Chapter 3
Explosion Operation of Fireworks Algorithm

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ABSTRACT

This chapter briefly reviews the basic explosion mechanism used in the fireworks algorithm (FWA) and comprehensively investigates relevant research on explosion operations. Since the explosion mechanism is one of the most core operations directly affecting the performance of FWA, the authors focus on analyzing the FWA explosion operation and highlighting two novel explosion strategies: a multi-layer explosion strategy and a scouting explosion strategy. The multi-layer explosion strategy allows an individual firework to perform multiple explosions instead of the single explosion used in the original FWA, where each round of explosion can be regarded as a layer; the scouting explosion strategy controls an individual firework to generate spark individuals one by one instead of generating all spark individuals within the explosion amplitude at once. The authors then introduce several other effective strategies to further improve the performance of FWA by full using the information generated by the explosion operation. Finally, the authors list some open topics for discussion.

INTRODUCTION

The fireworks algorithm (FWA) (Tan & Zhu, 2014) is a population-based meta-heuristic optimization algorithm that simulates the explosion process of real fireworks repeatedly in order to find the global optimum. Although it is a young member of the family of algorithms in the evolutionary computation (EC) community, it attracts a lot of attention from practitioners owing to its huge potential due to its e.g. ease of use, robustness, efficiency, parallelism, and other characteristics. With the rapid increase

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in its popularity and real-world applications, development of FWA is booming and it has become an important branch in EC algorithms.

Since the basic FWA was first proposed in 2010, researchers have frequently proposed many effective strategies to further improve its performance. For example, Zheng et al. modified five operations used in FWA to develop a more efficient version, enhanced FWA (EFWA) (Zheng, 2013). Yu et al. used the explosion information to calculate a convergence point that has a high possibility to locate in the global optimal area and used it as an elite individual to accelerate the convergence of FWA (Yu, Tan & Takagi, 2018). Pei et al. adopted different sampling methods to approximate the fitness landscape to accelerate the FWA search (Pei, 2012). Some work focuses on developing powerful hybrid algorithms by introducing operations from other EC algorithms into FWA to inherit their strengths, such as differential mutation (Yu & Kelley, 2014), covariance mutation (Yu & Tan, 2015), the gravitational search operator (Zhu, 2016), chaotic systems (Gong, 2016), and the firefly algorithm (Wang, 2019). Additionally, FWA has also been applied to solve various types of optimization problems, such as multimodal optimization (Yu, 2019), multi-objective optimization (Zhan, 2018), constrained optimization (Bacanin, 2015), dynamic optimization (Pekdemir, 2016), and large-scale optimization (Pandey, 2018).

FWA has not only flourished in an academic setting, but also appeared frequently in the industry in recent years. For example, FWA successfully solved the network reconfiguration required to reduce power loss and improve voltage distribution (Mohamed, 2014); it was also used to design the coefficients of a digital filter (Gao, 2011). Actually, FWA has also perfectly solved many other complex real-world problems, such as retinal image registration (Tuba, 2017), wireless sensor network coverage (Tuba, 2016), distributed resource scheduling (Reddy, 2016), image segmentation (Misra, 2017), capacitated vehicle routing problem (Yang, 2019), and others (Zhang, 2019).

The main objective of this chapter is to comprehensively analyze the explosion operation, one of FWA's three core operations, to thoroughly understand FWA and to highlight two effective new explosion strategies in detail. The second one is to introduce several strategies for accelerating FWA search by fully using the information generated by the explosion operation. Finally, the authors point out several potential research topics for discussion.

Explosion Operation

FWA was created by observing the explosion phenomenon of real fireworks and believing that an explosion can be thought of as corresponding to a local search centered on a particular point. Based on this inspiration, FWA simulates an explosion operation repeatedly and, through cooperation among firework individuals, gradually evolves to the global optimal area. Similar to other EC algorithms, FWA randomly generates multiple firework individuals to form an initial population, and then each firework individual is adaptively assigned an explosion amplitude and a number of generated spark individuals according to its fitness before the explosion operation is performed. Usually, a firework individual with better fitness generates many spark individuals within a small explosion amplitude for exploitation, while a poor firework individual generates a few spark individuals within a large explosion amplitude for exploration. FWA also employs mutation operations to increase individual diversity, and spark individuals generated in this way are referred to as mutation spark individuals. Next, a selection operation is used to select firework individuals in the next generation from all current individuals, including current firework individuals, explosion spark individuals, and mutation spark individuals. The above three operations - the

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