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EDITORIAL

Advanced dispatching rules for large-scale manufacturing systems

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Dispatching rules have been successfully applied to job sequencing and scheduling in large-scale manufacturing systems such as wafer fabrication plants, automatic guided vehicle systems, etc. Because they can be easily communicated and implemented, and because they can be speedily applied, dispatching rules are also one of the most prevalent approaches in this field. However, naysayers often criticize the sluggish performance levels of traditional dispatching rules. Furthermore, in many large-scale factories, scheduling systems have been installed and operational for more than 5 years with "satisfactory" results, but managers still believe that more beneficial modifications are possible. Specifically, better scheduling methods, dispatching rules, test environments, and reporting tools are needed.

Over the years, a few new solutions have been proposed to address these issues. For instance, most traditional dispatching rules are based on historical data. With the emergence of data mining and online analytic processing, dispatching rules can now take predictive information into account. Further, rather than concentrating on a single performance measure, some dispatching rules are designed to optimize multiple objectives at the same time. Moreover, the content of a dispatching rule can be optimized for a large-scale manufacturing system. In light of advanced computing systems, dispatching rules continue to be one of the most promising technologies for practical applications. This special issue focuses on innovative but practical dispatching rules rather than complex algorithms. This type of dispatching rule will continue to drive the mainstream of practical applications in factories for the foreseeable future.

This special issue is intended to provide the details of advanced dispatching rule development and applications of those rules to job sequencing and scheduling in large-scale manufacturing systems. We are very grateful for the positive responses we have received from the authors who submitted papers and the marvelous help provided by a number of referees in the paper reviewing process. After a strict review, 25 papers were finally accepted for publication in this special issue.

Zhang et al. used a genetic algorithm (GA) to optimize a set of dispatching rules for scheduling a job shop. Bayesian networks were also utilized to model the distribution of high-quality solutions in the population and to produce each new generation of individuals. In addition, some selected individuals were further improved by a special local search. One advantage of their method is that it can be readily applied in various dynamic scheduling environments which must be investigated with simulation.

Lu and Romanowski considered a dynamic job shop problem in which job shops are disrupted by unforeseen events such as job arrivals and machine breakdowns. They used multi-contextual functions (MCFs) to describe the unique characteristics of a dynamic job shop at a specific time and examined 11 basic dispatching rules and 33 composite rules made with MCFs that describe machine idle time and job waiting time. The experimental data showed that schedules made by the composite rules outperformed schedules made by conventional rules.

Lin et al. integrated an ant colony optimization (ACO) algorithm with a number of new ideas (heuristic initial solution, machine reselection step, and local search procedure) and

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proposed a new apparent tardiness cost (ATCw) heuristic to minimize the total weighted tardiness for unrelated parallel machines. The computational results showed that the proposed ACO algorithm outperformed other existing algorithms in terms of total weighted tardiness.

To consider uncertainty and improve the scheduling of a wafer fabrication factory, Chen proposed an innovative fuzzy rule that solves the problem of slack overlapping in a nonsubjective way. The fuzzy rule considers the uncertainty in the remaining cycle time and is aimed at the simultaneous optimization of the average cycle time and cycle time standard deviation. Chen established a systematic procedure to optimize the values of adjustable parameters in the fuzzy rule.

Kuo and Cheng solved a job shop scheduling problem with due date time windows and release times, in order to minimize the sum of earliness times and tardiness times. They proposed a novel hybrid meta-heuristic which combines ACO and particle swarm optimization (PSO), called ACPSO. The computational results indicated that ACPSO performs better than ACO and PSO.

Hung et al. dealt with the rescheduling of photolithography in semiconductor wafer fabrication. The objective was to minimize the weighted sum of makespan, maximum tardiness, and total setup time by considering machine breakdowns, limited number of available masks, restrictions on photoresist, production notices, and machine setups. After testing three popular search algorithms—simulated annealing (SA), GA, and tabu search—for this scheduling problem, they proposed a new sensitivity search approach.

Nguyen et al. proposed some iterative dispatching rules (IDRs) for job shop scheduling. A genetic programming method was used to evolve IDRs. Like traditional dispatching rules, the proposed IDRs are easy to implement and require little computational effort, but the proposed IDRs produce better schedules than traditional rules. This makes IDRs attractive for large-scale manufacturing systems. Testing on different problem instances showed that the evolved IDRs were superior to benchmark dispatching rules when makespan and total weighted tardiness were considered.

Chen et al. developed an advanced planning and scheduling (APS) system to automatically generate production schedules for a color filter factory with multiple lines. Both forward scheduling and backward scheduling were used in APS. The experimental results indicated that APS can significantly reduce manual scheduling time while maintaining the quality of scheduling results, which is especially important when rescheduling is needed due to production uncertainties such as equipment breakdowns or material shortages.

Traditional fluctuation smoothing rules are effective for scheduling a wafer fabrication system. However, traditional fluctuation smoothing rules usually do not consider the difference between bottleneck machines and non-bottleneck machines; some just consider a single bottleneck. To tackle this problem, Hu et al. proposed a multistage fluctuation smoothing method that divides the process flow into several stages and protects the bottleneck step at each reentrant stage from system fluctuations.

Xu et al. considered the flexible flowshop problem with multiprocessor tasks, which is strongly NP hard. Several novel dispatching rules were proposed, including the list-schedule-based hybrid job–machine rule, the permutation schedule-based hybrid job–machine rule, and the forward-schedule-based hybrid job–machine rule. These rules arrange the job processing order and machine assignment by narrowing the idle time between the consecutive operations in the processor and by increasing flexibility in the selection of processors to schedule the subsequent operations.

Bocewicz and Banaszak investigated an issue of cyclic scheduling that is usually observed in flexible manufacturing systems (FMSs). They considered the problem of scheduling a system of concurrent cyclic processes as a constraint satisfaction problem. After discussing the sufficient conditions that guarantee the schedulability of both local and multimodal cyclic processes, Bocewicz and Banaszak proposed a recursive schedule design approach.

Yu et al. considered input sequencing and scheduling problems in a reconfigurable manufacturing system. In particular, they considered the practical constraint that the number of fixtures is limited and hence a part can be released into the system only when the fixture required for the part is available. To solve integrated input sequencing and scheduling problems, Yu et al. used priority rules to combine some existing dispatching rules.

Yoon and Kim proposed several policies for scheduling wafer fabrication facilities, including an advanced operation due date (OPNDD) policy for sequence control, and an adaptive constant work-in-process (CONWIP) policy for input release control. The advanced OPNDD policy gave the highest priority to the front opening unified pod (FOUP) with the smallest operation due date, as computed by a generalized stochastic Petri net model. The adaptive CONWIP policy dynamically controlled the input release times of FOUPs according to the current WIP status of the wafer fabrication factory. The objective of the proposed scheduling policies was to reduce the variation of cycle times in the wafer fabrication factory.

Yang et al. investigated the single-machine assignment and scheduling problems with multiple common due dates in which the processing time of a job depends on its position in a job sequence and on its resource allocation. The general position-dependent deterioration effect and two models of resource allocation were also examined. The objective was to minimize a total penalty function that considered earliness, tardiness, due date, and resource consumption costs. To this end, Yang et al. proposed two algorithms that can solve the problem within polynomial time.

Wang et al. proposed a fuzzy-neural approach to optimize the performance of job dispatching in a wafer fabrication factory. They first applied a particularly effective fuzzy-neural approach to estimate the remaining cycle time of a job. Then, they established a systematic procedure to determine the optimal values of the parameters in the two-factor tailored nonlinear fluctuation smoothing rule for the mean cycle time, in order to optimize the schedule.

Golmakani and Birjandi considered a multiple-route job shop scheduling problem (MRJSP), in which each job may have more than one route for its production and the numbers of operations associated with the alternative routes of the job are not necessarily equal. Golmakani and Birjandi proposed a two-phase algorithm to deal with the two major subproblems in MRJSP, namely, the route selection subproblem and the sequencing subproblem.

Yang et al. considered the shortening of processing time as a learning process and discussed the effects of this learning process on scheduling. Various learning patterns for processing time were modeled: one was based on sum-of-processing-time, another was based on job position, and a third was based on the processing complexity of jobs already processed. Yang et al. then proposed a general learning effect model for scheduling. Some theoretical properties of single-machine and flowshop scheduling problems were explained in the context of finding optimal solutions under the general effect model.

For scheduling a job shop, Korytkowski et al. proposed a heuristic method based on ACO to determine the suboptimal allocation of dynamic multi-attribute dispatching rules. Four performance measures were considered: mean flow time, maximum flow time, mean tardiness, and maximum tardiness. Simulation was also used for evaluation of the local fitness function for ants.

Wang and Wang considered a two-machine flowshop scheduling problem in which the processing time of a job was a decreasing function of the starting time. The objective was to minimize the total weighted completion time. To this end, a branch-and-bound algorithm was proposed. To overcome the inefficiency of the branch-and-bound algorithm, several dominance properties and some lower bounds were derived; these contributions facilitated the elimination process.

Similarly, Wang and Wang studied a single-machine earliness–tardiness scheduling problem with due date assignment, in which the processing time of a job was a function of the starting time and the allocated resources. Two different processing time functions and three different due date assignment methods were analyzed. The goal was to minimize the weighted sum of earliness, tardiness, due date assignment, and total resource consumption costs.

In the technical note by Li et al., a single-machine scheduling problem with truncated sum-of-processing-times-based learning considerations was studied, where the processing time of a job depended not only on the total processing times of the jobs already processed, but also on a control parameter. The use of the truncated function was to emphasize that learning was limited. Two objective functions were considered, including the discounted total weighted completion time and the maximum lateness. For each objective function, a corresponding heuristic was proposed.

Lin and Lin considered the problem of scheduling n jobs on m unrelated parallel machines with release dates to minimize makespan, total weighted completion time, and total weighted tardiness individually. Several mixed integer programming models were built to find the optimal solutions for small problem instances. For large problem instances, Lin and Lin proposed several dispatching rules that found good solutions quickly. The computational results showed that the proposed dispatching rules outperformed some existing dispatching rules for problem instances of all sizes.

Xi and Jang minimized the total weighted tardiness of a single machine with sequence-dependent setup times and future ready times. Two dispatching rules—the apparent tardiness cost rule with ready times and continuous setups and the apparent tardiness cost rule with ready times and separable setups—were proposed for the problems whose setups were the continuous type and the separable type, respectively.

The aim of the study of Qin et al. was to enhance the overall efficiency of interbay material handling in a wafer fabrication system. To this end, a dynamic dispatching method based on a modified Hungarian algorithm was proposed. System parameters including cassette due date, cassette waiting time, and system load were considered. Then, the weights of different parameters were adjusted dynamically using a fuzzy logic-based control.

Caprihan et al. examined the extent of the adverse impact that information delays (IDs) have on FMS scheduling. According to the experimental results, IDs significantly degraded the performance of scheduling a FMS for due date-based measures (including mean tardiness and percentage of tardy jobs). For non-due date-based measures (mean flowtime and average machine utilization), IDs also degraded scheduling performance, albeit to a less severe degree. In addition, the experimental results also showed that routing flexibility tends to be superseded by status review ID.

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