ATMOS 2007 - Abstracts Collection

Selected Papers from the 7th Workshop on Algorithmic Approaches for Transportation Modeling, Optimization, and Systems

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Abstract. Proceedings of the 7th Workshop on Algorithmic Approaches for Transportation Modeling, Optimization, and Systems, held on November 15 and November 16, 2007 in Sevilla, Spain.

Keywords. Operations research, scheduled transport, railway optimization

Solving Large Scale Crew Scheduling Problems by using Iterative Partitioning

Erwin Abbink

This paper deals with large-scale crew scheduling problems arising at the Dutch railway operator, Netherlands Railways (NS). We discuss several methods to partition large instances into several smaller ones. These smaller instances are then solved with the commercially available crew scheduling algorithm TURNI. In this paper, we compare several partitioning methods with each other. Moreover, we report some results where we applied different partitioning methods after each other. With this approach, we were able to cut crew costs with 2% (about 6 million euro per year).

Keywords: Crew scheduling, large-scale optimization, partitioning

Joint work of: Abbink, Erwin; Van't Wout, Joel; Huisman, Dennis

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1168

A Simulation/Optimization Framework for Locomotive Planning

Ravindra K. Ahuja

In this paper, we give an overview of the Locomotive Simulater/Optimizer (LSO) decision support system developed by us for railroads. This software is designed to imitate locomotive movement across a rail network, and it simulates all four major components of the system; trains, locomotives, terminals, and shops in an integrated framework. It includes about 20 charts that allow evaluating system performance using standard measures. LSO can be used by locomotive management to per- form "what-if" analysis and evaluate system performance for different input data; it provides a safe environment for experimentation. We have tested the software on real data and output showed that the software closely imitates day-to-day operations. We have also performed differ- ent scenario analysis, and reports illustrate that the software correctly reflects input data changes.

Joint work of: Nahapetyan, Artyom; Ahuja, Ravindra K.; Sargut, F. Zeynep; John, Andy; Somani, Kamalesh

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1182

Experimental Study on Speed-Up Techniques for Timetable Information Systems

Reinhard Bauer

During the last years, impressive speed-up techniques for Dijkstra's algorithm have been developed. Unfortunately, recent research mainly focused on road networks. However, fast algorithms are also needed for other applications like timetable information systems. Even worse, the adaption of recently developed techniques to timetable information is often more complicated than expected.

In this work, we check whether results from road networks are transferable to timetable information. To this end, we present an extensive experimental study of the most prominent speed-up techniques on different types of inputs. It turns out that recently developed techniques are much slower on graphs derived from timetable information than on road networks. In addition, we gain amazing insights into the behavior of speed-up techniques in general.

Joint work of: Bauer, Reinhard; Delling, Daniel; Wagner, Dorothea

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1169

Models for Railway Track Allocation

Ralf Borndörfer

The optimal track allocation problem (OPTRA) is to find, in a given railway network, a conflict free set of train routes of maximum value. We study two types of integer programming formulations for this problem: a standard formulation that models block conflicts in terms of packing constraints, and a novel formulation of the 'extended' type that is based on additional 'configuration' variables. The packing constraints in the standard formulation stem from an interval graph and can therefore be separated in polynomial time. It follows that the LP-relaxation of a strong version of this model, including all clique inequalities from block conflicts, can be solved in polynomial time. We prove that the LP-relaxation of the extended formulation can also be solved in polynomial time, and that it produces the same LP-bound. Albeit the two formulations are in this sense equivalent, the extended formulation has advantages from a computational point of view. It features a constant number of rows and is amenable to standard column generation techniques. Results of an empirical model comparison on mesoscopic data for the Hanover-Fulda-Kassel region of the German long distance railway network are reported.

Keywords: Track allocation, train timetabling,integer programming, column generation

Joint work of: Borndörfer, Ralf; Schlechte, Thomas

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1170

Maintenance of Multi-level Overlay Graphs for Timetable Queries

Francesco Bruera

In railways systems the timetable is typically represented as a weighted digraph on which itinerary queries are answered by shortest path algorithms, usually running Dijkstra's algorithm.

Due to the continuously growing size of real-world graphs, there is a constant need for faster algorithms and many techniques have been devised to heuristically speed up Dijkstra's algorithm. One of these techniques is the multi-level overlay graph, that has been recently introduced and shown to be experimentally efficient, especially when applied to timetable information.

In many practical application major disruptions to the normal operation cannot be completely avoided because of the complexity of the underlying systems. Timetable information update after disruptions is considered one of the weakest points in current railway systems, and this determines the need for an effective

online redesign and update of the shortest paths information as a consequence of disruptions.

In this paper, we make a step forward toward this direction by showing some theoretical properties of multi-level overlay graphs that lead us to the definition of a new data structure for the dynamic maintenance of a multi-level overlay graph of a given graph G while weight decrease or weight increase operations are performed on G. Our solution is theoretically faster than the recomputation from scratch and allows fast queries.

Keywords: Timetable Queries, Speed-up techniques for shortest paths, Dynamic maintenance of shortest paths

Joint work of: Bruera, Francesco; Cicerone, Serafino; D'Angelo, Gianlorenzo; Di Stefano, Gabriele; Frigioni, Daniele

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1171

Solving a Real-World Train Unit Assignment Problem

Valentina Cacchiani

We face a real-world train unit assignment problem for an operator running trains in a regional area. Given a set of timetabled train trips, each with a required number of passenger seats, and a set of train units, each with a given number of available seats, the problem calls for an assignment of the train units to trips, possibly combining more than one train unit for a given trip, that fulfills the seat requests.

With respect to analogous case studies previously faced in the literature, ours is characterized by the fairly large number of distinct train unit types available (in addition to the fairly large number of trips to be covered). As a result, although there is a wide margin of improvement over the solution used by the practitioners (as our results show), even only finding a solution of the same value is challenging in practice. We present a successful approach, based on an ILP formulation in which the seat requirement constraints are stated in a ŞstrongŤ form, derived from the description of the convex hull of the variant of the knapsack polytope arising when the sum of the variables is restricted not to exceed two, illustrating computational results on our case study.

Keywords: Train Unit Assignment, Integer Linear Programming, Heuristic Algorithm, Convex Hull

Joint work of: Cacchiani, Valentina; Caprara, Alberto; Toth, Paolo

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1172

Periodic Railway Timetabling with Event Flexibility

Gabrio Curzio Caimi

This paper addresses the problem of generating conflict-free periodic train schedules for large railway networks. We follow a two level approach, where a simplified track topology is used to obtain a macro level schedule and the detailed topology is considered locally on the micro level.

To increase the solution space in the interface of the two levels, we propose an extension of the well-known Periodic Event Scheduling Problem (PESP) such that it allows to generate flexible time slots for the departure and arrival times instead of exact times. This Flexible Periodic Event Scheduling Problem (FPESP) formulation considerably increases the chance to obtain feasible solutions (exact train routings) subsequently on the micro level, in particular for stations with dense peak traffic. Total trip time and the time slot sizes are used as multiple objectives and weighted and/or constrained to allocate the flexibility where it is most useful.

Tests on an instance of the 2007 service intention of the Swiss Federal Railways demonstrate the advantage of the FPESP model, while it only moderate increases its solution time in most cases.

Solution of the Train Platforming Problem

Alberto Caprara

In this paper we study a general formulation of the train platforming problem, which contains as special cases all the versions previously considered in the literature as well as a case study from the Italian Infrastructure manager that we addressed. In particular, motivated by our case study, we consider a general quadratic objective function, and propose a new way to linearize it by using a small number of new variables along with a set of constraints that can be separated efficiently by solving an appropriate linear program. The resulting integer linear programming formulation has a continuous relaxation that leads to strong bounds on the optimal value. For the instances in our case study, we show that a simple diving heuristic based on this relaxation produces solutions that are much better than those produced by a simple heuristic currently in use, and that often turn out to be (nearly-) optimal.

Joint work of: Caprara, Alberto; Galli, Laura; Toth, Paolo

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1174

Robust Algorithms and Price of Robustness in Shunting Problems

Serafino Cicerone

In this paper we provide efficient robust algorithms for shunting problems concerning the reordering of train cars over a hump. In particular, we study algorithms able to cope with small disruptions, as temporary and local availability and/or malfunctioning of key resources that can occur and affect planned operations. To this aim, a definition of robust algorithm is provided. Performances of the proposed algorithms are measured by the notion of price of robustness. Various scenarios are considered, and interesting results are presented.

Keywords: Shunting, Hump Yard, Disruption, Robustness, Recoverability, Robust Algorithm

Joint work of: Cicerone, Serafino; D'Angelo, Gianlorenzo; Di Stefano, Gabriele; Frigioni, Daniele; Navarra, Alfredo

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1175

Applied Railway Optimization in Production Planning at DSB S-tog - tasks, tools and challenges

Jens Clausen

Efficient public transportation is becoming increasingly vital for modern capitals. DSB S-tog a/s is the major supplier of rail traffic on the infrastructure of the city-rail network in Copenhagen. S-tog has experienced a demand for increasing volume and quality of the transportation offered to the customers, and has concurrently been met with demands for higher efficiency in the daily operation.

The plans of timetable, rolling stock and crew must hence allow for a high level of customer service, be efficient, and be robust against disturbances of operations. It is a highly non-trivial task to meet these conflicting goals. S-tog has therefore on the strategic level decided to use software with optimization capabilities in the planning processes.

We describe the current status for each activity using optimization or simulation as a tool: Timetable evaluation, rolling stock planning, and crew scheduling. In addition we describe on-going efforts in using mathematical models in activities such as timetable design and work-force planning. We also identify some organizatorial key factors, which have paved the way for extended use of optimization methods in railway production planning.

Disruption Management in PassengerTransportation - from Air to Tracks

Jens Clausen

Over the last 10 years there has been a tremendous growth in air transportation
of passengers. Both airports and airspace are close to saturation with respect to
capacity, leading to delays caused by disruptions.

At the same time the amount of vehicular traffic around and in all larger
cities of the world has show a dramatic increase as well.

Public transportation by e.g. rail has come into focus, and hence also the ser-
vice level provided by suppliers ad public transportation. These transportation
systems are likewise very vulnerable to disruptions.

In the airline industry there is a long tradition for using advanced mathe-
matical models as the basis for planning of resources as aircraft and crew.

These methods are now also coming to use in the process of handling dis-
ruptions, and robustness of plans has received much interest. Commercial IT-
systems supplying decision support for recovery of disrupted operations are be-
coming available. The use of advanced planning and recovery methods in the
railway industry currently gains momentum.

The current paper gives a short overview over the methods used for plan-
ning and disruption management in the airline industry. The situation regarding
railway optimization is then described and discussed. The issue of robustness of
timetables and plans for rolling stock and crew is also addressed.

Fast Approaches to Robust Railway Timetabling

Matteo Fischetti

The Train Timetabling Problem (TTP) consists in finding a train schedule on
a railway network that satisfies some operational constraints and maximizes
some profit function which counts for the effciency of the infrastructure usage.
In practical cases, however, the maximization of the objective function is not
enough and one calls for a robust solution that is capable of absorbing as much
as possible delays/disturbances on the network. In this paper we propose and
analyze computationally four different methods to find robust TTP solutions
for the aperiodic (non cyclic) case, that combine Mixed Integer Programming
(MIP) and ad-hoc Stochastic Programming/Robust Optimization techniques.

We compare computationally the effectiveness and practical applicability of the four techniques under investigation on real-world test cases from the Italian railway company (Trenitalia). The outcome is that two of the proposed techniques are very fast and provide robust solutions of comparable quality with respect to the standard (but very time consuming) Stochastic Programming approach.

Keywords: Train timetabling, Robust Optimization, Stochastic Programming, Computational Experiments

Joint work of: Fischetti, Matteo; Zanette, Arrigo; Salvagnin, Domenico

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1176

A new concept of robustness

Ricardo García

In this paper a new concept of robustness is introduced and the corresponding optimization problem is stated. This new concept is applied to transportation network designs in which the set of scenarios arising from the uncertainty of the parameters follows a probability distribution. The p-robustness concept is aimed to problems where the feasibility of the solutions is not affected by the uncertainty of the parameters.

In order to compare the solution with those of other already known concepts of robustness, some computational experiments with real data are included.

Joint work of: García, Ricardo; Marín, Ángel; Mesa, Juan A.; Perea, Federico; Verastegui, Doroteo

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1177

Improved Search for Night Train Connections

Thorsten Gunkel

The search for attractive night train connections is fundamentally different from ordinary search: the primary objective of a costumer of a night train is to have a reasonably long sleeping period without interruptions due to train changes. For most passenger it is also undesired to reach the final destination too early in the morning.

These objectives are in sharp contrast to standard information systems which focus on minimizing the total travel time.

In this paper we present and compare two new approaches to support queries for night train connections. These approaches have been integrated into the Multi-Objective Traffic Information System (MOTIS) which is currently developed by our group.

Its purpose is to find all train connections which are attractive from a costumer point of view.

With a computational study we demonstrate that our specialized algorithms for night train connections are able to satisfy costumer queries much better than standard methods. This can be achieved with reasonable computational costs: a specialized night train search requires only a few seconds of CPU time.

Keywords: Timetable information system, multi-criteria optimization, night trains, computational study

Joint work of: Gunkel, Thorsten; Müller-Hannemann, Matthias; Schnee, Mathias

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1178

Multistage Methods for Freight Train Classification

Jens Maue

In this paper we establish a consistent encoding of freight train classification methods. This encoding scheme presents a powerful tool for efficient presentation and analysis of classification methods, which we successfully apply to illustrate the most relevant historic results from a more theoretical point of view. We analyze their performance precisely and develop new classification methods making use of the inherent optimality condition of the encoding. We conclude with deriving optimal algorithms and complexity results for restricted real-world settings.

Keywords: Freight trains, sorting algorithms, train classification, shunting, cargo

Joint work of: Jacob, Riko; Marton, Peter; Maue, Jens; Nunkesser, Marc

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1179

Modeling and solving a multimodal multicapacitated routing problem with scheduled services, time windows, and economies of scale

Luigi Moccia

This paper studies a routing problem in a multimodal network where consolidation of shipments yields economies of scale.

A freight forwarder can use a mix of flexible-time and scheduled transportation services. Time windows are prominent features of the problem. For instance, they are used to model opening hours of the terminals, as well as pickup and delivery time slots. The various features of the problem can be described as elements of a digraph and their integration leads to a holistic graph representation. This allows an origin-destination integer multi-commodity flow formulation with piecewise linear concave costs, time windows, and side constraints. Column generation algorithms are outlined to compute lower bounds by solving the LP relaxation of one of the two presented formulations. These column generation algorithms are also embedded in a heuristic aimed at finding feasible integer solutions.

Preliminary computational results will be presented.

Joint work of: Moccia, Luigi; Cordeau, Jean-Francois; Laporte, Gilbert; Ropke, Stefan; Valentini, Maria Pia

Approximate dynamic programming for rail operations

Warren Powell

Approximate dynamic programming offers a new modeling and algorithmic strategy for complex problems such as rail operations. Problems in rail operations are often modeled using classical math programming models defined over space-time networks. Even simplified models can be hard to solve, requiring the use of various heuristics. We show how to combine math programming and simulation in an ADP-framework, producing a strategy that looks like simulation using iterative learning. Instead of solving a single, large optimization problem, we solve sequences of smaller ones that can be solved optimally using commercial solvers. We step forward in time using the same flexible logic used in simulation models. We show that we can still obtain near optimal solutions, while modeling operations at a very high level of detail. We describe how to adapt the strategy to the modeling of freight cars and locomotives.

Keywords: Approximate dynamic programming; locomotive optimization; freight car optimization

Joint work of: Powell, Warren; Bouzaiene-Ayari, Belgacem

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1180

Branching Strategies to Improve Regularity of Crew Schedules in Ex-Urban Public Transit

Ingmar Steinzen

We discuss timetables in ex-urban bus traffic that consist of many trips serviced every day together with some exceptions that do not repeat daily.

Traditional optimization methods for vehicle and crew scheduling in such cases usually produce schedules that contain irregularities which are not desirable especially from the point of view of the bus drivers. We propose a solution method which improves regularity while partially integrating the vehicle and crew scheduling problems. The approach includes two phases: first we solve the LP relaxation of a set partitioning formulation, using column generation together with Lagrangean relaxation techniques. In a second phase we generate integer solutions using a new combination of local branching and various versions of follow-on branching. Numerical tests with artificial and real instances show that regularity can be improved significantly with no or just a minor increase of costs.

Keywords: Public transit, crew scheduling, branching strategies, regularity, local branching, follow-on branching

Joint work of: Steinzen, Ingmar; Suhl, Leena; Kliewer, Natalia

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2007/1167