# A survey on applications of black hole algorithm

**Zuwairie Ibrahim, Suad Khairi Mohammed, Norazian Subari, Asrul Adam, Zulkifli Md Yusof**
*Universiti Malaysia Pahang, Pahang, Malaysia*

**Nor Azlina Ab Aziz, Nor Hidayati Abdul Aziz**
*Faculty of Engineering and Technology, Multimedia University, Melaka, Malaysia*

**Tasiransurini Ab Rahman**
*Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia*

**Mohd Ibrahim Shapiai**
*Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia, Malaysia*

**Norrima Mokhtar**
*Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia*

*Email: zuwairie@ump.edu.my, suad.khairim@gmail.com, aziansubari@ump.edu.my, asrul@ump.edu.my, zmdyusof@ump.edu.my, azlina.aziz@mmu.edu.my, hidayati.aziz@mmu.edu.my, surini@uthm.edu.my, md_ibrahim83@utm.my, norrimamokhtar@um.edu.my*

**Abstract**

In recent years, there is a growing interest in the design and development of nature-inspired optimization algorithms. One of the algorithms is black hole algorithm (BHA), which is inspired by the black hole in general relativity and cosmology. This paper reports a review of the black hole algorithm (BHA). This survey emphasizes on the applications of BHA.

Keywords— application, black hole algorithm, optimization

## 1. Introduction

A black hole is a region of space packed with so much matter that its own gravity prevents anything from escaping – even a ray of light. Black holes can form when massive stars run out of fuel and collapse under their own weight, creating strong gravity.

The black hole algorithm (BHA) [1] is a population-based meta-heuristic algorithm inspired by the physical phenomenon of black hole. In BHA, the agent with the best solution mimics the black hole. The event horizon is calculated and any agent within the event horizon vanishes and re-initialized in the search space.

The BHA is shown in Figure 1. Since BHA is a population-based algorithm, $N$ number of agents are needed. Let $d$ as the number of dimension for an optimization problem, a solution, $X$, in a search space is kept by an agent $i$ at iteration $t$ as follows:

$$X_i(t) = \left(X_i^1(t), X_i^2(t), \dots, X_i^d(t)\right) \tag{1}$$

The BHA begins with initialization where a randomly generated population of candidate solutions are placed in the search space. For each agent $i$, the initial solution can be represented as:

$$X_i(0) = \left(X_i^1(0), X_i^2(0), \dots, X_t^d(0)\right) \tag{2}$$

After the initialization, the fitness values of the population are evaluated. The best agent, which has the best fitness value, is chosen as the black hole while other agents are selected as normal agents. For the case of function minimization problems, during initialization, the black hole agent is determined as follows:

$$BH = \min_{i\in\{1,\dots,N\}} fit_i(t)|_{t=0} \tag{3}$$

In this study, the black hole agent keeps the best-so-far solution, $X_{BH}$. The best-so-far solution is different than the best solution. The best solution is defined as the best solution obtained at specific iteration, $t$. On the other hand, the best-so-far solution is the best solution found from the initial iteration, $t = 0$, until current iteration, $t$. Hence, for $t \neq 0$, an agent $i$ is selected as the black hole agent if the fitness value of that agent, $f_i$, is better than the fitness value of the black hole agent, $f_{\mathrm{BH}}$. Specifically, for the case of function minimization, $f_i < f_{\mathrm{BH}}$.

Once the black hole agent and normal agents are identified, the radius of the event horizon, $R_{BH}$, is formulated as follows:

$$R_{BH} = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \tag{4}$$

where $f_{BH}$ is the fitness value of the black hole agent, $N$ is the number of agents, and $f_i$ is the fitness value of the $i^{\mathrm{th}}$ star.

The next step is solution update, which is applied to all agents except the black hole agent. Other than black hole agent, the agents can be categorized into two groups. The first group of agents is the agents located within the event horizon. This agent will be swallowed by the black hole agent. Then, a new agent following the swallowed one is generated and distributed randomly in the search space. This generation is to keep the number of agent constant. The second group of agents are agents located far from the black hole agent. In other words, these agents are not within the event horizon. These agents move towards the black hole agent and the updated solution can be computed as follows:

$$X_i(t+1) = X_i(t) + rand \times (X_{BH} - X_i(t)) \tag{5}$$

where $X_i(t+1)$ and $X_i(t)$ are the locations of the $i^{\mathrm{th}}$ agent at iterations $t+1$ and $t$, respectively. The *rand* is a random number belonging to [0,1] and $X_{BH}$ is the location of the black hole agent. This solution update can be summarized in the Pseudocode 1.

**PSEUDOCODE 1**: Solution update in BHA

**if** agent $i^{th}$ position is within the event horizon
**then**
do re-initialization
**if** agent $i^{th}$ position is not within the event horizon
**then**
update the position based on Eq. (5)
**else**
**end**

After all the agents have updated their position, the next iteration begins if the termination criteria is not met. Otherwise, the best-so-far, $X_{BH}$, solution is reported.

## 2. Applications of black hole algorithm

The BHA has been used to solve many problems and applied in many fields. The BHA has been used to train a neural network, which is used as workload prediction model [2]. The BHA has been also used with higher order neural network for solving nonlinear classification problems of data mining [3].

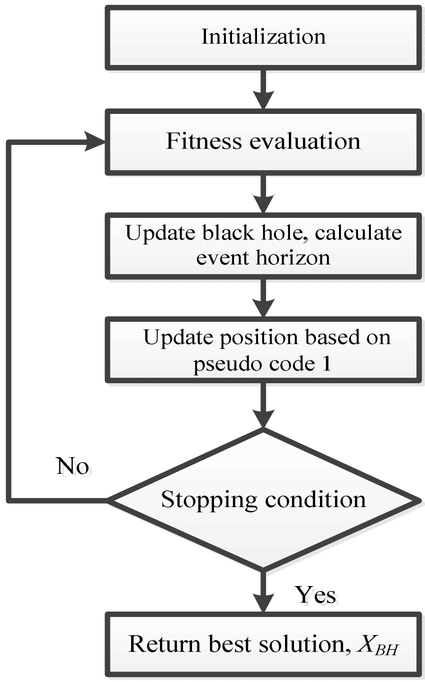


Fig. 1. Flowchart of BHA.

The BHA is used in engineering design of electromagnetic devices [4]. The new optimization technique based on the black hole phenomenon is called the black-hole-based optimization technique. To show the effectiveness of the proposed technique, it has been demonstrated on a magnetizer by optimizing its pole face to obtain a desired magnetic flux density distribution.

In the field of software engineering, Jeet and Dhir combined a nature-inspired black-hole algorithm and a genetic algorithm to propose a search-based technique for software clustering [5]. This technique is used to manage a software system by partitioning it into smaller subsystems containing highly related modules. Search-based software clustering techniques are found to be beneficial in effective partitioning of software systems.

Moreover, the BHA has been used to solve the manufacturing cell design problem, in which different machines are grouped into sets or cells with the objective to minimize the movement of materials. In order to increase the efficiency and productivity, machines that create products with similar requirements must be close to each other. This machine- grouping, known as cell, allow the production to be dedicated and organized [6].

In civil engineering, the BHA has been introduced in the generalized constitutive law. The problem of model identification is transformed to a problem of parameter back analysis, which is a typical and complicated optimization. To improve the efficiency of the traditional optimization method, a black hole algorithm is applied in this study, by combining the generalized constitutive law for an elastic–plastic constitutive model and black hole algorithm. A new back analysis method for model identification of rocks surrounding underground roadways in coal mine is proposed to solve a parameter back analysis for elastic-plastic constitutive model [7]. While the slope instability of embankment is very complex, which may develop locally, near the facing, within the embankment, or through the foundation soil as local, surficial, general, or deep-seated failure. The BHA is used to analyze the stability of one high embankment slope for one airport in the plateau loess area [8].

In the field of operations research, the BHA has been employed by Soto *et al.*, in which, they presented two new systems for online control of enumeration strategies based on bat algorithm and BHA [9]. The BHA is used to improve performance in the exploration of search tree and updating the enumeration strategy online [10].

The BHA has been actively applied in the field of power system. The BHA has been combined with GSA to solve day-ahead reactive power optimization problem in distribution network [11]. Also, BHA has been used in non-technical losses characterization [12] and optimal reactive power dispatch problem [13]. The BHA has been combined with BBO algorithm [14] and DE algorithm [15] to solve the economic dispatch problem incorporating the wind energy (EDIW) [16]. Bouchekara also used BHA to solve the optimal power flow problem in a power system [17]. Finally, in the field of power system, a gradient-based modified teaching–learning-based optimization combined with BHA to seek the optimum operational cost [18].

Image enhancement is considered as an optimization problem and a meta-heuristic optimization algorithm is used to solve this problem. Image enhancement is a nonlinear optimization problem with its constraints and the enhancement process will be done by intensifying each pixel's content. BHA is employed to find the image's optimum parameters of the transfer function in order to get the best results [19].

In the medical field, the BHA has been integrated with decision tree [20] in medical data classification. In addition, Binary Black Hole Algorithm (BBHA) and Random Forest Ranking (RFR) have been used for gene selection and classification of microarray data [21]. While in the same field, Pashaei and Aydin presented a binary version of BHA called BBHA for solving feature selection problem in biological data [22].

The original BHA was proposed for clustering problem. Many variants of BHA have been introduced in clustering. As an example, BHA has been used to accelerate the clustering speed by both software and hardware [23]. Also, for clustering, the BHA has been combined with bisecting k-means algorithm, this algorithm is called BH–BKmeans algorithm [24]. Jeet and Dhir proposed to use the hybrid of BHA, auxiliary archive, and GA to optimize multiple objectives for clustering of android mobile applications [25].

The BHA has been used as multi-objective scheduling method for workflow application [26]. Also in scheduling, the multi-objective BHA has been used to optimize scheduling of jobs on two machines taking into consideration the fuzziness in the environment involved [27].

In the field of industries and induction motors, the design, performance evaluation and control of induction motors are based on circuit parameters. Though conventional techniques produce good results for accurate measurement of electrical parameters, like resistance (or reactance), the swarm intelligence-motivated techniques still better results for real-world optimization problems. The disrupted Black Hole Artificial Bee Colony (DBHABC) algorithm is proposed and applied for optimizing induction motor parameter estimation [28].

The set covering problem (SCP) is one of the most representative optimization problems. The BHA is used to solve multiple instances of the problem with known benchmarks obtained from the OR-library [29]. Set covering problems were also solved in 2016 by employing a recent nature-inspired metaheuristic based on the black hole phenomena [30]. A multi-dynamic binary black hole algorithm for resolving the set covering problem has been introduced [31]. The same problems were also solved by cuckoo search and BHA [32].

Finally, an application of BHA in mission planning has also been reported. Unmanned combat aerial vehicle (UCAV) mission planning in realistic test fields is a well-known optimization problem, so many algorithms have been designed to solve this multi-constrained problem. The BHA is one of these swarm intelligence approaches which applied to the UCAV mission planning scheme [33].

## 3. Concluding remark

This paper reports a survey on the applications of BHA. At the moment, the BHA has been applied in artificial intelligence, engineering design, software engineering, manufacturing, civil engineering, operations research, image processing, wireless sensor network, scheduling, parameter estimation, power system, medical analysis, clustering, set covering problem, and mission planning. Due to the popularity of BHA, we expect the BHA will be applied in another area of applications such as routing in VLSI [34], DNA sequence design [35], and adaptive beamforming for antenna engineering [36].

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