Preface

Scheduling theory is concerned with the optimal allocation of scarce resources (for instance, machines, processors, robots, operators, etc.) to activities over time, with the objective of optimizing one or several performance measures. The study of scheduling started about fifty years ago, being initiated by seminal papers by Johnson (1954) and Bellman (1956). Since then machine scheduling theory have received considerable development. As a result, a great diversity of scheduling models and optimization techniques have been developed that found wide applications in industry, transport and communications. Today, scheduling theory is an integral, generally recognized and rapidly evolving branch of operations research, fruitfully contributing to computer science, artificial intelligence, and industrial engineering and management. The interested reader can find many nice pearls of scheduling theory in textbooks, monographs and handbooks by Tanaev et al. (1994a,b), Pinedo (2001), Leung (2001), Brucker (2007), and Blazewicz et al. (2007).

This book is the result of an initiative launched by Prof. Vedran Kordic, a major goal of which is to continue a good tradition - to bring together reputable researchers from different countries in order to provide a comprehensive coverage of advanced and modern topics in scheduling not yet reflected by other books. The virtual consortium of the authors has been created by using electronic exchanges; it comprises 50 authors from 18 different countries who have submitted 23 contributions to this collective product. In this sense, the volume in your hands can be added to a bookshelf with similar collective publications in scheduling, started by Coffman (1976) and successfully continued by Chretienne et al. (1995), Gutin and Punnen (2002), and Leung (2004).

This volume contains four major parts that cover the following directions: the state of the art in theory and algorithms for classical and non-standard scheduling problems; new exact optimization algorithms, approximation algorithms with performance guarantees, heuristics and metaheuristics; novel models and approaches to scheduling; and, last but least, several real-life applications and case studies.

The brief outline of the volume is as follows.

Part I presents tutorials, surveys and comparative studies of several new trends and modern tools in scheduling theory. Chapter 1 is a tutorial on theory of cyclic scheduling. It is included for those readers who are unfamiliar with this area of scheduling theory. Cyclic scheduling models are traditionally used to control repetitive industrial processes and enhance the performance of robotic lines in many industries. A brief overview of cyclic scheduling models arising in manufacturing systems served by robots is presented, started with a discussion of early works appeared in the 1960s. Although the considered scheduling problems are, in general, NP-hard, a graph approach presented in this chapter permits to reduce some special cases to the parametric critical path problem in a graph and solve them in polynomial time.

Chapter 2 describes the so-called multi-agent scheduling models applied to the situations in which the resource allocation process involves different stakeholders (“agents”), each having his/her own set of jobs and interests, and there is no central authority which can solve possible conflicts in resource usage over time. In this case, standard scheduling models become invalid, since rather than computing "optimal solutions", the model is asked to provide useful elements for the negotiation process, which eventually should lead to a stable and acceptable resource allocation. The chapter does not review the whole scope in detail, but rather concentrates on combinatorial models and their applications. Two major mechanisms for generating schedules, auctions and bargaining models, corresponding to different information exchange scenarios, are considered. Known results are reviewed and venues for future research are pointed out.

Chapter 3 considers a class of scheduling problems under unavailability constraints associated, for example, with breakdown periods, maintenance durations and/or setup times. Such problems can be met in different industrial environments in numerous real-life applications. Recent algorithmic approaches proposed to solve these problems are presented, and their complexity and worst-case performance characteristics are discussed. The main attention is devoted to the flow-time minimization in the weighted and unweighted cases, for single-machine and parallel machine scheduling problems.

Chapter 4 is devoted to the analysis of scheduling problems with communication delays. With the increasing importance of parallel computing, the question of how to schedule a set of precedence-constrained tasks on a given computer architecture, with communication delays taken into account, becomes critical. The chapter presents the principal results related to complexity, approximability and non-approximability of scheduling problems in presence of communication delays.

Part II comprising eight chapters is devoted to the design of scheduling algorithms. Here the reader can find a wide variety of algorithms: exact, approximate with performance guarantees, heuristics and meta-heuristics; most algorithms are supplied by the complexity analysis and/or tested computationally.

Chapter 5 deals with a batch version of the single-processor scheduling problem with batch setup times and batch delivery costs, the objective being to find a schedule which minimizes the sum of the weighted number of late jobs and the delivery costs. A new dynamic programming (DP) algorithm which runs in pseudo-polynomial time is proposed. By combining the techniques of binary range search and static interval partitioning, the DP algorithm is converted into a fully polynomial time approximation scheme for the general case. The DP algorithm becomes polynomial for the special cases when jobs have equal weights or equal processing times.

Chapter 6 studies on-line approximation algorithms with performance guarantees for an important class of scheduling problems defined on identical machines, for jobs with arbitrary release times.

Chapter 7 presents a new hybrid metaheuristic for solving the jobshop scheduling problem that combines augmented-neural-networks with genetic algorithm based search.

In Chapter 8 heuristics based on a combination of the guided search and tabu search are considered to minimize the maximum completion time and maximum tardiness in the parallel-machine scheduling problems. Computational characteristics of the proposed heuristics are evaluated through extensive experiments.

Chapter 9 presents a hybrid meta-heuristics based on a combination of the genetic algorithm and the local search aimed to solve the re-entrant flowshop scheduling problems. The hybrid method is compared with the optimal solutions generated by the integer programming technique, and the near optimal solutions generated by a pure genetic algorithm. Computational experiments are performed to illustrate the effectiveness and efficiency of the proposed algorithm.

Chapter 10 is devoted to the design of different hybrid heuristics to schedule a bottleneck machine in a flexible manufacturing system problems with the objective to minimize the total weighted tardiness. Search algorithms based on heuristic improvement and local evolutionary procedures are formulated and computationally compared.

Chapter 11 deals with a multi-objective no-wait flow shop scheduling problem in which the weighted mean completion time and the weighted mean tardiness are to be optimized simultaneously. To tackle this problem, a novel computational technique, inspired by immunology, has emerged, known as artificial immune systems. An effective multi-objective immune algorithm is designed for searching the Pareto-optimal frontier. In order to validate the proposed algorithm, various test problems are designed and the algorithm is compared with a conventional multi-objective genetic algorithm. Comparison metrics, such as the number of Pareto optimal solutions found by the algorithm, error ratio, generational distance, spacing metric, and diversity metric, are applied to validate the algorithm efficiency. The experimental results indicated that the proposed algorithm outperforms the conventional genetic algorithm, especially for the large-sized problems.

Chapter 12 considers a version of the open-shop problem called the concurrent open shop with the objective of minimizing the weighted number of tardy jobs. A branch and bound algorithm is developed. Then, in order to produce approximate solutions in a reasonable time, a heuristic and a tabu search algorithm are proposed.. Computational experiments support the validity and efficiency of the tabu search algorithm.

Part III comprises seven chapters and deals with new models and decision making approaches to scheduling. Chapter 13 addresses an integrative view for the production scheduling problem, namely resources integration, cost elements integration and solution methodologies integration. Among methodologies considered and being integrated together are mathematical programming, constraint programming and metaheuristics. Widely used models and representations for production scheduling problems are reconsidered, and optimization objectives are reviewed. An integration scheme is proposed and performance of approaches is analyzed.

Chapter 14 examines scheduling problems confronted by planners in multi product chemical plants that involve sequencing of jobs with sequence-dependent setup time. Two mixed integer programming (MIP) formulations are suggested, the first one aimed to minimize the total tardiness while the second minimizing the sum of total earliness/tardiness for parallel machine problem.

Chapter 15 presents a novel mixed-integer programming model of the flexible flow line problem that minimizes the makespan. The proposed model considers two main constraints, namely blocking processors and sequence-dependent setup time between jobs.

Chapter 16 considers the so-called hybrid jobshop problem which is a combination of the standard jobshop and parallel machine scheduling problems with the objective of minimizing the total tardiness. The problem has real-life applications in the semiconductor manufacturing or in the paper industries. Efficient heuristic methods to solve the problem, namely, genetic algorithms and ant colony heuristics, are discussed.

Chapter 17 develops the methodology of dynamical gradient Artificial Neural Networks for solving the identical parallel machine scheduling problem with the makespan criterion (which is known to be NP-hard even for the case of two identical parallel machines). A Hopfield-like network is proposed that uses time-varying penalty parameters. A novel time-varying penalty method that guarantees feasible and near optimal solutions for solving the problem is suggested and compared computationally with the known LPT heuristic.

In Chapter 18 a dynamic heuristic rule-based approach is proposed to solve the resource constrained scheduling problem in an FMS, and to determine the best routes of the parts, which have routing flexibility. The performance of the proposed rule-based system is compared with single dispatching rules.

Chapter 19 develops a geometric approach to modeling a large class of multithreaded programs sharing resources and to scheduling concurrent real-time processes. This chapter demonstrates a non-trivial interplay between geometric approaches and real-time programming. An experimental implementation allowed to validate the method and provided encouraging results.

Part IV comprises four chapters and introduces real-life applications of scheduling theory and case studies in the sheet metal shop (Chapter 20), baggage handling systems (Chapter 21), large-scale supply chains (Chapter 22), and semiconductor manufacturing and photolithography systems (Chapter 23).

Summing up the wide range of issues presented in the book, it can be addressed to a quite broad audience, including both academic researchers and practitioners in halls of industries interested in scheduling theory and its applications. Also, it is heartily recommended to graduate and PhD students in operations research, management science, business administration, computer science/engineering, industrial engineering and management, information systems, and applied mathematics.

This book is the result of many collaborating parties. I gratefully acknowledge the assistance provided by Dr. Vedran Kordic, Editor-in-Chief of the book series, who initiated this project, and thank all the authors who contributed to the volume.

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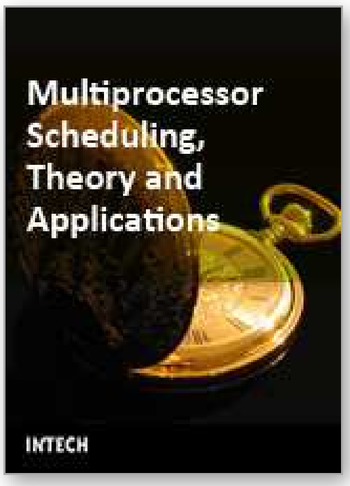

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