Discrete Fireworks Algorithm for Single Machine Scheduling Problems

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ABSTRACT

Over the recent years, Fireworks Algorithm has recorded an increasing success on solving continuous optimization problems, due to its efficiency, simplicity and more importantly its rapid convergence to good optimums. Thus, the Fireworks Algorithm performance is now widely comparable with the most popular methods in the optimization field such as evolutionary computation and swarm intelligence techniques. This paper introduces a discrete Fireworks Algorithm for combinatorial single machine scheduling problems. Taking advantage of the robust design of the original Fireworks Algorithm, a new adaptation of sparks generation is proposed with a novel use of the control parameters. To verify the explorative performance of the algorithm, a hybridization with Variable Neighborhood Search heuristic is implemented. To validate it, the proposed method is tested with several benchmarks instances of the single machine total weighted tardiness. A comparison with other optimization algorithms is also included. The obtained results exhibit the high performance of the proposed method.

KEYWORDS

Combinatorial Optimization, Discrete Fireworks Algorithm, Optimality, Single Machine Scheduling, Total Weighted Tardiness

1. INTRODUCTION

Today, many real world optimization problems are naturally combinatorial problems. The most challenging among them are those classified as NP-Hard problems, like routing, manufacturing cell formation, frequency assignment or scheduling problems. The main goal of the latter ones is the assignment of tasks (jobs) to a single or multiple machines in order to minimize one or many objective functions. In order to solve them, exact algorithms such as branch and bound techniques (Pascal, & Laurent, & Eric, 2004), and methods like greedy heuristics (Palominos, & Araya, & Silva, 2012) have been proposed, but they have experienced some issues on obtaining optimality, sometimes even in small scale problems. In response to this, many optimization techniques notably nature-inspired techniques, have been proposed to tackle these issues such as Particle Swarm Optimization (Fatih, & Sevkli, & Yun-Chia, Gencyilmaz, 2004), Ant Colony Optimization (Dorigo, & Di Caro, & Gambardella, 1999), Cultural Algorithms (Alami, & El Imrani, 2008), Genetic algorithms (Ferrolho, & Crisostomo, 2007), hybrid discrete particle swarm (Benamer, 2009), learning automata (Sabamoniri, Asghari, & Hosseini, 2012), evolutionary algorithms (Liu, & Yan, 2012) and many others.

Recently, Fireworks Algorithms (FA) record an increasing growth and success in continuous optimization. Inspired by the physical behavior of an exploding firework, FA (Zheng, & Li, &
Janecek, & Tan 2015) showed great performance on functions optimization. In fact, during a fireworks explosion, numerous sparks are generated around the explosion center. The process can be seen as a search process where the explosion’s location represents a solution, while sparks represent an exploration of the local search space.

To Our best knowledge, the FA hasn’t been yet widely used for combinatorial optimization, especially for scheduling problems. Thus, this paper introduces a Fireworks Algorithm adaptation to the combinatorial scheduling problems. To test its performance, the proposed algorithm is applied to the single machine total weighted tardiness problem.

The rest of the paper is organized as follows: Section 2 describes the single machine total weighted tardiness scheduling problem, the section 3 presents a global view of the Fireworks Algorithm while the section 4 details the proposed adaptation of the Fireworks Algorithm to scheduling problems, then a results’ discussion is given in section 5 at which we conclude after.

2. TOTAL WEIGHTED TARDINESS PROBLEM (SMTWT)

In engineering and computer science, the single machine total weighted tardiness problem (SMTWT) (Rathinam, & Ponnambalam, 2003) is a widely studied scheduling problem that is typed as NP-Hard. SMTWT considers \( n \) jobs (or tasks) to be processed sequentially on a single machine. Each job \( i \) is characterized by a processing time \( P_i \), representing the necessary time needed by the machine to process the job \( i \), a due date \( d_i \) indicating the date by which a job \( i \) should be completed, and a nonnegative weight \( w_i \) representing the relative importance of job \( i \). The tardiness of job \( j \) is then defined as:

\[
T_j = \max \left( C_j - d_j, 0 \right)
\]  

where:

\[
C_j = \sum_{i=1}^{j} P_i
\]

\( C_j \) denotes the completion time of a job \( j \). All jobs are assumed to be available for processing at time zero. The purpose of SMTWT is to find a job sequence minimizing the total weighted tardiness given by:

\[
T = \sum_{i=1}^{n} w_i T_i
\]

For more clarity, let’s illustrate the problem in the following example. Consider the scheduling of aircrafts takeoffs at an airport. Assuming that the airport has only one landing strip, there are planes waiting for taking off and there are no time constraints waiting between takeoffs. The processing machine can then model the airport runway, \( j \) models the task, in this case an aircraft takeoff, \( P_j \)
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