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Solver-Tractable Network Flow Models for Vehicle and Crew Scheduling by Designing and Reducing Graph Structures Involving Deadheads and Resource States

Abstract: Computer scientists often identify *intractable* problems with those for which specialized polynomial time algorithms are not found or not likely to exist due to their NP-hardness. Operations research specialists, at least those working on large-scale mathematical optimization, consider some of these difficult problems as *solvable* for large-scale instances of practice in reasonable time utilizing the strong capabilities of *today's solvers* especially for linear mixed-integer programming. The reported research in my talk strengthens the message of this finding that some of the "*intractable"* problems are in fact *solver-tractable* for practical settings and instance sizes. I will show this by presenting network flow based mixed-integer models which are *solver-tractable in a strong sense.* That means they are solved by almost directly using solver's capability without any solver-external techniques like decomposition or column generation. Our less common, but competitive approach with extensive experience in both academia and practice is rather based on directly modeling difficult requirements of practice instances of vehicle and crew scheduling problems by designing and considerably reducing graph structures and integrating them within the overall flow network underlying the resulting solver-tractable mathematical models.

We first discuss the design and the reduction of graph structures involving inter-trip deadheads for difficult vehicle scheduling extensions in bus transit and railways, and involving resource states to tackle maintenance routing for trains. We designed a powerful lossless aggregation scheme of all potential deadheads by grouping them into trip-pair matches (M) to each station-pair, then reducing them into latest-first-matches (LFM). For a case study of 'Deutsche Bahn' with 7000 trips and 30 stations, the M = 5 million potential matches can be reduced to only LFM = 25.000 (only 0.5%). Utilizing the LFM-technique to each network layer for each vehicle type, depot, or combination thereof, large-scale vehicle scheduling problems for bus transit and railways could be directly solved as multi-layered network flow models by MIP solvers. For maintenance requirement of trains, we *expand* timelines (used in fleet assignment models) by different *maintenance states* of trains and *link them* appropriately by state increment and reset arcs in order to produce weekly periodic rotations where trains visit maintenance stations regularly.

By an observed analogy that trains must pass every 3-4 days through maintenance stations like crew members who should pass through their domiciles after at most 5 days, we designed a similar state-expanded flow network for the crew pairing chain problem (CPCP), a strictly extended version to the well-known CPP. Further research efforts led to the design of "merged duty trees", a graph structure with concise implicit leg-crew state expansions where all crew working rules besides the pairing length are considered. The result of these academic investigations led to a crew scheduling system called *AutoPattern* being in productive use at the TUIfly airline for 15 years, routinely solving a CPCP as an integrated main part of their crew scheduling task with multiple domiciles.

Mercredi / Wednesday

20 février 2019 /
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Salle / Room 5441
Pavillon André-Aisenstadt
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Ouvert à tous / Open to all

Organisateur / Organizer
Louis-Martin Rousseau

Bio: Michael

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