Dynamic Search Fireworks Algorithm with Adaptive Parameters

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ABSTRACT

As a comparatively new algorithm of swarm intelligence, the dynamic search fireworks algorithm (dynFWA) imitates the explosion procedure of fireworks. With the goal of achieving global optimization and further boosting performance of dynFWA, adaptive parameters are added in this present study, called dynamic search fireworks algorithm with adaptive parameters (dynFWAAP). In this novel dynFWAAP, a self-adaptive method is used to tune the amplification coefficient Ca and the reduction coefficient Cr for fast convergence. To balance exploration and exploitation, the coefficient of amplitude α and the coefficient of sparks β are also adapted, and a new selection operator is proposed. Evaluated on twelve benchmark functions, it is evident from the experimental results that the dynFWAAP significantly outperformed the three variants of fireworks algorithms (FWA) based on solution accuracy and performed best in other four algorithms of swarm intelligence in terms of time cost and solution accuracy.

KEYWORDS

Fireworks Algorithm, Global Optimization, Parameters Adaption, Swarm Intelligence

1. INTRODUCTION

Swarm intelligence is a subset of artificial intelligence. The algorithms of swarm intelligence have the ability to self-learn and adapt to external changes, which has drawn enormous interest and recognized many application areas.

In the past three decades, several new algorithms of swarm intelligence based on social behavior or natural phenomena have been presented to resolve complex global optimization issues in the real world. Observing the behavior of ants trying to find food, an algorithm called ant colony optimization was developed (Dorigo, 1992). Ant colony optimization is a common algorithm for resolving problems of combinational optimization. Next, particle swarm optimization (PSO) was proposed (Kennedy, 1995, Chatterjee, 2017). This algorithm mimics the features of birds in their flight to their destination. Particles fly around to locate the best solution in the search space and obtain the best location in all paths. Simulating the evolution of biological species, differential evolution (DE) was proposed (Storn, 1997). Inspired by the features of fireflies flashing, firefly algorithm (FA) was developed (Yang, 2009, Dey, 2014). It can handle multimodal functions better than other algorithms of swarm intelligence.

The FWA is a novel algorithm of swarm intelligent (Tan, 2010). The FWA imitates the explosion procedure of fireworks in the dark sky. A firework creates a large number of sparks around its location during the explosion in the air. If the locations of the firework and sparks are as potential solutions to optimized problems in the search space, a better solution will be obtained based on these fitness values among the firework and sparks. In this new location, the next firework explodes and generates sparks, and a new better solution will also be obtained. Repeated the explosion process of

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fireworks, the optimal solution can be constantly approached. Different optimization problems have been resolved by using FWA, like matrix decomposition (Janecek, 2011), digital filter design (Gao, 2011), parameter’s optimization (Wen, 2013), network reconfiguration (Imran, 2014), minimization mass of trusses (Pholdee, 2014), parameter estimation of chaotic systems (Li, 2015), multi-satellite control (Liu, 2015), PID parameters’ tuning (Xue, 2016) and image segmentation (Misra, 2017).

2. RELATED WORK

However, there are deficiencies within the FWA approach. If the optimal value of the function is situated at the origin, the FWA converges to the origin very well. When the optimal value is not at the origin, it is difficult for the FWA to get the correct solution. In addition, the time cost in the selection phase of the FWA is long compared with other optimization algorithms. Therefore, the enhanced fireworks algorithm (EFWA) was introduced to enhance FWA (Zheng, 2013). The explosion size of the best firework tends to zero in EFWA, thus a new minimal amplitude check is employed. The magnitude is calculated based on the maximum number of evaluations, which does not take into account the adaptability and dynamics around the core firework. Thus, the dynFWA introduced a dynamic amplitude that will allow quick convergence or will decrease to narrow the local search (Zheng, 2014).

A new cooperative framework for fireworks algorithm (Zheng, 2015) uses the independent choice operator to improve the exploitation capacity of non-core fireworks and adopts a cooperative strategy of crowdedness-avoiding to increase the exploration capacity among fireworks. A new guiding spark in FWA (GFWA) was proposed to enhance the information utilization (Li, 2017). GFWA uses information of objective functions obtained from sparks to build a guiding vector, and to produce an elite solution. To further improve the performance of GFWA, two strategies are proposed, such as weight-based guiding strategy and quantitative increase strategy (Li, 2019).

The amplification coefficient $C_a$ and reduction coefficient $C_r$ in dynFWA are recommended empirically to be a value of 1.2 and 0.9, but our thorough experiments show the values of $C_a$ and $C_r$ should vary depending on the actual problems. With the goal of achieving global optimization and further boosting performance of dynFWA, adaptive parameters are added and dynFWAAP is proposed.

In dynFWAAP, a self-adaptive method is used to tune variables of $C_a$ and $C_r$. In the calculation of explosion amplitude and sparks, the coefficient of amplitude $\alpha$ and the coefficient of sparks $\beta$ are set as constants in dynFWA, which result in a lot of useless sparks with either a large amplitude or a relatively large number in the phase of the local search. To balance exploration and exploitation, the explosion amplitude should be larger and the quantity of explosion sparks should be more to increase the diversity of population during exploration. In order to obtain a better solution, the explosion amplitude should be smaller, and the quantity of explosion sparks should be less during exploitation. These values should also be adaptive in dynFWAAP. In dynFWA, since many poorer fireworks or sparks are selected to enter the next generation in the phase of local search, these fireworks cannot converge to the optimal value of the core fireworks at all, and are useless for a better result. In order to balance diversity and convergence, a new selection operator is proposed in dynFWAAP.

Therefore, in this novel dynFWAAP, three different proposals are presented to increase the performance of dynFWA. First, a self-adaptive method is used to tune above coefficients for fast convergence. Second, the coefficient of amplitude $\alpha$ and the coefficient of sparks $\beta$ are also adapted to balance exploration and exploitation. Third, a new selection method is proposed to balance diversity and convergence.

The remainder of this paper is separated into six sections. The dynFWA is presented in the third section. The section 4 demonstrates the details of proposed dynFWAAP. Twelve benchmark functions are listed in section 5. In section 6, simulation results and discussions are presented. Threats of validity is given in section 7. Finally, section 8 provides our conclusion.
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