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Fuzzy Black Holes Algorithm

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ABSTRACT

In this paper fuzzy version for black holes algorithm is proposed. The main idea of this article is based upon this principle that we should consider the distance between two black holes for calculating gravitational force (global search) and electrical force (local search). For this purpose, we have suggested Fuzzy distance notion. In this proposed idea, for calculating two forces, FQ and FG, considering the distance between black holes, we have defined a Fuzzy function, which receives distance value and depending on this value being low or high, produces a membership degree for gravitational and electrical constants to be used in the formulas related to the calculation of FG and FQ. The proposed method is verified using several benchmark problems used in the area of optimization. The experimental results on different benchmarks show that the performance of the proposed algorithm is better than basic BLA (Black holes Algorithm) and FPSO (fuzzyParticle Swarms Optimization).

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1. INTRODUCTION

Inspired from the natural and social phenomena, metaheuristic algorithms have attracted many researchers from various fields of science in recent years [1]. These algorithms are found to be more powerful than the conventional methods that are based on formal logics or mathematical programming [2]. The intensification phase searches around the current best solutions and selects the best candidates or solutions. The diversification phase ensures that the algorithm explores the search space more efficiently. The specific objectives of developing modern metaheuristic algorithms are to solve problems faster, to solve large problems, and to obtain more robust methods [3]. The PSO algorithm is one of the modern evolutionary algorithms. Kennedy and Eberhart first proposed this algorithm. PSO was developed through simulation of a simplified social system, and has been found to be robust in solving continuous non-linear optimization problems [4]. The Artificial Fish Swarm (AFS) algorithm is a recent and easy to implement artificial life computing algorithm that simulates fish swarm behaviors and has been successfully used in some engineering applications [5]. The league championship algorithm (LCA) is a algorithm originally proposed for unconstrained optimization which tries to metaphorically model a League championship environment wherein artificial teams play in an artificial league for several weeks (iterations) [6]. Gases Brownian Motion Optimization is a algorithm for optimization inspired by the gases brownian motion and turbulent rotational motion is introduced [7].

The rest of this paper is organized as follows: The next section gives a review about black holes algorithm. The proposed algorithms (fuzzyblack holes) introduced in section 3. In section 4 the computational and experimental results are presented to evaluate the performance of the proposed method. Finally, in Section 5 includes conclusions and discussions.

2. BLACK HOLES ALGORITHM

The black hole algorithm proposed in the paper [8] by Nemati et al. In this algorithm at first generated a random population a then evolve it in the generations to earn bestsolution. In this algorithm initialized step is production of a number of random black holes as initial solution. Each of this black holes has own position, mass and electrical charge. The name of this step is called big bang**.** Eachof black holes is a solution for the problem.

$$black\ hole_i = \begin{cases} Position = X \\ mass = m \\ charged = q \end{cases} \qquad i = 1,2,\dots,N \tag{1}$$

At second step, fitness evaluated for each of these black holes as formula (2), which $\boldsymbol{f}$ is Cost function and determine the best black hole in the population and call it ***global best***.

$$fitness_{i-th} = f(black\ hole_i)\ i = 1,2,\dots,N \tag{2}$$

In third step, evaluated the new position of the each black hole by calculating the forces .In algorithm each black hole attracted to the global best by gravity force and attracted to the local best position by the Coulomb's law, In the other words we assume FG (gravity force) for the global search and FQ (electricity force) for the local search. FG and FQ are calculated by (3) and (4) formulas.

$$Fg_i = G\frac{m_{gbest} * m_i}{r^2} i = 1,2,\dots,N \tag{3}$$

$$Fq_i = k\frac{q_{lbest} * q_i}{r^2} i = 1,2,\dots,N \tag{4}$$

Where ***Fg***is gravitationalforce, ***Fq*** is electrical force, $\boldsymbol{m_{gbest}}$ is mass of global best black hole, and $\boldsymbol{q_{lbest}}$is charge of local best black hole.***G*** and ***K*** are constant number. When ***Fg***and ***Fq*** were calculated, then we earn new position of the black holes by formula (5).

$$X_i(t+1) = X_i(t) + random1 * Fg + random2 * Fq \qquad i = 1,2,\dots N \tag{5}$$

Where $X_i(t+1)$ and $X_i(t)$ are the position of ***i-th*** black hole at iteration ***t+1*** and ***t***, respectivly.and***Fg***is gravitationalforce, ***Fq*** is electrical force. And also ***random1***, ***random2*** are random number between [0,1].

The algorithm also used of Hawking radiation as. At this step is the same mutation step in genetic algorithm.by hawking radiation the algorithm escape from trapping in local optimums. In this step, by randomly we changed the position of black holes. With this work the algorithm escape from trapping in local extermums.

3. FUZZY BLACK HOLES ALGORITHM (PROPOSED METHOD)

One of the flaws in the paper [8] is the fact that, G (gravity constant) and K (Coulomb's constant) values, throughout the entire process in the algorithm, remains fixed and unchanged. For resolving this issue, Fuzzy Distance notion has been suggested in this article. This solution is based on considering distance between black holes to determine G and K values to be used in calculating formulas 3 and 4.

In the proposed idea a Fuzzy function has been defined, for each gravity and Coulomb's constants, which receives distance between two black holes as input parameter and produces a membership degree for G and K values to be used in formula 3 and 4. According to the defined fuzzy function, the lower the distance between two black holes, membership degree values for G and K would decline which results in strengthening local search and the higher the distance between two black holes, values obtained for G and K, would grow higher, causing reinforcement of the universal search. Fuzzy functions defined for G and K are illustrated in Figure 4 and corresponding Fuzzy rules are described in Table 1.

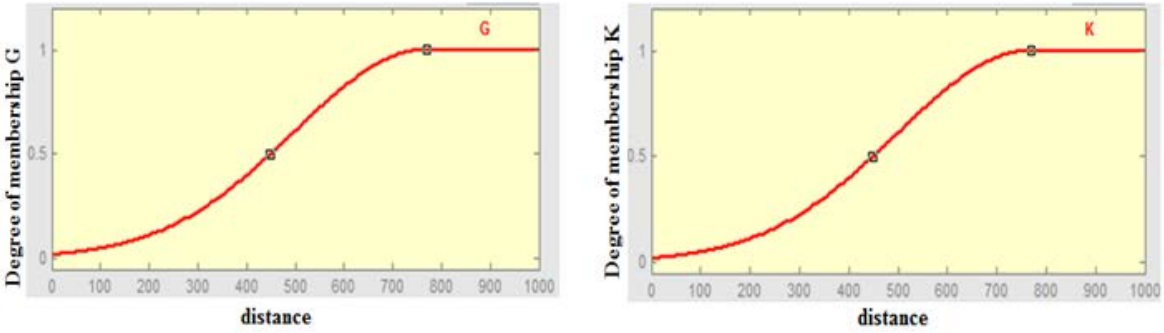


Figure 1. Fuzzy sets for G and K

Table 1. Benchmark Function

Rule No	Rule
1	If distance is low then G & K are low
2	If distance is medium then G & K are medium
3	If distance is high then G & K are high

Based on the above the main steps in the proposed binary black hole algorithm are summarized as follow Pseudo-code:

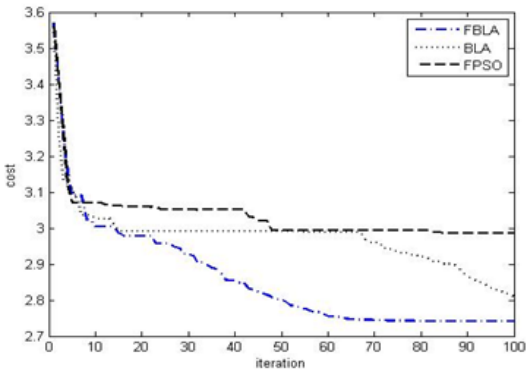
Input: objective function
Output: optimal solution
Initialize apopulation of black holes with random locations in the search space (**BinaryBig Bang**)
While (termination criteria satisfy) **do**
    For each black hole, evaluate the objective function
    Select the global best black hole that has the best fitness value
    Calculate the G and K by defined fuzzy function.
    Change the location of each black hole according to Eq. (5)
    Do Hawking radiation (as mutation in algorithm)
End of while

4. THE EXPERIMENTAL RESULTS

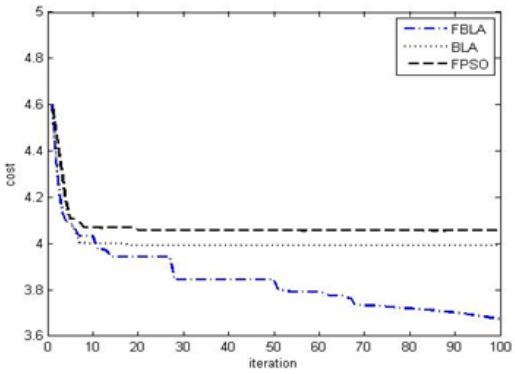
In this section the proposed fuzzy black hole algorithm (FBLA) is tested with benchmark functions. Six benchmark functions with a variety of complexity are used to evaluate the performance of proposed method. Benchmark function and properties is show on table 2. The performance of the proposed algorithm is compared with basic black hole algorithm (BLA) and fuzzy PSO (FPSO). The experiments for each function run for 10 times and average of result is reported. In figures2 for better distinction of four algorithms the Y-axis (fitness) is on logarithmic scale.

Table 2. Benchmark Function

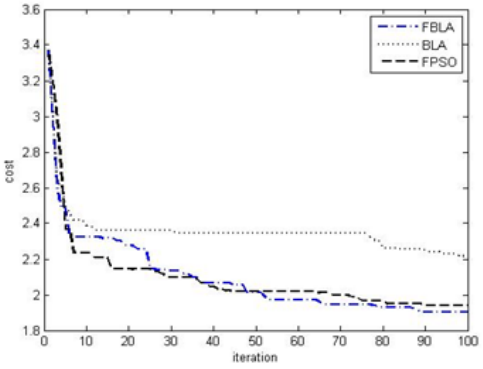
F	Equvalition	Dimensions	Min
f_1	$f_1(x) = \sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i) + 10]$	100, 1000	0
f_2	$f_2(x) = \sum_{i=1}^{n} ([x_i + 0.5])^2$	100, 1000	0
f_3	$f_3(x) = \sum_{i=1}^{n} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	100, 1000	0
f_4	$f_1(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$	100, 1000	0
f_5	$f_5(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right) + 20 + e$	100, 1000	0
f_6	$f_6(x) = \frac{1}{4000}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$	100, 1000	0



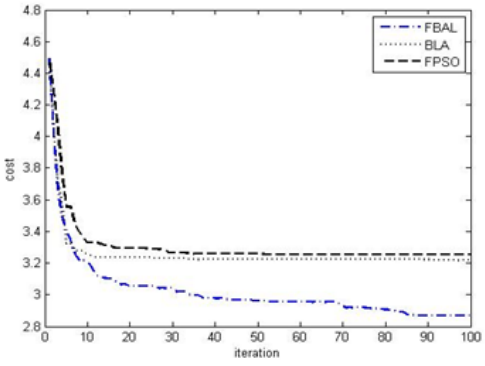
F1 function-100D



F1 function-1000D



F2function-100D



F2 function-1000D

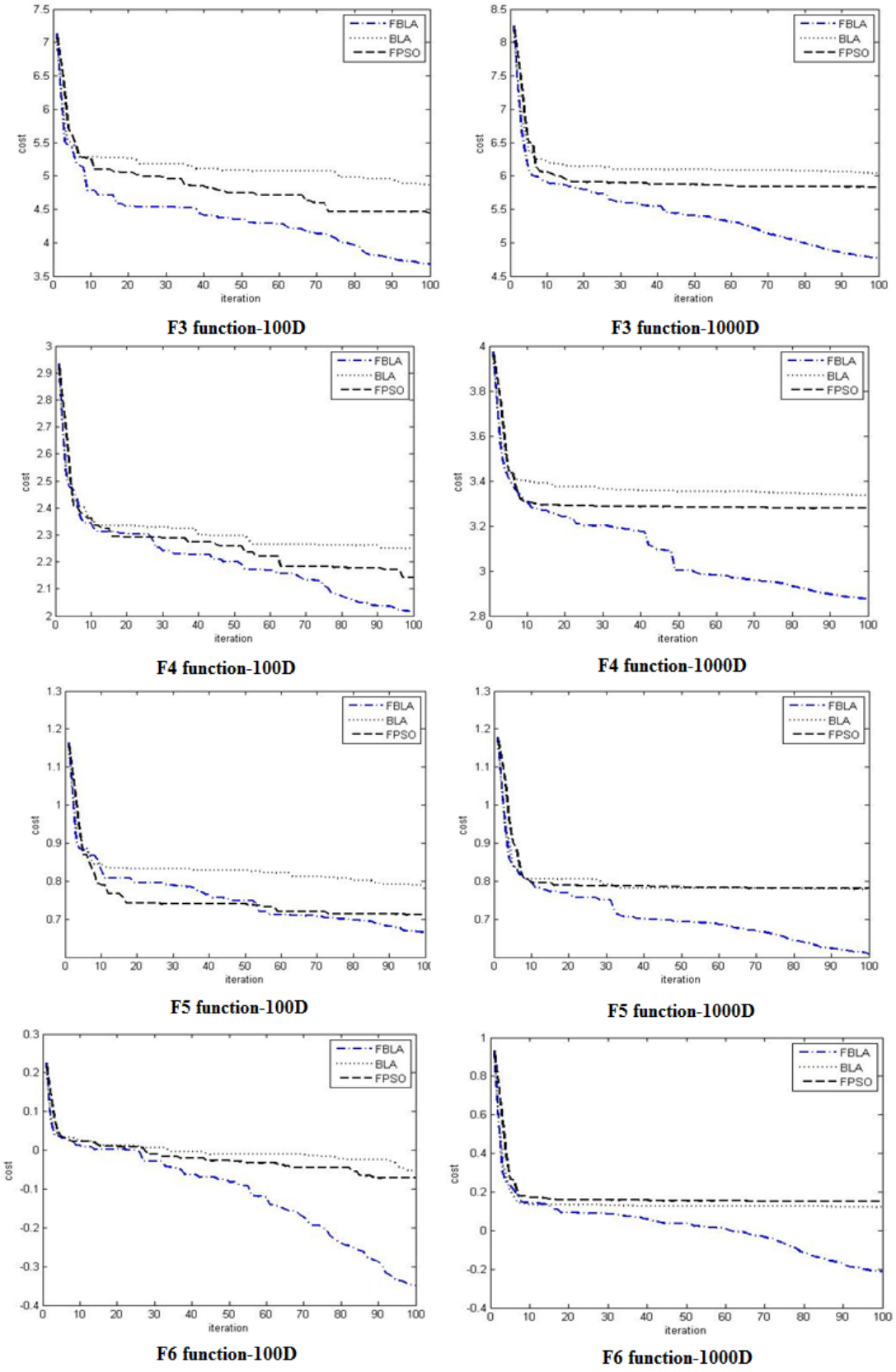


Figure 2. Convergence performance of fuzzy black hole (FBA), basic black hole (BLA) and fuzzy PSO (FPSO) on 6 Benchmark function (100D and 1000D)- X-axis is generation and Y-axis is fitness on logarithmic scale

Table 3. Global optimization results for function 1 (f_1)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	966.2709
BLA	[-10 10]	100	100	100	643.6753
FBLA	[-10 10]	100	100	100	**551.8535**
FPSO	[-5 5]	1000	1000	100	1.1337e+004
BLA	[-5 5]	1000	1000	100	9.7968e+003
FBLA	[-5 5]	1000	1000	100	**4.7350e+003**

Table 4. Global optimization results for function 2 (f_2)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	87
BLA	[-10 10]	100	100	100	164
FBLA	[-10 10]	100	100	100	**80**
FPSO	[-5 5]	1000	1000	100	1799
BLA	[-5 5]	1000	1000	100	1642
FBLA	[-5 5]	1000	1000	100	**738**

Table 5. Global optimization results for function 3 (f_3)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	2.7686e+004
BLA	[-10 10]	100	100	100	7.2830e+004
FBLA	[-10 10]	100	100	100	**4.7451e+003**
FPSO	[-5 5]	1000	1000	100	6.7860e+005
BLA	[-5 5]	1000	1000	100	1.1060e+006
FBLA	[-5 5]	1000	1000	100	**5.9114e+004**

Table 6. Global optimization results for function 4 (f_4)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	138.9133
BLA	[-10 10]	100	100	100	177.6972
FBLA	[-10 10]	100	100	100	**103.8853**
FPSO	[-5 5]	1000	1000	100	1.8942e+003
BLA	[-5 5]	1000	1000	100	2.1709e+003
FBLA	[-5 5]	1000	1000	100	**749.6797**

Table 7. Global optimization results for function 5 (f_5)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	5.1376
BLA	[-10 10]	100	100	100	5.9565
FBLA	[-10 10]	100	100	100	**4.6366**
FPSO	[-5 5]	1000	1000	100	6.0311
BLA	[-5 5]	1000	1000	100	6.0043
FBLA	[-5 5]	1000	1000	100	**4.0644**

Table 8. Global optimization results for function 6 (f_6)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FPSO	[-10 10]	100	100	100	0.8467
BLA	[-10 10]	100	100	100	0.8869
FBLA	[-10 10]	100	100	100	**0.4473**
FPSO	[-5 5]	1000	1000	100	1.4144
BLA	[-5 5]	1000	1000	100	1.3207
FBLA	[-5 5]	1000	1000	100	**0.6121**

5. CONCLUSION

In this paper fuzzy version for black holes algorithm is proposed. For this purpose, we have suggested Fuzzy distance notion. In this proposed idea, for calculating two forces, FQ and FG, considering the distance between black holes, we have defined a Fuzzy function, which receives distance value and depending on this value being low or high, produces a membership degree for gravitational and electrical constants to be used in the formulas related to the calculation of FG and FQ. The experimental results on different benchmarks show that the performance of the

proposed algorithm is better than other similar algorithms.To continue our work we decide to adapt black holes algorithms in multi objective optimization problems and introduced multi objective black hole algorithm (MBLA).

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