SynchroTrans 2013
1st International Workshop on Synchronization in Transport

26th to 28th May, Mainz, Germany

ABSTRACT BOOK

We thank our sponsor:

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Dear participants and friends:

A warm welcome to Mainz and SynchroTrans 2013, 1st International Workshop on Synchronization in Transport!

With this workshop we aim to provide a forum for scientific exchange and cooperation in the area of vehicle routing and synchronization. Synchronization is one of the few topics in vehicle routing which is present and relevant almost everywhere, but, up to now, only insufficiently touched in our community. Even more, synchronization problems are often extremely difficult to model and solve with both exact and heuristic approaches. This makes them at the same time very exciting objects of study. (That is probably the reason why you are here.)

The SynchroTrans workshop will be informal in character, it has single-streamed sessions allowing full length presentations and true discussion. We hope that it will foster new ideas for tackling at least some of the many challenging synchronization issues that you bring with you.

We wish you a rewarding workshop and a pleasant stay here in Mainz!

Stefan Irnich and Michael Drexl

General schedule

Sunday, 26th May
18:00 h: Welcome reception and informal get-together

Monday, 27th May
09:00 h - 17:20 h: Academic programme
18:30 h - 20:00 h: Guided tour through the city centre of Mainz
20:00 h: Conference dinner

Tuesday, 28th May
09:00 h - 15:40 h: Academic programme

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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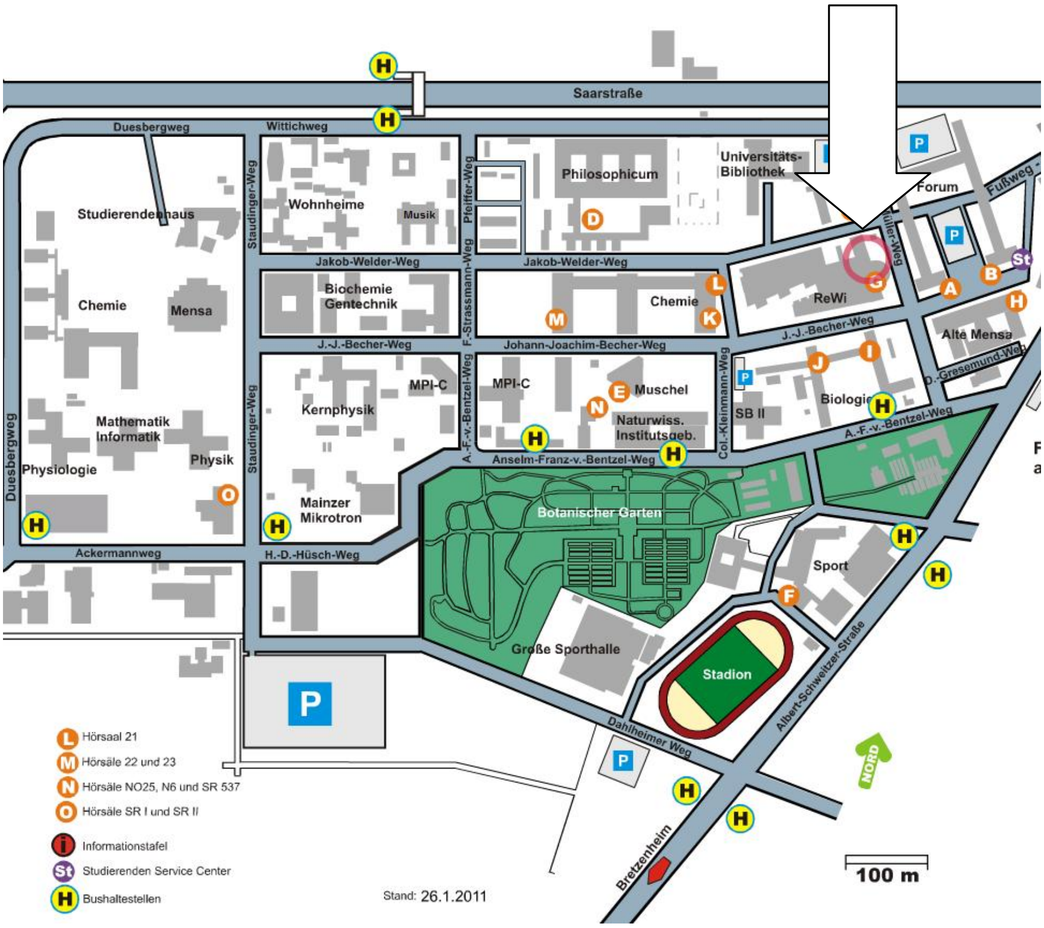

Scientific Programme

Monday, 27th May

09:00 h
Stefan Irnich
Welcome address

Session 1: Branch-and-price approaches in ship routing and scheduling
09:10 h
Mette Gamst
The boat and barge routing problem

09:50 h
Henrik Andersson
A ship routing and scheduling problem with cargo coupling and synchronization constraints

10:30 h
Coffee break

Session 2: Road maintenance and synchronization
10:50 h
André Langevin
Synchronized arc and node routing for road marking

11:30 h
Markus Brachner and Johan Oppen
Planning of Norwegian road construction and maintenance

12:10 h
Lunch break

Session 3: Vehicle routing and synchronization
13:40 h
Sebastian Sterzik
Analysis of layered routing problems

14:20 h
Lars Mönch
Solving the vehicle routing problem with backhauls and 3D loading constraints using metaheuristics

15:00 h
Anne Meyer
Modelling milk runs in lean manufacturing—PVRP with additional constraints

15:40 h
Coffee break

Session 4: Temporal operation synchronization
16:00 h
Han Hoogeveen
More efficient algorithms for parallel machine scheduling problems with synchronization constraints

16:40 h
Frank Meisel
Synchronization of technician routes and maintenance operations in electricity networks

Tuesday, 28th May

Session 5: Temporal synchronization of freight handling in vehicle routing
09:00 h
Jörn Schönberger
Split pickups and deliveries with synchronized arrival times

09:40 h
Dominique Feillet
The multi-trip vehicle routing problem with time windows and release dates

10:20 h
Coffee break

Session 6: Synchronized pickup-and-delivery
10:40 h
Fabien Lehuédé
Feasibility algorithms for two pickup and delivery problems with transfers

11:20 h
Michael Bögl
Synchronization issues in the school bus routing and scheduling problem with transfers

12:00 h
Timo Gschwind
A comparison of different column-generation formulations for the pickup-and-delivery problem with static and dynamic time windows

12:40 h
Lunch break

Session 7: Synchronization in practice
14:10 h:
Leendert Kok
Synchronized routing in practice

14:50 h:
Tore Grünert
Synchronising drivers, service staff and goods: Aspects of synchronization in practice

15:30 h:
Stefan Irnich
Closing speech

Mette Gamst:
The boat and barge routing problem

Coal must be delivered regularly to the thermal power plants in Denmark to ensure stable and reliable production of electricity and heat. Coal delivered from overseas is distributed from central depots to the power plants by an internal fleet of tug boats and barges. Coal is loaded onto a barge, which is then pulled by a tug boat to a power plant, where the barge is unloaded. While the barge is unloaded, the tug boat is not needed and can sail on, possibly with another barge. If a delivery cannot be made by the internal fleet, then an external delivery can be made at a significantly higher cost. The NP-hard Boat and Barge Routing Problem (BBRP) consists in finding paths for barges and tug boats such that all deliveries are made and such that the total cost of tug boat sailing and external deliveries is minimized.

We present a mathematical formulation for the problem and two branch-and-price algorithms. The first algorithm has two pricing problems for generating barge paths resp. tug boat paths. The second algorithm has only one pricing problem: barges are handled in the master problem and only tug boat paths are generated in the pricing problem.

The solution approaches are computationally evaluated on a set of real-life test instances provided by DONG Energy, a Danish utility company. Computational results show that the algorithm with one pricing problem has superior performance, which indicates that movement synchronization between two types of vehicles is better handled by modeling barges as resources in the master problem than as independent vehicles. This observation can be applied to other vehicle routing problems.

Henrik Andersson:
A ship routing and scheduling problem with cargo coupling and synchronization constraints

The purpose of this presentation is to present a branch-and-price method for a maritime pickup and delivery problem with time windows, cargo coupling, and synchronization constraints. The problem originates from a segment of tramp shipping called project shipping or "heavy duty" shipping. Tramp shipping is a mode of maritime transportation where ships act similar to taxis, picking up and delivering goods at ports around the world, trying to maximize their profit while selecting a subset of the available cargoes. What sets project shipping apart is that the cargoes transported are usually highly specialized and unique. They may be parts of an oil rig built at different yards in Europe or China that need to be shipped to the point of assembly on the African coast. Alternatively they may be turbines and generators that need to be shipped from their building locations in North America to the site of the factory in the Middle East.

There are many interesting aspects to study in this segment of shipping. One is the coupling between cargoes in the sense that the cargo owner has several pieces to ship, and one contract is offered for all pieces of cargo. This means that the shipping company has to transport all the cargoes in the contract, or none of them. Often there is also a requirement to synchronize the delivery times of the coupled cargoes. The coupled cargoes generally have different pickup locations but the same delivery point. The time windows for delivery are usually quite wide, but contracts often have a clause that limits the number of days between the delivery of the first and the last cargo.

The objective is to design a route and schedule for each ship in a heterogeneous fleet that maximizes the total profit from transporting a subset of the cargoes available. A new mathematical formulation is presented and solved using branch-and-price. The subproblem is a new variant of the elementary shortest path problem with resource constraints, which is solved by dynamic programming. The computational results show that this approach is a lot better than existing methods for solving this problem.

André Langevin:
Synchronized arc and node routing for road marking

This presentation introduces the synchronized arc and node routing problem (SANRP), inspired from a real application arising in road marking operations. In this setting, several capacitated vehicles are used to paint lines on the roads and a tank vehicle is used to replenish the painting vehicles. The aim of the problem is to determine the routes and schedules for the painting and replenishment vehicles so that the pavement marking is completed within the least possible time. This must be done in such a way that the routes of the painting and replenishment vehicles are synchronized. In the SANRP two routing problems must be solved simultaneously: a multi-vehicle capacitated arc routing problem and a node routing problem. The nodes at which the arc routes and the node route intersect are not given a priori, but must be determined together with the routes themselves. Finally, the routes generated should be synchronized so as to reduce the waiting time at the refill nodes.

We analyze three replenishment policies:
(i) there is no replenishment vehicle and the painting vehicles return to the depot when they need a refill;
(ii) the painting vehicles do not return to the depot when they need a refill, but are serviced by the replenishment vehicle;
and (iii) a combination of the first two policies, meaning that the painting vehicles can be refilled from the replenishment vehicle or directly from the depot.
Policies (ii) and (iii) are compared with policy (i) which is the standard practice.

The SANRP is considerably more difficult to solve than either the CARP or the node routing problem which it integrates. This is so because any change in the solution of one of the two subproblems affects the solution of the other one. A formal description of the problem is given. It is of course impractical to solve the SANRP exactly for any realistic size. We have designed a powerful adaptive large neighborhood search heuristic (ALNS) in which the solution space is explored by means of several operators. The heuristic was successfully tested over a large set of instances.

Johan Oppen:
Planning of Norwegian road construction and maintenance

Weather conditions are hard and remorseless in Norway, and they take their toll on the roads. This is one of various reasons for a multitude of construction and maintenance work on the Norwegian road network. Road construction companies are challenged in the planning of their projects, as they need to coordinate teams which conduct the work on-site on one hand and vehicles that provide the necessary asphalt at the locations at the right time on the other. Moreover, at the end of the working day everybody involved should be back at the depot at about the same time and as early as possible.

We present a VRP with exact temporal and spatial operation synchronization. Two classes of vehicles are synchronized, where a vehicle of one class needs to meet one of another class to proceed on its tour. This case can be found in many applications in practice. Examples include the coordination of construction teams and supplying vehicles for construction companies, the synchronization of special purpose tools with repair teams at offshore oil drilling platforms or the planning of routes for combine harvester and trucks for harvest collection.

In contrast to minimizing the overall travel time, the objective is to minimize the maximum travel time of each vehicle. By minimizing the maximum travel time all tours will be fair, keeping the difference between the tours small and the travel time as low as possible. Despite the good applicability in practice, min-max VRPs are quite rarely researched, and there has not been paid very much attention the past years to this kind of objectives.

A formulation as a linear program shows, that for practical applicability even small instances entail too long run times. As a consequence, a metaheuristic solution method based on a Greedy Randomized Adaptive Search Procedure was developed. When it comes to synchronization, one challenge is to construct good and feasible solutions. Thus, we discuss the possibilities of efficient construction algorithms and the impact on the search process. Furthermore, particular attention is paid to the move evaluation. The waiting times to synchronize the vehicles depend on the concrete solution and are therefore difficult to calculate. As an approach, the idea of discrete event simulation is proposed. An execution queue is introduced to keep track of all events. This helps to model more complex problems while still ensuring good computational performance. An implementation of the proposed algorithm in C++ and analysis of the results is shown and discussed.

Sebastian Sterzik:
Analysis of layered routing problems

In layered routing problems, transport requests are fulfilled jointly by passive means of transport and active means of transport. Passive means are either loading devices that hold cargo or transport devices that are not allowed to move without being accompanied by active means. The actually given transport requests must be fulfilled by passive means. The basic underlying transportation problem for the passive means may be of any type, e.g. a VRP(TW) or a PDP(TW). A well-known example for layered problems is given by the truck-and-trailer routing problem with truck being the active means and trailers constituting the passive means. Practical applications for layered problems can be distinguished into container situations and conducting situations. In the container situation, passive means represent the loading devices that are carried by vehicles. Typical scenarios for this situation are found in the transportation of containerized cargo within the hinterland of seaports or in production systems where load devices with materials are carried between work stations. For instance, fulfilling a PDP-request for a container scenario requires to let an active means carry a passive means to the pickup location, to load the passive means, and to carry the loaded passive means to the delivery location (using the same or some other vehicle) where it is dropped off and then unloaded. Scenarios for the conducting situation are given by escorted heavy-load transports, by pilots accompanying ships on dangerous passages, and by nurses or medics accompanying non-emergency patients between hospital facilities.

Conventional studies on routing problems consider solely one single type of transport resources which are used for fulfilling transport requests, whereas layered problems are composed of two or maybe even more layers which have to be synchronized by jointly routing the transportation means of the existing layers. The main challenge of layered routing problems arises from the fact that passive means can only move in combination with active means, which, from another perspective, necessitates that each travel of a passive means is enabled by a travel of an active means along the same arc of the logistics network. There is no fixed assignment of active means to passive means. From this, vehicles can drop off passive means (i.e. the process of decoupling an active and a passive means) at locations and, instead of waiting until the passive means have been (un-)loaded, they can leave the location and proceed carrying other passive means. Later on, any (i.e. the same or another) active means may grab the passive means (i.e. the process of coupling of an active and a passive means). This enables higher flexibility for vehicle utilization but makes the planning of layered routing problems more complex.

The advantages and disadvantages of being able to decouple/couple transportation means at customer locations will be considered for layered problems. Then mixed layered problems will be introduced. In mixed problems, decoupling and coupling is possible only for a subset of the customer location while the process of decoupling and coupling is impossible at all other customer location. Additionally, the significance of the width of the customer time windows and their impact on the benefits that can be taken from the possibility of decoupling/coupling will be discussed.

Lars Mönch:
Solving the vehicle routing problem with backhauls and 3D loading constraints using metaheuristics

In this talk, we discuss a vehicle routing problem with backhauls (VRPB). We consider 3D loading constraints as additional synchronization constraints. The VRPB is solved by Variable Neighborhood Search, while a tree search algorithm is responsible for packing the boxes. The results of some computational experiments with benchmark instances that are derived from standard VRPB instances are presented. The computational results demonstrate the importance of modeling the loading constraints.

Anne Meyer:
Modelling milk runs in lean manufacturing—PVRP with additional constraints

Milk runs are a transport concept of lean manufacturing for inbound and outbound logistics as well as for transports within a production site (see i.e. [1]). The key idea is to establish regularly recurring tours instead of planning new tours on a daily basis. Such a concept allows for applying the core lean principles to transportation processes as like: transparency, standardisation, levelled use of resources, stability, continuous flow or continuous improvement (see [2]).

To run these regular tours on the long term in a stable and at the same time efficient way, it is—especially in the in- and outbound case—necessary to establish a planning and feedback system which fulfils the following tasks: (1) solving the tactical planning task i.e. defining the milk run schedules, (2) instantiating the daily tours based on the tactical plan considering possible deviations from the forecasted volumes and (3) monitoring the system and detecting automatically the moment, where the current milk run schedule should be adapted to come back to a more stable or less inefficient tactical plan.

In this talk we focus on the way how to model the tactical milk run planning problem. We derive model requirements from lean principles or concepts—such as KANBAN control systems with and without HEIJUNKA levelling—and counter the few milk run models from literature as well as models from general literature on vehicle routing (VRP) and periodic vehicle routing problems (PVRP) (such as [3] or [4]). We focus in particular on requirements causing synchronization between tours and show their impact on small numerical examples.

References

[1] Baudin, M. (2004): Lean logistics: The nuts and bolts of delivering materials and goods. Productivity Press.
[2] Womack, J.; Jones, D.; Roos, D. (1990): The machine that changed the world: The story of lean production. Free Press.
[3] Groër, C.; Golden, B.; Wasil, E. (2009): The consistent vehicle routing problem. Manufacturing & service operations management 11, 630-643.
[4] Smilowitz, K.; Nowak, M.; Jiang, T. (2012): Workforce management in periodic delivery operations. Transportation Science, Forthcoming.

Han Hoogeveen:
More efficient algorithms for parallel machine scheduling problems with synchronization constraints

We consider the following machine scheduling problem, which can be viewed upon as a special case a vehicle routing or crew scheduling problem. We are given m parallel, identical machines, which are continuously available and can process no more than one job at a time; these machines have to process n jobs $J_1,..., J_n$. Processing J_j requires one, arbitrary processor during an uninterrupted period of length p_j , which period must fall in the time-window $[r_j, \bar{d}_j]$, where r_j and $\bar{d}_j$ denote the release date and deadline, respectively. Given a schedule σ, we denote the completion time of job J_j by $C_j(\sigma)$. The jobs are subject to generalized precedence constraints, which prescribe that for a pair of jobs J_i and J_j the difference in completion time $C_j(\sigma) - C_i(\sigma)$ should be at least, at most, or exactly, equal to some given nonnegative value q_{ij}. Observe that the exact completion time difference models the synchronization of jobs, e.g., synchronized operations of service technicians or home health care staff. The quality of the schedule is measured by the maximum lateness $L_{max} = \max_j L_j$, where $L_j = C_j - d_j$; here d_j is the due date of job J_j , at which the job ideally should be completed.

Van den Akker, Hoogeveen, and van Kempen [2] compute a destructive lower bound for this problem based on column generation. They put an upper bound L on L_{max}, which yields an additional deadline $d_j + L$ for each job J_j. This leads to the feasibility problem: is it possible to partition the jobs into m disjunct feasible subschedules? Here satisfying the release dates and deadlines is a prerequisite for feasibility of the subschedules, whereas the generalized precedence constraints are enforced by choosing a feasible combination of the subschedules. This feasibility problem is computationally intractable, but a quick and very strong lower bound on the required number of feasible subschedules can be computed by formulating this problem as in integer linear program and solve the LP-relaxation by column generation. Van den Akker et al. [2] then consider the problem of finding a feasible schedule with value greater than or equal to the smallest value of L that cannot be proved infeasible. The problem is formulated as a time indexed integer linear programming problem, and computational experiments show that a tight lower bound L is crucial to the running time.

In [1] we show that the above approach can model a myriad of resource constrained project scheduling problems. Here synchronization constraints, i.e. exact generalized precedence constraints, are important to model jobs that have resource consumption more than 1.

In case there are many synchronization constraints, finding a feasible solution by the time-indexed ILP requires a large amount of computation time. Recently we developed two methods to improve our algorithm. The first one is that we shrink the time windows for the jobs by deriving additional release dates and deadlines from the solution of the column generation lower bound. The second method is to enforce the exact synchronization constraints by adding valid inequalities. Our extensive computational experiments indicate that our methods reduce the computation time by a significant factor.

References
[1] van den Akker, J.; Diepen, G.; Hoogeveen, J.A. (2007): A column generation based destructive lower bound for resource constrained project scheduling problems. Van Hentenryk, P.; Wolsey, L. (Eds.). CPAIOR 2007. LNCS 4510, Springer, 376-390.
[2] van den Akker, J.; Hoogeveen, J.A.; van Kempen, J. (2012): Using column generation to solve parallel machine scheduling problems with minmax objective functions. Journal of Scheduling 15, 801-810.

Frank Meisel:
Synchronization of technician routes and maintenance operations in electricity networks

In this talk, we present a routing problem for technicians that perform maintenance jobs in an electricity network. The maintenance jobs comprise several subtasks like taking a power line off of the network, performing the actual maintenance, and reconnecting the power line afterwards. The subtasks occur at different locations of the network. Precedence relations may be given among pairs of these tasks. However, there are also tasks that can be processed in parallel. In order to achieve a shortest possible downtime of the affected power lines, the routes of the technicians have to be designed such that these tasks are processed in parallel whenever possible. This calls for a synchronization of the technicians' routes.

We present a corresponding optimization model that jointly assigns subtask to the workers, decides on the routing of each worker, and schedules the start time of each task. The goal is to minimize the downtimes of power lines and the travel effort of workers. Since these objectives are conflicting, we combine them in a weighted objective function that allows to trade off low downtimes and low travelling cost to different extent. For solving this problem, we combine a Large Neighborhood Search meta-heuristic with mathematical programming techniques. The method is evaluated on a large set of test instances which are derived from network data of a German electricity provider.

Jörn Schönberger:
Split pickups and deliveries with synchronized arrival times

In traditional vehicle routing applications the set of customer sites is partitioned into clusters (tours). Sites in a cluster are ordered so that explicit time requirements like time windows are respected. The determined sequence is called a route. Each route is fulfilled by a vehicle. The maximal route length is limited due to maximal working times or shift durations and/or the maximal payload capacity of the used vehicle. In case that the quantity of an individual customer request exceeds the maximal payload capacity of a single vehicle it is necessary to assign two (or even more) vehicles to such a request, e.g. the request is split between some vehicles. This class of the vehicle routing problem is named split vehicle routing. I investigate a split vehicle routing problem in which a homogeneous fleet of vehicles is available. Each individual request requires the pickup of a given demand quantity at a request-specific pickup location, the movement of this quantity by one or more vehicles to a request-specific delivery location as well as the unloading there.

It is necessary that two or more different vehicle visits the customer locations for picking up goods and/or unloading goods in order to fulfill a split request. It is also necessary to coordinate the arrival times of all vehicles serving a split request in the sense that all scheduled loading and all needed unloading times associated with this split request are scheduled close together and fall into a certain implicit time interval in order to prevent costly re-installations of special handling equipment, cleaning of equipment (in the food industry) or delays at downstream parts of customer processes. I investigate a routing problem in which all vehicles serving a certain split request must arrive at the corresponding pickup location as well as at the associated delivery location so, that the arrival times of the first and of the last involved vehicle differ not more than a given maximal time difference.

After the introduction of the decision scenario, a suitable mixed-integer linear optimization model is presented and discussed. Small instances of the model are exactly solved by CPLEX but for solving larger instances a heuristic approach becomes necessary. In this context, I propose a genetic searched-based hybrid meta-heuristic that combines a genetic algorithm with a problem specific construction heuristic. The major challenge is to ensure the feasibility of the evolved solution proposals with respect to the different restrictions as stated in the presented model. Neither a suitable representation nor the application of repair procedures can guarantee the feasibility with respect to all stated constraints. We propose a population model that consecutively eliminates the remaining constraint-specific infeasibilities and finally increases the quality of feasible solution proposals.

The need to coordinate the arrival times of different vehicles at a certain customer location requires new concepts for the determination of arrival times. It must be decided if and where a vehicle waits or if a vehicle starts with the fulfillment of another operation in order to prevent a too early arrival at a customer site (planned postponement). We present several scheduling techniques that consider this specific arrival time synchronization constraint. Results from computational experiments are reported.

Dominique Feillet:
The multi-trip vehicle routing problem with time windows and release dates

In this paper, we introduce the Multi Trip Vehicle Routing Problem with Time Windows and Release Dates (MTVRPTWR) and propose a memetic algorithm for its heuristic solution. This problem arises in the context of the MODUM[1] project, founded by the French National Research Agency. In MODUM the development of an efficient system of mutualized distribution is studied. Carriers allowed to enter city centers (vans in the following) are parked at platforms located around the beltway where trucks continuously arrive during the day and are unloaded. Synchronization is needed between trucks and vans since goods need to be available at the platform before being loaded in vans for the last mile delivery. However, trucks arrival times are exogenous data. This justify the introduction of the concept of release date associated with the merchandise. Precisely, the release date represents the time merchandise is available at the platform for final delivery.

Final distribution to customers is made by vans with limited capacity, due to laws restriction imposed and the narrowness of streets that characterize historical parts of downtowns. Then, they are allowed to accomplish several trips during the working day. This introduces the multi-trip aspect.

More formally, in the MTVRPTWR, a fleet of identical vehicles with limited capacity is based at the depot. A set of customer demands have to be fulfilled during the working day. The MTVRPTWR calls for the determination of a set of routes and an assignment of each route to a vehicle, such that the total routing cost is minimized and each customer is visited by exactly one route respecting capacity constraints on vehicles and time windows on customers. Moreover, each vehicle cannot leave the depot before the maximal release date associated with merchandise to be delivered in the trip vehicle is going to accomplish.

The MTVRPTWR is an extension of the Multi Trip VRP with Time Windows (MTVRPTW, [1]) that is in turn an extension of the Multi Trip VRP [3]. An adaptation of the Split procedure introduced by Prins [2], in the VRP context, is used to evaluate chromosomes and obtain MTVRPTWR solutions from them. A set of instances for the MTVRPTWR is introduced and the efficiency of the procedure is proved by result comparison on MTVRPTW instances.

References
[1] Hernandez, F.; Feillet, D.; Giroudeau, R.; Naud, O. (2011): A new exact algorithm to solve the multi-trip vehicle routing problem with time windows and limited duration. Tech. Rep.
[2] Prins, C. (2004): A simple and effective evolutionary algorithm for the vehicle routing problem. Computers & Operations Research 31, 1985-2002.
[3] Taillard, E.; Laporte, G.; Gendreau, M. (1996): Vehicle routing with multiple use of vehicles. Journal of the Operational Research Society 47, 1065-1070.

[1] `http://www-lipn.univ-paris13.fr/modum`, Agence Nationale de la Recherche

Fabien Lehuédé:
Feasibility algorithms for two pickup and delivery problems with transfers

This presentation follows the PhD thesis of Renaud Masson [1] on the Pickup and Delivery Problem with Transfers (PDPT). The motivating application is a dial-a-ride problem in which a passenger may be transferred from the vehicle that picked him/her up to another vehicle at some predetermined location, called transfer point. Both the PDPT and the Dial-A-Ride Problem with Transfers (DARPT) were investigated. An adaptive large neighborhood search has been developed to solve the PDPT [2] and also adapted to the DARPT [3]. In both algorithms, multiple insertions of requests in routes are tested. Efficiently evaluating their feasibility with respect to the temporal constraints of the problem is a key issue.

Allowing transfers in a pickup and delivery problem can reduce routing costs but it also introduces an interdependency between the routes of the problem: a transferred requested has to be delivered at its transfer point before it can be pickup up by a second vehicle. When the pickup or delivery times of requests, or the opening time of transfer points are subject to time windows, this precedence constraint has to be integrated in the feasibility / routes scheduling algorithm. We show that the standard algorithms can be adapted to evaluate in constant time the feasibility of a request insertion [5].

In dial-a-ride applications it is common to specify a maximum ride time for passengers in order to enforce a sufficient quality of service. This constraint is combined with time windows and precedence constraints at transfer points in the DARPT. We show that the resulting feasibility problem can be stated as a Simple Temporal Problem (STP), which is solved with a shortest path algorithm. The complexity of this new feasibility algorithm is larger than for the PDPT and the resulting solving time is significantly increased. As a result, we propose some necessary and sufficient feasibility conditions that reduce the time needed to validate or reject a request insertion [4].

References
[1] Masson, R. (2012): Problèmes de collectes et livraisons avec transferts. PhD thesis, Université de Nantes, Angers, Le Mans.
[2] Masson, R.; Lehuédé, F.; Péton, O. (2012):. An adaptive large neighborhood search for the pickup and delivery problem with transfers. Transportation Science, articles in advance, doi:10.1287/trsc.1120.0432.
[3] Masson, R.; Lehuédé, F.; and Péton, O. (2012). The dial-a-ride problem with transfers. Computers & Operations Research, submitted.
[4] Masson, R.; Lehuédé, F.; Péton, O. (2012): Simple temporal problems in route scheduling for the dial-a-ride problem with transfers. Beldiceanu, N.; Jussien, N.; Pinson, E. (Eds.). CPAIOR 2012, LNCS 7298, 275-291.
[5] Masson, R.; Lehuédé, F.; Péton, O. (2013): Efficient feasibility testing for request insertion in the pickup and delivery problem with transfers. Operations Research Letters 41, 211-215.

Michael Bögl:
Synchronization issues in the school bus routing and scheduling problem with transfers

The school bus routing and scheduling problem deals with the transportation of pupils from home to school in the morning and from school to home in the evening. Variants of this problem are often studied in literature. A comprehensive overview of existing publications can be found in [1].

This work is motivated by a real life problem with about 1600 pupils, 235 bus stations and 22 schools, where the area of operation is mostly rural. We deal with the morning problem only, i.e., the transportation of the pupils to their respective school before it begins. The goal is to generate an efficient transportation plan (according to some objective) so that every pupil arrives at school on time.

In this work we consider the school bus routing and the scheduling problem under consideration of pupil transfers, i.e. pupils may change the bus. Transfers allow lower costs while maintaining a certain service level, e.g., maximum riding time. School bus routing calculates the bus routes which are then scheduled to buses. Hence, a trip is serviced by a single bus but a bus may serve multiple trips.

Our solution approach is designed to automatically choose bus stations for pupil transfers. Due to the transfers of the pupils it is necessary to schedule the buses at the transfer bus stops under consideration of minimum and maximum waiting times for the pupils. Therefore operation synchronization is required. For example pupils must change from bus b to bus c at location l. So, bus b must arrive at l a certain amount of time before bus c picks up the pupils. Further, pupils must arrive at school within a certain time window before the school begins.

Our heuristic solution approach tackles this problem by dividing it into subproblems which are solved sequentially: routing and scheduling. At first a routing solution under consideration of transfers is calculated. Then, we use a two stage approach to solve the scheduling problem. First we resolve cycles in the bus routes, which may arise because of the transfers. Then we use a simple temporal network model formulation and a shortest path algorithm to detect whether a feasible schedule exists. If this is not the case we determine properties of the solution which may induce solution infeasibility using a simple scheduling algorithm. Those infeasibilities are mapped to certain solution properties and the routing solution is adapted accordingly.

In the workshop we want to present our current solution approach and point out issues which turned up during the development.

References

[1] Park, J.; Kim, B. (2010): The school bus routing problem: A review. European Journal of Operational Research 202, 311-319.

Timo Gschwind:
A comparison of different column-generation formulations for the pickup-and-delivery problem with static and dynamic time windows

The Pickup-and-Delivery Problem with Static and Dynamic Time Windows (PDPSDTW) is a Vehicle Routing Problem (VRP) with pairing and precedence, capacities, and static and dynamic time windows. Thereby, a static (or ordinary) time window restricts the point of time a specific customer can be serviced. A dynamic time window, on the other hand, couples the service times at two customer nodes in the following way: A delivery node has to be serviced within a given minimum and maximum time spread after the service at the corresponding pickup node has been completed. The PDPSDTW, thus, is the prototypical VRP with temporal intra-route synchronization constraints generalizing the Pickup-and-Delivery Problem with Time Windows (PDPTW) where no dynamic time windows are present and the Dial-a-Ride Problem where only a maximum time spread is specified. Many successful solution approaches for VRP variants rely on integer column generation using formulations that include all the constraints relating to single routes in the subproblem. These formulations have the advantage of tighter lower bounds compared to formulations where some route constraints are handled in the master problem. The overall success of an integer column-generation approach for VRPs, however, relies not only on strong bounds but also on the effective solution of the subproblem. Thus, it is a priori not clear if the integration of all route constraints into the subproblem pays off, especially if there are groups of constraints that are hard to handle in the subproblem. Subproblems of VRP variants are typically Elementary Shortest Path Problems (ESPP) with resource constraints that are solved using labeling algorithms. The strength of such a labeling algorithm can mainly be attributed to the use of strong dominance rules. While the ESPP with pairing and precedence, capacities, and static time windows has been well studied in the context of the PDPTW and effective labeling algorithms exist for its solution ([1,2]) the additional presence of dynamic time windows severely complicates the problem. Recently, [3] proposed labeling algorithms for the special case where only a maximum time spread is specified. By means of a simple example, we can show that a straightforward extension of their approach to also include minimum time spreads, however, is not possible.

Our contribution is twofold: First, we devise a new dominance rule that is valid for the ESPP with pairing and precedence, capacities, and static and dynamic time windows. For the first time both static and dynamic time windows (with minimum and maximum time spread) can be fully handled by an effective label setting algorithm. This allows for an integer column-generation algorithm for the PDPSDTW where all route constraints are handled in the subproblem. Second, we compare this algorithm to approaches based on alternative formulations in a computational study. These formulations use subproblems relaxing either the maximum or minimum time spreads, or both and, hence, can be solved using labeling algorithms with stronger dominance rules. Preliminary results, however, indicate that the additional effort in the subproblem pays off in the overall algorithm.

References
[1] Dumas, Y.; Desrosiers, J.; Soumis, F. (1991): The pickup and delivery problem with time windows, European Journal of Operational Research 54, 7-22.
[2] Ropke, S.; Cordeau, J.-F. (2009): Branch and cut and price for the pickup and delivery problem with time windows, Transportation Science 43, 267-286.
[3] Gschwind, T.; Irnich, S. (2012): Effective handling of dynamic time windows and synchronization with precedences for exact vehicle routing, Submitted.

Leendert Kok:
Synchronized routing in practice

Automated vehicle route planning is a major challenge in practice. On the one hand, vehicle route planning methods should become faster and faster to cope with ever growing problem sizes. On the other hand, there is a strong wish in practice for more and more elaborate vehicle routing models to cope with more real-life restrictions. Restrictions that require synchronization between the different vehicle routes, such as a limited loading capacity at a depot [1], are particularly challenging, for various reasons.

First of all, an effective way to speed up vehicle routing methods is to use estimations (both for feasibility and cost changes) for (small) changes to the vehicle route plan, before evaluating the changes exactly [2]. For example, when evaluating a move of a customer from one route to another route, the local change in distance may give a proper estimation of the quality of that move with respect to other moves. However, when synchronization constraints are present, a small change in one vehicle route may lead to substantial changes in other vehicle routes. Therefore, coming up with strong estimations is in general difficult when synchronization constraints are present.

Another problem of this propagation effect of synchronization constraints is that exact evaluations of (small) changes to the plan are in general expensive. In the worst case, a small change leads to a re-evaluation of the entire solution, including all its expensive subproblems (e.g., minimizing route duration, calculating load assignments).

Finally, objectives may have to be reconsidered when synchronization constraints are present. For example, time is one of the most important cost factors in vehicle route plans. Therefore, each route is optimized, such that truck driver duty times are minimal. However, when synchronization constraints are present, delaying one route to reduce waiting time in that route may increase the duration of another route.

In this talk, I will give an overview of the most important challenges we face in practice when considering synchronization constraints. I will provide some clear examples from practice, and relate them to the three previously mentioned challenges. Hereby, I will distinct between synchronization constraints resulting from resources (e.g., trailer swaps between truck drivers), orders (e.g., cross docking), and depots (e.g., loading dock constraints).

References

[1] Gromicho, J.; van Hoorn, J.; Kok, L.; Schutten, J. (2012): Vehicle routing with restricted loading capacities, Working paper, vol. 396, `http://alexandria.tue.nl/repository/books/741575.pdf`
[2] Ichoua, S.; Gendreau, M.; Potvin, J. (2003): Vehicle dispatching with time-dependent travel times, European Journal of Operational Research 144, 379-396.

Tore Grünert:
Synchronising drivers, service staff and goods: Aspects of synchronization in practice

In some practical applications of vehicle routing, synchronization plays an important role. To the best of my knowledge, only very little research has been devoted to this important topic—but as this workshop illustrates, scientific interest is growing. In my talk I will give examples of different synchronization aspects encountered in practical vehicle routing. I will try to rate them in terms of practical importance (which is, of course, always somewhat subjective) and to describe the main characteristics. My hope is that more scientific research will be devoted to these problems in the future. As pointed out by Michael Drexl in his survey (Drexl 2012), the main attributes of synchronization are location, time, load, service and resources. Whereas location and time are always essential in practical applications, load, service and resources may or may not be important. In the following I briefly describe practical applications we have been considering in the last few years.

1. Meet En-Route: Here several service technicians with different qualifications have to meet at a given location to jointly complete a service task. The associated time window may be wide or narrow, depending on the customer's preferences. Note that the technicians' routes only overlap at these meeting points. The routes before and after the meeting can (and usually will) be completely distinct. Also, several meetings with different technicians can occur in one route. This case has medium importance.

2. Consolidate – Time and Load: In this case, goods are delivered and/or picked up at customer locations and transported from or to a depot. Instead of all vehicles starting or ending their route at the depot, a transfer of goods occurs along the route, so that only a subset of the vehicles travels from or to the depot. There are two typical motivations for this type of consolidation: Cost and Time. Consolidation for cost reasons is usually applied when customers are far away from the depot and thus it is not economical that all vehicles travel this far distance. Consolidation for time reasons is usually necessary when one vehicle cannot service all customers in a region within one route, because the available time is not sufficient, hence its route needs to be 'divided' into routes for several vehicles. Note that in almost all practical applications of this kind, very narrow time windows both at the customer locations and the depot have to be taken into account. Also, the number of possible consolidation locations is high and one may choose several locations at different times. This case is the most important in practice.

3. Location-Based: Docks & Use of Local Staff: In contrast to the cases described above, we only consider one location. This location has a limited number of docks that can be used simultaneously. In some cases also, the staff at this location has to be paid from the first until the last loading or unloading process. We therefore seek a solution that never uses more docks than available and at the same time minimises the total time that loading staff has to be available at the location. This case has medium importance.

4. Input & Output Processing: In these cases, depending on whether we deliver or pick up, the goods either have to be processed before or after the transport. Examples are processing of post after pickup, consignment of goods at a warehouse or food processing (e.g. bakeries). As the processing plant has limited capacity, the inbound or outbound transport has to be balanced over time. This means that the number of vehicles (or rather the quantity of goods in these vehicles) that can depart from or arrive at the processing location during a time interval is limited. This case has medium to low importance.

In the talk I will also give examples of other synchronizations tasks with medium to low importance. These include: 5. Route Duration & Route End: Several vehicles need to meet at the same time at the end of their route or the route duration should be more or less the same for all vehicles. 6. Dependent Orders: First, a delivery takes place at a location. Second, a pickup needs to take place at the same location. The minimum and maximum time between these two actions is fixed. Pickup and delivery might take place with different vehicles. 7. Trailer Synchronization: Several trucks can carry trailers and the number of trailers is smaller than the number of trucks. Certain goods can only be transported in a truck or a trailer. Certain customers can only be visited without a trailer and a trailer can be decoupled and coupled to a truck during the route. This is very similar to the VRPTT described by Drexl (2012).

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