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GRASP with Path Relinking for Short-term Production Planning

In this project we address a real-world optimization problem from the automotive supply chain industry. Short-term production planning is concerned with allocating production lots and sizes and scheduling them on multiple resources, and is NP-hard. GRASP with Path Relinking metaheuristic is proposed as a solution method. Innovatively, a selection pressure concept and a path exploration strategy are introduced. Parallel GRASP is competitive to Mixed Integer Programming and Tabu Search and performs slightly better in some cases.

Production Planning
Discrete Lotsizing and Scheduling
Metaheuristic
Parallel Implementation
GRASP
Path Relinking

Introduction

The problem of production planning and scheduling addresses decisions on the effective and cost-efficient use of an in-house production system's resources in order to satisfy customer demands. In practice, such manufacturing environments are organized into several segments, often called parallel machines or plants. This scenario can be elaborated with heterogeneous configurable segments capable of producing different sets of products at different rates.

Short-term Production Planning

We consider short-term decisions, where the discrete planning horizon is 5 days. Production consists of 21 machines, 272 items and 15 time periods. Furthermore, we focus on determining production lots sizes and sequences in order to minimize setup costs, backlog costs for unmet demands and maximize production for future demands. No inventory costs are considered and non-trivial constraints for limiting parallel production of an item on multiple machines and maximum number of settings in a time period are introduced.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
M1	2	34	34	34	34	34	34	34	34	34	34	34	34	34	34
M2	37	37	37	37	37	37	16	16	16	16	16	16	16	16	50
M3	34	34	34	34	34	14	14	14	41	41	16	16	12	12	12
M4	12	12	12	12	12	34	34	34	34	12	12	50	50	50	50
M5	50	16	16	16	16	16	41	41	41	34	34	34	34	34	34
M6	14	14	14	14	14	14	14	18	18	18	18	18	18	18	2

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15
M1	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
M2	37	16	16	16	16	16	16	16	16	16	16	16	16	12	12
M3	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
M4	12	12	12	37	37	37	37	37	37	16	16	16	16	16	16
M5	50	50	41	41	41	41	41	41	41	41	50	50	50	50	2
M6	5	14	14	14	14	14	14	14	14	18	18	18	18	18	18

Figure 1. A trial and an enhanced solution of a "toy" instance.

To illustrate the optimization aspect, let's consider a smaller "toy" instance with 6 machines, 50 items and 15 time periods. In the figure we compare one trial solution with one enhanced solution of such a "toy" instance. In particular, in the first plan item 34 is produced with 4 production lots, while in the enhanced plan production is allocated by only 2 lots. In total, the enhanced solution has 6 settings less (approx. 18h less idle time) and produces 300 units more.

GRASP with Path Relinking

Typically, techniques that guarantee optimal or nearly optimal solutions like Mixed Integer Programming and Column Generation (with Lagrangean Relaxation) are applied when smaller problem instances are considered. On the other hand, heuristics are not guaranteed to find an optimal solution but they can generate practically acceptable, good quality solutions in short (polynomial) time.

Metaheuristics combine simpler diverse heuristics in order to make them more efficient and more robust for solving a general class of problems.
Greedy Randomized Adaptive Search Procedure (GRASP) metaheuristic is selected as a solution method because of its simple structure, fewer parameters, randomization capabilities and its complementary combination of diverse heuristics. In this context, a new selection pressure concept is introduced for randomized local search. Furthermore, advanced techniques based on adaptive memory and parallel implementations are easy to incorporate. GRASP is combined with Path Relinking (PR), which maintains adaptive memory of suitably diverse elite solutions in a pool. Innovatively, a path exploration strategy is applied which examines only "local path optima" and the best intermediate solution.
The enhanced metaheuristic is parallelized in Open-MP for the purpose of execution on multi-core personal computers. Paralle GRASP with PR performs better in quality due to the usage of parallel parameterization scheme of Fast Mersene Twister.

Computational Evaluation

GRASP is compared against two other approaches: a Mixed Integer Programming (MIP) of a custom solver (XPRES-MP) and a Tabu Search (TS) (by Jimborean et. al, 2009) for a runtime of 1 hour. Parallel GRASP with PR is competitive and very robust with respect to TS and MIP. In some cases it obtains better schedules. Hence, our best results are among the best known solutions in this particular problem configuration. Furthermore, shorter executions (approx. 10 min) result in plans of similar quality.

Future Research Directions

Self-adaptive parameter optimization can be applied to: randomization parameters of the construction heuristic (Reactive GRASP), selection pressure of randomized local search (relinking suboptimal solutions), diversity in pool (regular relinking, variation), improvement frequency (longer runtime, diversity).
Collaborative distributed strategies introduce a special concept of migration to control diversity in separate pools. Particularly, the interplay between a collaborative (distributed) and an evolutionary (shared memory) path relinking strategies is very promising.
Finally, a formal study of the effect of PRNGs on parallel GRASP with PR (as a Monte Carlo Hybridization) is an attractive area for future research.