JOSH Editorial

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Planning and scheduling have an interesting relationship. In informal usage, planning and scheduling are frequently treated almost interchangeably. In contrast, formally, their refined and tightly specified descriptions appear quite different: planning is a PSPACE-hard problem, while scheduling is an archetypal NP-hard problem. The research communities that examine these problems seem, to a large extent, to share this dichotomy, with surprisingly distinct research communities having developed around the two problems. Despite this division, there have been many individuals in both communities who have recognised the importance and relevance of the relationships between the two problems.

The apparent simplicity of the separation offered by the complexity classes of the different problems belies the difficulty of giving a clean intuition to the differences between planning and scheduling — a difficulty which seems to return to the much less sharply drawn boundaries of the informal usage of the terms. The common characterisation is that planning is the problem of deciding what actions should be performed to solve a problem, while scheduling is about deciding when to execute them and with what resources. For example, this is the characterisation used by Garrido et al in their paper in this issue. Although this characterisation is convenient, it is a simplification: which action to use to solve a problem frequently depends on how resources are to be allocated, so that plans depend on scheduling choices, while equally, what resources are available to support the scheduling decisions depend on which actions are selected to solve a problem. Thus, the choices made in planning and scheduling are interlocked and interdependent.

The papers in this special issue were carefully selected, following a relatively extended reviewing process, from a large number of original submissions. These papers were selected both for their quality (which, of course, had to meet the regular requirements of the journal) and for their relevance to the special relationship between planning and scheduling. The paper "A constraint programming reformulation for planning: from plan scheduling to plan generation" by Garrido et al particularly highlights the tight interdependence between the problems, while also highlighting some of the important differences in the methods commonly employed in solving problems within the two communities.

While scheduling researchers develop highly sophisticated solutions to particular problems, such as nurse rostering or vehicle routing, planning researchers look for generic solutions that are, necessarily, less sophisticated but have wider applicability. In the paper by Garrido et al, an interesting class of planning problems has been addressed that require resource management to be scheduled in time. Since the experiments were performed on a collection of planning bench marks it remains to be seen how well the approach taken will perform on more traditional scheduling problems prduction, inventory, distribution and routing problems.

While planners frequently depend on cleverly generated heuristics to guide a relatively simple search, schedulers more often rely on local search techniques to steadily refine and improve one or more candidate solutions. Tabu search is one such example, appearing as a basic tool in Bard's paper "The Integrated Production, Iventory and Distribution and Routing Problem for a Single Commodity" in this issue. This paper also exploits the use of a Mixed Integer Linear Programming (MILP) formulation in tackling the problem. Although the link with planning is not made highly explicit, there is a clear relationship between some of the strategies explored in this paper and those coming to the fore in recent developments in planning. In planning there is increasing interest in decomposition-based approaches, planning with numeric quantities and under complex resource constraints and integration of propositional planning with solvers for real, integer and mixed integer linear optimisation problems. Heuristics and bounds computations based on relaxations are also commonly explored in planning. In this paper an approach is proposed that combines

many of these elements in the solution of a problem with fixed planning horizons. These ideas are certainly of interest to the planning community in which the horizons are not determined in advance.

The planning research community has been steadily exploring more expressive problem formulations and, amongst more recent work, problems that include complex interactions between numbers and combinatorial constraints. The relationship between these problems and MILPs is still being investigated. The fact that the lengths of solutions to planning problems are not known before commencing to construct plans makes formulation in fixed-sized representations such as constraint programs or MILPs more difficult. Typically, an iterating approach is required, in which multiple formulations of increasing size are required. A slightly more general view of this approach is that an initial formulation is tackled, simplifying the original problem in some way, and a failure to solve it leads to the identification of new constraints that can be added to the original problem. This approach can be generalised so that successful solution of the reduced problem can also lead to bounding constraints that help in isolating a feasible and high quality solution to the original problem.

This iterating approach to the construction of a solution is used in the Benders decomposition approach to solving MILPs. The paper "Scheduling Projects with Multi-Skilled Personnel by A Hybrid MILP/CP Benders Decomposition Algorithm" by Li and Womer discusses an approach to solving a specific scheduling problem (scheduling the time of multi-skilled employees in a project-planning context) based on the use of Benders Decomposition with a MILP relaxed master problem and a CP-based sub-problem. The temporal and logical feasibility of the problem are separately modelled and solved by means of this decomposition. A clear link is drawn with planning. Planning tends to be rich in temporal constraints and, with the recent focus on numeric problems and complex temporal interactions, there is a need to find suitable decompositions that enable feedback between the sub and master problems and eventual convergence on high quality solutions. By solving a practical problem with both planning and scheduling features using this approach the authors draw the attention of the planning community to the power and relevance of MILP solving tools.

The paper "Solve-and-Robustify: Synthesising Partial Order Schedules by Chaining" by Policella et al also illustrates the same theme of iterated convergence on a good solution by solving successive variants of the original problem. In this paper, the approach is used to improve the robustness of an initial schedule through a series of iterated refinements: a process of "robustification". This idea is a novel application of the local search techniques for steadily seeking improvements in a candidate solution by considering small perturbations of an existing candidate. The novelty lies in the separation of the search for a solution into two phases, where the first phase is devoted to the construction of a good quality solution according to one metric (such as length of makespan) and the second phase to the application of iterative improvements along a different dimension — the robustness and flexibility of the schedule.

The last paper in the collection, "A Theoretic and Practical Framework for Scheduling in a Stochastic Environment" by Bidot et al, considers a topic of major significance in both communities: the handling of uncertainty. The authors focus on a scheduling problem as the vehicle for their investigation, but their insights apply equally to planning problems. They are most concerned with the division of decision-making and commitment between the planning or scheduling phase before execution and the period of execution itself. It is clear that in a completely deterministic and known world, there is no reason to postpone decisions until execution, since the entire problem can be solved, at least in principle, before execution begins. In contrast, once uncertainty enters the picture, the benefit of effort invested in making a decision before execution must be balanced against the possibility that the uncertain future makes early decisions inappropriate. This area of research has stimulated a great deal of research in both the planning and scheduling communities and there remains much to be done to combine the insights of both: this paper is an important step in that direction.

This special issue has highlighted a few of the common themes that unite the research efforts in planning and scheduling. There is more work to be done to bring the research communities together, combining the insights each has gained into the structure and solution of problems that share a considerable common ground. The research problems we face are as tightly interwoven as the decision-making processes that solve them and the editors hope that the papers in this issue will stimulate further fruitful interaction and cross-boundary research in the fertile ground between planning and scheduling.