White Hole-Black Hole Algorithm

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*Abstract***—** This paper proposes a new optimization algorithm based on the law of gravity. In the proposed algorithm, the black hole sucks up the star that crosses the event horizon, and a white hole emits the star from its event horizon. Both black and white holes attract stars. The white hole-black hole algorithm (WH-BH) starts with an initial population of candidate solutions to an optimization problem and an objective function that is calculated for them. The white hole is selected to be the worst candidate (star), and the black hole will be the best star at each iteration of the WH-BH algorithm. The CEC2014 test functions are applied to evaluate the performance of the WH-BH.

Keywords—Nature-inspired algorithm, White hole, CEC2014.

1. Introduction

Every technological process has to achieve optimality in terms of time and complexity, and this led the researchers to design and obtain best possible or better solutions. In previous studies, several mathematical solutions were provided by various researchers to solve optimization problems. The complexity of the proposed mathematical solutions is very high, which requires an enormous amount of computational work. Therefore, alternative solutions with lower complexity are appreciated. With this quest, nature-inspired solutions are developed such as GSA [1], BHA [2] and PSO [3].

This nature-inspired meta heuristic solutions became very popular as the algorithms provided are much better in terms of efficiency and complexity than mathematical solutions. Generally, these solutions are based on a biological, physical, and chemical phenomenon of nature.

Meta heuristic algorithms are one of the new fields that popular and powerful in solving optimization problems. Almost all meta heuristics is nature-inspired, and they make use of random variable components. In this paper, a population-based algorithm is proposed called White Hole- Black Hole Optimization Algorithm (WH-BH). This algorithm is inspired by the theory of black hole- white hole theory in physics. The remainder of this paper is organized as follows. Section 2 gives some concepts about the white hole. Section 3 develops the new proposed White Hole –Black Hole algorithm. Section 4 establishes the experiment results and discussion of the algorithm. Finally, some concluding remarks are made in Section 5.

2. The White Hole

In general relativity, based on the laws of physics, if black holes exist, then it should be possible to reverse the equations governing them to get something that's reversed but otherwise identical. That's what a white hole is. A white hole, is a region of space time, which cannot be entered from the outside; but matter and light can escape from it. In this sense, it is the reverse of a black hole, which can be entered from the outside, but from which nothing, including light, has the ability to escape. White holes appear in the theory of eternal black holes. In addition to a black hole region in the future, such a solution of the Einstein field equations has a white hole region in its past [4]. The rotation smudges the singularity into a circle, creating it imaginable in theory to travel through the spinning black hole without being crushed. General relativity's equations propose that someone dropping into such a black hole might go through a tunnel in space-time called a wormhole and appear from a white hole that its matters into a different areas of space or even period of time as shown in Figure 1.

Certainly, earlier research, proposes that anything that falls into a rotating black hole will basically plug up the wormhole, avoiding the creation of a channel to a white hole. The research finds that it is possible for an observer standing outside of a black hole to recover information about what lies within.

A white hole is a hypothetical feature of the universe. It is considered the opposite of a black hole. As black holes don't let anything escape from their surface, white holes are eruptions of matter and energy, and nothing can get inside them. White holes are a possible solution to the laws of general relativity. This law implies that if eternal black holes exist in the universe, then a white hole should also exist. It is a time-reversal of a black hole. They are expected to have gravity, so they attract objects, but anything on a collision course with a white hole would never reach it [5].

3. White Hole-Black Hole Algorithm

The idea of the proposed algorithm (WH-BHA) based on the theory of gravity (the Newtonian gravity), predicts black holes as a solution to a set of equations. Solutions to Newton's laws, the equations can have a "+" (plus or 'positive') or "-" (minus or 'negative') sign in front of them. This sort of thing all the time in mathematics. Depending the choice of sign in Newton's equations, the black hole which grows by sucking in matter from far away and the opposite, a "white hole." It's a black hole running backwards in time.

White holes are the opposite of black holes, objects into which nothing can enter but are constantly spewing out matter. The white hole is the counterpart of black hole; the name comes from the definite contrast between them, not because the hole itself is white. The gravitational pull of a white hole is the same as the corresponding black hole's gravitational pull. Except one small difference, the white hole contains a negative gravitational field.

As the escape velocity of a black hole can be represented, or it is the gravitational velocity equation. This is the same equation that can describe the repulsion velocity of a white hole. (Escaping the gravitational field of a white is impossible because white holes have a negative gravitational field.) Since velocity is the acceleration and direction the main difference is the direction, the general direction of a black hole escape velocity is "in," while the general direction of a white hole is "out."

So a white hole can be referred to as an "anti-black hole." Black holes are where star is sucked in, and white holes are where star is ejected out. The concept of white holes is a connection between the mass that disappears into a black hole and the mass that emerges from a white hole. By doing so, interactions between agents can range from attraction force to repulsion force.

White holes were understood as the time reversal of black holes, and therefore, it was believed that they should persistently throw away matter, and be detected much easier than the dark black holes. It was concluded, however, that in white holes that continuously eject stars (agent), these stars will be moved toward the black hole depending on the law of attraction of the black hole and a blue sheet of accreted highly accelerated matter will be formed on the event horizon of the white hole due to its gravitational force.

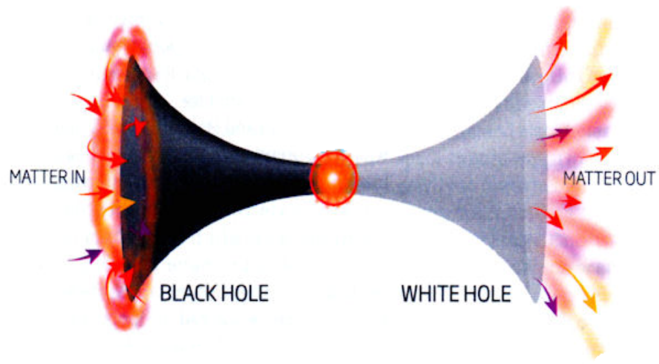

Figure 1: The concept of whit hole – black hole.

The gravitational interaction between the white hole and the accreted material (stars), will lead to an exponential suppression of the white hole emission. All the steps of the proposed algorithm are shown in Figure 2.

The force of any star near the white hole will be as in equation (1).

$$F_{i,wh}^{d}(t) = G(t)\frac{M_i(t) * M_{wh}(t)}{R_{i,wh}(t)+\varepsilon}\left(X_{wh}^{d}(t) - X_i^{d}(t)\right) \quad (1)$$

where

$F_{i,wh}^{d}$ is the force acting on agent i from white hole.
M_{wh} is the mass of the white hole.
X_{wh}^{d} is the position of the white hole.
$R_{i,wh}$ is the Euclidian distance between the agent *i* and the white hole at iteration *t*.

Equation (2) gives the acceleration *a* of this star, *M* is the mass of the star which is the worst mass the search space and ε is a small constant.

$$a_i^{d}(t) = \frac{F_{i,wh}^{d}(t)}{M_i(t)} \quad (2)$$

where

$a_i^{d}(t)$ the acceleration of the agent i at time t,

While the spited stars from the white hole will attracted to the black hole so the updated velocity and position is needed as shown in equations (3) and (4).

$$V_i^{d}(t+1) = rand_i * V_i^{d}(t) + a_i^{d}(t) \quad (3)$$

$$X_i^{d}(t+1) = X_i^{d}(t) + V_i^{d}(t+1) \quad (4)$$

where

$V_i^{d}(t)$ is the velocity of any agent at iteration *t* and dimension *d* and $X_i^{d}(t)$ its position.
$V_i^{d}(t+1)$ is the next velocity of an agent at iteration *t+1* and $X_i^{d}(t+1)$ its position.
$rand_i$ is a random number in the interval [0, 1].

While the radius of the event horizon of the black hole is as in equation (5), the radius of the event horizon of the white hole will be as in equation (6).

$$R_{BH} = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \tag{5}$$

$$R_{WH} = \frac{f_{WH}}{\sum_{i=1}^{N} f_i} \tag{6}$$

where

f_{WH} is the fitness value of the white hole.
f_{BH} is the fitness value of the black hole.
N is the number of candidate solutions (stars).
f_i is the fitness value of the ith star.

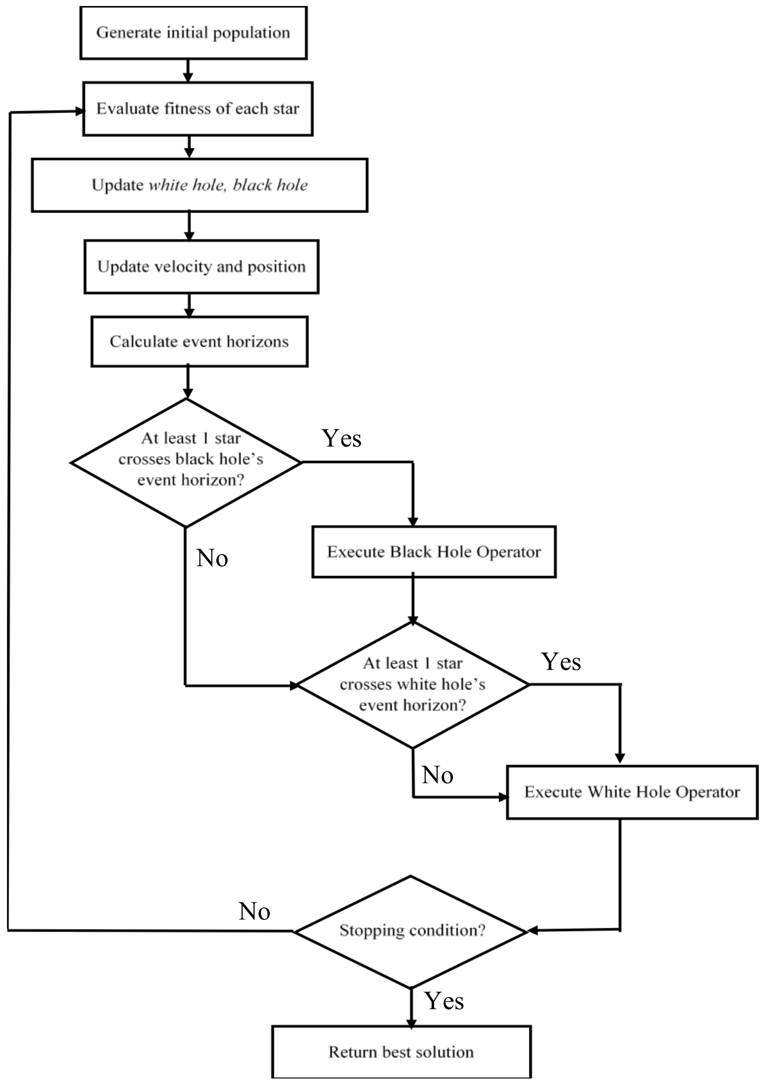

Figure 2: The flow chart of the proposed (BH-WH) algorithm.

4. RESULT AND DISCUSSION

The CEC2014 benchmark functions are selected to improve and test the proposed algorithm with the same search space for all the test functions, which is [-100, 100]. The dimension of the test functions is also considered 50 and to get a good comparison; the algorithm is run 50 times after 2000 iterations, all these setting parameters are shown in Table 1.

Table 1: The setting parameters.

Parameter	Value
Number of runs	50
Number of iterations	2000
Number of agents	100
Search space	[100 -100]

Table 2: The CEC2014 test function.

Type of function	N0. Of function	functions	The ideal value
Unimodal Functions	F1	Rotated High Conditioned Elliptic Function	100
	F2	Rotated Bent Cigar Function	200
	F3	Rotated Discus Function	300
Simple Multimodal Functions	F4	Shifted and Rotated Rosenbrocks Function	400
	F5	Shifted and Rotated Ackleys Function	500
	F6	Shifted and Rotated Weierstrass Function	600
	F7	Shifted and Rotated Griewanks Function	700
	F8	Shifted Rastrigins Function	800
	F9	Shifted and Rotated Rastrigins Function	900
	F10	Shifted Schwefels Function	1000
	F11	Shifted and Rotated Schwefels Function	1100
	F12	Shifted and Rotated Katsura Function	1200
	F13	Shifted and Rotated HappyCat Function	1300
	F14	Shifted and Rotated HGBat Function	1400
	F15	Shifted and Rotated Expanded Griewanks plus Rosenbrocks Function	1500
	F16	Shifted and Rotated Expanded Scaffers F6 Function	1600
Hybrid Functions	F17	Hybrid Function 1 (N=3)	1700
	F18	Hybrid Function 2 (N=3)	1800
	F19	Hybrid Function 3 (N=4)	1900
	F20	Hybrid Function 4 (N=4)	2000
	F21	Hybrid Function 5 (N=5)	2100
	F22	Hybrid Function 6 (N=5)	2200
Composition Functions	F23	Composition Function 1 (N=5)	2300
	F24	Composition Function 2 (N=3)	2400
	F25	Composition Function 3 (N=3)	2500
	F26	Composition Function 4 (N=5)	2600
	F27	Composition Function 5 (N=5)	2700
	F28	Composition Function 6 (N=5)	2800
	F29	Composition Function 7 (N=3)	2900
	F30	Composition Function 8 (N=3)	3000

The test functions can be divided into four groups: unimodal, Simple Multimoda, Hybrid and Composition, these functions with ideal values are shown in table 2. The mean values of the tested algorithms of these functions represent the average value after 50 runs and 2000 iterations in each one, these values are shown in table 3. The value written in bold indicates the best performance among all the algorithms for each function.

Table 3: The mean value of the tested CEC2014 function.

functions	WH-BH	BHA
F1	**90551893.38**	2472895000.25
F2	**5892255836.84**	167571789177.31
F3	**56083.02**	438046.16
F4	**1680.64**	47843.71
F5	**520.09**	521.19
F6	721.08	**673.85**
F7	**749.38**	2332.59
F8	**996.17**	1537.52
F9	**1249.03**	1795.57
F10	**5111.44**	14790.94
F11	**8678.42**	15029.09
F12	**1200.98**	1203.84
F13	**1301.30**	1308.89
F14	**1420.56**	1834.30
F15	**127124.34**	16257815.36
F16	**1622.12**	1622.97
F17	**18034363.43**	204008925.69
F18	**242498400.74**	8869606986.12
F19	**2061.4807**	3115.04
F20	**64221.90**	343988.15
F21	**7943089.71**	46325593.56
F22	**5245.69**	7248.82
F23	**2802.52**	4040.82
F24	**2689.99**	3089.08
F25	**2755.88**	2924.45
F26	2777.47	**2724.74**
F27	**4868.50**	5169.06
F28	**12473.15**	14138.96
F29	**140473696.28**	1061443110.45
F30	**2329252.36**	12338450.86

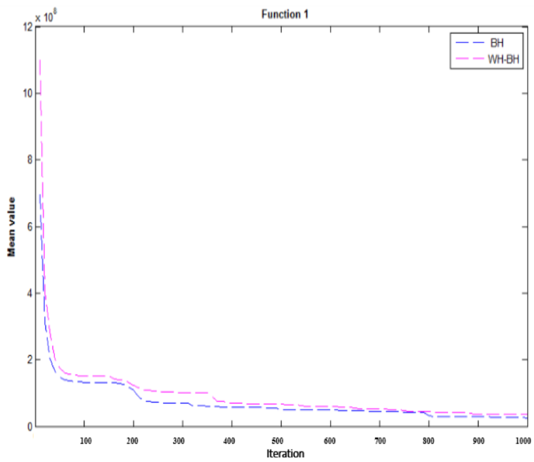

Figure 3: The convergence curve of function 1.

The proposed algorithm is able to provide good results on some test functions. The results of some functions show that the proposed algorithm able to provide very promising performance when these results compared with ideal value. For the verification of the results, the WH-BH algorithm is compared to BHA [2] as the best evolutionary algorithm among SI-based techniques as Black Hole Algorithm.

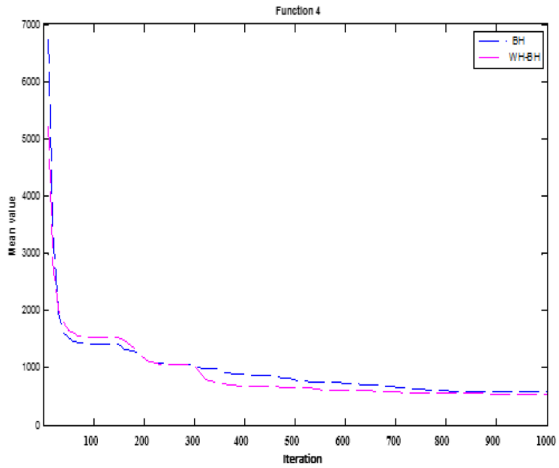

Figure 4: The convergence curve of function 4.

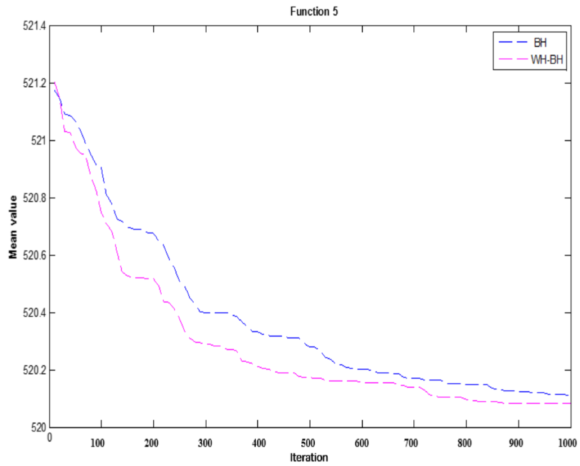

Figure 5: The convergence curve of function 5.

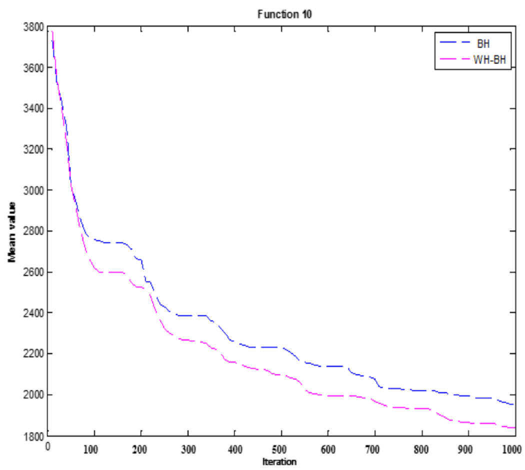

Figure 6: The convergence curve of function 10.

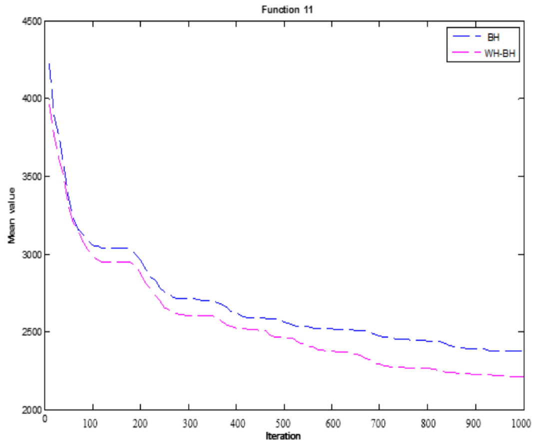

Figure 7: The convergence curve of function 11.

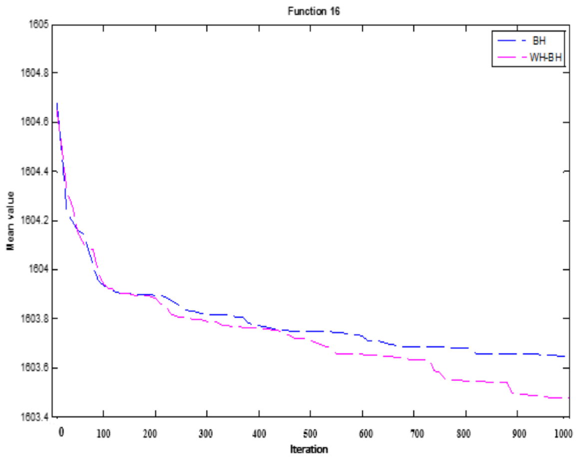

Figure 8: The convergence curve of function 16.

For unimodal functions and some functions of simple multimodal, the convergence curve comparison of function 1 and function 4 are shown in figures 3 and 4. In these figures, the WH-BH and BHA have the same slightly convergence, that's led to conclude the WH-BH algorithm can successfully improve better solutions as iteration increases. On the other hand, WH-BH able to converge faster than BHA in some functions for simple multimodal as in figures 5, 6, 7 and 8. Some functions are decreased gradually over the course of iterations, that because, the proposed algorithm converges to a point and search locally in a search space. In the composition functions, while these functions merge the properties of the sub- functions, in this case, these functions have different properties for different variable's sub components, with all these difficulties to solve the functions, the WH-BH able to get good performance in some cases such as function 27 and 30 as in figures 9 and 10.

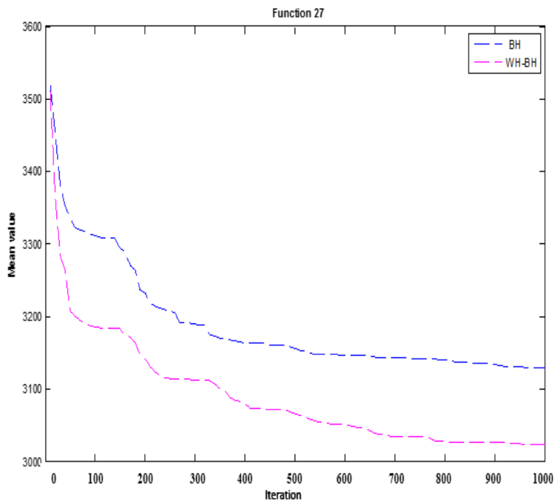

Figure 9: The convergence curve of function 27.

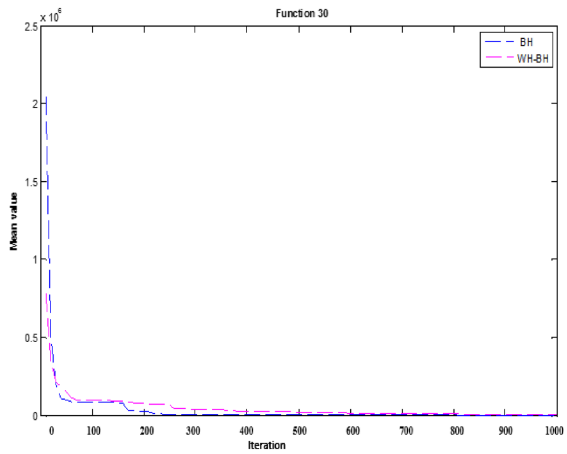

Figure 10: The convergence curve of function 30.

5. CONCLUSIONS

In this paper a new optimization algorithm known a hybrid White Hole-Black Hole algorithm is employed to solve the optimization problems. The experimental results on CEC2014 benchmark test functions support and demonstrate that the WH-BH algorithm is able to evaluate the performance of the proposed algorithm and comparing the results of the proposed approach with the traditional BHA. The results show that WH-BH is comparable with or even better than BHA in finding the optimal solutions. With these advantages, the WH-BH will find more applications in engineering domains and fields in the future.

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REFERENCES

[1] Rashedi, E., Nezamabadi-pour, H., and Saryazdi, S., GSA: A Gravitational Search Algorithm. Inf. Sci. (NY), 179(2009), 2232-2248.

[2] Hatamlou, A., Black hole: A new heuristic optimization approach for data clustering. Inf. Sci. 175-184, (NY), 222(2013).

[3] Russel C. Elberhart and Yuhui Shi. Particle Swarm Optimization: Developments, Applications and Resources. 2001, IEEE.

[4] Va. B. Zel'dovich, I. D. Novikov, ,and A. A. Starobinskil, "Quantum effects in white holes," Institute for Applied Mathematics, USSR Academy of Sciences L. D. Landau Institute fo.r Theoretical Physics, USSR Academy of Sciences, 1974.

[5] Seyedali Mirjalili, Seyed Mohammad Mirjalili and Abdolreza Hatamlou, Multi-Verse Optimizer: a nature-inspired algorithm for global optimization, Springer, 2015.