IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 2, No. 3, September 2013, pp. 143~150
ISSN: 2252-8938

Black Holes Algorithm: A Swarm Algorithm inspired of Black Holes for Optimization Problems

Mostafa Nemati*, Reza Salimi, Navid Bazrkar****
* Computer Science Department, Tabari Babol
** Computer Science Department, Tabari Babol

Article Info

Article history:

Received Mar 20, 2013
Revised May 13, 2013
Accepted May 15,2013

Keyword:

Black Hole
Swarm Algorithm
Optimization Problem
Global Search
Local Search

ABSTRACT

In this paper a swarms algorithms, for optimization problem is proposed. This algorithm is inspired of black holes. 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. Every black hole has mass, and charge. In this Algorithm we suppose each solution of problem as a black hole and use of gravity force for global search and electrical force for local search.The proposed method is verified using several benchmark problems commonly used in the area of optimization. The experimental results on different benchmarks indicate that the performance of the proposed algorithm is better than PSO (Particle Swarms Optimization), AFS (Artifitial Fish Swarm Algorithm) and RBH-PSO (random black hole particle swarm optimization Algorithm).

*Copyright © 2013 Institute of Advanced Engineering and Science.
All rights reserved.*

Corresponding Author:

Mostafa Nemati,
Computer Science Department,
Tabari Babol,
Manjil, Bahar Ave, P:67.
Email: Mostafa.manjil@gmail.com

1. INTRODUCTION

In real word problem, it is often required to optimize a given function. Lots of traditional algorithms are presents which find out best solution for a given function. However, for most real world problems, optimization is often a challenging problem because of huge and complex solution space [1]. There are different methods for solving an optimization problem. Some of these methods are inspired from natural processes. These methods usually start with an initial set of variables and then evolve to obtain the global minimum or maximum of the objective function [2]. The PSO algorithm is one of the modern evolutionary algorithms. Kennedy and Eberhart firstproposed this algorithm. PSO was developed through simulation of a simplified social system, and has beenfound to be robust in solving continuous non-linear optimization problems[3].Artificial fish Swarm Algorithm (AFSA) is a kind of intelligence optimization algorithm, which has some advantages that GA and PSO do not have [4]. It is a random search algorithm based on simulating fish swarm behaviours which contains searching behaviour, swarming behaviour and chasing behaviour. It constructs the simple behaviours of artificial fish (AF) firstly, and then makes the global optimum appear finally based on animal individuals' local searching behaviours [5].

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

2. PHYSICAL STRUCTURE OF BLACK HOLS

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. The theory of general relativity predicts that a sufficiently compact mass will deform space-time to form a black hole. Around a black hole there is a mathematically defined surface called an event horizon that marks the point of no return. If anything moves close to the event horizon or crosses the Schwarzschild radius it will be absorbed into the black hole and permanently disappear. The existence of black holes can be discerned by its effect over the objects surrounding it [6]. It is called "black" because it absorbs all the light that hits the horizon, reflecting nothing, just like a perfect black body in thermodynamics [7, 8]. A black hole has only three independent physical properties: mass, charge, and angular momentum [9]. A charged black hole repels other like charges just like any other charged object. The simplest black holes have mass but neither electric charge nor angular momentum. Figure1 showa schematic view of a black hole in the space.

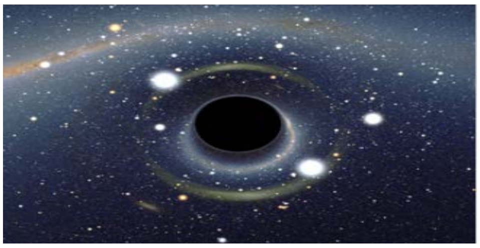


Figure 1. A schematic view of a black hole

2.1. Gravitational Force

Newton's law of universal gravitation states that every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. This is a general physical law derived from empirical observations by what Newton called induction [10]. Every point mass attracts every single other point mass by a force pointing along the line intersecting both points. The force is proportional to the product of the two masses and inversely proportional to the square of the distance between them [11]. As can be seen in the Figure 2, with using the formula (1) we can get gravitational force. Where F is the force between the masses, G is the gravitational constant, m1 is the first mass, m2 is the second mass, and r is the distance between the centers of the masses.

$$F = G\frac{m_1 m_2}{r^2} \quad (1)$$

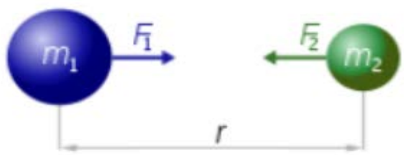


Figure 2. A schematic view of Gravitational Force

2.2. Coulomb's Law

Coulomb's law or Coulomb's inverse-square law is a law of physics describing the electrostatic interaction between electrically charged particles. It was first published in 1785 by French physicist Charles Augustin de Coulomb and was essential to the development of the theory of electromagnetism [11]. The scalar form of Coulomb's law is an expression for the magnitude and sign of the electrostatic force between two idealized point charges, small in size compared to their separation. This force (F) acting simultaneously on point charges (q1) and (q2), is given by formula (2), where r is the separation distance and k is proportionality constant. A positive force implies it is repulsive, while a negative force implies it is attractive [12]. Figure 3 show a shematic view of coulomb law.

$$F = K\frac{q_1 q_2}{r^2} \qquad (2)$$

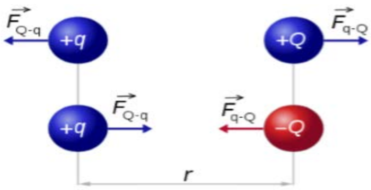


Figure 3. A schematic view of Coulomb's law

2.3. Evaporation (Hawking Radiation)

In 1974, Hawking showed that black holes are not entirely black but emit small amounts of thermal radiation [13], 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.

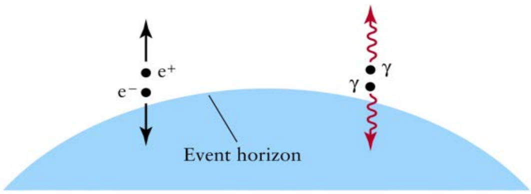


Figure 3. A schematic view of hawking radiation

3. THE PROPOSED ALGORITHM

The black hole algorithm proposed in this paper is a swarm intelligence algorithm that has features like other population based algorithms like PSO. In this algorithm at first we generate a random population a then evalve it in the generations to earn optimal solution. The term black hole at first time used in the [14, 15] for the solving optimization problems. The propose algorithm in [14] extende PSO algorithm and add a new particle and called it black hole. The term black hole also used in the [15] for solving data clustering problem. In [14] the auther onlyuseda radius for black hole a named id event horizon radius and notconsidered other featuers of black holes like mass and chared. The proposed algorithm in this paper we consider every features of black hole and regarding mass, chared and speed of black holes and also used different formula for global and local search and used evaporation of black holes as mutaion. In the proposed algorithm in this paper, 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 (**According to the Big Bang model, the Universe expanded from an extremely dense and hot state and continues to expand today**)**. We supposed each of these black holes as a solution for the problem.

$$black\ hole_i = \begin{cases} Position = X \\ mass = m \\ charged = q \end{cases} \qquad i = 1,2,\dots,N \qquad (3)$$

At second step we evaluated fitness for each of these black holes as formula (4), which ***f*** is Cost function and determine the best black hole in the population and call it ***global best***.

$$fitness_{i-th} = f(black\ hole_i)\ i = 1,2, \dots, N \tag{4}$$

In third step, we evaluate the new position of the each black hole by calculating the forces. In this algorithm we assumed that 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 (5) and (6) formulas.

$$Fg_i = G\frac{m_{gbest} * m_i}{r^2} i = 1,2, \dots, N \tag{5}$$

$$Fq_i = k\frac{q_{lbest} * q_i}{r^2} i = 1,2, \dots, N \tag{6}$$

Where ***Fg***is gravitionalforece, ***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 (7).

$$X_i(t+1) = X_i(t) + random1 * Fg + random2 * Fq \qquad i = 1,2, \dots N \tag{7}$$

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 gravitional forece, ***Fq*** is electrical force.and also ***random1***, ***random2*** are random number between [0,1].

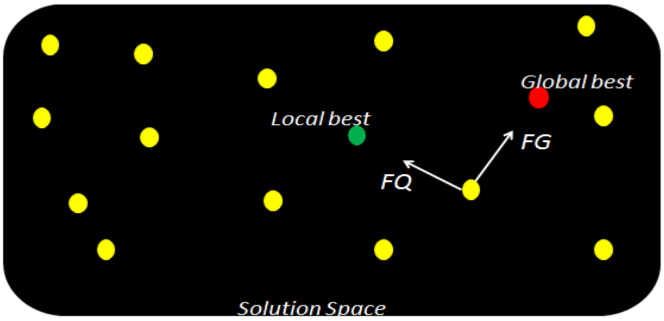


Figure 4. A schematic view impact of Fg and Fq forces

We also used of Hawking radiation as mutation in the proposed algorithm. Black holes emit small amounts of thermal radiation by Hawking radiation [14].we model this radiation by changing the a little change in the position of black holes. This step is the same mutation step in genetic algorithm.by hawking radiation the algorithm escape from trapping in local optimums. In this step me randomly change the position of a black hole. With this work the algorithm escape from trapping in local extermums.

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

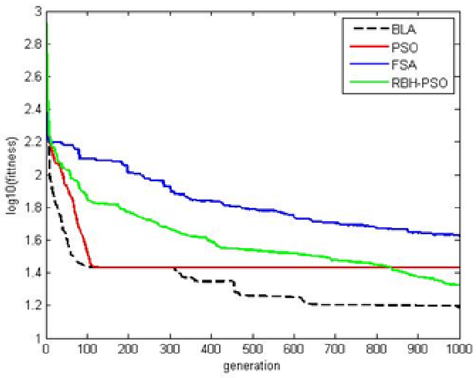
Input: objective function
Output: optimal soulotion
Initialize a population of black holes with random locations in the search space (**Big Bang**)
While (termination ceriteria satisfy)**do**
    For each black hole, evaluate the objective function
    Select the global best black hole that has the best fitness value
    Change the location of each black holes according to Eq. (7)
    Do Hawking radiation
End of while

4. THE EXPRIMENTAL RESULTS

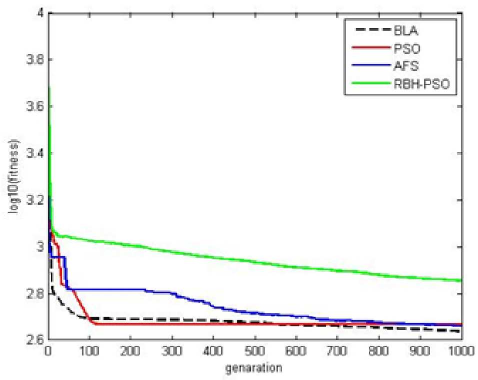
In this section the proposed black hole algorithm (BLA) is tested with benchmark functions. All the benchmark functions are minimization problems. Six benchmark function with a varity of complexity are use to evaluate the performace of proposed algorithm. Benchmark function and properties is show on table 1. The performaced of the proposed algorithm is compared against well known algorithm like than PSO (Particle Swarms Optimization), AFS (Artifitial Fish Swarm Algorithm) and RBH-PSO (random black hole particle swarm optimization Algorithm). The tests are implements in MATLAB 7. The experiments for each function run for 10 times and average of result is reported. In figures5 for better distinction of four algorithms the Y-axis (fitness) is on logarithmic scale.

Table 1. Benchmark Function

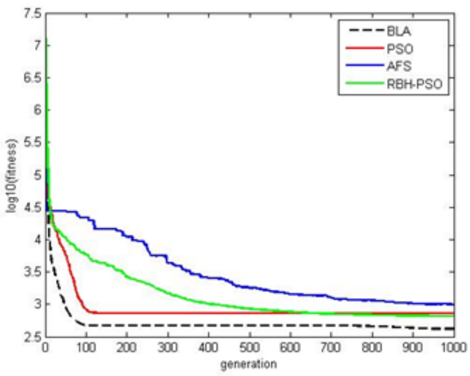
F	Equvalition	Domain	Min
f_1	$f_1(x)=\sum_{i=1}^{n}\lvert x_i\rvert+\prod_{i=1}^{n}\lvert x_i\rvert$	$[-10, 10]$	0
f_2	$f_2(x)=\sum_{i=1}^{n}[100(x_{i+1}-x_i^2)^2+(x_i-1)^2]$	$[-10, 10]$	0
f_3	$f_3(x)=\sum_{i=1}^{n}([x_i+0.5])^2$	$[-10, 10]$	0
f_4	$f_4(x)=\sum_{i=1}^{n}[x_i^2-10\cos(2\pi x_i)+10]$	$[-10,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



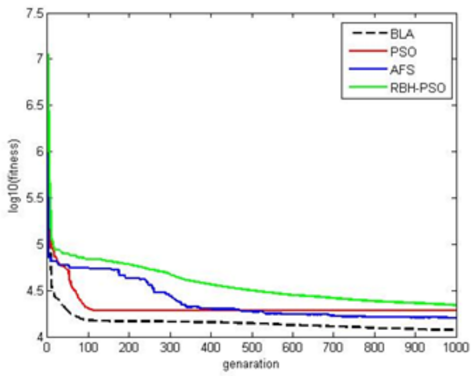
F1 function – 100D



F1 function – 1000D



F2 function – 100D



F2 function – 1000D

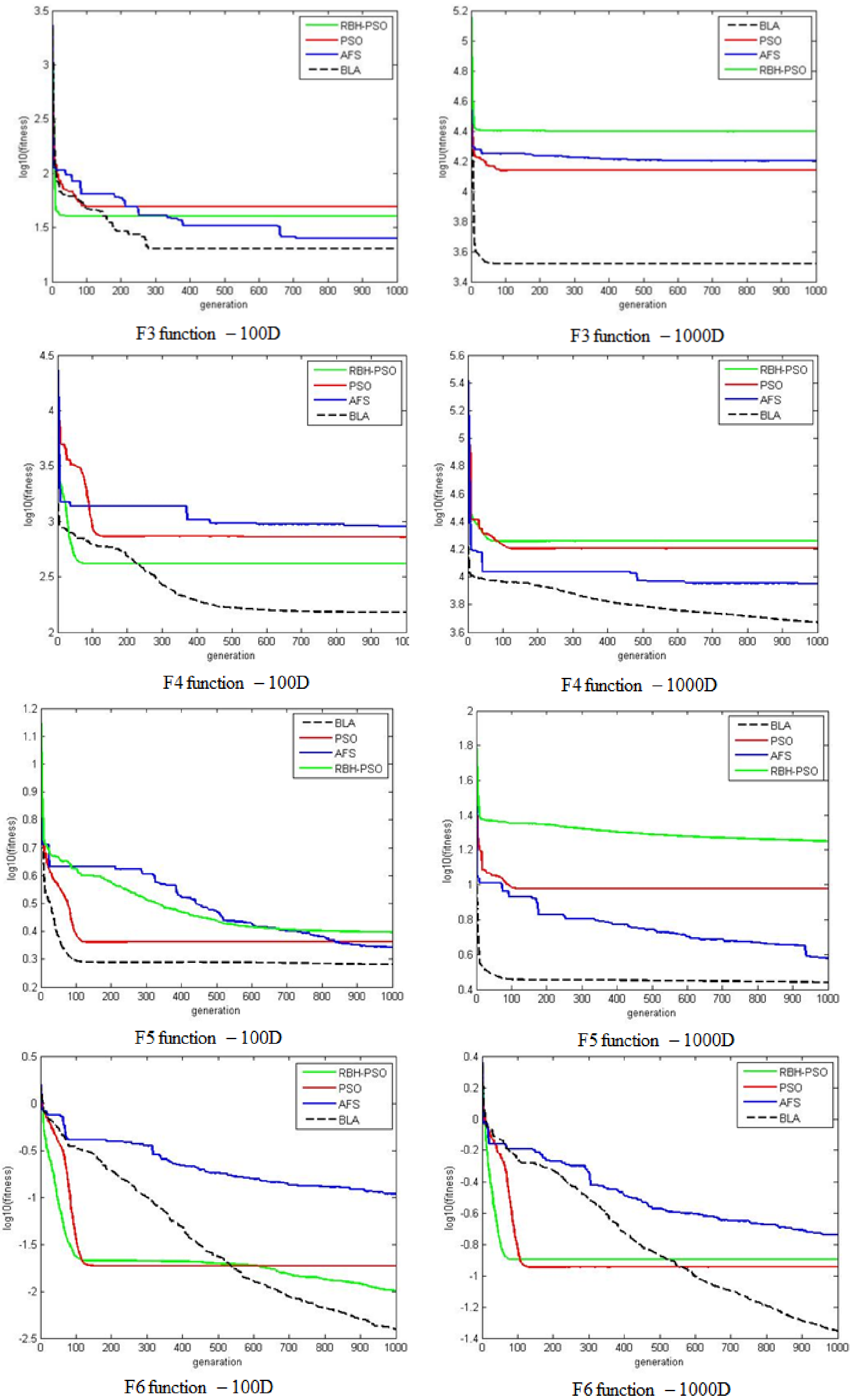


Figure 5. Convergenece performance of PSO, AFS, RBH-PSO and BLA (propose algorithm) on 6 Benchmark function (100D and 1000D)- X-axis is generation and Y-axis is fitness on logarithmic scale

Table 2. Global optimization results for function 1 (f_1)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	26.9427
FSA	[−10, 10]	1000	100	1000	41.7825
RBL-PSO	[−10, 10]]	1000	100	1000	21.1790
BLA	[−10, 10]	1000	100	1000	**15.4454**
PSO	[−5, 5]	1000	1000	1000	465.8277
FSA	[−5, 5]	1000	1000	1000	457.0324
RBL-PSO	[−5, 5]	1000	1000	1000	714.8475
BLA	[−5, 5]	1000	1000	1000	**434.7213**

Table 3. Global optimization results for function 2 (f_2)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	732.2226
FSA	[−10, 10]	1000	100	1000	986.0788
RBL-PSO	[−10, 10]	1000	100	1000	658.7629
BLA	[−10, 10]	1000	100	1000	**415.8357**
PSO	[−5, 5]	1000	1000	1000	1.9185e+004
FSA	[−5, 5]	1000	1000	1000	1.6016e+004
RBL-PSO	[−5, 5]	1000	1000	1000	2.1930e+004
BLA	[−5, 5]	1000	1000	1000	**1.1812e+004**

Table 4. Global optimization results for function 3 (f_3)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	49
FSA	[−10, 10]	1000	100	1000	25
RBL-PSO	[−10, 10]	1000	100	1000	40
BLA	[−10, 10]	1000	100	1000	**20**
PSO	[−20, 20]	1000	1000	1000	13728
FSA	[−20, 20]	1000	1000	1000	15897
RBL-PSO	[−20, 20]	1000	1000	1000	24965
BLA	[−20, 20]	1000	1000	1000	**3304**

Table 5. Global optimization results for function 4 (f_4)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	721.4418
FSA	[−10, 10]	1000	100	1000	903.3105
RBL-PSO	[−10, 10]	1000	100	1000	416.1813
BLA	[−10, 10]	1000	100	1000	**151.1325**
PSO	[−5, 5]	1000	1000	1000	1.5963e+004
FSA	[−5, 5]	1000	1000	1000	8.8965e+003
RBL-PSO	[−5, 5]	1000	1000	1000	1.8077e+004
BLA	[−5, 5]	1000	1000	1000	**4.7071e+003**

Table 6. Global optimization results for function 5 (f_5)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	2.2960
FSA	[−10, 10]	1000	100	1000	2.2010
RBL-PSO	[−10, 10]	1000	100	1000	2.4961
BLA	[−10, 10]	1000	100	1000	**1.9082**
PSO	[−5, 5]	1000	1000	1000	2.8791
FSA	[−5, 5]	1000	1000	1000	2.8674
RBL-PSO	[−5, 5]	1000	1000	1000	2.9727
BLA	[−5, 5]	1000	1000	1000	**2.7587**

Table 7. Global optimization results for function 6 (f_6)

Algorithm	Range	Population size	Dimension	Iteration	Best Answer
PSO	[−10, 10]	1000	100	1000	0.0187
FSA	[−10, 10]	1000	100	1000	0.1080
RBL-PSO	[−10, 10]	1000	100	1000	0.0101
BLA	[−10, 10]	1000	100	1000	**0.0039**
PSO	[−5, 5]	1000	1000	1000	0.1129
FSA	[−5, 5]	1000	1000	1000	0.1826
RBL-PSO	[−5, 5]	1000	1000	1000	0.1267
BLA	[−5, 5]	1000	1000	1000	**0.0442**

5. CONCLUSION

In this paper black hole algorithm which is a swarms algorithms, for optimization problem is proposed. This algorithm is inspired of black holes. This algorithm has three main step, birth of black holes, calculating forces and hawking radiation. The experimental results on different benchmarks indicate that the performance of the proposed algorithm is better than PSO, AFS and RBH-PSO. Six benchmark function with a varity of complexity are use to evaluate the performace of proposed algorithm. The next work of us is fit this algorithm for binary optimization problem and multi objective optimization problem.

REFERENCES

[1] Antariksha Bhaduri. “A Clonal Selection Based Shuffled Frog Leaping Algorithm”. *IEEE International Advance Computing Conference (IACC)*, Patiala, India. 2009.

[2] SN Sivanandam, SN Deepa. “*Introduction to Genetic Algorithms*”. Springer- Verlag, Berlin, Heidelberg. 2008.

[3] H Omranpour, et al. “Dynamic Particle Swarm Optimization for Multimodal Function”. *International Journal of Artificial Intelligence (IJ-AI)*, ISSN: 2252-8938. 2012; 1(1).

[4] Zhicheng Dong, Wei Xiao & Xiping Zhang. “Artificial Fish Swarm Algorithm-Assisted and Receive-Diversity Aided Multi-user Detection for MC-CDMA Systems”. *Jurnal Computer and Information Science*. 2009.

[5] Huadong Chen, Shuzong Wang, Jingxi Li, Yunfan Li. “A Hybrid of Artificial Fish Swarm Algorithm and Particle Swarm Optimization for Feedforward Neural Network Training”. *IEEE*. 2009.

[6] L Kaper, E Heuvel, P Woudt, R Giacconi. “*Black hole research past and future*”. in: Black Holes in Binaries and Galactic Nuclei: Diagnostics, Demography and Formation, Springer, Berlin/Heidelberg, 2001: 3-15.

[7] Schutz, Bernard F. *Gravity from the ground up*. Cambridge University Press, ISBN 0-521-45506-5. 2003.

[8] Davies PCW. “Thermodynamics of Black Holes”. *Reports on Progress in Physics , Rep. Prog. Phys*., Printed in Great Britain. 1978; 41.

[9] Heusler M. “Stationary Black Holes: Uniqueness and Beyond”. *Living Reviews in Relativity Retrieved*. 2011.

[10] Isaac Newton. “In [experimental] philosophy particular propositions are inferred from the phenomena and afterwards rendered general by induction”. *General Scholium, Andrew Motte's English translation published*. 2010.

[11] Isaac Newton. “*The Principia: Mathematical Principles of Natural Philosophy*”. Cambridge University Press. 2010.

[12] Robert S Elliott. “*Electromagnetics, History, Theory, and Applications*”. ISBN 978-0-7803-5384-8. 1999.

[13] Hawking SW. “Black hole explosions?”. *Nature Bibcode, Natur*. 1974.

[14] Junqi Zhang, Kun Liu, Ying Tan, and Xingui He. “Random Black Hole Particle Swarm Optimization And Its Application”. *IEEE Int. Conference Neural Networks & Signal Processing Zhenjiang*, China. 2008.

[15] Abdolreza Hatamlou. “Black hole: A new heuristic optimization approach for data clustering”. *Information Sciences, Elsevier*. 2013; 222: 175–184.