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Discrete Optimization

A tabu search and a genetic algorithm for solving a bicriteria general job shop scheduling problem

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Abstract

This paper deals with a general job shop scheduling problem with multiple constraints, coming from printing and boarding industry. The objective is the minimization of two criteria, the makespan and the maximum lateness, and we are interested in finding an approximation of the Pareto frontier. We propose a fast and elitist genetic algorithm based on NSGA-II for solving the problem. The initial population of this algorithm is either randomly generated or partially generated by using a tabu search algorithm, that minimizes a linear combination of the two criteria. Both the genetic and the tabu search algorithms are tested on benchmark instances from flexible job shop literature and computational results show the interest of both methods to obtain an efficient and effective resolution method.

Keywords: Scheduling; General job shop; Tabu search; Genetic algorithm; Bicriteria

1. Introduction

The problem we consider in this paper is issued from printing and boarding industry. Each job to perform is a set of operations which must be processed in a specific order that depends on the job. Routes are not necessarily linear as for the job shop problem. Resources are machines that can be used for processing different types of operations and the resource processing an operation can be selected in a set of resources, which is associated to the operation. The considered problem is a *general job shop* scheduling problem, denoted by GJSSP in the following. Furthermore, for some practical reasons, decision-makers are not just interested in a single objective function, but rather in best compromise solutions related to criteria like makespan or flow time and criteria involving tardiness measures. In the rest of this paper, the two criteria to be minimized are the makespan and the maximum lateness.

A software for solving the job shop problem with just a single criterion was developed in 2003 [15] (last version developed in 2007) and is used by more than 120 French customers including printing and boarding

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companies [7]. The work presented in this paper concerns the algorithms implemented in the future version of this software, integrating multiple criteria considerations. A user-interface will help the decision-maker to select the best compromise solution among those corresponding to non-dominated criteria vectors.

The literature contains an important number of papers dealing with job shop scheduling problems, multicriteria approaches in scheduling and scheduling and assignment problems. Less papers deal with general or flexible job shop scheduling problems with multiple criteria.

A branch-and-bound algorithm and some heuristic algorithms are proposed for the multi-purpose machine job shop scheduling problem by Jurisch in [11]. For the GJSSP, Paulli proposes a hierarchical approach in [16], where the first step is to solve the assignment problem and the second step to solve the job shop scheduling problem. In [4], Dauzère-Pérès and Paulli propose a Tabu search for the GJSSP with the makespan as objective function. In [14], Mastrolilli and Gambardella propose two neighborhood structures for the GJSSP. For one of them, the interest is that any feasible solution having an empty neighborhood is optimal. Kacem et al. propose in [12] a hybridization of an evolutionary algorithm and fuzzy logic. In [2], Alvarez-Valdes et al. propose a heuristic algorithm for a GJSSP dedicated to a glass factory industry with special *no-wait* or *overlapping* constraints. The objective is to find a schedule with a criterion based on earliness and tardiness penalties. The authors use a two-step algorithm. In the first step priority rules are used to solve the problem, in the second step a local search improves this solution. In [9], Ho et al. propose an architecture where a learning module is introduced into an evolutionary algorithm for solving GJSSP. The makespan is minimized and the authors show that their method outperforms existing ones [12,3] for some instances of the literature. We refer to [18] for a more precise survey on multicriteria scheduling problems.

In Section 2 we present a formal definition of the problem and notations. Section 3 presents a tabu search algorithm that minimizes a linear combination of the two objective functions. Section 4 presents the NSGA-II-based genetic algorithm for the solution of the GJSSP. Computational experiments are presented and discussed in Section 5 and Section 6 presents a conclusion and some future research directions.

2. Problem definition and notations

We consider the General Job Shop Scheduling Problem, which is a generalization of the classical job shop scheduling problem. We have a set $\mathscr{J}$ of n jobs to be scheduled on a set $\mathscr{M}$ of m disjunctive resources. Each job J_j needs n_j operations for being completed where operation i of job J_j is denoted by $O_{i,j}$. We assume that the routing constraints are not necessarily linear, that is an operation may have more than one preceding operation in the job routing. However, each job J_j has a unique ending operation $O_{n_j,j}$. Each operation $O_{i,j}$ can be processed by any resource of the set $\mathscr{R}_{i,j}$ which is the subset of resources that can perform $O_{i,j}$. We assume that the processing time of operation $O_{i,j}$ depends on the assigned resource M_k and is denoted by $p_{i,j,k}$. Before each operation, a setup time is required. This setup can be anticipated and is supposed to be sequence dependent. It is denoted by $s_{i,j,k,i',j'}$ if the setup concerns operation $O_{i',j'}$ on M_k after the process of operation $O_{i,j}$ ($s_{0,0,k,i',j'}$ is the setup time for operation $O_{i',j'}$ in first position on M_k). Release time r_j and dues dates d_j are associated to each job J_j. A release time means that the job cannot start before this date. Fig. 1 illustrates these notations.

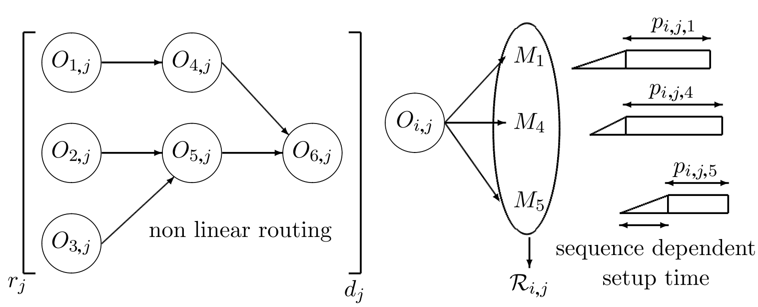

Fig. 1. GJSSP notation.