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Hybrid flowshop scheduling with machine and resource-dependent processing times

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A B S T R A C T

Most of research in production scheduling is concerned with the optimization of a single criterion. However the analysis of the performance of a schedule often involves more than one aspect and therefore requires a multi-objective treatment. In this research, with combination of two multiple objective decision-making methods, min–max and weighted techniques, a new solution presentation method and a robust hybrid metaheuristic, we solved sequence-dependent setup time hybrid flowshop scheduling problems. In this paper for reflecting real-world situation adequately, we assume the processing time of each job depends on the speed of machine and amount of resource allocated to each machine at the stage which is processed on it. In formulation of min–max type, the decision-maker can have the flexibility of mixed use of weights and distance parameter in expressing desired improvement on produced Pareto optimal solutions. To minimize makespan and total resource allocation costs, the proposed hybrid approach is robust, fast, and simply structured, and comprises two components: genetic algorithm and a variable neighborhood search. The comparison shows the proposal to be very efficient for different structure instances.

1. Introduction

A hybrid flowshop scheduling problem (HFSP), as described by Linn and Zhang [1], consists of series of production stages, each of which has multiple machines operating in parallel and at least one stage must have more than one machine to differ from traditional flow shop environment. The HFSP is an adequate model for several industrial settings such as semiconductors, electronics manufacturing, airplane engine production, and petrochemical production [2].

Many real-world problems involve simultaneous optimization of several objective functions. In general, these functions often compete and conflict with themselves [3]. Due to the impossibility to achieve optimal values in all objectives simultaneously, multiple criteria decision making (MCDM) always involves a choice problem. The final solution represents a compromise between the different objectives depending on the preferences of the decision-maker. The scientific area concerned with modeling and analyzing preference structures to formalize the choice process from usually small, explicit list of alternatives is called multi attribute decision analysis [4].

Many decision problems contain a large, possibly infinite number of decision alternatives. In such cases, it is impossible to explicitly compare all alternatives, and therefore the choice problem is accompanied by a search problem to filter promising (optimal) from unpromising (non-optimal) alternatives. Problems of this type are treated in the area called multi-objective optimization (MOO). A typical classification of methods for multi-objective decision making is given by Hwang and Masud

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[5], who distinguish four classes according to when the decision-maker's preferences enter the formal decision making process. These different possibilities are:

- No articulation of preference information (only search).
- Priori aggregation of preference information (choice before search).
- Progressive articulation of preference information (integration of search and choice).
- Posteriori articulation of preference information (search before choice).

Recently interest in multi-objective scheduling has been increasing but has been limited when compared to research in single criterion problems. In a real manufacturing environment, several objectives frequently need to be considered at the same time. In this study, the following criteria are to be minimized:

- f_1: makespan or maximal completion time of machines costs, and
- f_2: total resource allocation costs.

In many real-world cases, since older machines have high replacement costs, they may be used side by side with newer machines to perform the same operations. But because of older machines are less efficient, we expect they would generally require a longer operating time in comparison with new and modern ones [6].

Multi-objective problems are most commonly solved indirectly using conventional (single objective) optimization techniques. The solution process includes converting multi-objective to single objective formulations (i.e., scalarizing the vector optimization problems) by linear/convex combination, equality/inequality constraining, or using distance measure, etc. [7]. This paper focuses on direct selection methods that are based on the concept of least distance, i.e., approaching *as close as possible* certain desired objective values.

Several industries encounter setup times, which result in even more difficult classes of scheduling problems [8]. For instance this may occur in a painting operation, where different initial paint colors require different levels of cleaning when being followed by other paint colors. Due to great saving when setup times are explicitly included in scheduling decisions, we take into account the existence of sequence-dependent setup times (SDST) in our problem.

The underlying assumption in this paper is that, there are machines on hybrid flowshop problem with different speeds in each stage which processing time of each job depends on these speeds. We also assume the job processing times can be controlled by changing the allocation of resources to the jobs, which may result in further efficiencies. This means that the processing times of the jobs depend on the allocated resources to each machine and speed of machine on a particular stage and more speed or allocation more resource to work on the same job will decrease job completion time. Considering such real situation is common in many operations management, especially in breaking processing bottlenecks in the lean production [9].

To obtain an optimal solution for this type of complex problems using traditional approaches in reasonable computational time is extremely difficult. So in this paper, the hybrid metaheuristic (HMH) method composed of genetic algorithm (GA) and variable neighborhood search (VNS) metaheuristics is proposed to solve the problems. In proposed hybrid algorithm the VNS improves a solution using three neighborhood searches. In addition we used "no articulation of preference information given" technique as multi-objective method.

Our goal in this paper is to develop an efficient hybrid metaheuristic to bi-objective hybrid flowshop with sequence-dependent setup time and machine and resource-dependent processing times. The paper has the following structure. Section 2 gives the brief literature review of hybrid flowshop scheduling. Section 3 is the problem description, mathematical model and multi-objective technique. Section 4 introduces the proposed hybrid algorithm. Section 5 presents the experimental design which compares the results achieved by proposed hybrid algorithm with those achieved by past algorithm. Finally, Section 6 is devoted to conclusions and future works.

2. Literature review

2.1. Multi-objective metaheuristic

Various metaheuristic algorithms have ever been derived for bi-objective or multi-objective optimization problems. Vector evaluated genetic algorithm (VEGA) is the first method modifying the GA to solve multi-objective problems which is propsed by Schaffer [10] to solve the Pareto-optimal solution of multi-objective problem. Murata et al. [11] proposed multi-objective genetic algorithm (MOGA). One characteristic of MOGA is using the dynamic weighting to transform the multiple objectives into single objective, which randomly assigns different weight value to different objectives. Non-dominated sorting genetic Algorithm 2 (NSGA-II) was proposed by Deb et al. [12], where the elitism strategy was adopted. Besides, in order to keep the solution diversity, the algorithm also provided a crowding distance to measure the density of individuals in solution space. Zitzler et al. [13] modified strength Pareto evolutionary algorithm (SPEA) as SPEA II for multi-objective optimization. In addition, some sub-population like approaches also can be found in related literatures, such as segregative genetic algorithms [14], multi-population genetic algorithm [15], hierarchical fair competition model [16], and multi-objective particle swam optimization [17] and two phases sub-population genetic algorithm [18]. Recently the global archive sub-population genetic algorithm with adaptive strategy (GSPG) proposed by Chang et al. [19] for parallel machine scheduling.