Analysis of the Dynamical Characteristics of the Firefly Algorithm

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ABSTRACT

The firefly algorithm is a meta-heuristic algorithm, the fundamental principle of which mimic the characteristics associated with the blinking of natural fireflies. This paper, presents a rigorous analysis of the dynamics of the firefly algorithm, which the authors performed by applying a deterministic system that removes the stochastic factors from the state update equation. Depending on its parameters, the individual deterministic firefly algorithm exhibits chaotic behavior. This prompted us to investigate the relationship between the behavior of the algorithm and its parameters as well as the extent to which the chaotic behavior influences the searching ability of the algorithm.

KEYWORDS

Benchmark Function, Chaos, Diversity, Firefly Algorithm, Meta-Heuristics, Parameter, Search Performance, Swarm Intelligence

INTRODUCTION

Under the given constraints, an optimization problem is to find a solution that a certain objective function returns the maximum value or the minimum value. The optimization problem has been studied in various fields such as engineering and economics.

In recent years, many researchers pay attention to swarm intelligence as the application of the optimization problem solver. The swarm intelligence algorithm is to simulate emerging behavior of agents through their local interaction (Krishnanand & Ghose, 2008). For example, some methods are based on the behavior of ant colonies, slime mold colonies, fish flocks, and so on (Dorigo, Maniezzo & Colomi, 1996; Zengin & Tuncel, 2010).

A number of meta-heuristic algorithms with wide range of applications have been proposed. These algorithms are continuously being improved and studies are also underway to enhance the solution search performance of the algorithms. When considering such performance improvements, an analysis of the characteristics of the algorithm is very important. In general, the theoretical analysis of meta-heuristic algorithms is highly challenging because most of these algorithms contain stochastic factors, (Clerc & Kennedy, 2002; Koguma & Aiyoshi, 2010). Therefore, a stochastic analysis of the operations of meta-heuristic algorithms is considered to be very difficult. Therefore, to analyze the dynamics of firefly algorithm, the authors proposed a deterministic firefly algorithm.

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The firefly algorithm (FA) is one of these meta-heuristic algorithms, (Yang, 2010; Yang, 2013). The FA was developed by Xin-She Yang et al. and is based on the characteristics of the blinking of a natural firefly. The FA expresses the dynamics of the firefly by a simple update equation, however, apart from this the behavior of the FA is very complex.

The conventional FA is based on the following three rules, (Yang, 2010; Yang, 2013):

1. Fireflies are unisex creatures such that one firefly will be attracted to other fireflies regardless of their sex;
2. The attractiveness to a firefly is proportional to its brightness, with both of these properties decreasing as the distance between individual fireflies increases. Thus, for any two flashing fireflies, the less bright one would be expected to move towards the brighter one. In the absence of any firefly brighter than itself, it will move randomly;
3. The brightness of a firefly is determined by the landscape of the objective function.

In the work presented in this paper, the stochastic factors are removed from the update equation. Furthermore, the authors investigate and confirm the effect of the solution search performance of the FA when it exhibits chaotic behavior (Yang, 2013).

**FIREFLY ALGORITHM**

The dynamics of the FA are described by the following equation:

\[ x_i^{t+1} = x_i^t + \beta (x_j^t - x_i^t) + \alpha \epsilon_i^t \]  \hspace{1cm} (1)

where \( x_i^t \) denotes the position of the \( i \)-th firefly on the \( t \)-th iteration, \( \beta \) denotes the attractiveness of the \( i \)-th firefly as perceived by the \( j \)-th fireflies, \( \alpha_i \) represents the variation of the randomness with \( t \) and \( \epsilon_i^t \) denotes a random number vector on the \( t \)-th iteration.

**Light Intensity and Attractiveness**

The following two points have a significant effect on the solution search performance of the FA:

- Variation of light intensity;
- Formulation of attractiveness.

The distance between the \( i \)-th firefly and the \( j \)-th firefly is:

\[ r_{ij}^t = x_i^t - x_j^t = \sqrt{\sum_{d=1}^{n} (x_{i,d}^t - x_{j,d}^t)^2} \] \hspace{1cm} (2)

In the case of a simple maximization problem, the brightness \( I \) of a firefly is in proportion to the evaluation function value at the position \( x \):
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