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A novel meta-heuristic algorithm: Dynamic Virtual Bats Algorithm

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ABSTRACT

Nature-inspired algorithms are a very important part of meta-heuristics. A novel nature inspired algorithm called the Dynamic Virtual Bats Algorithm (DVBA) is presented in this paper. DVBA is inspired by a bat's ability to manipulate frequency and wavelength of the emitted sound waves when hunting. A role based search has been developed to improve the diversification and intensification capability of Bat Algorithm. In the DVBA, there are only two bats: explorer and exploiter bat. While the explorer bat explores the search space, the exploiter bat makes an intensive search of the local with the highest probability of locating the desired target. Depending on their location, bats exchange the roles dynamically.

The performance of the DVBA is extensively evaluated on a suite of 30 bound-constrained optimization problems from CEC 2014 and compared favorably with other well-known meta-heuristics algorithms. The experimental results demonstrated that the proposed DVBA outperform, or is comparable to, its competitors in terms of the quality of final solution and its convergence rates.

1. Introduction

Many nature-inspired algorithms have been invented and improved over the past few decades and applied with success to a variety of numerical and combinatorial optimization problems. Ant Colony Optimization [7,29,33], Particle Swarm Optimization [16,32], Artificial Bees Algorithm [15,18], Bat Algorithm [2,9,35], and Artificial Immune System [13,17] are some such examples. Since real-world optimization problems are becoming more complicated, higher dimensional, and more dynamic, it follows that meta-heuristics algorithms' popularity will continue to increase, as they can find acceptable solutions for non-linear, NP-hard optimization problems within a reasonable amount of time.

Bat Algorithm (BA) [35] is one of the nature-inspired algorithms which was introduced recently and has been successfully applied to solve numerous optimization problems in diverse fields. It is a population-based search algorithm that is inspired from the echolocation behavior of bats. BA, like Yang's previous algorithms, Cuckoo Search [37] and Firefly [34], combines the advantages of existing algorithms, especially Particle Swarm Optimization and Harmony search. Due to its simplicity, convergence speed, and population feature, there have been many studies investigating BA recently. Multiobjective Bat Algorithm [36], Self Adaptive Modified Bat Algorithm [4], Local Memory Search Bat Algorithm [40], Adaptive Bat Algorithm [30], Multi-population Cooperative Bat Algorithm [11], Binary Bat Algorithm [23], and Hybrid Self-Adaptive Bat Algorithm [9] are some of the improved versions of Bat Algorithm.

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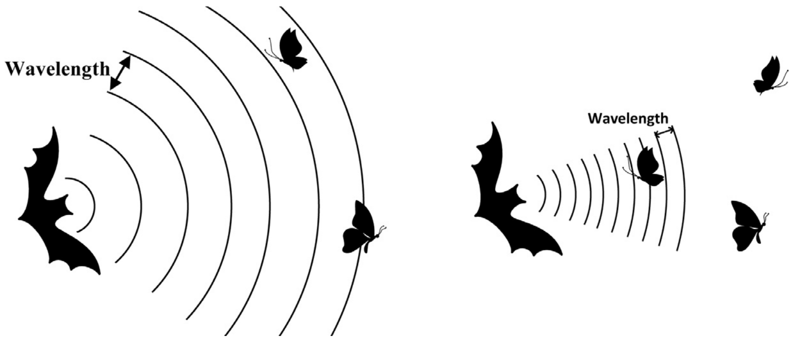

Fig. 1. (a) Low frequency and long wavelength. (b) High frequency and short wavelength. [26].

Directed Artificial Bat Algorithm (DABA) [25] is another bat-inspired algorithm proposed by Amr Rekaby in 2013. DABA differs from other versions of the Bat Algorithms in terms of how the bat's behavior is simulated. Bat is looking for a prey in its directed scope (echo waves), which has shape of a right triangle. This directed scope consists of a set of vectors and search points on these vectors. The number of vectors and visited solutions are changed during the search for prey but the distance between the visited solutions remain the same at all times. The direction of the bat does not change unless there is no better solution in its directed scope. These vectors represent the frequency and the visited locations represent the wavelength of the waves.

The main difference between DABA and BA is the interaction between bats. In BA, bats behave like the particles in PSO; however, in DABA they fly individually without any interaction with other bats. Although DABA simulated bats behavior better than BA in nature, because of the unconnected behavior of the bats in DABA, BA is more applicable and useful.

In this paper, we propose another bat inspired algorithm: Dynamic Virtual Bats Algorithm (DVBA). Although DVBA is a population based meta-heuristic, it needs just two bats to find the optimal solution. These bats are called explorer bat and exploiter bat. While the explorer bat explores the search space the exploiter bat makes a concentrated search around the best found solutions by using echolocation. Experimental results demonstrate that DVBA is more accurate and reliable at attaining the global optimum when compared with existing algorithms.

DVBA represents a unique way of coping with the "exploration and exploitation" conflict. In a preliminary work [28], DVBA compared with PSO and BA on 10 and 30 dimensional versions of 10 classical test functions. In this work, the performance of the DVBA is extensively evaluated on CEC 2014 benchmark functions and compared within three groups of algorithms. In group 1, standard Bat Algorithm, original Particle Swarm Optimization, Genetic Algorithm, and Simulated Annealing are used. In group 2, four state-of-the-art modified BA algorithms are compared and in group 3, six algorithms from a special session at CEC 2014 are used in comparison, as well.

The rest of the paper is organized as follows: In Section 2 we introduce bat's behaviors, especially the way bats use echolocation. Section 3 summarizes the Bat Algorithm. Section 4 describes the proposed DVBA. Experimental results and comparison with other algorithms on optimization test functions are presented in Section 5. Section 6 concludes this paper.

2. Bats and echolocation

Bats have the unique ability to detect insects and avoid obstacles around themselves by using a high frequency sound based system echolocation [26]. Bats emit sound waves and listen to the returning echoes. From these, bats can generate a 3D blueprint of their environment. Bats can distinguish the shape, size, and texture of a tiny prey, in which direction the prey is heading, and even the speed of the prey by using the delayed time and loudness of the response. Bats have also the ability to change the way they emit the sound pulses. By varying frequency of the pulse, bats can change the traveling range of the pulses. Frequency f is inversely proportional with the wavelength λ and multiplication of these gives us the speed of sound as in (1) where $V = 340$ m/s in air.

$$V = f\lambda \tag{1}$$

When bats hunt, they burst sound pulses with lower frequency and longer wavelength, hence the sound pulses can travel farther distance. In this long range mode it becomes hard to detect the exact position of the prey (Fig. 1a), but it becomes easy to search large area.

When bats detect prey, the pulses will be emitted with higher frequency and shorter wavelength, so that bats are able to update the prey location more often (Fig. 1b). Depending on the species, the range of the sound pulses could be from 2.4 m to 62 m [3].

Besides frequency and wavelength, bats also change the loudness of the sound which varies from loudest when searching for prey to a quieter base when approaching to prey; therefore, we can say that loudness and frequency of sound pulses (rate of pulse) are inversely proportional.

To summarize, there are two conspicuous properties of bat hunting strategy: