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NEW CHALLENGES IN SCHEDULING THEORY

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Machine scheduling is traditionally considered to be the sequencing of tasks on a single or several parallel machines that are not necessarily identical, subject to a set of constraints. The constraints frequently express the limited amount of resources available in order to find a favorable objective value. Meanwhile a huge variety of problems has been studied that has led to numerous sophisticated heuristics, approximation and exact algorithms, and complexity results. Many of these problems are computationally intractable and have been encountered in applications from production planning, staff rostering and personnel planning, scheduling in parallel and distributed systems, *etc.*, see [1].

Over the last years, researchers have begun studying the scheduling problems derived from new applications and settings. For example, there are scheduling problems in decentralized systems and selfish organizations, bioinformatics, big data processing, and logistical airport operations management processes as well as container transshipment in rail transshipment yards or sea ports. Some of these scheduling problems reflect real-life situations by including results on real industrial dataset, see e.g. rail optimization in the coal industry of Australia in this issue. This listing is only a small sample of the many new applications and scheduling problems that researchers are studying.

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Between 21st and 27th October 2012, the 10th scheduling workshop entitled "New Challenges in Scheduling Theory" was held in the Centre CNRS "La Villa Clythia" Frejus. (The participants really enjoyed the wonderful atmosphere and excellent organization.) The objective of the workshop was to explore new areas in scheduling theory and applications that have emerged in recent years.

The papers in this special issue highlight some of the results of this workshop. We received many high-quality submissions. After the normal thorough and rigorous refereeing process, only five papers were chosen for inclusion in the special issue. The papers are listed below alphabetically by the first author. The length of each summary does not reflect any relevancy or importance.

The paper "Scheduling multilayer divisible computations" by J. Berlinska and M. Drozdowski studies scheduling of multilayer distributed computations using to the MapReduce programming model, which plays an essential role in handling big data and may be used to handle lots of real-world tasks. They formulate mathematical models for the resulting problem, which encompasses load partitioning among processors assuming that the load can be divided in pieces of any size, and communication scheduling. A heuristic approach based on the state-of-the-art algorithms for the related (sub)problems is proposed.

The paper "Scheduling 2-dimensional grids with large communication delays" by E.M. Daoudi, D. Trystram and F. Wagner concerns large communication delays in scheduling jobs in a precedence graph of 2-dimensional grids, which is well motivated by the scenario of many parallel and distributed scheduling platforms with costly communications among the processors. The jobs are of unit length while the communication delay cost is equal to c units between two distinct processors. This paper provides close upper and lower bounds on the optimal makespan based on the size of grids and the parameter c for the case of an infinite number of processors and two processors, respectively.

Kononov's paper "O($\log m$)-approximation for the routing open shop problem" describes a combination of a routing problem with an open shop scheduling. The jobs are to be executed by the machines which have to travel on the network. The machines are initially located at the same node (depot) and must return to the depot after completing all jobs. The goal is to construct a non-preemptive schedule with a minimum makespan. He presents a new polynomial-time approximation algorithm with worst-case performance guarantee O($\log m$), where m is the number of machines.

The paper "A classification scheme for integrated staff rostering and scheduling problems" by M. Paul and S. Knust augments classic scheduling problem definition notation and provides new scheduling complexity results. They consider problems involving scheduling jobs and assigning employees to the jobs. There are various employee qualifications (skills) which must be matched to job requirements. Employees must also be assigned to shifts (the rostering problem). The new classification scheme adds fields to describe parameters and constraints for rostering and assignment and the objective function for those two pieces. The authors consider twenty papers for scheduling combined with assignment, rostering, or both, showing how the problem in each paper is expressed in the new classification notation. The scheme includes notation for many subclasses that may appear in problems, such as each employee having only one qualification. Problems with structure not explicitly represented are listed with “unrestricted” variants. But the scheme appears to be flexible enough to allow important subclasses their own designation if they become sufficiently popular. The authors summarize known complexity results in the context of the new scheme. They conclude by giving the first polynomial time algorithm for a restricted problem, and by showing that the combination of two polynomial-time solvable problems can be NP-complete. Specifically, they give a polynomial time algorithm to find a feasible shift and job assignment when job timing is given, each employee has one qualification, shifts do not overlap, an employee can take over for another at the end of shift, and some shift assignments are illegal. The authors show that is NP-complete to find a feasible shift and job assignment when jobs are fixed, employees can have more than one qualification, employees can move between jobs at any time, and all assignments to non-overlapping shifts are legal. This is a combination of a tractable rostering problem and a tractable job assignment problem.

Finally, “Rail schedule optimization in the Hunter Valley coal chain” by G. Singh, A. Ernst, M. Baxter and D. Sier describes how to solve efficiently a real-life problem in the coal industry in Australia. The problem is to schedule the amounts of brand from the different mines to the port terminals where they will be shipped. The authors present an original model where the operators of the rail network provide a number of paths with specified arrival and departure times that are used for all coal movements. The requirement to assign coal trains to these existing paths makes this rail-scheduling problem different from most of those discussed in the literature so far. The emphasis is to show that such problems are too large to be solved by existing commercial MILP solvers. Finally, an effective heuristic based on a Lagrangian method, which runs in acceptable time, is presented and tested on several datasets.

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