exploration [1]. Intensification (local search) examines about the existent preferable solutions and takes the preferable one, while diversification (global search) permits for the metaheuristic algorithms to investigate more efficiently in the search space [12]. To accentuate these two phases, two position updating equations have been modeled. The equations are represented as shown below:

$$Y_k^{l+1} = Y_k^l + A \times \sin(B) \times \left|C \times Pos_k^l - Y_k^l\right| \quad (1)$$

$$Y_k^{l+1} = Y_k^l + A \times \cos(B) \times \left|C \times Pos_k^l - Y_k^l\right| \quad (2)$$

Where Y_k^l is the position of the current solution in k^{th} dimension and l^{th} iteration. *A*, *B*, and *C* are the random numbers, *Pos* means the position of the target point in k^{th} dimension.

These two equations can be rearranged as follows:

$$Y_k^{l+1} = \begin{cases} Y_k^l + A \times sin(B) \times \left|C \times Pos_k^l - Y_k^l\right| & D < 0.5 \\ Y_k^l + A \times cos(B) \times \left|C \times Pos_k^l - Y_k^l\right| & D \geq 0.5 \end{cases} \quad (3)$$

Where *D* is a random number implemented by the standard uniform distribution.

-Sine-cosine algorithm (SCA) contains four parameters:

- Parameter ***A*** is decided the dimension of the movement of the next solution which might be either in the space between the solution and target or outside it. The range of sine and cosine functions is changing dynamically to achieve balance between the diversification and intensification properties of the Sine Cosine Algorithm (SCA) by the following equation:

$$A = z - itera \times \left(\frac{z}{Max\_itera} \right) \quad (4)$$

Where *itera* is the current iteration and *Max_itera* is the maximum number of iterations. *z* is a constant term.

- Parameter ***B*** is decided the amplitude of the movement in the search space.

- Parameter ***C*** is decided the effective of the target point on the course of iterations which represents a random weight.
- Parameter ***D*** is used to control the balance between diversification and intensification phases by switching between sine and cosine functions.

To exploit the solution space, the repeated pattern of the sine and cosine functions make a solution to turn around another solution. A more detailed can be found in [1].

Four various chaotic Sine Cosine Algorithm (CSCAs) methods have been proposed. Chaotic maps have been used instead of random parameters to boost the performance of the standard Sine Cosine Algorithm (SCA).

The original SCA has three random parameters: B, C, and D. This section is used the chaotic maps in four various methods to produce different variants of the chaotic Sine Cosine Algorithms (CSCAs) methods. Chaotic (CSCAs) methods with chaotic variants can be categorized and clarified briefly as follows:

-CSCA-I: ***B*** parameter of Eqs. (1-3) is exchanged with the chaotic map.

-CSCA-II: ***C*** parameter of Eqs. (1-3) is exchanged with the chaotic map.

-CSCA-III: ***D*** parameter of Eq. (3) is exchanged with the chaotic map.

-CSCA-IV: ***B***, ***C***, and ***D*** parameters of Eqs. (1-3) are exchanged with the chaotic maps.

III. Performance Analysis Criteria

Many criteria are found for evaluating the performance of the metaheuristic algorithms. In this paper, statistical measurements like Best, Worst, Mean, and standard deviation are used and success rate will calculate. Additionally, one of the most important statistical criteria for examining the reliability of an algorithm is a Success Rate (*SR*). Success Rate (*SR*) represents how many times the algorithm is able to obtain the global optimum during number of executions. It can be defined as follows [16-18]:

$$SR = \left(\frac{Se}{Te}\right) \times 100 \qquad (5)$$

Where (*Se*) represents the number of executions that can discover the optimal solution and (*Te*) is the total number of executions. A successful run can be obtained when the results is very near to the global optimum.

The criteria for a successful run can be calculated as follows:

$$|X^{globalb} - X^{*}| \leq (Up_b - Lo_b) \times \beta \qquad (6)$$

Where ($X^{global\ b}$) is the global best value by the new algorithms, (X^*) is the best solution; (Up_b) and (Lo_b) are the upper and lower bounds, respectively. In this study β equals to the values 10^{-14}, 10^{-25}, and 10^{-50}.

IV. Simulation Results

In this section, ten benchmark functions are used to appraise the performance of the chaotic (CSCAs) strategies [13-15]. Ten standard benchmark functions are used at different dimensions. These functions are classified into two categories: the first five functions are unimodals while the other five functions are multi-modals. The first category is used for benchmarking intensification while the second kind is used to evaluate exploration.

Table 1 tabulates the benchmark functions are used in this study, where LB and UB show upper and lower bounds of these functions. The global minimum value is zero for all functions. For all methods used in this study, the results are found over 30 independent runs. The population size and maximum iteration are assigned to 50, and 1000, respectively.

Different dimensions: 10, 30, 100, and 200 are used for scalability and various initial values are employed to test the sensitivity of the chaotic CSCAs methods. The best, worst, mean, standard deviation, and average time of execution are used to verify the performance of the proposed chaotic CSCAs methods. ‘Best’ represents the minimum result obtained of the total runs. While the ‘Worst’ shows the maximum result obtained of the total runs. Moreover, the chaotic CSCAs are compared with the standard SCA algorithm.

The Intermittency map is used as the best map for CSCA-I algorithm, and the Gauss map is used for CSCA-II and CSCA-III algorithms, respectively. While the CSCA-IV algorithm is used the Circle map as the most effective chaotic map [11].

A. Scalability analysis of CSCAs methods

To test the scalability of the chaotic CSCAs methods and show how the chaotic variants can boost the performance of the standard SCA, a series of simulation on different dimensions is performed. Ten benchmark functions with 50 population size and maximum number of iterations 1000 are carried out 30 independent runs at dimensions: 10, 30, 100, and 200.

Tables 2-11 show the results for the standard SCA, CSCA-I, CSCA-II, CSCA-III, and CSCA-IV algorithms at various dimensions and benchmark functions. These tables show the best, worst , mean , standard deviation (Std.),average time of execution (T) , and success rate at different values ($\beta=10^{-14}$ and $\beta=10^{-25}$). The initial value is set to 0.7 for all chaotic maps as a default value. Tables 2-11 clearly reveal that all chaotic CSCAs methods can improve the performance of the standard SCA at different dimensional like D=10, 30, 100, and 200, respectively and for various benchmark functions.

From Tables 2-11, the success rates test for the proposed chaotic algorithms at different values and dimensions have been significantly outperformed the success rate for the basic SCA for all functions. The fourth chaotic algorithm, CSCA-IV, has demonstrated better performance at all the statistics criteria that used in this study.

According to the scalability test of the chaotic (CSCAs) methods versus the basic SCA, all chaotic CSCAs methods can increase the solution precision, reduce the probability of dropping into local optima, and achieve balance between diversification and intensification.

Finally, the main advantage of the scalability test is to show the ability of the chaotic CSCAs methods to solve the complex problems at high dimensions.

B. Sensitivity Test of Chaotic CSCAs methods

The chaotic optimization algorithm represents a promising method for the engineering problems [19]. The chaotic optimization algorithms have advantages of short implementation time, easy to perform, and high reliability of absconding from the local optima.

These algorithms are significantly sensitive to the initial value; the small changes of the initial value can cause the large changes in the system output. In the experiment results, different results of 30 independent runs for Z_{N1}- Z_{N10} functions are summarized in Tables12-21. These tables displayed the best worst, mean, standard deviation (Std.), and average time of execution (T), for CSCA-I, CSCA-II, CSCA-III, and CSCA-IV ,respectively. For more reliable comparisons, success rate at different values ($\beta=10^{-14}$, $\beta=10^{-25}$, and $\beta=10^{-50}$).

Various initial values are used to demonstrate the sensitivity of the chaotic CSCAs methods for any change occurring in the initial values. These initial values are 0.29, 0.57, and 0.89 in addition to 0.7, resulting in CSCA0.29, CSCA0.57, CSCA0.89 and CSCA0.7, respectively, for all chaotic CSCAs strategies. All other variables are remained unchanged.

In Tables 12-17, and 21, at initial value 0.7, all proposed algorithms bring the best mean solutions and the best success rate at different values .The best are spotlighted in boldness. Seen from Tables 18-20, all chaotic CSCAs methods obtain the best mean solutions on Z_{N7}- Z_{N9} and at all initial values.

Generally speaking, the chaotic CSCAs methods with the initial values 0.29, 0.57, and 0.89 had a good performance but the initial value 0.7 made the performance of all chaotic CSCAs methods more effective. This recommends that the best option for the initial value is 0.7.

V. Conclusion

In this study, several statistical criteria were used like success rate at different values of stopping condition. The initial value 0.7 has been used as the default value for the chaotic algorithms. The behavior of the chaotic algorithms were studied under different dimensions 10,30,100, and 200.The results showed high quality solutions and outperformed all CSCAs methods on the standard SCA for all dimensions. All chaotic optimization algorithms sensitive to the initial value of chaotic map. To observe the behavior of the proposed algorithms under the influence of the different initial conditions, various initial values were used 0.29, 057, 0.7, and 0.89. The sensitivity test revealed that the initial value 0.7 was the best option for the all chaotic algorithms.

There are many important trends that can be worked out in the future. First, the CSCAs methods would be assigned to resolve practical engineering problems. Second, the CSCAs strategies could be combined with other state-of-art algorithms to introduce new hybridization algorithms. Last but not least, using other chaotic variants and study the performance of the proposed algorithms.

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TABLE 1 BENCHMARK FUNCTIONS.

$Z_{N\#}$	Name	LB	UP	Equation
Z_{N1}	Brown [13]	-1	4	$Z(x) = \sum_{i=1}^{n-1} [(x_i^2)^{x_{i+1}^2+1} + (x_{i+1}^2)^{x_i^2+1}]$
Z_{N2}	Powell [13]	-4	5	$Z(x) = \sum_{i=1}^{d/4} [(x_{4i-3} + 10x_{4i-2})^2 + 5(x_{4i-1} - x_{4i})^2 + (x_{4i-2} - 2x_{4i-1})^4 + 10(x_{4i-3} - x_{4i})^4]$
Z_{N3}	Schwefell 2.22 [13]	-10	10	$Z(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$
Z_{N4}	Sphere [14]	-5.12	5.12	$Z(x) = \sum_{i=1}^{n} x_i^2$
Z_{N5}	Quartic without noise[13]	-1.28	1.28	$Z(x) = \sum_{i=1}^{n} i x_i^4$
Z_{N6}	Ackley [13-15]	-32	32	$Z(x) = -20 e^{-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}} - e^{\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)} + 20 + e$
Z_{N7}	Griewank [13-15]	-600	600	$Z(x) = \frac{1}{4000} \sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$
Z_{N8}	Rastrigin [13-15]	-5.12	5.12	$Z(x) = 10n + \sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i)]$
Z_{N9}	Wavy [13]	-π	π	$Z(x) = 1 - \frac{1}{n} \sum_{i=1}^{n} \cos(k x_i)\ e^{-\frac{x_i^2}{2}}$ Where k=10. The number of local minima is kn and (k+1) n for odd and even k respectively.
Z_{N10}	Csendes [13]	-1	1	$Z(x) = \sum_{i=1}^{n} x_i^6 \left(2 + \sin\frac{1}{x_i}\right)$

TABLE 2: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N1} FUNCTION.

	Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
	SCA	5.31079E-45	3.02960E-32	1.36823E-33	5.60926E-33	1	100	100
	CSCA-I	2.33095E-109	6.22421E-90	2.07678E-91	1.13634E-90	0.9	100	100
D=10	**CSCA-II**	5.98723E-120	6.27381E-105	2.09278E-106	1.14541E-105	1.13	100	100
	CSCA-III	2.16929E-75	7.49936E-68	4.25875E-69	1.47538E-68	1.03	100	100
	CSCA-IV	1.36094E-241	2.05104E-241	1.54819E-241	0	1.03	100	100
	SCA	2.270757E-12	4.94007E-05	2.58460E-06	9.26510E-06	3.03	0	0
	CSCA-I	2.59029E-61	1.55811E-53	1.40429E-54	3.96379E-54	1.27	100	100
D=30	**CSCA-II**	1.55600E-83	2.68481E-68	1.41250E-69	5.34915E-69	1.17	100	100
	CSCA-III	2.36710E-39	8.09325E-32	4.65610E-33	1.50952E-32	1.47	100	100
	CSCA-IV	1.11576E-241	7.96349E-241	5.00331E-241	0	1.23	100	100
	SCA	2.76607E-01	1.00897E+01	3.07476E+00	2.65758E+00	4.47	0	0
	CSCA-I	1.25466E-40	1.43998E-35	8.76661E-37	2.73632E-36	3	100	100
D=100	**CSCA-II**	3.65109E-54	1.41996E-45	5.39012E-47	2.58541E-46	3.43	100	100
	CSCA-III	2.77089E-20	4.70832E-16	6.64277E-17	1.26603E-16	3.4	100	0
	CSCA-IV	1.40682E-241	8.44438E-240	2.46608E-240	0	2.9	100	100
	SCA	1.11464E+01	1.00512E+02	3.21773E+01	2.08786E+01	8.3	0	0
	CSCA-I	3.05989E-34	8.79594E-29	4.70090E-30	1.61606E-29	5.87	100	100
D=200	**CSCA-II**	1.66486E-46	1.33756E-37	5.23135E-39	2.43910E-38	6	100	100
	CSCA-III	7.57525E-15	1.52905E-10	1.56596E-11	3.42730E-11	9	3	0
	CSCA-IV	1.37022E-240	1.45592E-239	7.07588E-240	0	4.77	100	100

TABLE 3: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N2} FUNCTION.

	Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
	SCA	8.34713E-14	1.63075E-04	6.20268E-06	2.97543E-05	1	0	0
	CSCA-I	9.11124E-87	3.67041E-26	1.22347E-27	6.70122E-27	1.03	100	100
D=10	**CSCA-II**	4.53848E-124	1.77966E-106	6.52838E-108	3.24699E-107	1.1	100	100
	CSCA-III	1.74422E-66	1.04694E-24	3.48980E-26	1.91144E-25	1	100	96
	CSCA-IV	2.74739E-246	3.61730E-238	4.03418E-239	0	1.3	100	100
	SCA	1.08050E-05	1.96244E+00	8.05865E-02	3.56720E-01	1.57	0	0
	CSCA-I	1.53140E-57	2.76851E-44	2.04085E-45	6.52629E-45	1.27	100	100
D=30	**CSCA-II**	6.70856E-76	3.22333E-66	3.12454E-67	8.38768E-67	1.47	100	100
	CSCA-III	7.85060E-36	4.41021E-26	1.59816E-27	8.05044E-27	1.2	100	100
	CSCA-IV	3.11719E-245	1.00313E-237	6.97165E-239	0	1.17	100	100
	SCA	1.16926E+02	4.20578E+03	1.88090E+03	1.19561E+03	3.17	0	0
	CSCA-I	1.54629E-38	1.16812E-31	1.31209E-32	3.05481E-32	2.67	100	100
D=100	**CSCA-II**	1.51094E-49	5.39904E-43	2.52196E-44	1.03529E-43	2.63	100	100
	CSCA-III	2.47430E-16	2.13117E-13	3.82353E-14	6.03701E-14	3.17	46	0
	CSCA-IV	3.88243E-244	1.48499E-237	1.34286E-238	0	2.73	100	100
	SCA	2.41458E+03	1.39401E+04	9.22255E+03	3.42848E+03	5.43	0	0
	CSCA-I	9.45343E-37	1.24776E-26	1.31411E-27	2.91479E-27	5.9	100	100
D=200	**CSCA-II**	1.14545E-43	9.43505E-36	4.30902E-37	1.72715E-36	4.3	100	100
	CSCA-III	7.15149E-12	5.49377E-08	3.64272E-09	1.00991E-08	6.77	0	0
	CSCA-IV	7.20139E-244	1.27303E-237	1.98061E-238	0	4.9	100	100

TABLE 4: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N3} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	**SCA**	1.44824E-24	1.43303E-19	9.35624E-21	2.86332E-20	1.2	100	0
	CSCA-I	1.49924E-55	4.75629E-48	2.51446E-49	8.85669E-49	1.23	100	100
	CSCA-II	5.42413E-61	2.20587E-55	2.35571E-56	4.59547E-56	1.07	100	100
	CSCA-III	6.71880E-42	1.49873E-36	1.08049E-37	2.77092E-37	1.23	100	100
	CSCA-IV	4.56193E-123	9.48816E-120	4.22778E-120	2.29326E-120	1.27	100	100
D=30	**SCA**	1.79144E-08	8.15548E-05	9.30590E-06	1.79768E-05	2.1	0	0
	CSCA-I	1.38806E-33	1.04196E-29	9.25295E-31	2.09331E-30	1.33	100	100
	CSCA-II	1.23149E-41	5.61346E-35	2.09669E-36	1.02541E-35	1.37	100	100
	CSCA-III	3.63138E-22	8.30662E-18	5.38152E-19	1.53085E-18	1.03	100	0
	CSCA-IV	1.33917E-121	3.17607E-119	9.13249E-120	8.42748E-120	1.1	100	100
D=100	**SCA**	1.93951E-02	2.92834E+01	1.88547E+00	5.31937E+00	2.37	0	0
	CSCA-I	6.59695E-25	3.13820E-20	3.69366E-21	7.01142E-21	2.67	100	0
	CSCA-II	6.60991E-31	3.92215E-26	4.92012E-27	1.01094E-26	2.63	100	100
	CSCA-III	1.02883E-12	1.57220E-09	1.85865E-10	3.27062E-10	2.37	0	0
	CSCA-IV	1.40414E-120	1.15318E-118	4.88990E-119	3.46507E-119	2.33	100	100
D=200	**SCA**	1.95030E+00	4.04402E+01	1.42505E+01	1.07728E+01	4.23	0	0
	CSCA-I	1.29742E-22	1.40036E-16	1.06533E-17	2.88456E-17	4.2	100	0
	CSCA-II	3.96819E-30	7.45245E-21	2.90668E-22	1.36326E-21	3.13	100	100
	CSCA-III	3.46460E-10	7.06833E-07	6.34898E-08	1.45523E-07	5.87	0	0
	CSCA-IV	2.78823E-120	2.14880E-118	1.29937E-118	7.09955E-119	3.03	100	100

TABLE 5: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N4} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	**SCA**	2.67389E-40	2.08265E-32	8.35740E-34	3.78743E-33	1.1	100	100
	CSCA-I	3.21393E-106	2.07872E-90	7.96441E-92	3.80382E-91	1.17	100	100
	CSCA-II	2.15944E-122	9.59716E-105	3.40235E-106	1.75059E-105	1.13	100	100
	CSCA-III	3.40507E-78	1.49764E-68	1.04567E-69	3.24390E-69	1.23	100	100
	CSCA-IV	7.90725E-247	1.15908E-239	1.01352E-240	0	1.03	100	100
D=30	**SCA**	1.16502E-09	2.43776E-05	2.62831E-06	5.13399E-06	1.77	0	0
	CSCA-I	1.14637E-59	5.06575E-52	3.41314E-53	1.07345E-52	1.03	100	100
	CSCA-II	5.13397E-86	6.41604E-67	3.38068E-68	1.27263E-67	1.43	100	100
	CSCA-III	5.55880E-39	4.78242E-32	5.54061E-33	1.24667E-32	1.23	100	100
	CSCA-IV	1.87512E-246	2.31607E-240	2.12140E-241	0	0.93	100	100
D=100	**SCA**	9.86362E-01	4.70672E+01	1.34734E+01	1.20113E+01	2.23	0	0
	CSCA-I	2.40839E-41	9.92877E-35	5.70668E-36	1.81925E-35	2.43	100	100
	CSCA-II	2.58177E-53	2.52806E-43	8.69809E-45	4.61171E-44	2.47	100	100
	CSCA-III	1.31404E-20	1.32549E-14	1.07455E-15	3.04971E-15	2.33	93	0
	CSCA-IV	7.39629E-246	2.54161E-240	1.05285E-241	0	2.03	100	100
D=200	**SCA**	9.82938E+00	1.49327E+02	8.18274E+01	3.51547E+01	4.2	0	0
	CSCA-I	1.67243E-33	2.38336E-28	1.00984E-29	4.33142E-29	4	100	100
	CSCA-II	5.41571E-50	1.10977E-37	8.41104E-39	2.47530E-38	3.23	100	100
	CSCA-III	1.28694E-14	1.20358E-10	1.73166E-11	2.88252E-11	4	0	0
	CSCA-IV	1.54462E-245	9.05280E-243	3.06062E-243	0	2.57	100	100

TABLE 6: RESULTS OF SCA, CSCA-I , CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N5} FUNCTION.

	Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	**SCA**	2.03337E-70	2.83532E-52	9.51562E-54	5.17541E-53	1.37	100	100
	CSCA-I	4.19274E-199	6.60632E-175	2.20230E-176	0	1.37	100	100
	CSCA-II	1.56448E-230	3.15836E-205	1.32494E-206	0	1.23	100	100
	CSCA-III	4.29489E-153	8.88199E-128	4.24572E-129	1.73680E-128	1.4	100	100
	CSCA-IV	0	0	0	0	1.43	100	100
D=30	**SCA**	1.36213E-13	3.49142E-06	2.86375E-07	6.61172E-07	3.2	0	0
	CSCA-I	5.86023E-114	1.13840E-98	3.92976E-100	2.07678E-99	1.5	100	100
	CSCA-II	8.67503E-150	3.97401E-129	2.37731E-130	9.11034E-130	2.07	100	100
	CSCA-III	2.82915E-70	6.55695E-57	6.46828E-58	1.58592E-57	1.7	100	100
	CSCA-IV	0	0	0	0	1.73	100	100
D=100	**SCA**	5.02745E+00	1.40356E+02	5.55117E+01	4.04311E+01	3.33	0	0
	CSCA-I	3.82221E-73	2.03676E-64	8.58202E-66	3.70742E-65	3.8	100	100
	CSCA-II	4.55829E-98	2.55085E-85	9.71267E-87	4.65647E-86	3.73	100	100
	CSCA-III	3.40183E-34	4.87833E-26	1.99102E-27	8.91562E-27	4.13	100	100
	CSCA-IV	0	0	0	0	3.43	100	100
D=200	**SCA**	3.89842E+02	1.31179E+03	8.06160E+02	2.61025E+02	6.83	0	0
	CSCA-I	4.69485E-60	2.27590E-50	7.82367E-52	4.15243E-51	7.53	100	100
	CSCA-II	2.77709E-85	2.62108E-70	9.07805E-72	4.77998E-71	5.4	100	100
	CSCA-III	9.04494E-24	3.16527E-17	1.32078E-18	5.75573E-18	6.4	100	0
	CSCA-IV	0	0	0	0	6.2	100	100

TABLE 7: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N6} FUNCTION.

	Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	**SCA**	4.44089E-15	7.89947E-01	2.63316E-02	1.44224E-01	1.97	63	0
	CSCA-I	8.88178E-16	4.44089E-15	1.00660E-15	6.48634E-16	1.97	100	0
	CSCA-II	8.88178E-16	8.88178E-16	8.88178E-16	0	1.43	100	0
	CSCA-III	8.88178E-16	4.44089E-15	1.00660E-15	6.48634E-16	1.57	100	0
	CSCA-IV	8.88178E-16	8.88178E-16	8.88178E-16	0	1.93	100	0
D=30	**SCA**	2.91908E-06	2.00968E+00	2.79048E-01	4.95246E-01	2.9	0	0
	CSCA-I	8.88178E-16	4.44089E-15	2.42769E-15	1.79059E-15	1.87	100	0
	CSCA-II	8.88178E-16	8.88178E-16	8.88178E-16	0	2.27	100	0
	CSCA-III	8.88178E-16	4.44089E-15	4.32247E-15	6.48634E-16	1.77	100	0
	CSCA-IV	8.88178E-16	8.88178E-16	8.88178E-16	0	2.03	100	0
D=100	**SCA**	7.34277E-01	3.10378E+00	1.95019E+00	6.34500E-01	3.4	0	0
	CSCA-I	8.88178E-16	4.44089E-15	4.32247E-15	6.48634E-16	3	100	0
	CSCA-II	8.88178E-16	8.88178E-16	8.88178E-16	0	2.83	100	0
	CSCA-III	1.03464E-11	1.89183E-09	4.72277E-10	4.93030E-10	3.3	0	0
	CSCA-IV	8.88178E-16	8.88178E-16	8.88178E-16	0	2.83	100	0
D=200	**SCA**	1.14370E+00	3.35347E+00	2.28426E+00	5.48829E-01	5.87	0	0
	CSCA-I	4.44089E-15	4.44089E-15	4.44089E-15	0	5.3	100	0
	CSCA-II	8.88178E-16	8.88178E-16	8.88178E-16	0	3.67	100	0
	CSCA-III	6.32078E-10	7.16166E-07	7.62112E-08	1.39348E-07	5	0	0
	CSCA-IV	8.88178E-16	8.88178E-16	8.88178E-16	0	4.6	100	0

TABLE 8: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N7} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	SCA	0	3.10175E-01	2.96751E-02	7.20985E-02	1.53	53	46
	CSCA-I	0	0	0	0	1.53	100	100
	CSCA-II	0	0	0	0	1.43	100	100
	CSCA-III	0	0	0	0	1.4	100	100
	CSCA-IV	0	0	0	0	1.6	100	100
D=30	SCA	1.07066E-02	2.63240E+00	9.98753E-01	4.73989E-01	3.83	0	0
	CSCA-I	0	0	0	0	1.23	100	100
	CSCA-II	0	0	0	0	1.93	100	100
	CSCA-III	0	0	0	0	1.63	100	100
	CSCA-IV	0	0	0	0	1.53	100	100
D=100	SCA	1.59420E+00	1.69618E+02	3.91968E+01	3.56211E+01	3.5	0	0
	CSCA-I	0	0	0	0	2.83	100	100
	CSCA-II	0	0	0	0	2.6	100	100
	CSCA-III	0	2.00551E-12	3.56089E-13	6.48113E-13	3.07	40	6
	CSCA-IV	0	0	0	0	2.83	100	100
D=200	SCA	6.45130E+01	5.61922E+02	2.68266E+02	1.17969E+02	5.57	0	0
	CSCA-I	0	0	0	0	5.13	100	100
	CSCA-II	0	0	0	0	3.93	100	100
	CSCA-III	2.85472E-12	1.06836E-07	4.82399E-09	1.94171E-08	4.93	0	0
	CSCA-IV	0	0	0	0	4.2	100	100

TABLE 9: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N8} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	SCA	0	1.05635E-01	4.13587E-03	1.94592E-02	1.6	90	90
	CSCA-I	0	0	0	0	1.3	100	100
	CSCA-II	0	0	0	0	1.6	100	100
	CSCA-III	0	0	0	0	1.33	100	100
	CSCA-IV	0	0	0	0	1.5	100	100
D=30	SCA	3.81381E-08	9.72059E+01	1.29502E+01	2.18861E+01	1.93	0	0
	CSCA-I	0	0	0	0	1.23	100	100
	CSCA-II	0	0	0	0	1.93	100	100
	CSCA-III	0	0	0	0	2.1	100	100
	CSCA-IV	0	0	0	0	1.4	100	100
D=100	SCA	3.96335E+01	4.33242E+02	2.08883E+02	1.04293E+02	2.87	0	0
	CSCA-I	0	0	0	0	3.17	100	100
	CSCA-II	0	0	0	0	2.6	100	100
	CSCA-III	0	0	0	0	2.73	100	100
	CSCA-IV	0	0	0	0	3.27	100	100
D=200	SCA	1.38693E+02	7.89454E+02	4.35881E+02	1.85909E+02	5.4	0	0
	CSCA-I	0	0	0	0	5.07	100	100
	CSCA-II	0	0	0	0	4.2	100	100
	CSCA-III	0	5.78211E-10	4.97948E-11	1.36272E-10	4.77	43	43
	CSCA-IV	0	0	0	0	3.97	100	100

TABLE 10: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N9} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	SCA	0	2.38129E-02	7.94041E-04	4.34758E-03	1.57	93	93
	CSCA-I	0	0	0	0	1.43	100	100
	CSCA-II	0	0	0	0	1.27	100	100
	CSCA-III	0	0	0	0	1.6	100	100
	CSCA-IV	0	0	0	0	1.63	100	100
D=30	SCA	8.66052E-12	1.32765E-01	1.19911E-02	2.88365E-02	2.63	0	0
	CSCA-I	0	0	0	0	1.47	100	100
	CSCA-II	0	0	0	0	1.87	100	100
	CSCA-III	0	0	0	0	1.67	100	100
	CSCA-IV	0	0	0	0	1.57	100	100
D=100	SCA	6.71028E-03	3.36951E-01	2.06359E-01	7.60038E-02	3.13	0	0
	CSCA-I	0	0	0	0	2.9	100	100
	CSCA-II	0	0	0	0	3.17	100	100
	CSCA-III	0	2.56462E-14	8.99281E-16	4.67708E-15	2.9	96	90
	CSCA-IV	0	0	0	0	3.1	100	100
D=200	SCA	4.76367E-02	4.36118E-01	2.16821E-01	9.57544E-02	5.87	0	0
	CSCA-I	0	0	0	0	4.9	100	100
	CSCA-II	0	0	0	0	4.47	100	100
	CSCA-III	0	4.51639E-13	1.76229E-14	8.20996E-14	4.93	83	50
	CSCA-IV	0	0	0	0	4.23	100	100

TABLE 11: RESULTS OF SCA, CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV METHODS FOR Z_{N10} FUNCTION.

Methods		Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$
D=10	SCA	5.26896E-104	5.54808E-74	2.90280E-75	1.14824E-74	1.73	100	100
	CSCA-I	1.08211E-301	5.15230E-254	1.71750E-255	0.00000E+00	1.87	100	100
	CSCA-II	0	4.38600e-313	2.85445e-314	0	1.6	100	100
	CSCA-III	9.75261E-222	1.92998E-192	6.55556E-194	0	1.27	100	100
	CSCA-IV	0	0	0	0	2.33	100	100
D=30	SCA	3.43376E-21	8.63213E-04	3.35543E-05	1.58855E-04	2.5	16	0
	CSCA-I	1.14909E-178	8.23765E-145	4.77542E-146	1.83867E-145	2.4	100	100
	CSCA-II	6.78373E-235	6.78373E-235	6.78373E-235	6.78373E-235	3.3	100	100
	CSCA-III	3.87147E-103	1.87641E-86	8.17097E-88	3.44919E-87	2.67	100	100
	CSCA-IV	0	0	0	0	2.9	100	100
D=100	SCA	1.20282E-01	2.82634E+00	6.60852E-01	5.12533E-01	4.43	0	0
	CSCA-I	8.18824E-107	2.31190E-90	9.34628E-92	4.28480E-91	9.07	100	100
	CSCA-II	9.58840E-155	4.36238E-125	1.53783E-126	7.96191E-126	6.83	100	100
	CSCA-III	9.22734E-53	6.33329E-39	2.48951E-40	1.16076E-39	6.47	100	100
	CSCA-IV	0	0	0	0	9.57	100	100
D=200	SCA	2.91908E+00	9.22059E+00	5.70988E+00	1.67869E+00	7.87	0	0
	CSCA-I	1.24118E-87	3.06802E-78	1.05571E-79	5.59568E-79	16.67	100	100
	CSCA-II	9.85851E-134	5.48495E-102	1.82912E-103	1.00139E-102	12.6	100	100
	CSCA-III	4.02262E-40	1.39183E-25	4.73560E-27	2.53955E-26	13.03	100	96
	CSCA-IV	0	0	0	0	15.73	100	100

TABLE 12 : STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N1}.

Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$	$SR_{10^{-50}}$
Initial value =0.29								
CSCA-I$_{0.29}$	3.36568E-57	1.45176E-49	9.20205E-51	2.78780E-50	1.77	100	100	86
CSCA-II$_{0.29}$	2.06649E-44	1.66662E-36	1.19425E-37	3.47882E-37	1.6	100	100	0
CSCA-III$_{0.29}$	1.72228E-39	1.59633E-30	5.41267E-32	2.91285E-31	1.93	100	100	0
CSCA-IV$_{0.29}$	1.55478E-236	7.66616E-231	2.81384E-231	0	1.67	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	5.94485E-57	1.66863E-48	9.45324E-50	3.57688E-49	2.03	100	100	86
CSCA-II$_{0.57}$	3.90327E-43	3.71207E-35	3.78878E-36	7.98296E-36	2	100	100	0
CSCA-III$_{0.57}$	2.07333E-37	1.48463E-32	1.35453E-33	2.87447E-33	1.83	100	100	0
CSCA-IV$_{0.57}$	1.17809E-242	1.87971E-237	1.95470E-238	0	1.1	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	2.59029E-61	1.55811E-53	**1.40429E-54**	3.96379E-54	1.27	**100**	**100**	**100**
CSCA-II$_{0.7}$	1.55600E-83	2.68481E-68	**1.41250E-69**	5.34915E-69	1.17	**100**	**100**	**100**
CSCA-III$_{0.7}$	2.36710E-39	8.09325E-32	**4.65610E-33**	1.50952E-32	1.46	**100**	**100**	**0**
CSCA-IV$_{0.7}$	1.11576E-241	7.96349E-241	**5.00331E-241**	0	1.23	**100**	**100**	**100**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	1.23952E-53	6.94711E-43	2.94812E-44	1.28415E-43	1.63	100	100	6
CSCA-II$_{0.89}$	3.84256E-43	1.38451E-36	7.02880E-38	2.52497E-37	1.5	100	100	0
CSCA-III$_{0.89}$	2.91918E-39	1.66907E-31	7.81186E-33	3.14182E-32	1.56	100	100	0
CSCA-IV$_{0.89}$	3.94970E-251	2.63276E-235	8.77588E-237	0	1.17	100	100	100

TABLE 13: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N2}.

Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$	$SR_{10^{-50}}$
Initial value =0.29								
CSCA-I$_{0.29}$	2.58288E-50	1.01433E-39	6.76092E-41	2.37892E-40	1.33	100	100	0
CSCA-II$_{0.29}$	1.45648E-40	1.91610E-32	6.94230E-34	3.49708E-33	1.57	100	100	0
CSCA-III$_{0.29}$	3.24800E-34	2.11951E-27	1.47989E-28	5.34849E-28	1.67	100	100	0
CSCA-IV$_{0.29}$	4.50807E-233	6.93322E-219	2.31231E-220	0	1.3	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	5.01428E-52	4.61123E-43	2.18478E-44	8.48701E-44	1.5	100	100	13
CSCA-II$_{0.57}$	5.35576E-38	1.54898E-30	1.24007E-31	3.18168E-31	1.33	100	100	0
CSCA-III$_{0.57}$	4.15794E-34	6.86937E-26	2.34506E-27	1.25319E-26	1.56	100	100	0
CSCA-IV$_{0.57}$	4.82725E-241	2.40230E-226	1.31786E-227	0	1	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	1.53140E-57	2.76851E-44	**2.04085E-45**	6.52629E-45	1.27	**100**	**100**	**43**
CSCA-II$_{0.7}$	6.70856E-76	3.22333E-66	**3.12454E-67**	8.38768E-67	1.47	**100**	**100**	**100**
CSCA-III$_{0.7}$	7.85060E-36	4.41021E-26	**1.59816E-27**	8.05044E-27	1.2	**100**	**100**	**0**
CSCA-IV$_{0.7}$	3.11719E-245	1.00313E-237	**6.97165E-239**	0	1.17	**100**	**100**	**100**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	2.48758E-44	1.17555E-36	5.87550E-38	2.22898E-37	1.57	100	100	0
CSCA-II$_{0.89}$	9.05644E-43	1.75744E-32	7.64110E-34	3.23124E-33	1.63	100	100	0
CSCA-III$_{0.89}$	1.00967E-35	7.03896E-26	2.36818E-27	1.28474E-26	1.4	100	100	0
CSCA-IV$_{0.89}$	1.50549E-249	8.92555E-232	4.32250E-233	0	1.17	100	100	100

TABLE 14: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N3}.

Initial value =0.29								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.29}$	1.32981E-32	5.66430E-27	7.36955E-28	1.53349E-27	1.37	100	100	0
CSCA-II$_{0.29}$	1.23307E-25	4.33336E-20	2.07575E-21	7.94008E-21	1.53	100	100	0
CSCA-III$_{0.29}$	2.83651E-22	2.33768E-17	2.07385E-18	5.03151E-18	1.43	100	0	0
CSCA-IV$_{0.29}$	3.07445E-116	1.26237E-112	4.47825E-114	2.29986E-113	1.07	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	5.26428E-33	3.32348E-27	4.16633E-28	8.03404E-28	1.53	100	100	0
CSCA-II$_{0.57}$	1.53748E-26	3.81340E-19	3.80321E-20	8.85778E-20	1.87	100	3	0
CSCA-III$_{0.57}$	4.10300E-23	9.64434E-18	1.04166E-18	2.14971E-18	1.6	100	0	0
CSCA-IV$_{0.57}$	2.23663E-118	1.60977E-113	8.58924E-114	2.63684E-114	1.2	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	1.38806E-33	1.04196E-29	**9.25295E-31**	2.09331E-30	1.33	**100**	**100**	**0**
CSCA-II$_{0.7}$	1.23149E-41	5.61346E-35	**2.09669E-36**	1.02541E-35	1.37	**100**	**100**	**0**
CSCA-III$_{0.7}$	3.63138E-22	8.30662E-18	**5.38152E-19**	1.53085E-18	1.03	**100**	**0**	**0**
CSCA-IV$_{0.7}$	1.33917E-121	3.17607E-119	**9.13249E-120**	8.42748E-120	1.1	**100**	**100**	**100**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	2.40038E-30	1.47666E-23	1.16993E-24	3.25152E-24	1.67	100	60	0
CSCA-II$_{0.89}$	1.49752E-25	1.66889E-20	1.70475E-21	4.01854E-21	1.6	100	0	0
CSCA-III$_{0.89}$	1.26282E-22	1.22149E-17	1.01427E-18	2.31650E-18	1.46	100	0	0
CSCA-IV$_{0.89}$	5.00193E-126	5.50526E-116	2.38305E-116	2.18647E-116	1.03	100	100	100

TABLE 15: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N4}.

Initial value =0.29								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.29}$	1.94642E-55	2.88648E-48	1.44068E-49	5.45109E-49	1.13	100	100	79
CSCA-II$_{0.29}$	1.76510E-45	1.27515E-35	7.81335E-37	2.60441E-36	1.47	100	100	0
CSCA-III$_{0.29}$	2.95061E-37	1.55091E-29	6.32136E-31	2.83206E-30	1.26	100	100	0
CSCA-IV$_{0.29}$	3.73929E-236	1.99873E-230	2.26772E-231	0	0.9	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	3.07846E-57	1.24081E-48	5.69483E-50	2.27772E-49	1.4	100	100	73
CSCA-II$_{0.57}$	4.26844E-42	1.06403E-32	4.03284E-34	1.93695E-33	1.37	100	100	0
CSCA-III$_{0.57}$	1.05720E-37	2.39447E-30	1.33017E-31	4.46447E-31	1.3	100	100	0
CSCA-IV$_{0.57}$	7.16236E-243	1.94123E-228	3.57854E-229	0	1.07	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	1.14637E-59	5.06575E-52	**3.41314E-53**	1.07345E-52	1.03	**100**	**100**	**100**
CSCA-II$_{0.7}$	5.13397E-86	6.41604E-67	**3.38068E-68**	1.27263E-67	1.43	**100**	**100**	**100**
CSCA-III$_{0.7}$	5.55880E-39	4.78242E-32	**5.54061E-33**	1.24667E-32	1.23	**100**	**100**	**0**
CSCA-IV$_{0.7}$	1.87512E-246	2.31607E-240	**2.12140E-241**	0	0.93	**100**	**100**	**100**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	7.38170E-51	1.79268E-42	9.08138E-44	3.31159E-43	1.47	100	100	3
CSCA-II$_{0.89}$	2.32053E-46	3.53396E-35	3.35181E-36	8.34910E-36	1.43	100	100	0
CSCA-III$_{0.89}$	5.36774E-36	3.93156E-31	2.99341E-32	7.29872E-32	1.3	100	100	0
CSCA-IV$_{0.89}$	1.45506E-250	2.58582E-233	8.61941E-235	0	1.07	100	100	100

TABLE 16: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N5}.

Initial value =0.29								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.29}$	8.21696E-103	3.18273E-88	2.14264E-89	7.49488E-89	1.9	100	100	100
$CSCA\text{-}II_{0.29}$	3.30450E-81	3.86498E-65	1.93067E-66	7.61749E-66	2.37	100	100	100
$CSCA\text{-}III_{0.29}$	3.72004E-69	2.10128E-57	1.00855E-58	4.00660E-58	1.76	100	100	100
$CSCA\text{-}IV_{0.29}$	0	0	0	0	2.1	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.57}$	9.16738E-103	2.61567E-89	1.18420E-90	4.96871E-90	2.03	100	100	100
$CSCA\text{-}II_{0.57}$	1.11905E-76	3.42247E-60	1.36467E-61	6.32499E-61	1.93	100	100	100
$CSCA\text{-}III_{0.57}$	2.35320E-69	2.14212E-55	8.61063E-57	3.96399E-56	1.46	100	100	100
$CSCA\text{-}IV_{0.57}$	0	0	0	0	1.53	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.7}$	5.86023E-114	1.13840E-98	**3.92976E-100**	2.07678E-99	1.5	**100**	**100**	**100**
$CSCA\text{-}II_{0.7}$	8.67503E-150	3.97401E-129	**2.37731E-130**	9.11034E-130	2.07	**100**	**100**	**100**
$CSCA\text{-}III_{0.7}$	2.82915E-70	6.55695E-57	**6.46828E-58**	1.58592E-57	1.7	**100**	**100**	**100**
$CSCA\text{-}IV_{0.7}$	0	0	**0**	1.73	100	**100**	**100**	**100**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.89}$	2.10208E-96	2.19296E-78	1.26972E-79	4.86616E-79	1.93	100	100	100
$CSCA\text{-}II_{0.89}$	2.14032E-80	9.13592E-62	3.13403E-63	1.66700E-62	2.2	100	100	100
$CSCA\text{-}III_{0.89}$	1.21357E-67	1.88777E-56	8.67519E-58	3.59863E-57	1.93	100	100	100
$CSCA\text{-}IV_{0.89}$	0	0	0	1.93	100	100	100	100

TABLE 17: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N6}.

Initial value =0.29								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.29}$	8.88178E-16	4.44089E-15	3.37508E-15	1.65589E-15	2.03	100	0	0
$CSCA\text{-}II_{0.29}$	8.88178E-16	4.44089E-15	2.54611E-15	1.80270E-15	2.2	100	0	0
$CSCA\text{-}III_{0.29}$	8.88178E-16	4.44089E-15	4.32247E-15	6.48634E-16	2.33	100	0	0
$CSCA\text{-}IV_{0.29}$	8.88178E-16	8.88178E-16	8.88178E-16	0	2.7	100	0	0
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.57}$	8.88178E-16	4.44089E-15	3.73035E-15	1.44538E-15	2.3	100	0	0
$CSCA\text{-}II_{0.57}$	8.88178E-16	4.44089E-15	3.49350E-15	1.59793E-15	2.43	100	0	0
$CSCA\text{-}III_{0.57}$	8.88178E-16	4.44089E-15	4.32247E-15	6.48634E-16	2.1	100	0	0
$CSCA\text{-}IV_{0.57}$	8.88178E-16	8.88178E-16	8.88178E-16	0	1.73	100	0	0
Initial value =0.7								
Methods	Best	Worst	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.7}$	8.88178E-16	4.44089E-15	**2.42769E-15**	1.79059E-15	1.87	**100**	**0**	**0**
$CSCA\text{-}II_{0.7}$	8.88178E-16	8.88178E-16	**8.88178E-16**	0	2.27	**100**	**0**	**0**
$CSCA\text{-}III_{0.7}$	8.88178E-16	4.44089E-15	**4.32247E-15**	6.48634E-16	1.76	**100**	**0**	**0**
$CSCA\text{-}IV_{0.7}$	8.88178E-16	8.88178E-16	**8.88178E-16**	0	2.03	**100**	**0**	**0**
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.89}$	8.88178E-16	4.44089E-15	3.25665E-15	1.70340E-15	2.27	100	0	0
$CSCA\text{-}II_{0.89}$	8.88178E-16	4.44089E-15	3.25665E-15	1.70340E-15	2.27	100	0	0
$CSCA\text{-}III_{0.89}$	4.44089E-15	4.44089E-15	4.44089E-15	0	2.1	100	0	0
$CSCA\text{-}IV_{0.89}$	8.88178E-16	8.88178E-16	8.88178E-16	0	1.9	100	0	0

TABLE 18: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N7}.

Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$	$SR_{10^{-50}}$
Initial value =0.29								
CSCA-I$_{0.29}$	0	0	0	0	1.97	100	100	100
CSCA-II$_{0.29}$	0	0	0	0	1.83	100	100	100
CSCA-III$_{0.29}$	0	0	0	0	1.7	100	100	100
CSCA-IV$_{0.29}$	0	0	0	0	1.47	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	0	0	0	0	1.83	100	100	100
CSCA-II$_{0.57}$	0	0	0	0	2	100	100	100
CSCA-III$_{0.57}$	0	0	0	0	1.76	100	100	100
CSCA-IV$_{0.57}$	0	0	0	0	1.43	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	0	0	0	0	1.23	100	100	100
CSCA-II$_{0.7}$	0	0	0	0	1.93	100	100	100
CSCA-III$_{0.7}$	0	0	0	0	1.63	100	100	100
CSCA-IV$_{0.7}$	0	0	0	0	1.53	100	100	100
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	0	0	0	0	1.93	100	100	100
CSCA-II$_{0.89}$	0	0	0	0	2	100	100	100
CSCA-III$_{0.89}$	0	0	0	0	1.9	100	100	100
CSCA-IV$_{0.89}$	0	0	0	0	1.53	100	100	100

TABLE 19: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N8}.

Methods	Best	Worst	Mean	Std.	T(s)	$SR_{10^{-14}}$	$SR_{10^{-25}}$	$SR_{10^{-50}}$
Initial value =0.29								
CSCA-I$_{0.29}$	0	0	0	0	2.1	100	100	100
CSCA-II$_{0.29}$	0	0	0	0	2	100	100	0
CSCA-III$_{0.29}$	0	0	0	0	1.9	100	100	100
CSCA-IV$_{0.29}$	0	0	0	0	1.73	100	100	100
Initial value =0.57								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.57}$	0	0	0	0	1.9	100	100	100
CSCA-II$_{0.57}$	0	0	0	0	1.83	100	100	0
CSCA-III$_{0.57}$	0	0	0	0	1.6	100	100	100
CSCA-IV$_{0.57}$	0	0	0	0	1.47	100	100	100
Initial value =0.7								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.7}$	0	0	0	0	1.23	100	100	100
CSCA-II$_{0.7}$	0	0	0	0	1.93	100	100	0
CSCA-III$_{0.7}$	0	0	0	0	2.1	100	100	100
CSCA-IV$_{0.7}$	0	0	0	0	1.4	100	100	100
Initial value =0.89								
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
CSCA-I$_{0.89}$	0	0	0	0	1.97	100	100	100
CSCA-II$_{0.89}$	0	0	0	0	2.1	100	100	0
CSCA-III$_{0.89}$	0	0	0	0	1.83	100	100	100
CSCA-IV$_{0.89}$	0	0	0	0	1.43	100	100	100

TABLE 20: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N9}.

			Initial value =0.29					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.29}$	0	0	0	0	2.03	100	100	100
$CSCA\text{-}II_{0.29}$	0	0	0	0	2.07	100	100	0
$CSCA\text{-}III_{0.29}$	0	0	0	0	1.9	100	100	100
$CSCA\text{-}IV_{0.29}$	0	0	0	0	1.37	100	100	100
			Initial value =0.57					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.57}$	0	0	0	0	2.1	100	100	100
$CSCA\text{-}II_{0.57}$	0	0	0	0	2.03	100	100	0
$CSCA\text{-}III_{0.57}$	0	0	0	0	1.86	100	100	100
$CSCA\text{-}IV_{0.57}$	0	0	0	0	2.5	100	100	100
			Initial value =0.7					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.7}$	0	0	0	0	1.47	100	100	100
$CSCA\text{-}II_{0.7}$	0	0	0	0	1.87	100	100	0
$CSCA\text{-}III_{0.7}$	0	0	0	0	1.66	100	100	100
$CSCA\text{-}IV_{0.7}$	0	0	0	0	1.57	100	100	100
			Initial value =0.89					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.89}$	0	0	0	0	1.9	100	100	100
$CSCA\text{-}II_{0.89}$	0	0	0	0	2.2	100	100	0
$CSCA\text{-}III_{0.89}$	0	0	0	0	1.9	100	100	100
$CSCA\text{-}IV_{0.89}$	0	0	0	0	1.63	100	100	100

TABLE 21: STATISTICAL RESULTS OF CSCA-I, CSCA-II, CSCA-III, AND CSCA-IV ALGORITHMS FOR 10 BENCHMARK FUNCTIONS AT D=30 AND DIFFERENT INITIAL VALUES FOR FUNCTION Z_{N10}.

			Initial value =0.29					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.29}$	6.13910E-151	3.87577E-125	1.29192E-126	7.07615E-126	3.5	100	100	100
$CSCA\text{-}II_{0.29}$	1.62170E-123	1.50171E-97	5.63601E-99	2.74768E-98	3.37	100	100	100
$CSCA\text{-}III_{0.29}$	5.65418E-107	6.16614E-82	2.06057E-83	1.12568E-82	3.16	100	100	100
$CSCA\text{-}IV_{0.29}$	0	0	0	0	3.2	100	100	100
			Initial value =0.57					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.57}$	6.40463E-154	6.01585E-134	2.68655E-135	1.12732E-134	3.53	100	100	100
$CSCA\text{-}II_{0.57}$	3.11673E-105	1.06745E-89	3.55879E-91	1.94887E-90	3.3	100	100	100
$CSCA\text{-}III_{0.57}$	8.89384E-101	1.61436E-85	5.51476E-87	2.94558E-86	2.86	100	100	100
$CSCA\text{-}IV_{0.57}$	0	0	0	0	4.5	100	100	100
			Initial value =0.7					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.7}$	1.14909E-178	8.23765E-145	**4.77542E-146**	1.83867E-145	2.4	**100**	**100**	**100**
$CSCA\text{-}II_{0.7}$	6.78373E-235	6.78373E-235	**6.78373E-235**	6.78373E-235	3.3	**100**	**100**	**100**
$CSCA\text{-}III_{0.7}$	3.87147E-103	1.87641E-86	**8.17097E-88**	3.44919E-87	2.67	**100**	**100**	**100**
$CSCA\text{-}IV_{0.7}$	0	0	**0**	0	2.9	**100**	**100**	**100**
			Initial value =0.89					
Methods	**Best**	**Worst**	**Mean**	**Std.**	**T(s)**	**$SR_{10^{-14}}$**	**$SR_{10^{-25}}$**	**$SR_{10^{-50}}$**
$CSCA\text{-}I_{0.89}$	5.34798E-134	2.93216E-118	1.53196E-119	5.89551E-119	4.07	100	100	100
$CSCA\text{-}II_{0.89}$	1.64181E-117	8.98041E-97	4.21253E-98	1.67647E-97	5.17	100	100	100
$CSCA\text{-}III_{0.89}$	4.40637E-104	2.55654E-82	8.88621E-84	4.66451E-83	3.1	100	100	100
$CSCA\text{-}IV_{0.89}$	0	0	0	0	3.2	100	100	100