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Flow-shop Problems: A Heuristic Search Algorithm

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Abstract

This article presents an intelligent heuristic search algorithm (IHSA) for solving flow-shop problems with two or three machines and an arbitrary number of jobs. Following its initial development the algorithm has been modified in two different ways in order to reduce backtracking and to improve its performance. The first modification concerns the choice of the best heuristic function to use, and the second modification concerns the way in which heuristic estimates at nodes on the search path are determined as the search progresses. Experimental evidence of the improved performance of the algorithm as a result of each of these modifications is presented.*

Keywords: *Admissible heuristic function/estimate, dominance, flow- shop problems, heuristic search algorithm*

Introduction

The solution to the general flow-shop scheduling problem involving *n* jobs and *m* machines determines the sequence of jobs on each machine in order to complete all the jobs on all the machines in the minimum total time (i.e. with minimum makespan) where each job is processed first on machine *1* then on machine *2* and so on until it is finally processed on machine *m*. The complexity of the general problem is of the order $(n!)^m$. It is known that there is an optimal solution where the sequence of jobs is the same on the first two machines and the sequence of jobs is the same on the last two machines (Conway *et al*. 1967). Consequently, for a flow-shop problem with two or three machines there is an optimal solution where the jobs are processed in the same sequence on each machine and in this case it is among *n!* possible sequences.

Early research on flow-shop problems is based mainly on Johnson's theorem, which gives a procedure for finding an optimal solution with only two machines, or three machines with certain characteristics (Johnson 1954; Kamburowski 1997). Other approaches for the general problem include integer linear programming and combinatorial programming, which use intensive computation to obtain optimal solutions and are generally not feasible from a computational standpoint because the number of variables increases exponentially as the number of machines increases (Pan 1997). The branch-and-bound method uses upper or lower bounds to guide the direction of the search. Depending on the effectiveness of the heuristic and the search strategy this method may return only near optimal solutions but with long computation time (Ignall and Schrage 1965; Lomnicki 1965; McMahon and Burton 1967; Pan and Chen 1997). The genetic algorithm has been applied to these problems and, depending on the nature of the problem, it may find an optimal solution but, due to the evolutionary nature of this approach, the computation time is unpredictable (Cleveland and Smith 1989; Chen *et al*. 1996). Also, heuristic search methods and methods based on fuzzy logic have been applied to the general flow-shop problem (Lai 1996; Wang *et al*. 1996; Hong and Wang 1999; Hong *et al*. 2000; Hong and Chuang 1998a, 1998b, 1999; Hong *et al*. 1998). In particular, Fan (1999a, 1999b, 2002) developed an intelligent heuristic search algorithm (IHSA*) for 2 or 3 machine problems based on the Search and Learning A* (SLA*) algorithm (Zamani and Shue 1995, 1998; Zamani 2001), which is a modified and improved version of the Learning Real Time