A Novel Fuzzy Inspired Bat Algorithm for Multidimensional Function Optimization Problem

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ABSTRACT

This article introduces Fuzzy Inspired Bat Algorithm (FIBA), which is an improved variant of the original Bat algorithm. The novelty of FIBA lies in the integration of a fuzzy controller with the basic Bat algorithm that tries to bring balance between the degree of explorations and exploitations during the mutation operation. Another novelty of FIBA is the introduction of a step size parameter, maintained separately for every candidate solution, to customize and control the mix of explorative and exploitative operations around each candidate solution. FIBA is tested on a standard benchmark set that includes 10 complex, scalable, high dimensional functions. The results on benchmark functions reveal that FIBA can perform sufficiently well, and often better than the original Bat algorithm and another recently proposed improved Bat variant. Such improvements on the experimental results imply that the fuzzy technique adopted by FIBA might be effective on other existing problems as well, and hence demand further research and investigation.

KEYWORDS
Bat Algorithm, Exploration and Exploitation, Fuzzy Logic Controller, Swarm Intelligence

1. INTRODUCTION

The Bat Algorithm (BA) is a recently introduced (Yang, 2010) meta-heuristic algorithm that is founded on the dynamic echolocation behavior of bats. The micro bats found in nature demonstrate excellent capability to locate and catch prey insects by using echolocation technique and distributed intelligent swarm behavior. However, some of the recent studies (e.g., Kabir, Sakib, Chowdhury, & Alam, 2014) have revealed that BA is good at search space explorations, but relatively weak at exploitations, which compromise the quality of its final solutions. For good performance, any optimization algorithm requires a sound balance between its explorative and exploitative characteristics. Excessive explorations provide resilience against local optima, but compromising the speed of convergence of

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the algorithm. On the other hand, excessive exploitations provide sufficient convergence speed, but at the cost of premature convergence towards local optima.

The novelty of this paper is to introduce an innovative fuzzy controller to bring an adaptive balance between the degree of exploitative and explorative operations of the original Bat algorithm. The input to the fuzzy controller is the mutation success rate at every time step (i.e., generation), which is used by the fuzzy controller to decide whether the ongoing optimization process requires more explorations or exploitations. The output from the fuzzy controller is a scaling factor value which affects the degree of exploration and exploitation by controlling the mutation step size at the next time step. Larger step sizes (produced by large scaling factor values) are likely to conduct more search space explorations, while smaller step sizes (from small scaling factor values) are required for more exploitation. In addition to the fuzzy controller, FIBA maintains a step size value, separately for each bat (i.e., candidate solution) to employ random walk exploitations on the best group of candidate solutions. This allows FIBA to customize the degree of exploitation and exploration at the individual solution level, i.e., separately for every candidate solution of the population. FIBA has been tested and evaluated by optimizing ten different benchmark functions, consisting of both unimodal and multimodal, inseparable and separable, continuous and discrete functions. The experimental results are compared with the basic bat algorithm (Yang, 2010) and an improved bat variant — the Novel Adaptive Bat Algorithm (NABA) (Kabir, Sakib, Chowdhury, & Alam, 2014). The performance of FIBA is found to be superior to these other algorithms in comparison on most of the benchmark functions.

The organization of the article is as follows. Section 2 briefly discusses some of the existing algorithms and related works. The next section 3 briefly provides a description of the original Bat algorithm, which acts as the foundation of our proposed algorithm — FIBA. Section 4 describes FIBA in detail. The next two sections 5 and 6 present the benchmark problems, experimental setup of the algorithms and their comparison on the benchmark problem set. Finally, section 7 concludes the paper with a brief discussion and summary.

2. EXISTING ALGORITHMS

The core idea of the proposed algorithm — FIBA is to design and hybridize a novel fuzzy logic based controller with the basic Bat algorithm. There exist a number of different evolutionary and swarm intelligence algorithms that have employed fuzzy logic based improvements, e.g., Rani, Gulati, & Garg (2016), Garg (2016), Garg (2015), Garg, Rani, Sharma, & Vishwakarma (2014), Garg, Rani, Sharma, & Vishwakarma (2014). Also, there exist several hybrid algorithms (e.g., Garg & Sharma (2013), Garg (2016), Pytel (2016)) that tries to combine the strengths of two (or, more) evolutionary and swarm intelligence algorithms, avoiding their individual weaknesses. The hybrid Fuzzy Logic-Genetic Algorithm (Pytel, 2016) improves the performance of genetic algorithm on complex clustering problems by employing a fuzzy controller to determine the number and distribution of clusters. Other hybrid fuzzy-genetic approaches are used to efficiently solve feature and instance subset selection problem (Leon-Barranco, Reyes-Garcia, & Zatarain-Cabada, 2006), to design adaptive traffic signal system (Odeh, Mora, Moreno, & Merelo, 2015) and so on. The fuzzy logic based approach is also hybridized with differential evolution algorithm to solve reservoir operational problems (Vucetic & Simonovic, 2013), optimizing multimodal functions (Liu & Lampinen, 2005) and so on. Swarm intelligence algorithms, such as particle swarm optimization (PSO), Ant colony optimization (ACO) and Artificial bee colony (ABC) algorithms have also employed ideas and techniques based on fuzzy logic and fuzzy set theory to solve complex and widely diverse range of problems, e.g., job scheduling (Abraham & Hassanien, 2010), traveling salesman problem (Robati, Barani, Pour, Fadaee, & Anaraki, 2012), supply chain management (Mehdizadeh & Moghaddam, 2008), dynamic design of control policies (Van-Ast, Babuska, & De-Schutter, 2009), topology design of distributed local
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