Black Holes Algorithm With Fuzzy Hawking Radiation

Mostafa Nemati, Hossein Momeni

Abstract: In this paper we improved efficiency of black holes algorithm with using of fuzzy Hawking radiation. A black hole is a region of space-time whose gravitational field is so strong that nothing which enters it, not even light, can escape. In the black holes algorithm there is a phase with name Hawking radiation. In this phase the position of the some black hole changes a little. This phase as equal mutation in genetic algorithm. We proposed a fuzzy Hawking radiation for these phase. The experimental results on different benchmarks show that the performance of the proposed algorithm is better than basic Black holes Algorithm (BLA) and firefly algorithm (FA).

Index Terms: Fuzzy, Mutation,Hawking radiation,Black holes Algorithm.

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 an 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 an 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 (fuzzy black 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.

- *MostafaNemati, Research Student in computer Science. College of Computer Science, Tabari University of Babol, Iran, E-mail: mostafa.manjil@gmail.com*
- *HosseinMomeni, Assistant Professor in Software Engineering, Faculty of Engineering,Golestan University, Gorgan, Iran, E-mail: h.momeni@gu.ac.ir*

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 best solution. 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**.** Each of black holes is a solution for the problem.

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

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

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

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.

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

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

Where ***Fg***is gravitational force, ***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).

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

Where $X_i(t+1)$ and $X_i(t)$ are the position of ***i-th*** black hole at iteration ***t+1*** and ***t***, respectively and ***Fg***is gravitational force, ***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 PROPOSED METHOD

In 1974, Hawking showed that black holes are not entirely black but emit small amounts of thermal radiation [9], an effect that has become known as Hawking radiation. If a black hole is very small the radiation effects are expected to become very strong. Even a black hole that is heavy compared to a human would evaporate in an instant. A black hole the weight of a car would have a diameter of about 10–24 m and take a nanosecond to evaporate, during which time it would briefly have luminosity more than 200 times that of the sun.

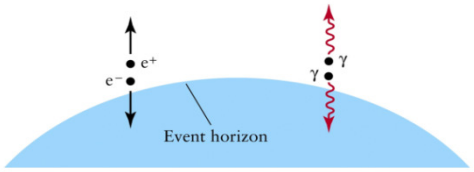

Figure1. A schematic view of hawking radiation

At the basic black holes algorithm introduced in paper [8] Hawking radiation is a simple phase so that a little change occurs in the position of some of black holes. This work the algorithm escapes from trapping in local extermums. One of the flaws of the Hawking radiation in paper [8] is that never pay attention to the fitness of black holes. With a random method a black hole select and position take a little change. In this paper proposed a fuzzy Hawking radiation. One of the powers note for this idea is that we regards to the fitness of black holes so that black holes with bad fitness are more susceptible to mutation and have more chance for improve their finesses. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. [1] Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. Irrationality can be described in terms of what is known as the fuzzjective. In the proposed idea a fuzzy function has been defined, received fitness of black holes and gives a membership degree for the Hawking radiation. As fitness that received is low then the chance of Hawking radiation is higher. Fuzzy rules described in Table 1.

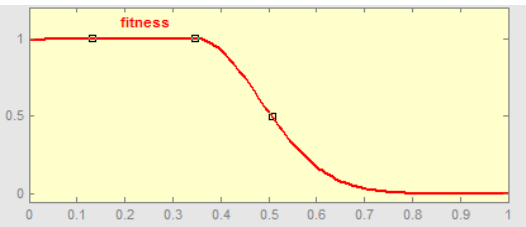

Figure2. Fuzzy Hawking radiation by gauss2mf function

Table 1. Benchmark Function

Rule No	Rule
1	If fitness is low then chance for mutation is higher
2	If fitness is medium then chance for mutation is medium
3	If fitness is higher than chance for mutation is low

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 a population of black holes with random locations in the search space (**Big 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
Change the location of each black hole according to Eq. (5)
Do fuzzy Hawking radiation (as mutation in algorithm)
End of while

4 THE EXPERIMENTAL RESULTS

In this section the proposed method (Black Holes Algorithm with Fuzzy Hawking radiation) is tested with benchmark functions. Four 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 firefly algorithm. The experiments for each function run for 10 times and average of result is reported. In figures 2 for better distinction of four algorithms the Y-axis (fitness) is on logarithmic scale.

Table 2. Benchmark Function

F	function	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	$f_3(x) = \sum_{i=1}^{n} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	100, 1000	0
f_3	$f_1(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$	100, 1000	0

f_4	$f_5(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}}\right) - \exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right) + 20 + e$	100, 1000	0

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

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FA	[-10 10]	100	100	100	1.1209e+003
BLA	[-10 10]	100	100	100	1.0562e+003
Our method	[-10 10]	100	100	100	**695.8479**
FA	[-5 5]	1000	1000	100	1.0927e+004
BLA	[-5 5]	1000	1000	100	1.0089e+004
Our method	[-5 5]	1000	1000	100	**3.6466e+003**

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

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FA	[-10 10]	100	100	100	93
BLA	[-10 10]	100	100	100	151
Our method	[-10 10]	100	100	100	**57**
FA	[-5 5]	1000	1000	100	1477
BLA	[-5 5]	1000	1000	100	1651
Our method	[-5 5]	1000	1000	100	**574**

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

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FA	[-10 10]	100	100	100	3.2152e+004
BLA	[-10 10]	100	100	100	6.4367e+004
Our method	[-10 10]	100	100	100	**7.4730e+003**
FA	[-5 5]	1000	1000	100	6.1002e+005
BLA	[-5 5]	1000	1000	100	9.8402e+005
Our method	[-5 5]	1000	1000	100	**2.7066e+004**

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

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
FA	[-10 10]	100	100	100	142.5146
BLA	[-10 10]	100	100	100	199.8181
Our method	[-10 10]	100	100	100	**127.5697**
FA	[-5 5]	1000	1000	100	1.8517e+003
BLA	[-5 5]	1000	1000	100	2.0871e+003
Our method	[-5 5]	1000	1000	100	**848.8884**

5 CONCLUSION

In this paper we improved efficiency of black holes algorithm with using of fuzzy Hawking radiation. In the black holes algorithm there is a phase with name Hawking radiation. In this phase the position of the some black hole changes a little. This phase as equal mutation in genetic algorithm. We proposed a fuzzy Hawking radiation for these phase. The experimental results on different benchmarks show that the performance of the proposed algorithm is better than basic Black holes Algorithm (BLA) and firefly algorithm.

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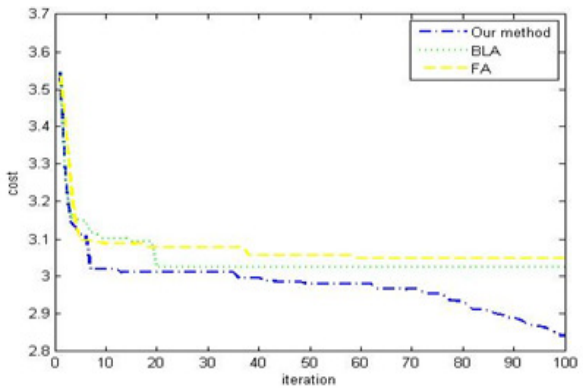
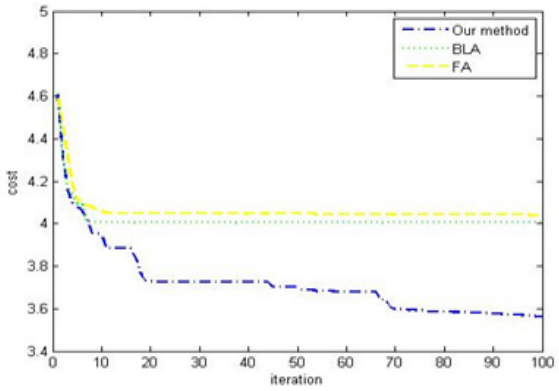
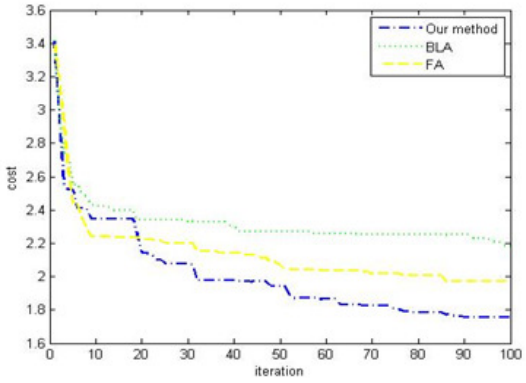


F1 function-100D

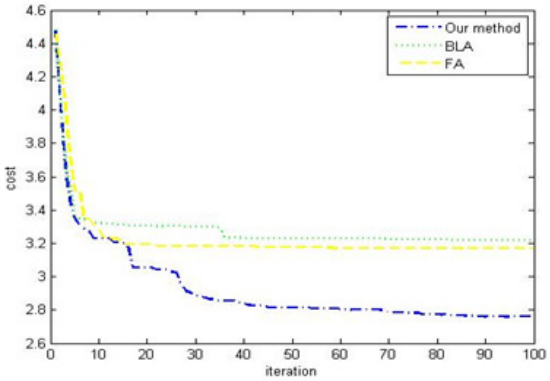


F1 function-1000D

Figure3. Convergence performance of our method and basic black hole algorithm (BLA) and firefly algorithm on F1 function (100D, 1000D) - X-axis is generation and Y-axis is fitness on logarithmic scale



F2 function-100D



F2 function-1000D