An Adaptive Genetic Algorithm to the Single Machine Scheduling Problem with Earliness and Tardiness Penalties

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Abstract. This paper deals with the Single Machine Scheduling Problem with Earliness and Tardiness Penalties, considering distinct due windows and sequence-dependent setup time. Due to its complexity, an adaptive genetic algorithm is proposed for solving it. Many search operators are used to explore the solution space where the choice probability for each operator depends on the success in a previous search. The initial population is generated by the combination between construct methods based on greedy, random and GRASP techniques. For each job sequence generated, a polynomial time algorithm is used for determining the processing initial optimal date to each job. During the evaluation process, the best individuals produced are added to a special group, called elite group. The individuals of this group are submitted to refinement, aiming to improve their quality. Three variations of this algorithm are submitted to computational test. The results show the effectiveness of the proposed algorithm.

1 Introduction

Scheduling problems are one of the most studied problems in combinatorial optimization [1]. It occurs mainly by two aspects: the first one concerns their practical importance, with various applications in several industrial fields. The second aspect is about the difficulty for solving the majority problems of this class. This paper deals with the Single Machine Scheduling Problem with Earliness and Tardiness Penalties (SMSPETP) with distinct due windows and sequence-dependent setup time. To our knowledge, this problem has not been still object of great attention of the scientific community, as it could seen in the recent survey [1].

The criteria to penalize the tardiness and earliness production goes to the Just-in-Time philosophy goal, that is, the production is done just when necessary.
The existence of a due window for each job, according to [2], is because of an uncertainly situation or tolerance related to due date. It is accepted that this time interval operations can be finalized without costs. On the other hand, in most industrial processes the machines should first be prepared for doing new jobs, including the time to obtain tools, positioning materials that will be used in the process, cleaning process, preparing process, tools adjustment and materials inspection. The necessary time to this preparation is known by setup time. Many production scheduling researches disregard this time or include it in the operation processing time. This act simplifies the analysis but affect the solution quality when the setup time has a relevant variability in function of the job sequence in machine. This work considers that the setup times are dependents from the production scheduling. Since it was showed in [3] that a simplified version of this problem is NP-Hard, the application of metaheuristics for solving this problem is justified.

In order to solve this scheduling problem with the presented characteristics, an Adaptive Genetic Algorithm, so-called AGA, is proposed here. To generate different individuals having good quality, the initial population is generated by a construction method based on GRASP [5], which uses five dispatch rules to form the individuals. During the evolution process, the population passes through mutation and crossover conventional process. However, the crossover uses criteria based on solution quality generated by each crossover operator to choose which operator will be used. By the way, according to how well an operator performs, the probabilities it be chosen is increased or decreased during the evolution. A local search is applied in the best offspring produced for each operator, to refine it. The survival population is composed by individuals chosen by elitism technique. Mutation process is then applied to a slice of the surviving population for diversifying it. Periodically, a Path Relinking module is applied taking the best one so far generated by the algorithm as base individual and each one of the five best individuals generated by each crossover operator as guide individual. The population improvement occurs until the stop criteria is reached.

The remaining of this work is organized as follows: section 2 details the studied problem; section 3 presents the adaptive algorithm for solving SMSETP; section 4 shows and discuss the results; finally, section 5 ends this work.

2 Problem Description

This work studies the single machine scheduling problem, with earliness and tardiness penalties, distinct due windows and sequence-dependent setup time. In this problem, one machine must process a set of \( n \) jobs. Each job \( i \) has processing time \( P_i \), initial date \( E_i \) and final date \( T_i \), desired for ending the processing. The machine executes one job per time and, if a job processing is started, it must be finished, since processing interruptions are not allowed. All jobs are available for processing in the instant 0. When a job \( j \) is sequenced immediately after a job \( i \), for setting the machine is necessary a setup time \( S_{ij} \). Setup times equal 0 mean products of the same family. The initial setup times are considered, i.e., the setup