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Genetic local search for multi-objective flowshop scheduling problems

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Abstract

This paper addresses flowshop scheduling problems with multiple performance criteria in such a way as to provide the decision maker with approximate Pareto optimal solutions. Genetic algorithms have attracted the attention of researchers in the nineties as a promising technique for solving multi-objective combinatorial optimization problems. We propose a genetic local search algorithm with features such as preservation of dispersion in the population, elitism, and use of a parallel multi-objective local search so as intensify the search in distinct regions. The concept of Pareto dominance is used to assign fitness to the solutions and in the local search procedure. The algorithm is applied to the flowshop scheduling problem for the following two pairs of objectives: (i) makespan and maximum tardiness; (ii) makespan and total tardiness. For instances involving two machines, the algorithm is compared with Branch-and-Bound algorithms proposed in the literature. For such instances and larger ones, involving up to 80 jobs and 20 machines, the performance of the algorithm is compared with two multi-objective genetic local search algorithms proposed in the literature. Computational results show that the proposed algorithm yields a reasonable approximation of the Pareto optimal set.

Keywords: Multi-objective combinatorial optimization; Metaheuristics; Genetic local search; Flowshop scheduling

1. Introduction

It is well known that in a large number of real problems, production scheduling managers face multiple, often conflicting, decision criteria. Up to the 1980s, scheduling research was mainly concentrated on optimizing single performance measures such as makespan (C_{max}), total flowtime (F), maximum tardiness (T_{max}),

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total tardiness (T) and number of tardy jobs (n_T). C_{max} and F are related to maximizing system utilization and minimizing work-in-process inventories, respectively, while the remaining measures are related to job due dates. Dileepan and Sen (1988) and Fry et al. (1989) survey the scarce research, at that time, on single-machine multi-objective scheduling problems. The survey by Nagar et al. (1995a) includes a few multiple machine problems. T'kindt and Billaut (2001) present a comprehensive state-of-art survey on multi-criteria machine scheduling, including single-machine, parallel machines and flowshop. They list 105 papers, which shows the increasing interest to such an important area.

Multi-objective optimization was originally conceived with finding Pareto optimal solutions (Pareto, 1981), also called efficient solutions. Such solutions are nondominated, i.e., no other solution is superior to them when all objectives are taken into account. From a decision maker perspective, the choice of a solution from all presented efficient solutions, is called a posteriori approach.

In this paper we adopt a posteriori approach for multi-criteria flowshop scheduling problems to obtain approximate efficient solutions for the following pairs of objectives: (C_{max}, T_{max}) and (C_{max}, T). The sequence of jobs processed in every machine is the same, characterizing a permutational flowshop.

The literature on this type of problem is rather scarce. Branch-and-Bound algorithms for two-machine problems have been proposed. Daniels and Chambers (1990) address the pair of objectives (C_{max}, T_{max}), Liao et al. (1997) deal with the pairs (C_{max}, T) and (C_{max}, n_T), while Sayin and Karabati (1999) consider (C_{max}, F). These papers report results for instances involving at most 30 jobs. From the heuristic viewpoint, Daniels and Chambers propose the only multi-objective constructive heuristic we are aware of, for two and more than two machines. Murata et al. (1996) develop a genetic algorithm to minimize (C_{max}, T, F). Ishibuchi and Murata (1998) extend the above approach and include a local search procedure in the genetic algorithm to minimize (C_{max}, T_{max}, F) and (C_{max}, T_{max}).

There is also a literature on multi-objective flowshop scheduling which can be classified as a priori and interactive approaches. In the a priori approach, the decision maker expresses his preference relative to the objectives in one of two ways. The first one consists of attaching weights to each objective and combining them in a linear function (Rajendran, 1995; Nagar et al., 1995b; Şerifoğlu and Ulusoy, 1998). In the second approach, objectives are ranked in decreasing order of importance; the problem is solved for the first objective, and then the second problem is solved for the second objective under the constraint that the optimal solution of the first objective does not change. This single-objective problem process is continued until the last objective (Rajendran, 1992; Gupta et al., 1999, 2001, 2002; T'kindt et al., 2001). In the interactive approach, the decision maker intervenes in the optimization process to guide it to most suitable solutions (Bernardo and Lin, 1994).

This paper suggests a new genetic local search algorithm to obtain approximate efficient solutions for multi-objective combinatorial optimization (see Ehrgott and Gandibleux, 2000 for an annotated bibliography). The algorithm is then applied to the flowshop problems mentioned above. Metaheuristics such as genetic algorithms (Holland, 1975), tabu search (Glover and McMillan, 1986) and simulated annealing (Kirkpatrick et al., 1983) were originally conceived for single-objective combinatorial optimization and the success achieved in their application to a very large number of problems has stimulated researchers to extend them to multi-objective combinatorial optimization problems. Jones et al. (2002) list 115 articles published in the period of 1991–1999 and note that almost 80% of the articles are dedicated to real problems, especially in the discipline of engineering. This number reflects not only the increasing awareness of problems with multiple objectives, but also that metaheuristics are effective techniques to cope with such problems. Moreover, 70% of the articles use genetic algorithms as the primary metaheuristic, and the common argument for such a preference is that such algorithms generate at each iteration a population of solutions and in multi-objective optimization the goal is to obtain the set of efficient solutions. Nevertheless, local search based metaheuristics, also provide at each iteration a ''population'' comprised of the neighboring solutions. Therefore suitable implementation designs of tabu search and simulated annealing can lead to algorithms that are very competitive to genetic algorithms, as in single-objective optimization. Coello