A relax-and-repair procedure for the Swap-Body VRP

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In the Swap-Body VRP (SB-VRP) a set of customers has to be served by a fleet of trucks. Trucks are allowed to pull one or two trailers, called bodies. Customers are partitioned in two subsets. The first set contains all customers that must be visited by trucks pulling only one body. The second set contains the customers that can be visited by trucks pulling two bodies. In order to visit the first set of customer, trucks with two bodies can visit the so-called swap-locations where they can leave a body that they need to retrieve afterwards.

We propose a population based algorithm, where individuals are permutations of the customers. Solutions are obtained by a two-phase method. In the first phase, a Heterogeneous VRP (HVRP) is solved. The fleet is composed of two types of vehicles: one with the capacity of a body; the other with the capacity of two bodies. In this phase swap-locations are not considered. Initial solutions are obtained from individuals by an adaptation of the split procedure (Prins, 2004). They are optimized by a local search procedure. The second phase transforms HVRP solutions into SB-VRP solution. Swap-locations are introduced by a procedure that slightly modifies HVRP solutions.

Keywords: VRP, swap-body, population based algorithm, split procedure

A Cluster-First-Route-Second-Approach for Solving Rich Vehicle Routing Problems in Urban and Suburban Areas

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Every day various goods have to be transported and distributed to different locations in a big city. Experience has shown, a tour that spans half the city is seldom practical. It is often prudent to divide the city into suitable territories, and plan tours within these territories. Many logistics service providers plan their tours in this fashion. With this in mind, we present a cluster-first-route-second approach. We use clustering methods that take into account geographic obstacles like rivers and bottleneck road segments in the underlying street network. Then, for each cluster, we plan tours that fulfil the given real life restrictions. We also present experimental results obtained by applying our approach to solve practical instances of the problem mentioned above.

Keywords: Transport Logistics, Vehicle Routing Problem, Clustering, Algorithms

The Electric Vehicle Routing Problem with Time Windows: recent trends and insights for future research

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Inspired by the SMILE project that aims to improve the energy efficiency of Mediterranean cities through the promotion of innovative "green" and cost effective solutions for urban freight logistics addressing the target of green and smart urban development, we focused on the study of the development and implementation of intelligent and sustainable electric mobility solutions. It is obvious that the use of electric vehicles in urban freight distribution has become imperative for modern societies seeking to minimize the energy consumption and the environmental pollution. This paper studies the Electric Vehicle Routing Problem with Time Windows (EVRPTW) and focus is given on significant factors affecting commercial electric vehicle competitiveness such that the route feasibility, minimum fleet size, minimum traveled distance and charge capacity. To that end, a mathematical model that incorporates real-life limitations is provided inspired of the known VRPTW and current trends are analyzed producing valuable insights for future research. The existing studies reveal that approximate methods have received special attention of the research society due to the computational complexity of the EVRPTW and computational experiments are conducted to illustrate their competitiveness. However, benchmark data sets are derived from instances previously generated for the classic Capacitated VRP and therefore, a valuable pointer to future research is the input of practitioners. Empirical studies dealing with realistic constraints and dynamic information about travel times and customer requests could go the research a step further in an effort to capture the dynamic nature of real problems encountered in industry.

Keywords: Electric vehicles, routing and scheduling, mathematical formulation, current trends, pointer research

Integrated production planning and distribution in the newspaper industry

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One of the defining characteristics of the newspaper industry is that the products are virtually worthless at the end of the day; nobody wants to pay for yesterday's news. In addition, strict delivery deadlines and no inventories lead to very short time-frames for production and distribution. Consequently production and outbound distribution are intimately linked and should be coordinated to achieve the objective of on-time delivery performance at minimum total cost.

In this talk we will introduce a production allocation problem with production scheduling and routing (PAPPSR) that originates from the newspaper industry. The main objective of the PAPPSR is to determine where to produce which newspaper products in order to minimize production and first echelon distribution costs. This includes deciding production allocation of newspaper products to printing facilities, production scheduling, as well as vehicle routing from the facilities to drop-off points or customers. A mathematical model of the problem will be presented together with some computational results.

Keywords: Production planning, Distribution, Newspaper industry

Matheuristics for routing problems

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Due to the advances in exact methods and in technology, several mixed integer linear programming (MILP) models can be solved to optimality or close to optimality within a reasonable amount of time. This has encouraged a number of researchers to design heuristics that incorporate phases where MILP or more generally mathematical programming models are solved, the so-called matheuristics. The relation between the original problem and the mathematical programming model or models incorporated in a matheuristic may vary significantly. Surveys on matheuristics are due to Ball (2011) and Maniezzo et al. (2010) and cover a large variety of approaches and problems. The scope of this talk is to present the literature on matheuristics proposed for the solution of routing problems, classify the approaches proposed and analyze the characteristics of the different methodologies. The goal is to understand which are the features that make a matheuristic a competitive solution approach for a routing problem and to highlight promising lines of research.

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Keywords: Mixed Integer Linear Programming, Matheuristics, Routing problems

On the Orienteering Arc Routing Problem

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In the Orienteering Arc Routing Problem (OARP), in addition to a possible set of regular customers that have to be serviced, another set of potential customers is available. Each customer is associated with an arc of a directed graph. Each potential customer has a profit that is collected when it is serviced, that is, when the associated arc is traversed. The objective is to identify the customers which maximize the total profit collected. In this paper we propose a formulation for this problem and study a relaxation of its associated polyhedron. We present some families of valid and facet-inducing inequalities that we use in the implementation of a branch-and-cut algorithm for the resolution of the problem. Computational experiments are run on a large set of benchmark instances.

Keywords: Orienteering Arc Routing Problem, Profits, Facets, Branch and Cut

The Vehicle Routing Problem with Divisible Deliveries and Pickups

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The vehicle routing problem with divisible deliveries and pickups is a new and interesting model within reverse logistics. Each customer may have a pickup and a delivery demand that have to be served with capacitated vehicles. The pickup and the delivery quantities may be served, if beneficial, in two separate visits. The model is placed in the context of other delivery and pickup problems and formulated as a mixed integer linear programming problem. In this paper we study the savings that can be achieved by allowing the pickup and delivery quantities to be served separately with respect to the case where the quantities have to be served simultaneously. Both exact and heuristic results are analysed in depth for a better understanding of the problem structure and an average estimation of the savings due to the possibility of serving pickup and delivery quantities separately.

Keywords: Pickup and delivery vehicle routing, Worst-case analysis, Heuristics

Cutting planes for Multi-Vehicle Inventory Routing Problems

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The Inventory Routing Problem (IRP) involves the distribution of one or more products from a supplier to a set of customers over a discrete planning horizon. Each customer has a known demand to be met in each period and can hold a limited amount of stock. The product is shipped through a distribution network by a fleet of vehicles of limited capacity.

The version treated here, the so-called Vendor Managed Inventory Routing Problem (VMIRP) is the Inventory Routing problem arising when replenishment policies are decided by the supplier. We consider two replenishment policies, both assuming that a stock upper bound is given for each customer. The first is known as Order-up (OU): if a customer is visited in a period, then the amount shipped to a client must bring the stock level up to the upper bound. The latter is called Maximum Level (ML): the stock level in each period cannot cannot exceed the upper bound.

The objective is to find replenishment decisions minimizing the sum of the storage and of the distribution costs. VMIRP contains two important subproblems: a lot-sizing problem for each client and a classical routing problem. In a recent paper we introduced reformulations of VMIRP-OU and VMIRP-ML derived from the single-item lot-sizing substructure and presented computational experience on single-vehicle benchmark instances.

Here we address Vendor Managed Inventory Routing Problems with multiple vehicles, introducing some cutting plane families derived from the relations between the lot-sizing and the routing substructures, based on the capacity of the vehicle and on the OU and ML replenishment policies. The cutting planes have been embedded into a Branch-and-Cut framework to demonstrate their effectiveness. Computational results on benchmark instances with a single product and multiple vehicles are presented.

Keywords: Logistics, Inventory routing, Cutting planes

On the Distance-Constrained Generalized Directed Rural Postman Problem

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The Generalized Directed Rural Postman Problem (GDRPP) is an arc routing problem with some interesting real-life applications, such as routing for meter reading. In this problem, we have a family of arc subsets and the goal is to find a minimal cost tour traversing an arc in each subset. The Distance-Constrained GDRPP is a generalization of this problem in which a fleet of identical vehicles is available and the goal is to minimize the sum of the costs of all the routes, provided that no route exceeds a maximum distance. In this talk we introduce and compare several formulations for this problem. Moreover, different families of valid inequalities are proposed. Some results with preliminary branch-and-cut algorithms are reported.

Keywords: Multi-vehicle arc routing problem, Generalized Rural Postman Problem, Close-Enough Arc Routing Problem, branch-and-cut

A Branch-and-Cut-and-Price Algorithm for the Mixed Capacitated General Routing Problem

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We consider the Mixed Capacitated General Routing Problem which is a combination of the Capacitated Vehicle Routing Problem and the Capacitated Arc Routing Problem. We propose a Branch-and-Cut-and-Price algorithm for obtaining optimal solutions for the problem and present computational results based on a set of standard benchmark instances.

The MCGRP is defined on a connected multi-graph with nodes, directed arcs, and undirected edges, all of which can be demanded. There are non-negative costs for traversing an edge/arc with or without servicing it. The demands must be serviced by a fleet of identical vehicles each with limited capacity. The vehicles are initially located in a special depot node. The fleet of vehicles can be bounded. The goal is to identify a number of tours for the vehicles such that all demands are satisfied, while respecting the limited capacity and minimizing the cost of the tours.

We have tested our algorithm on a large set of benchmark instances from the existing literature. In some instances we provide new best known solutions. The obtained lower bound is generally strong and we improve several best known lower bounds. We are able to prove optimality for many instances.

Keywords: Mixed Capacitated General Routing Problem, Branch-and-Cut-and-Price, Capacitated Vehicle Routing Problem, Capacitated Arc Routing Problem

Stochastic network design with rerouting

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Service network design under uncertainty is fundamentally crucial for all freight transportation companies. The main challenge is to strike a balance between two conflicting objectives: low network setup costs and low expected operational costs. Together these have a significant impact on the quality of freight services. Increasing redundancy at crucial network links is a common way to improve network flexibility. However, in a highly uncertain environment, a single predefined network is unlikely to suit all possible future scenarios, unless it is prohibitively costly. Hence, rescheduling is often an effective alternative. In this paper, we proposed a new stochastic freight service network design model with vehicle rerouting options. The proposed model explicitly introduces a set of integer variables for vehicle rerouting in the second stage of the stochastic program. Although computationally more expensive, the resultant model provides more options (i.e. rerouting) and flexibility for planners to deal with uncertainties more effectively. The new model was tested on a set of instances adapted from the literature and its performance and characteristics are studied through both comparative studies and detailed analyses at the solution structure level. Implications for practical applications are discussed and further research directions are also provided.

Keywords: Stochastic programming, Service network design, Rerouting

Adapting the Savings Heuristic to Capacitated Open Vehicle Routing

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In open vehicle routing problems, vehicle routes correspond to paths with one endpoint being a customer and the other being the depot. Most heuristics proposed for open vehicle routing use sophisticated search strategies, whereas the probably best-known heuristic for vehicle routing is the simple Clarke and Wright Savings Heuristic. We adapt its savings' calculation to open routes.

Unlike closed routes, where both end customers of a route must be connected to the depot, open routes introduce a great deal of flexibility with respect to the choice of depot connections. For any route with multiple customers we generally can choose between the two end customers when determining which customer to connect to the depot. This flexibility is present not only for the final routes, but at each iteration of the savings algorithm. In order to take full advantage of this flexibility, we propose a modification of the savings heuristic which dynamically determines and updates the set of customers that are directly connected to the depot.

We evaluate the quality of these solutions by comparing them to optimal solutions and other heuristics' solutions.

Keywords: capacitated open vehicle routing, heuristics, savings heuristic

A computational study of efficient Local Search implementations for the Vehicle Routing Problem

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We have implemented a number of commonly used techniques for speeding up Local Search-based algorithms for the Vehicle Routing problem. We compare the effect of these techniques both on algorithm runtime and on algorithm accuracy in order to map out the tradeoff between both criteria. We use a flexible implementation allowing us to combine complementary techniques without sacrificing efficiency; by minimizing implementational overhead we aim to provide a fair comparison between techniques. The results provide some key insights into using these techniques and offer practical advice for implementing them.

Keywords: Vehicle Routing Problem, Efficient Local Search, Granular Local Search, Candidate Restriction, Static Move Descriptors

A large-scale fleet management problem

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A problem of optimally routing empty railcars by a company that owns a large fleet of several types of railcars and competes with other owners of railcar fleets (of both comparable and smaller sizes) in a market of transportation services is considered. Cargo owners place their orders for supplying them with empty railcars, and while each order determines the point to which the company should supply a particular number of empty railcars of each particular type, at the time of placing the order, this order may not necessarily contain the cargo destination point for each railcar to be supplied. After delivering the cargo to its destination point, each unloaded railcar is to be returned to a company's service center to be chosen by the company from a set of these centers in a network of railroad stations, where this (empty) railcar is to be processed to be made available for further use. The problem is formulated as a large-scale mathematical programming one with linear constraints possessing a quasi-block structure, and different linear and non-linear goal functions are considered. The structure of the problem constraints allows one to decompose this problem and to solve it by standard mathematical programming software packages.

Keywords: routing, railcar, large-scale mathematical programming problems, linear constraints

A Multi-Start Biased algorithm for the Vehicle Routing Problem with Backhauls

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We consider the Vehicle Routing Problem with Backhauls (VRPB) described in Toth and Vigo (2002). According to that VRPB definition, the group or cluster of delivery customers has to be served before the first pickup customer can be visited. Thus, the problem belongs to a sub-class called VRP with Clustered Backhauls (VRPCB). Our resolution procedure uses a multi-start approach designed in order to avoid the local minima and to be easily parallelizable. The algorithm is based on an adaptation of the SR-GWCS-CS method introduced by Juan et. al (2011). The inner sub-algorithm is the traditional savings procedure (Clarke and Wright, 1964), where the edges that connect one delivery customer with a pick-up customer are penalized to be chosen at a later stage on the list as proposed by Deif and Bodin (1984). The savings list of edges is randomized using a biased probability distribution. Some classical benchmark instances for the VRPB (http://www2.isye.gatech.edu/~mgoetsch/lineback.html) were selected in order to compare the efficiency of our approach. Promising solutions have been obtained from our method implementation.

Keywords: Vehicle Routing Problem with Backhauls, Biased randomization, Heuristics

The multiple vehicle pickup and delivery problem with LIFO constraints

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The Vehicle Routing Problem with Pickups and Deliveries consists of routing a fleet of vehicles in order to satisfy a set of customer requests. Each request specifies the size of the load to be transported, the origin location and the destination location. The same vehicle, with limited capacity, must service the request by visiting the origin location before the destination one. In this paper we consider a LIFO (last-in-first-out) rule of service. Moreover we also consider an upper bound on the total time used by each vehicle since it left the depot. The objective is to find a set of routes with minimum total time satisfying all the constraints. We propose two mixed integer formulations of this problem and a tabu search heuristic. The first formulation is a compact one, that is the number of variables and constraints is polynomial in the number of requests, while the second one contains an exponential number of constraints. We have implemented separation procedures for several families of constraints in this last formulation that were embedded in a branch-and-cut algorithm. The proposed methods are able to optimally solve, for the first time, medium size instances, with up to 30 requests, and provide tight lower bounds for larger instances.

Keywords: vehicle routing, pickup and delivery, LIFO constraints, mixed integer programming

An exact solution approach for the Split Commodities Mixed Routing problem

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In this work we consider the Split Commodities Mixed Routing (SCMR) problem, a vehicle routing problem where customers request for multiple commodities, the vehicles can deliver any set of commodities, and multiple visits of a customer are allowed only if the customer requests multiple commodities. When a commodity is delivered by a vehicle to a customer, the entire amount requested by the customer is carried. If the customer is visited more than once, the different vehicles will deliver different sets of commodities.

The problem has been introduced in [2], where different models are considered to study the impact on cost from using vehicles dedicated to a single commodity compared with using flexible vehicles capable of carrying any set of commodities, and from allowing or not split deliveries of individual commodities. Allowing splitting the demand of a customer for different commodities on different vehicles can be more costly than allowing splitting the delivery of each individual commodity, but at the same time it is more natural and likely more acceptable to customers.

We modeled the SCMR problem by means of a set partitioning formulation and devised a branch-and-price-and-cut algorithm. In the pricing phase, the ng-path relaxation of a constrained elementary shortest path problem is solved by means of a label setting dynamic programming algorithm (see [1]). Capacity cuts are then considered in order to strengthen the bound. We have been able to solve to optimality instances with up to 40 customers and 3 commodities per customer.

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Keywords: Vehicle routing, Multiple commodities, Split deliveries, Branch-and-price

A Revenue Management Approach for Barge Transportation Service Network Design

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Revenue Management concepts are not generally used when planning operations for inland barge transportation, but new trends are showing a significant increase in the interest of practitioners and scientific research community alike. Most of the work is still to be done, however. At the tactical level of decision-making, market segmentation and differential pricing of different types of service packages offered should be explicitly taken into account. We present such a mathematical model for scheduled service network design with asset management and revenue management considerations, including specificities related to barge transportation on a general physical network. We generate a wide range of problem instances in order to address various settings of the general network design problem in terms of service provider's resource characteristics and types of demands. We evaluate the quality of the design solutions from the perspective of several categories of service network performance indicators: economic impact, resource utilization, and quality of service. Numerical results are obtained by performing extensive experiments. Based on those, we perform an analysis of the different types of information and the insights into the system's behaviour the network design solutions provide.

Keywords: barge intermodal transportation, revenue management, service network design, performance indicators

A two-stage column generation based method for a field service routing problem with stochastic travel and service times

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The problem, we are interested in, is the single-period field service routing problem with priority and stochastic travel and service times. We consider two types of customers: mandatory and optional. Optional customers have an associated time window corresponding to the time horizon and may be postponed at any time. Mandatory customers have an associated hard time window. We associate with each technician a vehicle with unlimited capacity and with its own origin and destination depots (with hard time window). We consider that travel and service times are stochastic. The objective is to visit as many optional customers as possible while minimizing the total travel time.

To solve this problem, we propose a two-stage column generation based method consisting in a planning stage followed by an execution stage. In the planning stage, we use some a priori known values for travel and service times within a column generation framework to build routes. In this column generation framework, the subproblem consists, for each vehicle, in building feasible routes containing both optional and mandatory customers, whereas the master problem consists in assigning a feasible route to each vehicle, while ensuring that each mandatory customer is served at least once and that each optional customer is served at most once. In the execution stage, we use a dynamic programming algorithm to determine the optimal policy given stochastic distributions for travel and service times.

Keywords: Column generation, Field service routing, Vehicle routing, Stochastic travel and service times, Priority within customers

Design of a hybrid public transit system in a rural area

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Public transit systems in rural areas in Austria have a declining number of users (even though the transportation network is dense with an average bus stop distance of approximately 850 meter). At the same time individual motor car traffic increases. This leads to the conclusion that the current public transit network structure and vehicle schedule does not match the transportation needs of the public. Within this applied project we design and implement a framework for the planning of the public transit network in rural areas. We combine line based bus systems with demand responsive transportation systems as, e.g., the dial-a-ride problem. The planning is based on actual transport requests gathered by a survey carried out by the administration of Upper Austria. The region of interest covers an area 970 square kilometer and a population of about 58000 people with about 120000 ways per average working day. The aim is to compare the current costs and service-level of the public transit system with the new system designed according to the needs of the public, i.e., to evaluate if the service-level can be increased at the current costs.

Keywords: public transit, network design, heuristic optimization

New Generation Container Port

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An innovative concept for a container port has been designed for an annual throughput of 20 million TEU. The area available was 250 ha, the quay wall

2 x 2.5 km with 12 berths for ultra large container vessels.

Simulation models helped provide evidence for the feasibility of

- an annual throughput of 20 million at the quay (of which 80% transshipment containers and 20% local inbound/ outbound containers)
- effective storing of standard, reefer, dangerous and empty containers
- equipment and transport network for internal moves
- berth availability on arrival: at least 90%
- average container dwell time: 4 days
- reliability and sustainability of the overall concept

Keywords: sea container terminal design, container handling, container port logistics

An Adaptive Large Neighborhood Search Heuristic for the Truck & Trailer Routing Problem

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The Truck & Trailer Routing Problem (TTRP) consists in optimizing the visit of a set of customers by a fleet of trucks couple-able with trailers given that some customers may be visited only by trucks without trailers. Many heuristic approaches have been proposed for the TTRP, for instance, tabu search (Chao, 2002 and Scheuerer, 2006), simulated annealing (Lin et al., 2009), GRASP and evolutionary algorithms (Villegas et al., 2009), column generation (Villegas et al., 2013). In this talk, we first review the literature related to the TTRP then we present an adaptive large neighborhood search, exploiting intelligent removal and insertion operators, to tackle the TTRP. Extensive computational experiments are presented.

Keywords: Truck & Trailer Routing Problem, Adaptive Large Neighborhood Search, Vehicle Routing

Optimizing fleet relocation operations for one-way electric car-sharing systems

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Car-sharing systems provide an attractive transportation alternative to their users with beneficial societal, environmental, and energy impacts. Alternative types of operational concepts of car-sharing systems have been proposed that are in operation around the world. One of these operational concepts allows for vehicles to be dropped at any station. The one-way car-sharing systems offer significant advantages to the users due to their flexibility. However, this flexibility may lead to accumulation and shortage of vehicles at certain stations that have limited capacity. To cope with this problem, operators of one-way car-sharing systems need to perform costly relocation operations. Electric vehicles apply an additional constraint of charging levels in the operational framework.

This research is focused on the modelling of vehicle relocation decisions of one-way electric car-sharing systems. A MILP formulation is proposed in order to optimally relocate vehicles and personnel among the system stations, and to optimally assign relocation personnel to shifts. The proposed model is solved using data from Nice, France and provided the opportunity to examine the trade-off between operational cost and vehicle availability.

Keywords: car-sharing, vehicle relocation, scheduling

A Periodic VRP Model for Optimizing Courier Collection Operations

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We consider the problem of a national courier company that performs “reverse logistics” by collecting documents from its clients for storage or re-forwarding. This is a periodic vehicle routing problem with side constraints, where each client location must be visited with a certain frequency. Clients further request that they always receive service on the same day(s) of the week. We model this problem as a mixed-integer programming problem, and due to its complexity, resort to a meta-heuristic approach for solving it. We provide details of our methodology and report computational results on the real dataset from different regions of the country. Finally we provide specifics on a GIS-based decision support system we have developed and how this system aids the company in planning periodic operations in the field.

Keywords: Periodic VRP, Reverse Logistics, Meta-heuristics

Planning Strategies for Home Care services

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Home care services are among the most important practical applications of the vehicle routing models. We shall discuss the real-life challenges and detailed modeling issues as well as suitable algorithms. Moreover, we will present several case studies, including results and experiences reported by home care organizations based on long-term follow-up. The obtained results show significant improvement potential. The worker productivity can be increased by over 60% compared to current practice and the time available for direct client encounter can be increased up to 75% of the shift length. Compared to other elderly care models, the results show that optimized home care is up to twenty times cheaper, even in case of frequent visits and distant patient locations.

Keywords: home care, vehicle routing, heuristics, case study

A simple but effective LNS for the 2-Echelon VRP

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The 2-Echelon Vehicle Routing Problem (2EVRP) originates from ancient cities, where large trucks cannot enter the center due to narrow roads. The specific setup may also reduce nuisances of transport in urban areas. On the first level trucks deliver goods to intermediate facilities, which are often located in the outskirts of the city. From there smaller vehicles deliver the goods to the customers in the city, forming the second ecehlon.

We implemented an efficient and simple Large Neighbourhood Search for the problem and compare the results with existing literature. We also show the advantages and disandvantages of a hybrid approach, i.e. combining the meta-heuristic with an exact solver. Furthermore we show some reasonable extensions to the problem. Slight changes in the way of cost calculation as it is used in literature so far could help to make the problem more realistic. We also explore implications for the use of electric vehicles on the second level.

References: V.C. Hemmelmayr, J.-F. Cordeau and T.G. Crainic, An adaptive large neighborhood search heuristic for Two-Echelon Vehicle Routing Problems arising in city logistics, Computers & Operations Research, Volume 39, Issue 12, December 2012, Pages 3215-3228, ISSN 0305-0548, http://dx.doi.org/10.1016/j.cor.2012.04.007

Keywords: metaheuristic, large neighbourhood search, green vehicle routing, 2-echelon VRP

MINIMAX SCHOOL BUS PROBLEM

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We consider the following problem of class SBRP (School Bus Routing Problem). Let we know the following. For each of the N stops it is known the number of students that must be delivered to this stop. 0-th stop is the school. For each of the K buses it is known the number of seats. There exist roads between some pairs of stops with travel time Aij (from i-th stop to j-th). Corresponding graph is strongly connected. Using the matrix A we define the matrix C of order N+1 with elements – the minimum travel times between stops. It is necessary to find the number of students, which should be delivered by the k-th bus to the n-th stop and to form routes in such manner that the maximum student's delivery time was minimal. By the introduction of additional variables, the problem is reduced to a partially integer linear form with a number of variables and constraints O(N2K). We use a complex goal function, which allows to provide the forming of relevant routes and reduce the number of constraints. We consider (together with the main problem) the relaxed problem where the main variables are not integer. We transform its solution to an integer by applying a simple procedure (with complexity O(N2)) based on multigraphs of some special kind. We constructed a simple heuristic algorithm of Clarke and Wright type too. Were organized numerical experiments using CPLEX for the original and relaxed problems and specially designed program for the heuristic algorithm. During the experiment the solution of the relaxed problem was always integer. The research supported by Russian Foundation for Basic Research (project 13-01-00005).

Keywords: optimization, transportation, school bus problem

The Time-dependent Quickest Path Problem: Properties and Bounds

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The fast computation of point-to-point quickest paths on very large time-dependent road networks (TD-QPP) will allow next-generation web-based travel information services to take into account both congestion patterns and real-time traffic information.

The contribution of this paper is threefold. Firstly, we prove that under special conditions the TD-QPP can be solved as a static quickest path problem (QPP), with suitable-defined (constant) travel times.

Secondly, we show that, if the special conditions do not hold, the QPP optimal solution provides a heuristic solution for the original TD-QPP with a worst-case guarantee.

Thirdly, we develop a lower bound on the time-to-target which is both accurate and fast to compute. We show the potential of this bound by embedding it into an unidirectional A* (A star) algorithm which is tested on large metropolitan graphs. Computational results show that the new lower bound allows to achieve reduced computing times with respect to the Euclidean lower bound.

Keywords: Time-Dependent, Quickest Path, New lower Bound, Properties, Bounds

A hybrid evolutionary algorithm for the biobjective capacitated m-ring star problem

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The capacitated m-ring star problem consists of finding a set of m simple cycles (rings) starting and ending at a central depot so that each node of the network is either in a ring or allocated to another node or to some Steiner point present in a ring. The rings must be node-disjoint (except for the central depot) and the total number of nodes assigned to a ring (in the ring or allocated to a node in the ring) is limited by the capacity of the ring. The goal is to minimize the total cost which is the sum of the ring cost (due to the links of the rings) and the allocation cost (due to the connections to nodes in the rings). This work addresses the biobjective capacitated m-ring star problem in which the ring cost and the allocation cost are considered individually. In order to approximate the set of nondominated outcome vectors or Pareto front, we propose a hybrid evolutionary algorithm. Chromosomes provide the nodes in the rings. From them, feasible solutions of the problem are constructed by using heuristics. Two variants of the method are proposed based on IBEA and NSGA-II and their performance is compared.

Keywords: ring star, biobjective, evolutionary algorithm

An Adaptive Large Neighborhood Search Approach for Solving the Electric Vehicle Routing Problem with Time Windows

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The Electric Vehicle Routing Problem with Time Windows (EVRPTW) is an extension to the well-known Vehicle Routing Problem with Time Windows (VRPTW). Different from VRPTW, the fleet in EVRPTW consists of electric vehicles which have a limited driving range due to their battery charge capacities. Since the battery charge level decreases proportional to the distance traveled an electrical vehicle may need to visit recharging stations to have its battery recharged in order to be able to continue servicing the customers along its route. The recharging may take place at any battery level. In this study, we propose an Adaptive Large Neighborhood Search (ALNS) approach to solve this challenging problem. ALNS is based on a destroy-and-repair framework where the current feasible solution is destroyed by removing some customers from their routes and then repaired by inserting them to the solution in an intelligent way. Several removal and insertion algorithms are utilized by selecting them dynamically and adaptively based on their past performances. Our approach combines the removal and insertion mechanisms from the literature with some new mechanisms specific to EVRPTW. Our computational results show that the proposed method is effective in finding good solutions fast.

Keywords: Vehicle routing, Electrical vehicles, Large neighborhood search

An Iterated Local Search for the Multi Commodity Multi Trip Vehicle Routing Problem with Time Windows

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ps during the working day in order to serve a set of customers that requires different commodities. In particular, commodities are incompatible, i.e., they cannot be transported together into the same vehicle. On the other side, vehicles can transport different commodities in different trips. The objective is to minimize the fleet size first and the routing cost second. The problem has been introduced by Battarra et al. (2009) and arises in the distribution of goods to supermarkets. We propose an Iterated Local search (ILS) for the problem. The ILS manages permutations of customers (giant-tours) that are turned into solution by means of a split-procedure (Prins, 2004). Results outperform those obtained by Battarra et al. (2009).

We run our ILS on the well-known Solomon's and Gehring and Homberger's instances designed for the VRPTW. The goal is to analyze the benefits of letting vehicles to perform multiple trips during the working day in fleet sizing problem. Results show that, in some cases, the fleet can be halved.

Keywords: Iterated local search, Multi trip, Incompatible commodities

On Solving the Swap Body Vehicle Routing Problem

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We present the Swap Body Vehicle Routing Problem (SBVRP), and provide a heuristic solver implementation for which we provide computational results. The problem is similar to the Truck-and-Trailer Vehicle Routing Problem (TTVRP) in that certain customers may only be served by smaller vehicles, (trucks), which may be formed mid-route from larger vehicles (truck-and-trailers) which have a higher carrying capacity. The major additional complications that the SBVRP introduces over the TTVRP are a multifaceted objective function that attempts to model both variable costs (e.g. driver cost, cost of gas, etc.) as well as fixed costs (e.g. vehicle rental / purchase), and constraints on the locations where vehicles may (de)couple. This submission is made as participants of the VeRoLog 2014 Challenge.

Keywords: Swap Body, SBVRP, VRP, Heuristic, Vehicle, Routing

The minimum complete cycle problem

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A complete cycle in a directed graph is a cyclic path that visits each node at least, but not necessarily exactly, once. Given a directed graph and length of its arcs, the minimum directed complete cycle problem (MDCCP) is to find a complete cycle of minimal length. The MDCCP can be easily reduced to the TSP by creating a graph with arcs of length equal to the shortest path between each pair of nodes. However, this reduction may be involved in increasing the dimension of the problem substantially. In this talk we present an integer programming formulation, in the arcs space of the graph, for the MDCCP and a branch and cut algorithm to solve it. We demonstrate numerically that for sparse graphs, constructed based on real road networks, this algorithm outperforms the approach of reducing the problem to the TSP and solving it with a standard branch and cut algorithms. In addition, we propose a successful math-heuristic for the TSP that is based on a solution of (a much smaller) MDCCP. Finally, we discuss the applicability of this new modeling approach to richer vehicle routing problems.

Keywords: TSP, Integer Programming, Math-Heuristics

A Hybrid Metaheuristic for the Pickup and Delivery Problem with Time Windows and LIFO Loading

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We address the pickup and delivery problem with time windows and last-in-first-out (LIFO) loading (PDPTWL). LIFO loading ensures that no handling is required while unloading objects from the vehicle: objects are loaded according to a linear stack structure and an object can only be delivered if it is on top of the stack. To solve large instances of this problem, we propose a population-based metaheuristic. First, a set of initial solutions are generated with a GRASP. The evaluation cost for each request is based on a savings criterion. For each of these solutions, local search is applied in order to first decrease the total number of vehicles and then the total traveled distance. Two parents are selected and an offspring is created with a crossover operator. We have adapted the order crossover based on the giant tour representation of Prins (2004). Local search is then performed on the child solution. Finally, the child is added to the population and the best survivors are kept. The population is managed so as to maintain good quality solutions with respect to the total cost and to population diversity. Computational results on medium to large-sized instances will be presented.

Keywords: vehicle routing with pickup and delivery, last-in-first-out loading, population-based metaheuristic

A heuristic approach to the Swap-Body Vehicle Routing Problem

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The Swap-Body Vehicle Routing Problem (SB-VRP) is a generalization of the classical Vehicle Routing Problem (VRP), in which customers are served by vehicles that may be enlarged with an additional swap body (trailer). The inclusion of a swap body increases the vehicle cost while doubling its capacity. However, not every customer can be served by a vehicles consisting of more than one body. Therefore, swap locations are present, where one of the bodies can be temporary parked to allow customers to be served by a single body. Both travel time and distance induce a certain cost which should be minimized. The number of customers that can be visited by a single vehicle is limited both by its capacity and by a maximum travel time. To approach the problem, we developed a local search algorithm with several heuristic components and a learning scheme. A specialized data structure and a pre-processing procedure reduce the solution space allowing the heuristics to efficiently explore it. We tuned the parameters of the algorithm using the iRace package on the instances provided by the Verolog Challenge 2014.

Keywords: VRP, swap body, data structures, heuristics, optimization

Classification, models and exact algorithms for multi-compartment delivery problems

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The distribution of products using compartmentalized vehicles involves many decisions such as the allocation of products to vehicle compartments, vehicle routing and inventory control. These decisions often span several periods, yielding a difficult optimization problem. We define and compare four main categories of the Multi-Compartment Delivery Problem (MCDP). We propose two mixed-integer linear programming formulations for each case, as well as specialized models for particular versions of the problem. Known and new valid inequalities are introduced in all models. We then describe a branch-and-cut algorithm applicable to all variants of the MCDP. In the fuel distribution problem, which is the central application of our problem, vehicles are often not equipped with debit meters (sometimes called flow meters), which implies that whenever a delivery is made, the full content of the compartment must be emptied. In other words, the load of a compartment cannot be split between different tanks. However, technology to equip vehicles with debit meters is readily available. From a modeling point of view, this means that the quantity delivered to tanks then becomes a continuous decision variable. The ability to split the content of a compartment between several deliveries yields a first classification of the problem. Likewise, a customer may or may not allow different vehicles to fill the same tank in a given period. If a tank may receive deliveries from different vehicles, it is said to be split. This distinction yields the second class of classification of the problem. Split compartments and split tanks yield an extra layer of difficulty to the problem. Even the single-period version of the problem is much more complicated than the classical vehicle routing problem because it still contains several products, several compartments and multiple tanks, which significantly increases the number of binary variables in the model.

We develop mathematical programming formulations which are adapted to handle all four combinations of split and unsplit compartments and tanks. We also propose an exact branch-and-cut algorithm applicable to all variants of the problem. We have performed extensive computational experiments on single-period and multi-period cases of the problem. The largest instances that could be solved exactly for these two cases contain 50 and 20 customers, respectively.

Keywords: Classification, Models, Exact algorithms, Multi-compartment delivery problems

Non-overlapping routes for the mixed capacitated arc routing problem

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Real world applications for collecting or delivering products along streets usually lead to arc routing problems with additional and complicating requirements. Among them there is the undesirable overlapping of the routes of different vehicles while performing their services. In this work we focus on the mixed capacitated arc routing problem (MCARP) with a limited number of intersections of the routes as a way to avoid the overlapping. Then, we define the bounded overlapping MCARP (BCARP), which results from the MCARP by adding a constraint ensuring an upper bound on the number of nodes shared by different routes. We also introduce a new model to compute the best feasible value for this upper bound. Mixed integer linear programming formulations are presented for the BCARP, and a heuristic is proposed to obtain feasible solutions for the bigger instances. Computational results are reported for well-known benchmark instances. The BCARP seems more suitable for real applications. In fact, the results show that better shaped service routes are obtained (more compact and with fewer intersections), with a small increase in total traveled time, when compared to the MCARP.

Keywords: capacitated arc routing problems, district design, integer linear programming, heuristics

A heuristic approach to the multiple-product inventory-routing problem

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We focus on an integrated logistics planning problem arising in systems where multiple products are resupplied to a set of customers from a common vendor and deterministic demands occur at the customers. In every period of a finite planning horizon, the vendor must decide how much to deliver and how to sequence customers in vehicle routes. In order to tackle the problem, we decompose the decision process into planning and routing subprocesses, and integrate the two parts with the help of a mathematical programming model. Specifically, heuristic methods are used to define replenishment plans and construct vehicle routes in separate phases. Finally, planning and routing decisions are incorporated into a mixed-integer linear programming formulation aimed at finding a good solution to the integrated problem. We demonstrate the effectiveness of the solution approach through an extensive computational study.

Keywords: Inventory-routing, Heuristic approach, Mixed-integer linear programming

Meta-heuristics for residential waste collection problems

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This paper addresses a residential waste collection problem, as a real world application of the sectoring arc routing problem. The aim is to assign the street services to the different vehicles, and then to determine the set of trips to be performed by each single vehicle such that all the required streets are serviced within a minimum objective. Three objectives are taken into account: the total traveled time, the workload balance among the sectors, and the connectivity of each sector. The proposed solution methods were designed in order to favor the concentration of each vehicle service area in a geographical region.

A constructive heuristic and meta-heuristics are presented. Preliminary computational results with both a set of benchmark and a set of real world based instances are performed.

The results show that the constructive heuristic is very fast but tends to produce imbalanced sectors concerning the traveled time. They also highlight the importance of considering the aforementioned criteria simultaneously on the evaluation of the solutions during the search process: if only one criteria is considered then the quality of the solution increases for the criteria that is being considered but decreases, in some cases largely, for the other two criteria.

Keywords: Capacitated Arc Routing problems, Sector Design, Meta-heuristics

A branch-and-price algorithm for 2-period vehicle routing problems

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We consider a 2-period vehicle routing problem (VRP) where deterministic demands in two periods exist for each customer. Each demand can be postponed or advanced but a penalty is imposed for any diversion from the initial demands. Despite the penalties, such diversions from the initial demands could still be beneficial if saving in the routing costs outweigh the penalties. In this paper, we introduce a new model where we seek a better solution, compared to solving two independent VRPs with fixed demands, by allowing demands to be fully postponed or advanced. We apply a branch-and-price algorithm to solve this model to exact optimality. Algorithmically, besides the state-of-the-art tricks and acceleration techniques, we investigate two new ideas in the branching tree in order to potentially improve the upper bound during the branching process; likely integer solutions and solving an IP in the end of column generation in each node. Our experimental results shows that the first idea is not efficient but the second idea leads to a very good upper bound in the root node. In managerial terms, the results demonstrate that we can decrease the routing costs by %30 when demands are allowed to be advanced and postponed.

Keywords: branch-and-price, column generation, inventory routing, multi-period vehicle routing

A framework for vehicle routing: an application for the swap-body vehicle routing problem

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We consider the capacitated vehicle routing problem (VRP) and various modifications of this problem. We suggest a general framework which is flexible enough to be used for many modifications of the VRP. The main idea behind the framework is based on the well-known Held & Karp dynamic programming algorithm for the travelling salesman problem.

In this talk we report the details of application of this approach to Swap-Body Vehicle Routing Problem.

Keywords: vehicle routing, swap-body, framework, dynamic programming

Robust planning of transportation systems

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In many transportation systems schedules are made before demand is realized. This has several advantages for its customers as they can plan their trip well before and by consolidating demand prices can be kept low. For the carrier it also means that capacity can be optimized. Creating fixed schedules further allows a coordination with other bottlenecks in the transportation system, such as berths at a container terminal, platforms at stations and gates at airports. Yet demand may vary and transportation times may be subject to all kind of disturbances, so the question is how robust are these schedules and what can be done to make them more robust. In principle there are two ways to tackle this problem. First of all, one can insert buffer time or slack in the schedule and secondly, one can apply all kind of recovery actions, like speeding up or cutting stops in order to compensate delays. We will first review approaches for the recovery actions, e.g. optimizing ship speeds in a given schedule. Approaches to the buffer time optimization are more complex as increasing buffer time implies a loss of capacity and this may even lead to higher occupation of the infrastructure. E.g. increasing buffer times may lead to a longer stationing of trains at stations, thereby creating more bottlenecks. We will present models for the optimal distribution of buffer time, both for railways, shipping lines and vehicles. Finally we consider the integrated model of determining both buffer time and recovery actions. This combines a tactical and operational problem in one. Apart from presenting and analyzing the model we will also consider practical cases and pay attention to the problem of obtaining input data for the problems as well as the practical value of the models.

Keywords: Robust, Planning, Transportation systems

An Adaptive Iterated Local Search for the Mixed Capacitated General Routing Problem

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We study the Mixed Capacitated General Routing Problem (MCGRP) in which a fleet of capacitated vehicles has to serve a set of requests by traversing a mixed weighted graph. The requests may be located on nodes, edges, and arcs. The problem has theoretical interest because it is a generalization of the Capacitated Vehicle Routing Problem (CVRP), the Capacitated Arc Routing Problem (CARP), and the General Routing Problem (GRP). It is also of great practical interest since it is often a more accurate model for real world cases than its widely studied specializations, particularly for so-called street routing applications. Examples are urban-waste collection, snow removal, and newspaper delivery. We propose a new Iterated Local Search metaheuristic for the problem that also includes vital mechanisms from Adaptive Large Neighborhood Search combined with further intensification through local search. The method utilizes selected, tailored, and novel local search and large neighborhood search operators, as well as a new local search strategy. Computational experiments show that the proposed metaheuristic is highly effective on five published benchmarks for the MCGRP. The metaheuristic yields excellent results also on seven standard CARP datasets, and good results on four well-known CVRP benchmarks.

Keywords: Vehicle Routing, Arc Routing, Mixed Capacitated General Routing Problem, Node Edge and Arc Routing Problem, Metaheuristics

An iterated greedy algorithm for the Bike-sharing Rebalancing Problem

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We present an iterated greedy algorithm to solve the Bike-sharing Rebalancing Problem (BPR)and the one-commodity Pickup and Delivery Vehicle Routing Problem (1-PDVRP). The BRP is a particular case of the class of many-to-many pickup and delivery problems that arises when redistributing bicycles among stations in bike-sharing systems. The 1-PDVRP is a similar problem where a maximum duration constraint for the routes is also considered.

In our work we rstly adapted a formerly developed branch-and-cut algorithm for the BRP to solve the 1-PDVRP, presenting new valid inequalities and separation procedures. Secondly we developed an iterated greedy algorithm to solve both problems. We considered eight constructive heuristics, 15 destruction procedures, three construction procedures, and 13 local searches making use of an ecient evaluating strategy. These procedures and specic policies to combine them have been assessed. We evaluated the possible congurations and the parameter setting by using the automatic algorithm conguration program irace.

Preliminary tests on literature instances and on newly collected real and large ones show very good results.

Keywords: Iterated greedy, Bike-sharing, Pickup and Delivery

A methodological framework to optimize and compare VRP algorithms

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Vehicle Routing Problems (VRP) are an extensively studied class of combinatorial optimization problems, with a wide spectrum of real-life applications. An impressive number of heuristic procedures have been proposed for VRP problems. However, no common, agreed-upon methodology is used to compare heuristic performance on vehicle routing problems. In VRP literature, (meta-)heuristics are rarely compared by means of statistical techniques. In this paper a methodological framework is proposed to optimize and compare heuristic algorithms. The optimization of algorithms relates both to setting the optimal algorithmic parameter values and testing the effects of various components of an algorithm. The methodological framework is demonstrated by analyzing the performance of the ALNS algorithm (Pisinger and Ropke, 2007) for the vehicle routing problem with time windows. Based on a thorough and reliable understanding of the relationship between algorithm performance, problem characteristics and algorithm properties, one can determine the optimal parameter setting and construct rules stating which heuristic elements should be activated for a particular instance. Alternatively, the statistical insight also provides robust parameter and algorithmic components settings, resulting in an optimized algorithm independent of the specific environment and variability in the data, because it is designed to handle a general situation.

Keywords: optimization of algorithms, added value of heuristic components, parameter setting, statistical methodology

The Hybrid Electric Vehicle - Vehicle Routing Problem

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Although, the market for parcel deliveries to end customers is growing, the situation for small package shippers is quite competitive. Distinguishing features beside cost efficiency are essential for the prosperousness of a company.

The use of hybrid electric vehicles for last mile deliveries is able to address both aspects. On one hand the increasing customer request for more ecological services is satisfied and on the other hand the fuel consumption and therefore, the variable costs for diesel are reduced.

We introduce a new optimization problem that extends the well-known Capacitated Vehicle Routing Problem to the use of hybrid electric vehicles for the delivery tours. We consider vehicles with a combustion engine and an electric motor providing four different modes of operation: Pure combustion, pure electric, charging the battery while driving in combustion mode and a boost mode using the combustion and electric drive combined.

Moreover, we present a linear problem formulation of the problem and highlight some first numerical results for small test instances obtained with the IBM ILOG CPLEX Optimization Studio.

Keywords: Electric Vehicle Routing, Hybrid Electric Vehicles, Vehicle Routing Problem

Collection of Recyclable Materials with Unknown Filling Rate

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We consider an approach for scheduling the multi-period collection of recyclable materials. Citizens can deposit glass and paper for reuse in cubes located at several collection points. To establish a high service level for the citizens, the cubes must not be over-filled. A vehicle carrying two containers is used to empty the cubes. Glass and paper are therefore collected jointly, but must be handled separately, due to different procedures for reuse of the materials. This problem can be categorized as a multi-period Vehicle Routing Problem (VRP) with two commodities and inventory constraints. However, the solution methods for these problems cannot tackle multi-period routing problems with combined collection in multi-compartment vehicles. We examine how scheduling of emptying cubes and related transportation to final destinations should be done in order to minimize the transportations cost while ensuring that the cubes are not over-filled and capacity constraints of the containers on the vehicle are not exceeded. We apply a construction heuristic once and reoptimize the solution every subsequent period. We investigate if an inclusion of a future cost in the objective function could lead to better planning and minimization in the total cost.

Keywords: multi-period routing, inventory routing problem, stochastic demand, multi-compartment vehicle

Vehicle routing problems with multiple trips: using specific local search operators

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In vehicle routing problems with multiple trips (VRPM), each vehicle is allowed to perform more than one trip during its working period. Classical solution techniques for this problem make use of existing VRP heuristics to create trips, together with bin packing methods aimed at assigning these trips to the available vehicles. The first contribution of this work is to propose specific local search operators for the VRPM. The operators directly integrate the multi-trip structure of the problem within well-known VRP operators. As a second contribution, heuristics using these operators are compared with classical solution techniques mentioned above. The comparison is performed by using the adaptive large neighborhood search metaheuristic as a common basis for both methods. The most classical version of the problem is studied as well as a variant involving time windows.

Keywords: VRPM, MTVRP, Multiple Trips

A model for a multi-size Hinterland Container Transportation Problem

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About 40% of container flows in Seaport Hinterland are caused by repositioning empty containers. That is why research on Hinterland Container Transportation (HCT) is steadily increasing. There are several papers in literature for HCT considering and solving more or less simultaneously the combined problem of routing containers and trucks. Most of the existing models and solution approaches for HCT are restricted to the transportation of 40-foot containers with each truck moving at most one container. In our presentation we extend the commonly considered HCT problem to the multi-size HCT (m-HCT) problem by introducing two kinds of commodities, namely 20-foot and 40-foot containers, with each truck being able to transport up to two 20-foot containers or one 40-foot container. By this extension, the problem turns from a full truckload to a less-than truckload problem, while the complexity of the problem increases a lot. Some papers can be found in literature dealing with simplifications of the m-HCT problem. We consider a graph representation and a mathematical formulation for the full m-HCT problem and present the results of computational experiments on small randomly generated instances.

Keywords: Hinterland, Multi-size Container Transportation, Pickup and delivery

Exact and Heuristic Solutions of the Carrier-Vehicle Travelling Salesman Problem

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Carrier-vehicle systems generally consist of a slow carrier vehicle (e.g., a ship) with a long operating autonomy and a faster vehicle (e.g., an aircraft) with a limitated operative range. The carrier has the property of transporting the faster vehicle and of deploying, recovering and servicing it.

The goal of the Carrier-Vehicle Travelling Salesman Problem (CV-TSP) is to make the faster vehicle visit a given collection of points in the shortest time while using the carrier vehicle as a base for possible multiple tours. As a consequence, carrier and vechile tours should be synchronized (see [1]). The present work focuses on the case in which the visiting sequence of the targets is not a priori given. Related problems on Carrier-Vehicle problems may be found in [2].

We present a new exact formulation for CV-TSP that is also used as a starting point for the heuristic solution of this problem. Computational results are shown for the resolution with the BONMIN and MOSEK solvers.

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Keywords: travelling salesman problem, carrier-vehicle system, exact formulation, heuristic algorithms, vehicle routing

An Iterated Variable Neighborhood Search Approach for the VeRoLog Solver Challenge 2014

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The talk presents our contribution to the VeRoLog Solver Challenge 2014, which introduced a variant of the Capacitated Vehicle Routing Problem, namely the Swap-Body Vehicle Routing Problem (SB-VRP). Our solution approach is based on the principles of Iterated Local Search and Variable Neighborhood Search. In detail, a set of neighborhoods is used to search for good routes of trucks and truck-trailer-combinations (so-called “trains”). It is worth mentioning that the implemented neighborhoods are rather generic/ general, and not adapted to the particular SB-VRP-problem variant (and thus hopefully applicable to a range of similar problems). However, with respect to the specific problem characteristics of the SB-VRP, a compact route-representation is introduced for the routes driven by trains. Computational experiments show that this representation allows the fast investigation of local search moves, and thus contributes to the effectiveness of the solution approach. A partial de- and re-construction heuristic is used to escape local optima. Extensive tests have been carried out, studying the effects of several parameter settings of our approach. This also includes algorithmic variants such as different neighborhood-operator-sequences.

Keywords: Swap-body vehicle routing problem, variable neighborhood search, iterated local search

Scheduling of Intelligent and Autonomous Vehicles under pairing/unpairing collaboration strategy in container terminal: Exact Approaches

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The container shipping volume is daily experiencing a permanent growth. Ports' competitiveness is essentially dependent on their ability to minimize the turnaround time of vessels while maximizing the port throughput. In this way, they can compete with other neighboring ports and survive in such a highly competitive market. Because of the dynamism and scale of competition, the goal is not reached unless some strategic, tactical and operational aspects of terminals are being constantly reviewed and addressed in better ways. This includes three main aspects: the layout and equipment, the routing decisions and the scheduling of machines and resource allocation. Along with the enhancements in Information and Communication Technologies, the concept of automated and semi-automated infrastructures emerged and the port authorities started to gradually incorporate tools to improve their efficiencies. Intelligent and Autonomous Vehicles (IAVs) are technologically superior to the existing Automated Guided Vehicles, in many respects. They offer more flexibility and intelligence in maneuvering within confined spaces where the logistic operations take place. This includes the ability of pairing/unpairing enabling a pair of 1-TEU (20-foot Equivalent Unit) IAVs dynamically to join, transport containers of any size between 1-TEU and 1-FFE (40-foot Equivalent) and disjoin again. Optimizing the routing decisions and the scheduling of IAVs open a way to new and challenging studies in the Combinatorial Optimization area. The poor results offered by the existing models require the application of new solution methods to find optimal solutions of medium size instances within an acceptable time limit. In this context, this project aims a deeper study an the proposal of new solution techniques to this new and challenging problem. We propose in this work a solution method based on a double decomposition of a new model describing the optimization problem underlying the scheduling of IAVs. This double decomposition consist of a combination of a Benders' decomposition that takes advantage of column generation approach for solving its subproblem. The Benders' decomposition will give a branch and cut algorithm, which is combined with a column generation stage during the resolution of the subproblem.

Keywords: Intelligent Autonomous Vehicle, Automated guided vehicle, Benders' decomposition, Dantzig Wolfe's decomposition

An adaptive large neighborhood search algorithm for the pickup and delivery problem with fixed scheduled line services

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Integrating passenger and freight flows creates attractive business opportunities because the same transportation needs can be met with fewer vehicles and emissions. This research seeks an integrated solution for these two transportation flows, so that fewer vehicles are required in the execution of the transportation activities. We introduce the pickup and delivery problem with fixed scheduled line services (PDP-FSL), which concerns scheduling a set of vehicles to serve a set of freight requests, subject to a set of service level constraints, such that a part of the journey can be carried out on a fixed scheduled passenger transportation service.

We propose an adaptive large neighborhood search (ALNS) heuristic for the PDP-FSL. ALNS explores the solution space by repeatedly applying destroy-and-repair principle using several neighborhood operators. The enhanced ALNS uses new, as well as existing removal and insertion operators, which improve the solution quality. Computational results on a set of realistic instances provide a clear understanding on the benefits of integrating passenger and freight transportation in the current networks, considering multi-modality of traditional passenger-oriented transportation modes, such as bus, train or tram.

Keywords: Transportation, Integrated transport networks, Routing and scheuduling, Heuristics

Eco-friendly Vehicle Routing via Balanced and Compact Clustering

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We investigate the vehicle routing problem with time windows (VRPTW) under a new approach, consisting of three major phases:

(i) A first clustering of customers with compatible time windows, by computing strongly connected components on a suitably define graph;

(ii) A second clustering of customers with close geographic proximity based on various methods (natural cuts, KaHIP, quad trees);

(iii) A refinement phase that either splits a cluster into smaller ones, or merges clusters to form a bigger cluster. A merge operation takes place if clusters from the first phase have compatible time windows and are geographically close, thus forming compact clusters. A split operation takes place if a cluster created from the first phase has customers that are geographically far away, thus forming more balanced clusters.

Our approach turns out to be beneficial when used in an on-line environment, where changes to the initial tour are requested (adding a new customer to the tour or dropping some customers). The new method serves as a warm starting point for re-evaluating and further optimizing the solution of VRPTW. Experiments with real data sets demonstrate that our approach compares favorably with standard approaches that start from a basic (cold) solution.

Keywords: Innovative heuristic solutions, Planning tools and tool-based environments, Compact and balanced route planning

Modeling and Solving the One-to-One Multi-Commodity Pickup and Delivery Traveling Salesman Problem

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Abstract: We address the one-to-one multi-commodity pickup and delivery traveling salesman problem (m-PDTSP) which is a generalization of the TSP and arises in several transportation and logistics applications. The objective is to find a minimum-cost directed Hamiltonian path which starts and ends at given depot nodes, the demand of each given commodity is transported from the associated source to its destination, and the vehicle capacity is never exceeded.

In contrast, the many-to-many one-commodity pickup and delivery traveling salesman problem (1-PDTSP), just considers a single commodity and each node can be a source or target for units of this commodity. We show that the m-PDTSP is equivalent to the 1-PDTSP with additional precedence constraints defined by the source-destination pairs for each commodity and explore several models based on this equivalence. In particular, we consider a formulation based on a 3-dimensional layered graph that combines time and load together and achieves tight LP bounds, at the cost of a large model size.

Especially for tightly capacitated instances with a large number of commodities our branch-and-cut algorithms outperform the existing approaches. For the uncapacitated m-PDTSP (sequential ordering problem) we are able to solve to optimality several open instances from the TSPLIB.

Keywords: traveling salesman problem, pickup and delivery problem, precedence constraints, sequential ordering problem, mixed integer linear programming, branch-and-cut algorithm

An adaptive large neighborhood search for the Two-Echelon Multi-Trip Vehicle Routing Problem with Satellite Synchronization

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Urban freight transportation is known as one of the major challenge in logistics. Because of increasing traffic congestion, environmental issues and new regulations, direct shipping strategies are dropped in favor of two-tiered distribution systems. In such system a fleet of large vehicles leave an urban distribution center to visit satellites via major roads (first echelon). At such location, goods are transferred to smaller and “green” vehicles, which will drive the remaining kilometers to deliver orders (second echelon).

Several algorithms, both exact methods and heuristics, have been proposed for a simpler model of such distribution strategy: 2E-VRP (Two Echelon Vehicle Routing Problem). We propose a model closer to real-life by incorporating time windows constraints, synchronization constraints at satellites and multiple trips for the second level vehicles : the Two-Echelon Multi-Trip Vehicle Routing Problem with Satellite Synchronization (2E-MTVRPSS). We have developed an Adaptive Large Neighborhood Search to solve the problem. It features custom ruin and recreate heuristics, as well as an efficient scheduling algorithm that ensures synchronization at satellites.

Keywords: City Logistics, transfers, synchronization, adaptive large neighborhood search

A full truckload routing and scheduling problem with split delivery and resource synchronization

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We present a two-phase method to solve a routing and scheduling problem that arises in public works. In this problem, the quantity of demands generally exceeds the capacity of a truck. As a result, demands have to be split into full truckloads, taking account of the various capacities in the heterogeneous fleet of vehicles that perform the transportation. Full truckload routes have to be designed and scheduled according to construction or loading constraints on pickup and delivery sites. In the first phase, we propose a linear program to split demands into full truckload requests. The second phase is a heuristic that solves a heterogeneous full truckload pickup and delivery problem with time windows and resource synchronization. The method is evaluated on instances from a real case study.

Keywords: Vehicle routing, synchronization, full truckload

Departure Time Optimization in Vehicle Routing

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Optimizing departure times in vehicle routes is a crucial step in developing good vehicle route schedules. In practice, restrictions such as time-dependency resulting from traffic congestion, driving and working time legislation, and multiple time windows make departure time optimization a challenging scheduling problem. On top of that, vehicle routes are often interdependent, due to, e.g., trailer swaps between truck/driver combinations. This increases the complexity of the problem, since optimizing the departure time of a single route may disrupt the schedules of dependent routes. In this talk, we illustrate these challenges through several examples from practice. An important observation hereby is that departure time optimization is not only done to reduce costs by better utilization of resources, but is also required to find feasible schedules with respect to driving and working time legislation. Finally, practice does not allow complete freedom in planning waiting times or breaks in vehicle route schedules whenever it improves the overall cost. For example, planning early breaks to consume some inevitable waiting time is only accepted in practice if a reasonable amount of time has passed since the previous break. These limitations should also be considered in solution methods for the departure time optimization problem.

Keywords: Vehicle Routing, Departure Times, Route Scheduling, Synchronization

An Integrated Inventory-Transportation System with Periodic Pick-Ups and Leveled Replenishment

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In this paper we develop a combined inventory-transportation system. The general idea is to integrate a simple replenishment policy with a routing component to derive operationally consistent standard routes as a basis for milk run design. The most interesting feature of the approach is that we combine stochastic vehicle routing with a replenishment policy which makes use of inventory to level the variability propagated into transportation operations. To evaluate the approach, we compare its performance with stochastic vehicle routing as well as sequential vehicle routing and replenishment planning. With respect to these approaches, substantial gains are achieved.

Keywords: inventory routing, milk run design, inbound logistics

Kernel search for capacitated facility location problems

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Capacitated Facility Location Problems (CFLPs) can be broadly classified into two classes. In the Single Source CFLP each customer has to be assigned to one facility that supplies its whole demand. Conversely, in the Multi Source CFLP each customer demand may be supplied by one or more facilities. In both versions, the total demand supplied by each facility cannot exceed its capacity. An opening cost is associated with each facility and is paid if at least one customer is supplied from it. The objective is to minimize the total cost of opening the facilities and supplying all the customers. Both problems are NP-hard.

In this talk, we present a Kernel Search heuristic for the solution of CFLPs. The heuristic is based on the solution to optimality of a sequence of subproblems, where each subproblem is restricted to a subset of the decision variables. Computational results demonstrate the effectiveness of the approach. It found the optimal solution for almost all the instances with a proven optimum. Several best known solutions have been improved for those instances whose optimal solution is still unknown. Variants of the general framework based on variable fixing are proposed aiming at improving the efficiency of the algorithm.

Keywords: Capacitated Facility Location Problems, Heuristic Algorithm, Kernel Search Framework

A bi-objective mixed capacitated general routing problem

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The mixed capacitated general routing problem (MCGRP) is a generalization of the vehicle routing problem and the capacitated arc routing problem. It is defined on a mixed graph with required nodes, edges and arcs. The problem then consists of finding a set of vehicle routes over the mixed graph such that each route starts and ends at the depot with each required node, edge and arc serviced by exactly one vehicle. The total demand serviced by each vehicle cannot exceed the vehicle capacity and the objective is to minimize the total travel cost. Typical applications are waste collection and newspaper distributions where arcs/edges represent housing streets and nodes larger facilities like apartment buildings, schools and commercial buildings.

We study a bi-objective MCGRP where we in addition to minimize travel cost also want the routes traveled by each vehicle to be balanced, i.e. to be of similar length. This is an extension to the MCGRP that is relevant for many real-life applications, e.g. when each vehicle driver should have similar workloads. The objective of balancing routes can be formulated in different ways, and we study the implications of such objectives to the final solutions.

Keywords: Vehicle routing, Mixed graph, Bi-objective

The tactical planning model for rail freight transportation with empty cars movements and periodic inspections: a case study

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With the promotion of the environmental friendly transportation modes, (the European Commission supports the freight transport operations in the rail sector) the increase of demand's diversification for rail freight services is observed. While most rail freight companies tend to apply fixed schedules, meeting the customer's specific requirements causes that this approach is not effective.

The scope of this paper is to present a case study of rail freight planning over a medium term horizon and to discuss the opportunities of improvement this plans by discrete optimization. The problem of routing freight traffic is modeled as a dial-a-ride problem with two additional groups of constraints. In proposed approach the optional transportation requests are considered. Such requests correspond to empty cars movements and are not specified before solution procedure is lunched. Additionally the need of periodic inspections of locomotives are took into consideration. Based on our experience this issue plays very important role in tactical planning process. Despite a thorough review of the literature the presented extensions were not yet considered in this area.

Keywords: rail freight, discrete optimization, dial-a-ride problem

Simultaneous Vehicle Routing and Resource Assignment

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In this talk, we address a problem from practice on simultaneous vehicle routing and resource assignment. The first part of the problem, in which we construct trailer routes, is a capacitated vehicle routing problem with time windows, driving legislation, and congestion. The second part is a resource assignment problem, where trailer routes are assigned to resources, i.e., a truck and driver combinations. To provide greater flexibility and better utilization of resources, we divide trailer routes further into sections and assign the sections to resources. This new challenge that we face in practice, raises dependency issues among sections of the same trailer route that are assigned to different resources. Currently, we have a software product that uses column generation, where complete trailer routes are assigned to resources (columns), but this approach is not applicable with sections, because then the columns are no longer independent. In literature, we see few papers on this problem where limitations are introduced on the sections resulting from the trailer routes phase, to make them independent during the resource assignment phase. However, we need a solution approach that handles the dependencies, because circumventing them diminishes the benefits of planning with sections.

Keywords: Vehicle Routing, Resource Assignment, Trailer Routes, Route Sections, Synchronization

A General Short Sea Inventory-Routing Problem

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In this work a general short sea inventory routing problem is considered. To solve the problem an iterative metaheuristic is proposed based on the idea of converting the inventory-routing problem to a ship routing and scheduling problem. Using inventory limits and production and consumption rates, we generate a set of cargoes with time windows which are be updated based on the information gained during the interaction with an adaptive large neighborhood search which solves the ship routing problem. Computational results will be presented, discussed and compared with exact solutions.

Keywords: Maritime transportation, Inventory management, Metaheuristic

An Exact Approach to the Multi-Compartment Vehicle Routing Problem with Flexible Compartment Sizes

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In this presentation, a multi-compartment vehicle routing problem with flexible compartment sizes is regarded. The problem arises in a variety of real world applications where several product types are considered which have to be kept separated from each other while being transported. Examples include the collection of glass waste, the distribution of petroleum products, and the collection of milk.

For this problem, an exact solution approach based on a mathematical model formulation has been developed and implemented. The approach uses valid inequalities, symmetry-breaking constraints and a separation procedure for adding subtour elimination constraints iteratively. Extensive numerical experiments have been conducted in order to gain insights on the characteristics of the problem and on the performance of the algorithm. The corresponding results will be presented.

Keywords: vehicle routing, multiple compartments, mathematical model, exact algorithm

The Technician Routing Problem with Experience-based Service Times

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The technician routing problem is often seen in the fast-growing home services sector; e.g. revenues in the heating, ventilation, and air conditioning sector are expected to grow at an annual rate of 5.9% over the next five years. We study a technician routing problem wherein operational planning is done on a daily basis, but there are long term impacts to those decisions as today's decisions also impact efficiencies in the future.

Specifically, we present a new model of technician routing, one that includes a descriptive model from the literature on human learning to recognize that the time required for a technician to perform a task depends on his/her experience level. Consequently, our model is multi-period in order to capture the impacts of learning. We assume a planning setting wherein today's customer requests for service are known, but there is uncertainty regarding requests in future days. We present a rolling horizon solution technique that anticipates the impacts of learning on future days when performing daily planning. With an extensive computational study, we demonstrate the value of these anticipation techniques and derive policies to help organizations make daily planning decisions that are beneficial in both the short and long term.

Keywords: technician routing, human learning, stochastic customers

Incorporating preferences of a decision maker in a bi-objective Inventory Routing Problem

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Eliciting preferences of a decision maker (DM) is a key issue to successfully combine search and decision making in an interactive method. Since a human DM is often not available to test an approach, simulating the DM's feedback might be a fruitful idea. We contribute in this direction by proposing an interactive method based on a reference point-based guided local search for the bi-objective Inventory Routing Problem (IRP), a true multi-objective optimization problem on the intersection of Inventory Management and Transportation. In the investigated bi-objective IRP, delivery quantity decisions as well as route planning take place simultaneously. This issue is addressed by proposing delivery periods for each customer that subsequently defines delivery dates throughout a planning horizon. A local search metaheuristic, working on the delivery intervals, and the Clarke & Wright savings heuristic is employed for the subsequently obtained Vehicle Routing Problem. To incorporate preferences, the responses of the decision maker are imitated in order to guide the search towards interesting (sub)regions. Computational results are evaluated by means of experiments for the bi-objective Inventory Routing Problem to show the applicability and the advantages of the approach.

Keywords: Inventory Routing Problem, Interactive approach, Simulation of the decision maker

Rescheduling airside operations of an airport for optimality and stability

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A key challenge in Air Traffic Management (ATM) is to provide a schedule with high throughput on the runways, and at the same time meet objectives connected to taxiing times and punctuality while ensuring safe operations within the apron, taxiway, runway, and terminal manoeuvring area. High throughput is achieved through optimized runway sequences, ensuring a minimum separation between the flights. These sequences must frequently be revised, for example due to uncertainty relating to the completion of ground handling activities. Hence, as updated information become available, the flight scheduling process continues throughout the day. Furthermore, since many of the activities and operations at the airport are prioritized and planned due to the previous schedule, it is important that the rescheduling process does not create too much deviation from one plan to another. We present an approach for rescheduling, where we have modelled the stability requirement in the objective function. Stability is formulated both with respect to departure time and the runway sequence. We look at the costs associated with restricting our new schedule to the previous solution, and provide computational results where we analyse the trade-off between stability and optimality. Data sets from Arlanda were used.

Keywords: Air Traffic Management, Multi-objective optimization, Reactive scheduling, Rescheduling Stability, Minimal perturbation

Decision support for maritime fleet size and mix

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What a fleet should be composed of in terms of size and mix is a core decision for all shipping companies. In any given market situation, the number of vessels and the variety of vessel types will determine the profit potential for the company. Operational optimization in terms of capacity utilization can only be done within the bounds imposed by the available fleet resources. History has shown that being positioned with the right fleet is even more important for profit than operational excellence, and that the most successful companies are those who are able to manage both.

We present an optimization model for improved support for strategic fleet size and mix decision-making. Our research has been performed in close collaboration with a major RoRo (Roll-on Roll-off) shipping company, which has provided us with real case data and tested our methods and tools.

Keywords: Decision support, Vehicle Routing, Fleet Size and Mix, Maritime Transportation

Physics-Inspired Optimization Algorithm for Obtaining Initial Routes of Capacitated Vehicle Routing Problem

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Capacitated vehicle routing problem (CVRP) is NP-Hard and computing exact solutions in real life situations is mostly infeasible. Therefore, heuristic methods are used as an alternative. In heuristic methods the quality of the final solution is directly related with the initial solution space. In this study, artificial physics based optimization algorithm is applied to CVRP in order to obtain the initial population pool of a heuristic method. The A, B and P group 74 test instances of Augerat et al are considered. The group average deviations of the initial solutions from best known solutions is calculated as 37.95%, 32.10% and 31.45% for A, B and P groups respectively. Then, a conventional genetic algorithm (GA) with one point crossover and one point mutation is chosen as a heuristic search algorithm and the initial solutions obtained are used for the first generation of the GA. The GA is executed 1000 generations with crossover and mutation rates as 0.9 and 0.1, respectively. For each problem, GA is executed 10 times and best output is recorded. As a result, 7.15%, 4.37% and 6.33% group average deviations are obtained after heuristic search.

Keywords: Capacitated Vehicle Routing, Heuristic Search, Physics-Inspired Optimization, Artificial-Physics Optimization, Genetic Algorithms

Partial Parking Reservation Policies in One-Way Vehicle Sharing Systems

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In station based one-way metropolitan vehicle sharing systems, users can rent vehicles in one of many unmanned stations scattered in the city and return them after a short ride at any station. Previously, we have studied a Complete-Parking-Reservation (CPR) policy, under which, all users are required to reserve a parking space upon renting a vehicle. If the destination station is full, the transaction is denied. The CPR policy was shown to outperform a base policy, entitled No-Reservation (NR). However, in some cases it might be impossible or inexpedient to require that all users will place parking reservations. In this study, we examine the effect of partially enforcing parking reservations. We propose three types of partial parking reservation policies, each is based on a different concept. The performance of the system under such policies is evaluated. In addition, a bound on the performance under any policy is obtained using an adapted network model. Case studies of real systems demonstrate that implementing partial parking reservations can improve performance, but only slightly relative to the CPR policy. This reinforces the effectiveness of reservations, and in particular of the CPR policy, and suggests that parking space reservations should be practiced, even if only partially.

Keywords: Vehicle Sharing, Bike Sharing, Reservations, Simulation, Network Model

Optimization of Inter-depot Trunking with heterogeneous fleet and Semi-Trailer Swap option

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This paper deals with the point-to-point inter-depot trunking by using heterogeneous fleets located at different depots. The unique feature of this problem are swapping of semi-trailers between different vehicles in order to abide by the distance and driver time constraints; loading of two types of products in adjustable-size compartments at each leg of journey by considering the capacity constraints; and minimizing the overall objective of reduction in number of vehicles used. The problem is presented in detail followed by a linear programming formulation. The solution is tested by using real-life data and results are compared in the end. The results suggest that model can produce better solutions than made by multiple human planners thus reducing the dependence and cost associated with human-planners.

Keywords: Vehicle Routing Problem, multi-depot and multi-fleet, Inter-depot trunking, Trailer Swap, Adjustable size multi-compartment

Modeling fashion inventory management in a multi-store setting

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Fashion inventory, as opposed to commodity inventory, has a short shelf life as compared to more commodity clothing such as tee-shirts and blue jeans. In this talk we discuss the modeling of a fashion inventory management problem, where inventory is stored in multiple store locations and there is a possibility to transship items between stores. We approach this problem from two perspectives: stochastic programming, in which the most critical decision is the one to be made today, subject to recourse decisions in the future, and approximate dynamic programming in which one looks for an approximate value function and constructs feedback policies.

Keywords: Inventory modeling, stochastic programming, fashion industry

Intermodal journey planning with real-time events

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Intermodal journey planning (IJP) provides travel itineraries for personal journeys combining several modes of transportation such as public transport (bus, train, boat, airplane) and private transport (car, bicycle, walking). Each mode permits travels within a defined transportation network and a journey may traverse several networks at transition points. Travel time, travel cost, and number of transits are important criteria. In a real-world setting a transportation network is frequently subject to real-time events that affect which journey is optimal at a given time. We propose a system for optimized IJP able to handle large transportation networks while immediately taking real-time information into consideration. The requirement for fast response while handling real-time events makes it hard to utilize popular speed-up techniques relying on pre-processing of the networks. We present the main challenges relating to this approach, how they are modelled, algorithms applicable for the model,and preliminary computational results.

Keywords: Journey planning, Intermodal transportation, Dynamic, Real-time

Estimating times of arrival and reacting to changing scenarios for a tour in progress

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Scheduling breaks and rests for truck drivers complying with the EU regulation is a tricky task. This task becomes even more complex if driving times depend on the time of day. In this case it is possible to depart later and arrive earlier.

Suppose a tour as a sequence of places to visit and the departure time from the first place is given. This tour is about to start or is already being executed. Our aim is to calculate the estimated times of arrival according to the given time-dependent driving times. These might be derived from up-to-date traffic messages or from historic data.

The questions that arise are: Will the truck still arrive in time at the next places? Should the driver take a different route to the next place? Should even the order of places be changed?

Moreover, the truck must be parked at an appropriate location while the driver takes a break. Which parking site would be most favorable? This recommendation might change over time as new information about traffic and the degree of capacity utilization at the parking sites comes in.

In our talk, we try to give answers to some of the above questions.

Keywords: break scheduling, time-dependent, estimated time of arrival

A Hybrid Evolutionary Algorithm for Heterogeneous Fleet Vehicle Routing Problems with Time Windows

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This paper presents a hybrid evolutionary algorithm (HEA) to solve heterogeneous fleet vehicle routing problems with time windows. There are two main types of such problems, namely the Fleet Size and Mix Vehicle Routing Problem with Time Windows (F) and the Heterogeneous Fixed Fleet Vehicle Routing Problem with Time Windows (H), where the latter, in contrast to the former, assumes a limited availability of vehicles. The main objective is to minimize the fixed vehicle cost and the distribution cost, where the latter can be defined with respect to en-route time (T) or distance (D). The proposed algorithm is able to solve the four variants of heterogeneous fleet routing problem, called FT, FD, HT and HD, where the last variant is new. The HEA successfully combines several meta-heuristics and offers a number of new advanced efficient procedures tailored to handle the heterogeneous fleet dimension. Extensive computational experiments on benchmark instances have shown that the mix of ingredients used in the HEA is highly effective on FT, FD and HT. In particular, 149 of the 360 best known solution values for the three previously studied variants have been retrieved or improved within reasonable computational times. New benchmark results on HD are also presented.

Keywords: vehicle routing, time windows, heterogeneous fleet, genetic algorithm, neighborhood search

The Green Ship Routing and Scheduling Problem (GSRSP)

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Maritime transport is the backbone of international trade and a key engine driving globalization. International shipping is responsible for approximately 3% of the world's anthropogenic CO2 emissions. This paper is motivated by the increasing attention to sustainable routing and scheduling within the area of maritime transportation. We also note a parallel body of research in road transportation on the vehicle routing problem with emission considerations.

The aim of this paper is to be a starting point for synthesizing two research areas: (a) the area of ship routing and scheduling and (b) the area of emissions from ships. We shall call this category of problems as 'Green Ship Routing and Scheduling Problems' (GSRSP).

The purpose of this paper is to stimulate more research in this emerging area and to enhance the state of the art in this area by investigating possible reformulations of existing models so as to incorporate emissions considerations that explicitly include the emissions dimension. To that extent, we address the fundamental parameters (e.g fuel consumption and emissions estimation formulas) and other considerations that are necessary to formulate the GSRSP based on existing models.

Keywords: maritime transport, ship emissions, green shipping, green maritime VRP

Solid Transportation Problem with Rough Cost Parameters

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In this paper, a solid transportation problem with unit transportation costs as rough variables is considered. We formulate three different models namely, rough chance-constrained programming model, rough expected value model and rough dependent-chance programming model for the problem on the basis of trust measure. The three models are transformed into corresponding deterministic forms to solve the problem. Numerical example is presented to illustrate the problem and corresponding models. The results are obtained by using the standard optimization solver LINGO based upon gradient based optimization - Generalized Reduced Gradient (GRG) technique.

Keywords: Solid transportation problem, Rough variable, Trust measure, Chance-constrained programming, Dependent-chance programming

A Decision Support System for the Management of Petroleum Distribution

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This paper describes a decision support system (DSS) that has been developed to manage petroleum deliveries from a bulk terminal to petrol stations using a heterogeneous fleet of compartmented petrol tanker trucks. The problem is related to the petrol station replenishment problem (PSRP) [1]. However, the standard PSRP formulation, as stated by Cornillier et al.[1] is for known demands at petrol stations whereas this problem requires that the demands are synthesised from historical sales and delivery data. The requirement leads to a two-fold objective. The first is to minimize delivery charges. The second is to minimize potential losses due to petrol station stock-outs.

The problem is defined as a bi-criteria Petrol Station Replenishment Problem (PSRP) with customer demands determined using a prediction algorithms based on time series of daily sales. The DSS employs a user-defined road network as the underlying transport to meet governmental hazardous goods transport regulations.

Vehicles are multi-compartment with a requirement to fill each compartment with a single product destined for a single customer as there are no metering facilities on the truck. Additional rules constrain the possible compartment utilisation patterns and there are vehicle to delivery site restrictions. Petrol stations have multiple tanks of different sizes and there is a signification variation in the sales rate between products and petrol stations. The system has been successfully implemented and has been in operation for approximately 2 years with positive results: Firstly, the petrol stations had no stock-outs other than those caused by force majeure during the period of 2012-2013. Secondly, the number of truck visits per station has decreased by more than 20%. Thirdly, total charges for delivery of light petroleum product have decreased by approximately 15%. Fourthly, the perception, by senior management, of the project's success has resulted in a significant reorganisation in favour of the areas managed by the DSS. Last but not the least, the logistic decision process is transformed to be transparent, controllable, and to have reduced dependence on human intervention.

Keywords: Logistics, Combinatorial Optimization, Forecasting, Petrol Station Replenishment Problem

An Adaptive Variable Neighborhood Search Algorithm for the Capacitated Vehicle Routing Problem

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We propose an Adaptive Variable Neighborhood Search (AVNS) algorithm for the Vehicle Routing Problem, in which a set of routes must be planned at lowest total cost to efficiently service the demands of a number of customers located at one or several points (e.g., depots, warehouses), by using a limited amount of resources (i.e., fleet of vehicles). The AVNS is applied to the standard capacitated vehicle routing problem. The proposed algorithm combines an adaptive shaking procedure with well known local searches. The shaking step is performed by using cyclic exchanges on a set of routes. The first such route is selected according to several criteria that are chosen through the adaptive mechanism, while the remaining ones are chosen on the basis of a closeness measure among routes. Experimental tests on several standard benchmark instances demonstrate that the suggested method is robust and competitive, being able to nd high-quality solution for these extensively studied benchmarks.

Keywords: Capacitated Vehicle Routing Problem, Adaptive VNS, Heuristics

A branch and cut algorithm for the Undirected Capacitated General Routing Problem with profits

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We study the General Routing Problem, in which deterministic demands and profits are associated with some vertices and edges of an undirected graph. Such a problem models the situation in which a delivery service performed by a freight company is not provided to all customers. In fact, a profit is associated with each customer which is gained when the customer is visited. We assume that the number of vehicles is unbounded. The aim is to maximize the total collected profit, minus the total cost to serve all the selected customers. A comprehensive review of the literature on the Vehicle and Arc Routing problems can be found in Feillet et al. (2005), and Archetti et al. (2013a, 2013b). We propose an upper bound based on a surrogate edge-formulation, and a branch and cut algorithm based on a flow-edge formulation.

The key idea consists in exploiting all the valid inequalities found in solving the surrogate upper bound formulation with a cutting plane algorithm, with the aim to strengthen the relaxation at the root node of the branch and cut tree. Computational results show the effectiveness of the proposed algorithm.

Keywords: Routing, branch and cut, profits

A unified math-heuristic framework for multi-constraint travelling salesman problems with profits

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This paper addresses a rich variant of the TSP with profits dealing with a large class of temporal and physical incompatibility characteristics. We propose a unified and hybrid math-heuristic based on routing heuristics and exact loading neighborhoods to solve a large class of TSP with profits, from the pure academic problem to multi-attribute problems. We propose a portfolio of removal and insertion heuristics and a broad range of local search procedures. A focused attention has been paid to the loading aspect of the problem which was barely considered in previous works. We propose two mathematical programming solution approach, which target to re-optimize the loading component.

Several data sets with instances of up to 288 customers were used to evaluate the unified math-heuristic from the Orienteering Problem and the Orienteering Problem with Time Window literature. Experimental results demonstrate that the proposed math-heuristic may compete with the best known state-of-the-art methods proposed for these problems. Expanded computational experiments on more complex generated instances substantiate the effectiveness of the proposed approach to handle more complex constraints following the same parameters tuning. Sensitivity analysis reveals the importance of some algorithmic setups and loading neighborhoods components for reaching high quality solutions.

Keywords: Profitable Tour Problem with Compartments, Math-heuristic, Exact and Approximate Neighborhoods, Orienteering Problem, Orienteering Problem with Time Windows

A framework for solving stochastic vehicle routing problems in a dynamic setting using a deterministic solver

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Reacting to stochastic elements present in real life vehicle routing problems, have become increasingly possible in recent years with the advent of smartphones, GPS trackers and connected devices in general. The increase in data collection also makes quantifying stochastic elements increasingly accurate. Many methods from the literature has focused on the deterministic versions of the problems, and finding ways of applying these to stochastic problems in a generalized way, provides an efficient way of obtaining good solutions.

A framework will be presented that, given a solver for a deterministic version of a large subset of VRPs, provides robustness analysis of solutions, and scriptable ways of handling reoptimization schemes in a dynamic setting for the stochastic version of the problem. The framework analyses future events using Monte Carlo simulation, and uses discrete event simulation to evaluate reoptimization schemes. To demonstrate the feasibility of the framework, a set of primitive and advanced reoptimization schemes will be presented and compared.

The comparison includes strategies for: When to reoptimize (timed, triggered by analysis of Monte Carlo simulations etc.), what to reoptimize (how to generate a deterministic instance), and what to reoptimize for.

Keywords: Vehicle routing, dynamic, stochastic, framework

An Adaptive Meta-heuristic for the Share-a-Ride Problem

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The Share-a-Ride Problem (SARP) is aimed at minimizing the cost of serving a given set of passengers and parcels using a given set of homogeneous vehicles. We propose a metaheuristic for the SARP – Hybrid Adaptive Neighborhood Search Algorithm, which is based on the genetic and large neighborhood search algorithms. Furthermore, a speed-up technique is introduced to improve the performance of the subroutines. The solution approach was tested on a set of instances. Computational experiments indicate that, for these particular data instances, our metaheuristic outperforms a state-of-the-art solver in both the solution times and the quality of the obtained solutions (given limited CPU time).

Keywords: Transportation, The Share-a-Ride Problem (SARP), Large Neighborhood Search, Speed-up Technique

Cost allocation for a Balanced Real-World Open Vehicle Routing Problem

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The present research is motivated by a real-world problem which concerns the planning of bus services for the workers of a company. The problem is modeled as a Balanced Open Vehicle Routing Problem (BOVRP), in which the number of routes (buses) and the makespan i.e., the maximum duration of the routes, is minimized. The first objective is related with the reduction of costs, and the second one refers to the route balancing. In this paper, a multi-start algorithm specifically designed for the BOVRP is proposed.

If the cost of the shuttle service has to be paid by the workers, the problem is how to allocate the total cost among them. Once the workers have been grouped into clusters, a cooperative game theory approach can be used to solve the problem. In the game the players are the clusters, and the characteristic function associates to each coalition the minimum transportation cost that the group can guarantee. The Shapley value and the nucleolus of the game provide two different distributions of the total costs which rely in different notions of fairness.

Keywords: Open vehicle routing problema, Multi-start algorithm, Local Search algorithm, Cost allocation

The single vehicle routing problem with variable capacity

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This paper considers the classical Vehicle Routing Problem (VRP) where a single vehicle may return several times to the depot. We consider the variant where the vehicle capacity is not fixed (here refereed as SVRPVC). Indeed, at the moment to acquire a new vehicle or to rent one, there is some freedom of choice. Selecting a vehicle with a larger size may reduce the number of returns to the depot. It is clear however that larger vehicles are more costly, both to acquire as to operate. Thus, a larger vehicle capacity implies a lower total distance travelled but larger operating costs. The reverse is true for a smaller vehicle. We first consider an enumerative approach, which consists of solving a sequence of VRP's, starting from the one having the largest capacity. The number of VRP's to solve in this approach is unknown in advance. Based on computational experiments, this number is mostly large in our benchmark instances. We then proceed to a direct approach based on the two-index formulation of the VRP. We introduce several valid inequalities that allow us to have an Integer Linear Programming formulation of the SVRPVC. We describe separation procedures for these inequalities. We conclude with computational results that confirm the utility of these inequalities when solving benchmark VRP instances.

Keywords: Vehicle Routing, Variable capacity, Single vehicle

Metaheuristics for multi-objective Mixed Capacitated General Routing Problems

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The Mixed Capacitated General Routing Problem (MCGRP) is a generalization of the Capacitated Vehicle Routing Problem (CVRP) and the Capacitated Arc Routing Problem (CARP). It is defined on a mixed graph, and tasks may be located on nodes, edges, and arcs. A homogeneous fleet of capacitated vehicles is based in a special node called the depot. The aim of the problem is to generate a set of vehicle routes, starting and ending at the depot, such that every task is serviced exactly once and the total demand serviced by each vehicle does not exceed the vehicle capacity. The objective is to minimize the total travel cost. The general definition of the problem makes MCGRP more suited than the CVRP and the CARP for modeling certain real-life cases. Examples are waste collection and newspaper delivery. In the modeling of dense urban areas, demand on housing streets may be aggregated and represented as tasks on links. Larger facilities, like hospital and apartment buildings, and other isolated demand locations, are more adequately represented as nodes.

In contrast to the usual formulation of the MCGRP as a standard optimization problem, we study multi-objective variants of the MCGRP, where total route cost is still minimized, but additional objective component(s) must be optimized at the same time. For instance, it can be important to balance the work load of the different vehicles. Our approach is to find a set of Pareto optimal solutions, called a Pareto front. We propose metaheuristics that find high quality approximations to the Pareto front for multi-objective MCGRPs. The major challenges in solving multi-objective problems are to achieve diversity along the Pareto front and convergence towards optimal solutions while keeping the running time of the algorithm low. We present results from experiments on multi-objective versions of standard benchmarks for the MCGRP.

Keywords: Vehicle routing, Arc routing, General routing, MCGRP, Multi-objective optimization, Meta-heuristics

Optimal vehicle routing with lower and upper bounds on route durations

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This paper is concerned with the problem of finding optimal vehicle routes to minimize the overall travel time, with constraints on the minimum and maximum amount of time spent on each route. The problem extends previous work on the distance-constrained vehicle routing problem by introducing lower bounds on route durations in order to ensure that the resulting routes are balanced. The paper also explicitly addresses the situation where a solution is artificially balanced as a result of inoptimal orders of visits. The paper describes alternative ways in which the restrictions on route connectivity, duration and artificial balancing can be formulated, and introduces an exact algorithm based on cutting planes and mixed-integer linear programming. Computational results are presented for three versions of the exact algorithm using TSPLIB instances.

Keywords: vehicle routing, distance constraints, route balancing

Models for intermodal transportation integrating container assembling and routing

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The ability to move goods safely, quickly and cost-efficiently to markets is important for international trade, national distributive trades, and economic development. The presentation will discuss the door-to-door freight transportation problem in its two phases: consolidation phase and transportation between the platforms. In a general way, the problem is described as a set of orders that have a release and delivery date and must be consolidated and routed from a source to a destination point. Two models are proposed, each integrating several aspects of the problem such as long-haul transportation, freight consolidation, freight storage and intermodal transport. The first is a time-space based model and the second a implicit time representation model. Models are formulated as integer programming problems and some results of small practical instances are shown along with some considerations. Finally, future orientations are presented, specially the multiobjective aspect of the problem considering, for instance, not only economical cost optimization but environmental objectives as well.

Keywords: long-haul intermodal transportation, integer programming, freight consolidation

Optimal train dispatching in Norway

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Running trains often deviate from official timetables. In order to minimize delay costs, re-scheduling and re-routing decisions must be taken in real-time. This task is still mostly performed by human operators. Indeed, despite the huge literature on automatic train dispatching, there is only a handful of systems actually in operations, typically based on some simple optimization heuristic approach. In this talk we present an exact approach to train dispatching, its implementation on a Norwegian line and its impact on railway operations.

Keywords: Railway Traffic Optimization, Routing and Scheduling, Benders decomposition

An Evolutionary – GRASP Algorithm with Path Relinking for the Vehicle Routing Problem with Stochastic Demands

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In this paper, an evolutionary-GRASP algorithm with path relinking is proposed for the solution of the Vehicle Routing Problem with Stochastic Demands (VRPSD). The VRPSD is a well known NP-hard problem in which a vehicle with finite capacity leaves from the depot with full load and has to serve a set of customers whose demands are known only when the vehicle arrives to them. The algorithm uses an elite set of solutions and an evolutionary strategy that combines the new solutions with the elite solutions. The route failure is treated using a threshold value where if the residual load after a customer's service is greater or equal to the threshold value, then, it is better to move to the next customer, otherwise it is better to return to the depot. This approach leads to the usage of only one vehicle in our algorithm. The expected length of a set of a priori routes beginning and ending at the depot is calculated. The algorithm is evaluated on a set of benchmark instances from the literature and a number of new best solutions are found. The algorithm is compared with a number of algorithms from the literature.

Keywords: Vehicle Routing Problem with Stochastic Demands, GRASP, Path Relinking

A Multi-Start Variable Neighborhood Search Algorithm with Path Relinking for the Location Routing Problem with Stochastic Demands

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Abstract: In Stochastic Location Routing Problems (SLRP) usually a single depot and one vehicle are used. In this paper, we formulate the problem using a number of capacitated depots, each one having a number of vehicles with restricted capacities and the customers' demands are stochastic variables. We use a two phase algorithm based on Variable Neighborhood Search (VNS) for solving the problem. In the first phase, the open depots are determined and in the second phase an a priori route is constructed for each one of the depots. The cost is the sum of the set up cost of the depots and the expected length of the routes. A number of solutions are created using a multi-start VNS algorithm and from these a pool of elite solutions is created and then they are improved using a path relinking strategy. As there are no benchmark instances in the literature, a set based on the classic benchmark instances used in the LRP is created. We assume that customers' demands are independent Poisson random variables with the mean demand for each customer equal to the deterministic value of the demand given in the corresponding LRP problem. The algorithm is compared with other metaheuristic algorithms.

Keywords: Location Routing Problem with Stochastic Demands, Variable Neighborhood Search, Path Relinking

Vehicle Routing for a Complex Waste Collection Problem

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We consider a complex waste collection problem with time windows and intermediate disposal facilities. It is modeled as a mixed binary linear program, which is solved by a common MIP solver with the objective of minimizing the number of tours and their spatial and temporal costs. The model introduces several new features to the vehicle routing problem with intermediate facilities (VRP-IF) found in the literature, including a realistic cost-based objective function, multiple depots, a fixed heterogeneous fleet, accessibility restrictions, and a rest period that is not restricted by a time window but depends on when the vehicle started its tour. Moreover, we include a relocation term in the objective function which incentivizes, rather than enforcing, the vehicle to return to its original depot. We evaluate the model's performance on randomly generated instances with various characteristics and investigate classes of valid inequalities and exact elimination rules to speed up the branch-and-bound process. We also present a variable neighborhood search (VNS) heuristic that tackles larger instances based on real data. The performance of the latter is assessed by its optimality gap compared to the exact solution on small and mid-sized instances.

Keywords: vehicle routing, waste collection, mixed binary linear programming, heuristics

VRP-REP: a vehicle routing community repository

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Since their introduction in the 1950's, vehicle routing problems have received an ever-increasing level of interest from the operational research community. As a result, researchers have proposed methods to tackle numerous problem variants. To test methods and benchmark them against alternative approaches, researchers usually rely upon standard instances. When starting to work on a given VRP variant, a researcher is required to answer several questions: what instances are available for that problem? What approaches have been tested on those instances? Are solutions being correctly evaluated? The absence of a common database of instances and benchmark solutions makes these questions difficult to answer. The VRP-REP project aims to provide the community with a collaborative open data platform where, among other things, users can: build instance and solution files using a predefined universal format; propose evolutions to the format; upload/download instance and solution files; link instances and solutions to publications; track the best solutions for a single, or set of, instances over the years; access open-source code for solution checking; and contribute their own solution checkers. In this presentation we set out the main services provided by the platform and invite the community to join this initiative.

Keywords: vehicle routing, web, instances, benchmarks, literature

A computational comparison of different formulations for a rich VRP arising in homecare staff routing and scheduling

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In the ageing western societies, qualified homecare staff is becoming an increasingly scarce resource which, consequently, must be used effectively and efficiently. To support this, we consider a planning problem for determining a work plan for the provision of different types of homecare services to a set of customers. Such a plan consists of daily routes for each staff member. Several service tasks may have to be performed for the same customer on the same day, and the tasks must be performed during given time windows. A large number of further constraints apply. Most importantly, the tasks require (and the staff members possess) different qualifications and skill levels. Moreover, working time rules for the staff have to be respected, and various soft constraints must be taken into account. For example it is necessary to ensure a balanced workload across all staff and to assign the same staff member to the same customer on each day whenever possible.

The problem can be modelled as a rich VRP with time windows, heterogeneous fleet, accessibility constraints, working time rules, and additional soft constraints. We developed two different three-index vehicle flow formulations. The first formulation is based on a network with one vertex per task to be performed. The second has an underlying network with one vertex per customer.

The formulations are solved by exact and heuristic branch-and-cut with a commercial solver. We discuss the computational results obtained on real-world instances from a non-commercial homecare provider in Germany.

Keywords: VRP, Home Care Staff Routing and Scheduling, Model Comparison

Operational Effects of Variations in Service Level Criteria for the Dial-a-Ride Problem

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A dial-a-ride system is an application of demand-dependent, collective people transportation. Users formulate trip requests, combined with service level requirements. The provider strives for efficient routing schedules which respect these requirements, in addition to vehicle capacity, flow conservation, pairing and precedence constraints. This balancing between human perspectives and costs is particularly required when organizing effecient quality-oriented transportation for users with special needs, such as elderly and disabled. The problem may be approached dynamically, including new requests, cancelations or traffic circumstances in non-executed paths.

This study quantifies the operational effects of variations in two common service level criteria, being the maximum deviation from the user's preference time and the detour allowed during a trip. A deterministic annealing technique is applied, both on an artificial heterogeneous data set, containing 24 400 requests for 473 Flemish providers, and on benchmark data from literature. The magnitude and the pattern of the effect are analyzed, distinguishing between different characteristics of providers and requests. Operational costs are found to decrease if service level criteria are loosened, as more possibilities for request combinations can be exploited. Inter alia, increasing relative advantages are observed for larger providers and during off-peak hours.

Keywords: dial-a-ride problem, service level criteria, deterministic annealing

A simple hybrid heuristic for the Green Vehicle Routing Problem

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The green vehicle routing problem (Green-VRP) is an extension of the VRP in which routes are performed using zero emission vehicles (ZEV). Given ZEV limited tank capacity routes may visit alternative fuel stations en-route to restore the vehicle's autonomy. In sum, in the Green-VRP the objective is to find a set of routes of minimum total distance such that: each customer is visited exactly once; each route respects a maximum duration limit; and each route starts and ends at the depot.

We propose a simple, yet effective, two-phase heuristic to tackle the Green-VRP. In the first phase our heuristic builds a pool of routes via a randomized route-first cluster-second heuristic. In the second phase our approach assembles a Green-VRP solution by solving a set partitioning formulation over the columns (routes) stored in the pool. To test our approach, we performed experiments on a set of 52 instances from the literature. The results show that our heuristic obtains competitive results when compared to state-of-the-art methods.

Keywords: Vehicle routing problem, Alternative fuel fleet operations, Refueling

A bi-objective orienteering problem for activity scheduling with multiple time windows and dependencies

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We optimize the daily tours of people, who want to integrate irregular appointments and tasks into their everyday life. For instance, individuals who have to coordinate flexible work tasks with private tasks, such as family chores or shopping, typically have to accomplish complex trip sequences every day. Available tools, such as digital calendar systems or routing tools are not designed to meet the requirements of this target group. Therefore, we introduce this novel problem inspired by real world aspects and formulate a mathematical model based on an orienteering problem to represent it. Various activities, such as work-related appointments or leisure activities, associated with profits, are to be scheduled within a predefined period. Decisions are to be made on when a task is performed, at which location the task is performed and how this location is reached, with respect to two objectives: (i) maximize profit and (ii) minimize the number of free time slots. Each task can be performed at various locations, where each location has a time window, and precedence as well as minimal and maximal delay between tasks have to be considered. We compare different approaches to solve this bi-objective orienteering problem and provide preliminary results.

Keywords: Orienteering problem, Multiple time windows, Bi-objective optimization

The Windy Rural Postman Problem with a Time-Dependent Zigzag Option

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In this research, we focus on the windy rural postman problem with the additional option to zigzag street segments during certain times of the day. If a street is narrow or traffic is light, it is possible (and often desirable) to service both sides of the street in a single pass by zigzagging. However, if a street is wide or traffic is heavy, we must service the street by two single traversals. For some streets we further impose the restriction that they may only be zigzagged at specific times of the day, e.g., in the early morning. Real-life applications arise, among others, in trash collection and newspaper delivery. This outlined arc routing problem combines two classes of problems known from the literature, arc routing problems with zigzag options and arc routing problems with time dependencies. We present and discuss several (mixed) integer model formulations for the problem at hand and suggest exact and heuristic solution approaches. Furthermore, we analyze the effects of zigzag options on the objective function value and test our solution approaches on real-world instances.

Keywords: Rural Postman Problem, Zigzag Service, Time Windows

Analysis of different levels of service for a static multi depot dial-a-ride problem

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Demographic changes in Austria led to a growing demand of patient transportations and emergency rescue services over the last years. The providers face an increasing pressure on their available resources. Therefore, the use of optimization methods becomes a crucial factor to secure the quality of the provided services. In this study a static multi depot dial-a-ride problem with a heterogeneous fleet and mandatory breaks concerning patient transportations is solved by a two stage approach. In the first stage the optimal combination of patients in terms of operating time is computed. The solution of this stage leads to tasks that are afterwards assigned to vehicles and iteratively improved by Tabu Search strategies. Different levels of service concerning time windows, exclusive transports and excess ride times are analyzed and compared to the actual routing that was carried out by the provider. The results of the instances with a problem size of up to 2540 requests show the trade-off of the level of service and the required resources. Furthermore, the developed algorithms will be benchmarked with suitable approaches that have been published during the past few years.

Keywords: Dial-a-ride Problem, Patient Transportation, Healthcare Logistics

Hungarian method for solving the shortest route problem

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Network models are an important category of mathematical programs that have numerous practical applications. Two problems are well known in this field: the shortest route problem (SRP) and the assignment problem (AP). In this paper we propose a simple and intuitive procedure for modeling a SRP as an AP, and to use the classical Hungarian method for solving it. This procedure is the following one. Given a SRP with information in a square matrix of order n, we consider an AP with information in a new matrix of order n-1 where each row will be associate to each one of the nodes of the network except a the end-node of the route, and each column will be associate to each one of the nodes of the network except a the start-node of the route. Thus, we considere that the coefficients by rows and columns are the corresponding ones to the costs between each one of the nodes, with 0 in the cases where the row and column are associate to the same node. In this situation, solving the AP by the Hungarian method, we find the solutions of the SRP.

Keywords: Shortest route., Hungarian method., A simple and intuitive procedure.

Branch and bound for the biobjective team orienteering problem with time windows

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In the team orienteering problem with time windows (TOPTW), a set of control points can be visited, each of them providing a certain profit. A limited fleet of vehicles, each subject to a total time limit, is used to maximize the profit of visited control points. In this work we tackle the biobjective TOPTW (BITOPTW). It is a variant of the TOPTW in which the constraint on total duration is relaxed and reintroduced as an objective. We use the Pareto approach, in which every nondominated solution is considered efficient and part of the optimal set. We develop an exact method, meaning that every solution in the efficient set is generated.

In order to produce the whole efficient set we design a generalization of the branch-and-bound algorithm to biobjective optimization with integer variables. Lower- and upper-bound sets are considered and fathoming rules are extended to consider sets instead of single values. The lower bound set is generated using column generation, since it typically provides a tighter bound than compact formulations for routing problems. Specific branching rules are designed for (i) the problem at hand and (ii) any biobjective problem. Experimental results demonstrate the viability of our approach.

Keywords: Orienteering, Biobjective optimization, column generation, Branch and price

Field Staff Routing and Scheduling

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In field staff routing and scheduling, a given number of tasks have to be completed by a given number of field employees. Each field employee disposes of a given set of skills at a certain level and each task requires an employee with a given set of skills of at least a certain level. Some or all of the tasks have time windows and working time restrictions limit the maximum duration of an employee's tour. The aim is to construct minimum cost routing and scheduling plans. The considered cost may be only routing cost or like in the case of the infrastructure service provider we were working with, also working time costs and outsourcing costs. In a first step, a large neighborhood search algorithm was developed for a simplified problem. This algorithm is now extended and adapted to deal with several additional requirements. These requirements involve, e.g., route synchronization constraints for tasks that require more than one field employee, precedence relationships between the different tasks, and walking only subtours in residential areas and pedestrian zones with no or only limited vehicle access. Each aspect is first treated individually and then integrated into the existing algorithm.

Keywords: large neighborhood search, synchronization, park and loop

STRATEGY LOCATION IN CHAIN EXPANSION UNDER DELIVERED PRICING

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We deal with the facility location decision problem for an expanding chain which competes with other chains offering the same goods or service. The competing chains offer a selling price in each market area and customers in the area buy from the chain offering the lowest price. Goods or service are delivered to the customers at their site locations. It is assumed that facilities in a chain may have different owners. After the expansion some of the old facility owners might lost market share due to the entrance of the new facilities. The aim of starting up new facilities is to ensure the largest possible market share or profit for the entire chain, but counteracting the loss in market share of the old facilities. We present a practical location model based on a trade-off between the owner of the entire chain and the owners of its facilities. We show that the loss in market share of the old facilities can be significantly reduced by sacrificing a small portion of profit when side payments are used. A study with data of Spanish municipalities is presented and conclusions are drawn from a sensitivity analysis.

Keywords: Chain expansion, Delivered price competition, Facility Location

Multi-period vehicle assignment problem with stochastic load availability

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In this research, we want to investigate optimization techniques for a generic vehicle assignment problem including a limited fleet of vehicles within a full-truck-load (FTL) multi-period setting including forecasts on load availability. Several policies are generated from simple heuristics through state of the art approaches such as consensus and restricted expectation algorithms up to the optimization of a subtree of scenarios. Moreover, myopic and a-posteriori deterministic optimizations (including no or fully revealed information) set bounds for policies performance comparisons. Tests are performed for different graphs sizes and sparsity, several distribution laws and number of loads. Performances are compared statistically over paired samples. The robustness of performing policies against a false valuation of the probability distribution is also analyzed. Results highlight the efficiency of an algorithm based on a subtree of scenarios. Moreover, this subtree calibrated with a 50% probability distribution is robust against a false evaluation of the probability distribution.

Keywords: Multiperiod, Stochastic, Transportation problem, Optimization, Robustness

Integrating axle weight restrictions in a two-dimensional vehicle routing problem with sequence based loading

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A mixed integer linear programming model for a two-dimensional capacitated vehicle routing problem (2L-CVRP) with sequence based loading and axle weight restrictions is provided. To the authors' knowledge, it is the first time that axle weight restrictions are incorporated in a VRP. Axle weight limits impose a great challenge for transportation companies. Trucks with overloaded axles represent a significant threat for traffic safety and may cause serious damage to the road surface. Transporters face high fines when violating these limits. The problem is based on a real-world problem from a Belgian logistics service provider. The demand of the customers consists of europallets. Pallets can be placed in two horizontal rows inside the vehicle. No vertical stacking is allowed. The center of gravity of the pallets inside the vehicle is calculated to determine the axle weights. Results of the model are compared to results of a 2L-CVRP with sequence based loading without axle weight restrictions. Numerical experiments demonstrate that the model performs adequately and that the integration of axle weight constraints in vehicle routing models is necessary for a feasible route planning.

Keywords: axle weight restrictions, vehicle routing problem, two-dimensional loading, sequence based loading

Dynamic vehicle routing problems: three decades and counting

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According the recent survey of Pillac et al (2013), the first reference to a dynamic vehicle routing problem (DVRP) is due to Wilson and Colvin (1977) and the first periodic reoptimization approach is due to Psaraftis (1980). Since that time, much work in this area has been done, and in fact the survey of Pillac et al catalogues more than 150 related references. In this paper we develop a taxonomy of DVRPs according to several criteria. These include (1) logistical context, (2) objective function, (3) transportation mode, (4) fleet size, (5) existence of time constraints, (6) nature of the stochasticity (if any), (7) mathematical formulation, (8) solution method. In the process, we also identify some DVRPs that are really not dynamic even though they may give the appearance of being so.

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Wilson, N.H.M., N. Colvin (1977), Computer control of the Rochester dial-a-ride system. Technical report R77-31, Dept. of Civil Engineering, MIT, Cambridge, Mass.

Keywords: Dynamic vehicle routing, On line routing, Stochastic routing

Some contributions to mathematical modeling of ship inventory routing in the oil industry

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This study addresses a real life ship routing and scheduling application that arises in pickup and delivery operations of different types of crude oil from several offshore oil rigs to coastal terminals. Oil transportation largely results from the need to maintain inventories at each supply point (oil rigs) and demand point (terminals) between minimum and maximum levels, considering production or consumption rates in these operational points. Routing and scheduling of the available fleet aims to obtain solutions of minimum variable cost, subject to various constraints such as the maximum number of consecutive pickups and/or deliveries, the maximum volume of cargo carried on each ship, simultaneous cargo unloading in some terminals, ship docking in the ports of the operational points, among others. In this research, optimization models from the literature have been modified and extended in order to represent the problem and to solve small-to-moderate sized instances generated from data collected in a case study conducted at a major Brazilian oil company.

Keywords: Ship inventory routing, Crude oil transportation, Mixed Integer Programming

A Lin-Kernighan Heuristic for the DVRP

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The Distance-constrained Vehicle Routing Problem (DVRP) deals with the construction of a minimum length set of tours in an undirected graph, each of bounded individual length, that start from a depot and visit all nodes. We show that the Lin-Kernighan heuristic for the TSP can successfully be adapted to solve large scale DVRPs. We use our method to solve DVRPs arising in an application at DB Regio AG, which is one of the largest operators of public local transport in Germany.

Keywords: Distance-constrained Vehicle Routing, Lin-Kernighan heuristic, Local search

Conflict resolution between flights at airports using network simplex

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Given today's limited capacity at airports and the continuous increase in air transportation, the need for new ways to handle airport logistics will soon be needed. The task of managing arrivals and departures is complex, and is today solved by several air traffic managers at each airport. While these managers operate well within their zone, the overall performance with respect to capacity and punctuality would benefit from viewing the airport as a whole. In addition, this may increase accuracy in predicting take-off times, allowing more reliable information for the arrival flights. Our presentation provides insight to how the network simplex algorithm can be used to solve ground conflicts between flights. The focus lies on mitigating the overall delay at airports and reduce the taxi time of each individual flight while at the same time comply with safety regulations on the runway. This research also provides a basis for future integration with other airport operations such as gate allocation and arrival sequencing. Datasets from Stockholm-Arlanda airport were used to test the algorithms. The research is part of a Master's thesis relating to an ongoing SESAR project at SINTEF.

Keywords: Air Traffic Management, Conflict resolution, Network simplex

Integrating stochastic time-dependent travel speed in solution methods for the dynamic dial-a-ride problem

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In urban areas, logistic transportation operations often run into problems because travel speeds change, depending on the current traffic situation. If not accounted for, time-dependent and stochastic travel speeds frequently lead to missed time windows and thus poorer service. Especially in the case of passenger transportation, it often leads to excessive passenger ride times as well. Therefore, time-dependent and stochastic influences on travel speeds are relevant for finding feasible and reliable solutions. This study considers the effect of exploiting statistical information available about historical accidents, using stochastic solution approaches for the dynamic dial-a-ride problem (dynamic DARP). The authors propose two pairs of metaheuristic solution approaches, each consisting of a deterministic method (average time-dependent travel speeds for planning) and its corresponding stochastic version (exploiting stochastic information while planning). The results, using test instances with up to 800 requests based on a real-world road network, show that in certain conditions, exploiting stochastic information about travel speeds leads to significant improvements over deterministic approaches.

Keywords: dial-a-ride problem, dynamic, stochastic, time-dependent, variable neighbourhood search, multiple plan approach, multiple scenario approach

Integrated scheduling and routing at an airport

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It is air traffic control that organizes and guides the flow of traffic on the airport and the adjacent airspace. This has to be done in a safe and effective manner - a very complex task. To tackle this complexity, the overall responsibility is distributed across several controllers where each controller manages their own focus area. This division makes air traffic control manageable, but there still exists a large potential to improve the overall performance in terms of punctuality and fuel efficiency. The effect of one individual controller's decision propagates through to other controllers, e.g., a small adjustment of one controller might not be the optimal decision for the whole trajectory, and in worst case can create havoc for the other controllers. However, real-time optimization techniques can handle such complexity and assist the human controllers in making good global decisions. Currently, SINTEF is developing an optimization algorithm which is able to coordinate in real-time arrival and departure flights while finding optimal, conflict–free routes on the airport. Later this year, the algorithm will be validated for Arlanda airport in Stockholm through a near real-life simulation exercise.

Keywords: Air Traffic Management, Scheduling, Routing

Hybrid Metaheuristic for the Team Orienteering Problem with Time Windows and Service Time Dependent Profits.

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In this talk we present an extension of the team orienteering problem with time windows (TOPTW). The aim is to find tours, which needs to be feasible with respect to time windows and a maximum tour length restriction, while maximizing the profit collected. The profit however, as opposed to the standard TOPTW, depends on the service time spent at each customer. This setting is very common to arise in the service and health care sector.

A solution hence can be represented by the sequence of customers to be visited, as well as the corresponding length of stay. The proposed algorithm is a hybrid metaheuristic. In order to solve the problem it will be decomposed in two parts: the search for good sequences will be guided by means of Large Neighborhood Search. Any sequence may then be evaluated using Dynamic Programming to determine the optimal length of stay. We are able to provide very favorable results for this new problem variant, as well as for standard TOPTW benchmark instances.

Keywords: team orienteering problem, service time dependent profits, hybrid metaheurstic, large neighborhood search

Recharging Decisions in Electric Vehicle Routing

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Driven by environmental considerations, laws and regulations on vehicle emissions, and the offer of major subsidies, Electric Commercial Vehicles (ECVs) are receiving ever stronger attention in logistics companies. Route planning for ECV fleets requires consideration of the special characteristics of ECVs, like limited driving range and the potential need to recharge en route at a dedicated recharging station. To the best of our knowledge, previous works on routing ECVs have assumed the recharging process to be complete, i.e., the battery of an ECV is always recharged to the maximum capacity at a recharging station. In this work, we study the impact of allowing partial recharges on the efficiency of ECV routing solutions. We address variants of the Electric VRP with Time Windows, in which partial recharges are allowed and different restrictions on the number of (full and partial) recharges per route apply. To solve the variants, we develop an Adaptive Large Neighborhood Search.

Keywords: Electric Vehicle Routing, Recharging Decision, Metaheuristic, Infrastructure Planning and Routing of Electric Vehicles

A GPU-based TSP-solver

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Due to physical limits, hardware development no longer results in higher speed for sequential algorithms, but rather in increased parallelism. Modern commodity PCs include a multi-core CPU and at least one GPU, providing a low cost, easily accessible heterogeneous environment for high performance computing. New solution methods that combine task parallelization and stream processing and self-adapt to the hardware at hand are needed to fully exploit modern computer architectures and profit from future hardware developments.

In this talk, we first give an introduction to modern PC architectures and the GPU, and survey the literature on GPU-based solution methods in discrete optimization that currently consists of some 100 papers. Many of them describe GPU implementations of well-known metaheuristics and report impressive speedups relative to a sequential version. As for applications and problems studied, 26 papers describe research on routing problems of which 9 focus on the Shortest Path Problem, 15 discuss the Travelling Salesman Problem, and only 2 study the Vehicle Routing Problem.

In the second part of this talk we present a GPU-based TSP solver which is inspired by the highly successful and leading TSP solver LKH2 of Keld Helsgaun. To our knowledge this is the first GPU based TSP-solver that provides a competitive solution quality for large sized TSP problems. During the development of the GPU solver we examined two different ways of adapting the Lin-Kernighan heuristic to the data-parallelism of the GPU. In contrast to LKH2, one of these approaches leads to fewer random restarts, but with more heavy and involved local searches. The other version uses the same number of restarts as in LKH2, but with a different distribution into the two kinds of restarts in LKH2. For a selected number of large-scale instances we will present numerical results.

Keywords: TSP, VRP, SPP, Parallel computing, Heterogeneous computing, Stream processing, GPU

Problem of Time Inconsistency in Multi-period Vehicle Routing Problems

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In our talk we discuss and demonstrate effect of time inconsistency of vehicle routing plans constructed by some heuristic algorithms in multi-period VRP. Results of experiments evaluating level of the heuristics time inconsistency are presented. An approach and methods to decrease level of heuristics time inconsistency is proposed. Based on this approach we treat the problem of constructing subadditive characteristic function for multi-period cooperative vehicle routing game of freight carriers. Computational difficulties of finding the values of the characteristic function in a cooperative vehicle routing game (CVRG) are caused by the large size of the problem, which makes it unacceptable to use exact methods for solving wide class of routing problems with a comparatively small number of customers to be served. To provide subadditivity of characteristic function we have developed the direct coalition induction algorithm (DCIA). To upgrade joint optimal routing plan and values of characteristic function of grand coalition we have developed iterative coalition induction algorithm (ICIA). Both algorithms were built on the basis of the combination of various heuristic algorithms which are appropriate for solving large-scale VRP. For implementation of the algorithms special software has been developed and used for solving sample examples. Presented approach could be applied for study collaboration in cargo transportation and routing.

Keywords: vehicle routing problem, vehicle routing games, heuristics, multi-period VRP, cooperative games, time inconsistency

Metaheuristics for the robust vehicle routing problem with discrete scenarios

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The robust vehicle routing problem with discrete scenarios is defined on a complete directed graph G=(V,A). V includes one depot with m vehicles of capacity Q and n customers with demands d(i). The arc costs are defined by p scenarios, c(i,j,k) denoting the cost of arc (i,j) in scenario k. The goal is to determine a VRP solution minimizing the worst total cost over all scenarios. A mixed integer program and four metaheuristics using a common local search are presented for this extremely hard problem: one GRASP, one Iterated Local Search (ILS), one multi-start ILS (MS-ILS) and one MS-ILS involving giant tours and a new splitting procedure. 18 small instances (max n=10-20, m=2-3 and p=10-20) and 24 larger ones (max n=50-100, m=5-20 and p=10-20) are randomly generated. The two MS-ILS give the best results. On a 2.2 GHz Intel Core i7 PC, they retrieve in less than 5 seconds the optima found by CPLEX on small instances, and even improve three upper bounds when the solver cannot reach an optimum in 4 hours. On large instances, they last less than one minute and the giant tour version is significantly better than the one working only on complete RVRP solutions.

Keywords: robust vehicle routing, iterated local search, tour splitting procedure

The Discrete Driver Assignment Vehicle Routing Problem

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We introduce the discrete time window assignment vehicle routing problem (DTWAVRP). It can be viewed as a two-stage stochastic optimization problem; Given a set of customers that must be visited on the same day regularly within some period of time, the first-stage decisions are to assign to each customer a time window from a set of candidate time windows before demand is known. In the second stage, when demand is revealed for each day of the time period, vehicle routes satisfying vehicle capacity and the assigned time windows are constructed. The objective of the DTWAVRP is to minimize the expected total transportation cost. To solve this problem, we develop an exact branch-price-and-cut algorithm for the case that demand uncertainty is modeled using a limited number of scenarios. From this algorithm, we derive several column generation heuristics that allow solving larger instances than those solved by the exact algorithm. We illustrate the performance of these algorithms by means of computational experiments performed on randomly generated instances.

Keywords: Vehicle routing, Time window assignment, Stochastic demand, Column generation

Introducing Vendor Managed Inventory Service in Tramp Shipping

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We present a new maritime transportation problem that combines traditional tramp shipping with a vendor managed inventory (VMI) service. Such a service may replace the more traditional contract of affreightment (COA) which for decades has been the standard agreement between a tramp shipping company and a charterer. A new mathematical formulation describing the routing and scheduling problem faced by a tramp shipping company that offers a VMI service to its customers is presented and solved using a hybrid approach that combines branch-and-price with a priori path-generation. In order to investigate the economic impact of introducing such a VMI service, we compare the results of our VMI model with results obtained by solving the traditional routing and scheduling problem faced by tramp shipping companies offering COA. Two types of COAs are considered: "More or less owner's option" and "more or less charterer's option". The computational results show that it is possible to substantially increase supply chain profit and efficiency by replacing the traditional COAs with VMI services.

Keywords: Maritime Transportation, Inventory Routing, Branch-and-Price, Vendor Managed Inventory

A Hybrid Heuristics for the Vehicle Routing Problem with Swap Location

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We present solution algorithms for a complicated variant of VRP-Vehicle Routing Problem with Swap Location (VRPSL). In this problem, the customers are served by a heterogeneous fleet, while some swap locations are available for vehicles to improve the efficiency. Firstly, we model the VRPSL problem with a combination of three-index vehicle flow and commodity formulation. Due to its NP-Hard complexity, an iterative two phase heuristic algorithm is proposed to solve the problem. Phase I is conducted repeatedly to obtain a local-optimal routing solution through two procedures: cluster-first route-second and exploitation method. Moreover, a tabu search (TS) is adopted to make an overall improvement in phase II. To evaluate the algorithm performance, computational results are reported on certain instances with different scales.

Keywords: Vehicle Routing, Swap Location, Cluster-first Route-Second, Exploitation, Tabu Search

A Vehicle Routing Problem with Flexible Time Windows

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The classical Vehicle Routing Problem with Time Windows (VRPTW) aims at obtaining least cost routes where each customer is served within its predetermined time window by a single vehicle. In several real-life applications, time window constraints can be violated to a certain extent. This paper introduces the Vehicle Routing Problem with Flexible Time Windows (VRPFlexTW), which enables vehicles to deviate from time windows by a given tolerance. More specifically, this setting provides savings in operational costs of carrier companies as customers may be served before and after the earliest and latest time window bounds, respectively. Since time window violations are undesired from the customers' point of view, they are penalized. To obtain high-quality solutions, we propose a solution procedure based on a tabu search algorithm. An initialization method is developed to generate feasible routes. Solutions provided by the tabu search metaheuristic are further improved by solving a linear programming model. We validate our solution algorithm by experimenting with well-known problem instances and by testing its performance with various criteria. Moreover, we compare solutions of the VRPFlexTW with those of the classical VRPTW to assess the operational gains achieved by implementing a fixed relaxation of time window constraints.

Keywords: Vehicle routing problems, Time windows, Flexible time windows

Same Day Delivery for Online Purchases

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Where instant gratification was once the largest advantage of brick-and-mortar stores over online retailers, same day delivery now brings near instant gratification to online shoppers. Same day delivery, however, is a logistically complicated and expensive service to operate. Further, despite its challenges and growing use, there is no academic literature that directly addresses the problem. We introduce a dynamic pick-up and delivery problem with deadlines that incorporates key features associated with same day delivery logistics. A key challenges is the many options for how the routing of these deliveries can occur. These options include which packages to load onto which vehicle, when a vehicle should wait at the depot or a customer location, when a vehicle should return to the depot, and which customer should be visited next. As a result, we are challenged not only by the traditional curse of dimensionality associated with a large state space, but also with a curse of dimensionality around the actions. We develop a sample-scenario planning approach that incorporates demand uncertainty and the myriad of decision options. Our results demonstrate the value of the dynamic solution over a simpler, but managerially desirable solution, as well as the effectiveness of our methodology.

Keywords: Dynamic, Sample-Scenario Planning, Pick-up and Delivery

Solving the liner shipping network design problem using branch-and-price

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We solve the network design problem in liner shipping to optimality by using a branch-and-price algorithm. We use a two stage model, where we find the optimal cargo flow for the existing set of services before looking for new improving services, and repeat this until optimality. We discuss the challenges of proving such optimality given the cyclic nature of the routes. The subproblem of finding new services is solved using a set of simple heuristics, more advanced metaheuristics, and finally a MIP formulation. We present a path flow model, discuss the quality of various route-generating procedures, and show results from applying our method to benchmark instances.

Keywords: Liner shipping, Network design, branch-and-price

Efficient Dynamic Programming for the Minimum Tour Duration Problem

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We consider a variant of the traveling salesman problem with time windows (TSPTW) in which the objective is the minimization of the tour duration (Savelsbergh 1992). There is no consistent naming of this problem in the literature. We will use the name minimum tour duration problem (MTDP). We present a new effective dynamic programming (DP) approach to solve the MTDP. It is motivated by the DP-based solution approach of Baldacci et al. (2011c), who successfully solve the TSPTW with a DP-based algorithm. When solving TSPTW, just two independent resources are propagated along partial paths, one for costs and one for earliest arrival times (Mingozzi et al. 1997). For dealing with tour duration minimization, there exist several possibilities to define resources: We will follow ideas presented in (Irnich 2008) in order to apply effective dominance and bounding procedures. This is a non-trivial task because in the MTDP at least two resources will depend on each other in a non-additive and non-linear way. In particular, we will define consistent resource extension functions (REFs, see Desaulniers et al. 1998) so that dominance is straightforward and forward DP or any of its relaxations provides bounds for backward DP, and vice versa. Using relaxations to obtain lower bounds is common practice in routing problems, e.g., using a state-space relaxation (Christofides et al. 1981). We present a new relaxation for the MTDP with only one resource, which is attractive due to its low computational complexity. This and other relaxations can be combined with the *ng*-tour relaxation and the *ngL*-tour relaxation (Baldacci et al. 2011b,c). To improve the lower bounds, we use two methods: First, we adapt a penalty method, first suggested by (Christofides et al. (1981a) for solving a TSPTW with the objective of makespan minimization. Second, we generate the neighborhoods for the *ng*-tour and *ngL*-tour relaxations dynamically, a technique successfully applied for solving different routing problems (Baldacci et al. 2011b, Bode and Irnich 2012). To our knowledge, we present the first exact algorithm for the MTDP and provide computational results with optimal solutions on many known benchmark instances for the TSPTW.

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Keywords: TSPTW, minimum tour duration, dynamic programming, relaxations, bounding

Efficient solution methods for stochastic and dynamic maritime transportation problems

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Maritime transportation is central in worldwide logistics and most of the world trade in volume is transported at sea. An efficient utilization of transportation resources in this context is thus crucial to provide accessible transportation services and contribute to a sustainable society. The shipping industry is characterized by a large degree of uncertainty, and the routes and schedules for a vessel fleet must be updated dynamically while reacting to new information. This makes the scheduling and routing problems that must be solved to design efficient plans very complex. Due to recent technological advances in communications and information technologies, the explicit incorporation of uncertainty and dynamic aspects in maritime transportation planning has become increasingly important, and the potential savings generated by adapting routing decisions to dynamic or stochastic contexts are substantial. In this work, we present ongoing research related to solving stochastic and dynamic maritime transportation problems. This research is based on solving the stochastic and dynamic vehicle routing problems within a simulator framework by using metaheuristics, and by using sampled scenarios to represent stochastic information.

Keywords: routing, uncertainty, scenario, metaheuristics

VNS based heuristic for the Swap-Body Vehicle Routing Problem

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Swap-Body Vehicle Routing Problem may be stated as follows. The vehicle fleet which consists of trucks, semi-trailers and swap bodies, is located at a single depot. The fleet is used to serve a given set customers. Each customer has to be delivered a given quantity. The delivery at each customer takes a given amount of time. Valid vehicle combinations are the following: truck carrying one swap body or train (truck with semi-trailer attached to it) carrying two swap bodies. Each vehicle (truck or train) must perform route starting and ending at the depot. However not all customers are allowed to be visited by train. Additionally, it is given a set of swap locations were semi-trailers and swap bodies may be parked or swapped. The duration of each route, which includes the driving period, the different swap actions and time to service customers on the route, must not exceed the predefined limit. Also, the loading capacity of the swap bodies must be respected. The goal is to minimize the total costs consisting of fixed costs and variable route and time costs. In this paper we propose an approach based on Variable neighborhood search to solve this problem. The quality of the proposed method has been evaluated on the instances provided by the organizers of VeRolog Solver Challenge 2014.

Keywords: Vehicle Routing, Swap Body, Variable Neighborhood Search

Anticipatory Optimization for a Dynamic Multi-Period Routing Problem

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We consider a multi-periodic pickup-problem. A single vehicle has to serve customer requests for a finite number of days. The tour starts in a depot, where the vehicle has to return every day within a given time limit. Each day, known early request customers (ERCs) have to be served. During the day, late-request-customers (LRCs) subsequently request service. The LRCs can be postponed to the next day, where they become ERCs. A postponement is permanent and has to be made immediately after the request appears. Objective is a high service level and hence, to maximize the number of LRCs served at the same day. Therefore, we examine the results of a (myopic) greedy heuristic, a (one period anticipatory) cost-benefit heuristic (CBH), and a long-term approach using Approximate Dynamic Programming (ADP). For all tested scenarios, both ADP and CBH reach far better results than the greedy heuristic. Especially for a high number of days, ADP outperforms all the other approaches.

Keywords: Dynamic Multi-Period Routing Problems, Postponable requests, Anticipatory Optimization, Approximate Dynamic Programming

Outbound Logistics Optimization to Coordinate Aggregate-level Production-Distribution Decisions with Operational-level Vehicle Routing Decisions

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Frito-Lay North America (FLNA) operates a complex supply chain network for production and distribution of snack products in the US, Canada, and Mexico. We consider the outbound logistics network affiliated with FLNA's factory in Irving, TX for simultaneous optimization of aggregate-level production, inventory, factory-direct shipment, and operational-level vehicle routing decisions. The problem comprises 15 snack items in various package sizes, 8 regional distribution centers, 75 local warehouse bins, 11 client FLNA plants, 8460 retail customers, Irving plant's fleet of 75 dead-stack and roller-bed type trucks with different volume capacities and loading capabilities, and schedule restrictions at the delivery sites. We develop a heuristic framework with three modules namely, the weekly production, inventory and factory-direct shipment selection module (AWM), the vehicle routing module for daily shipments (ODM), and the quantity partition module (QPM) that interfaces AWM and ODM. The QPM incorporates multiple objectives, with one objective for each delivery site to minimize the consignment frequency with an additional objective that balances the day-to-day factory output. We devise procedures to assign different priorities for the objectives and generate an efficient frontier of heuristic solutions. The heuristic solutions demonstrate significant cost savings over a benchmark representing the current FLNA's system.

Keywords: coordinated logistics, integrated inventory transportation, lot sizing, vehicle routing

Consolidation planning in transportation networks with transshipments

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In the transportation of low-volume, low-frequency orders, the realization of high fill rates is essential. In this study, we concentrate on operational order consolidation in networks with transshipments, i.e., intermodal networks. Existing planning algorithms focus on optimization of single orders; the operational planning of less-than-vehicle loads has received minimal attention. We introduce a k-shortest path matching algorithm to consolidate orders in a dynamic setting. Based on a leg-expansion procedure, multiple high-quality routes are generated and stored for each order. For each incoming order, we aim to combine the k-best routes for the order at hand with those of already planned yet uncompleted orders. We do so based on identified overlap in the utilized legs, taking into account idle capacity, time restrictions, handling operations and modality properties, fixing the route combination yielding the highest cost reduction. As we do this for the k-best routes, we need only to evaluate the most promising consolidation opportunities, keeping the search space relatively small. The algorithm recalculates the time schedules and available capacity per leg for each combination of routes. We test our approach on a real data set of a Dutch logistics service provider as well as on various virtual networks, with promising results.

Keywords: consolidation, intermodal networks, dynamic planning, k-shortest path

Optimized time differentiated parcel delivery using private and public transport

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Online customers are demanding faster deliveries as well as more flexibility in delivery options. To enable faster deliveries, in both urban and rural areas, we study the combination of parcel delivery with private and public transport. To provide more flexibility, we provide a comparison between multiple time-slots to the user. We use a label-setting algorithm to find the minimum cost for each time-slot. By separating the time component, we reduced the bi-criterion objective to a single-criteria objective, resulting in polynomial running time. In addition, we study the situation with a single time-window, which is sufficient in case parcels can be delivered to lockers, and propose a method that optimizes cost and on-time delivery reliability. Both methods give the user multiple options. Regarding the combination with public transport, we distinguish between fixed transport with a schedule, unscheduled transport requiring a reservation, and unscheduled transport that is freely available. The proposed approach is more widely applicable, e.g., to the routing problems concerned with (i) the delivery of prescription medicines, such that these can be stored in a central warehouse, while maintaining on-time delivery, and (ii) to drop-off designated drivers to nightspots at given time-slots to take people home with their own car.

Keywords: shortest path, multi-criteria, scheduled transport, unscheduled transport, parcel delivery, ride sharing

Heuristically Solving the Swap-Body Vehicle Routing Problem

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To solve the swap body vehicle routing problem, we use a seed and insertion algorithm multiple times with different parameters. The parameters we used are: (i) number of seeds, (ii) insertion algorithm, and (iii) seeding algorithm. The used seeding algorithms differ in the criterion used for determining seeds, such as demand and distance to the depot.

Given a ten minute window to generate a solution, our philosophy is to try a large range of values for our parameters to maximize the likeliness to use the best values for these parameters. After trying reasonable values for the parameters, we use the best solution found as input for a simulated annealing algorithm. Allowed changes are moving a customer to a different truck, or swapping two customers. To ensure feasibility in the final solution, we perform a feasibility check before accepting a better solution.

In this talk, we highlight some of the challenges we faced. In addition, we discuss the strengths and weaknesses of our method.

Keywords: Seed and insertion, Simulated annealing, Heuristic, VRP, swap body

An insertion heuristic for a dynamic Dial-a-Ride Problem using geographical maps

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We present an insertion heuristic for a dynamic Dial-a-Ride Problem, applied to a real-world application on taxi sharing . The application relies on city-sized geographical maps and location coordinates for taxis and customers. A customer sends a ride request to a taxi call center, which assigns to it in (quasi) real-time the most appropriate taxi, with respect to capacity and time constraints: maximal waiting time before pick up and maximal drive duration for each passenger's request. Passenger may share a taxi along some part of their journey. Our methodology relies on a constrained quadruple shortest path search algorithm, followed by an insertion algorithm with a validity check. Each new request is so tentatively inserted into a taxi route. Experiments on real data shows the viability of our methods.

Keywords: Dynamic DARP, Shortest paths, Taxi sharing, Geographical Maps

Ordering of packages in the single vehicle many-to-many pickup and delivery problem

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In this paper, we consider a new variant of the single vehicle pickup and delivery problem with a many-to-many structure, that addresses the order of packages in the vehicle. In this problem, each type of package can have several pickup and delivery locations, and the depot only serves as a location to start and end the vehicle route. Packages can only be (un)loaded at the rear of the vehicle, as usually in practice. When a package is unloaded from the vehicle at its destination, all packages closer to the rear are unloaded from and reloaded into the vehicle. We want to reduce these handling operations, since there is time and effort associated to them. The goal of this paper is to develop solution methods to simultaneously solve the routing and reordering problem, by minimizing travel distance and handling operations. Packages loaded at pickup locations should be unloaded at delivery locations. Therefore, the reordering decisions are heavily intertwined with the route choice. Since the pickup and delivery problem is already NP-hard, we first develop solution methods to solve the optimal reordering of packages for a given route. After that, we use these methods to simultaneously consider reordering and routing decisions.

Keywords: Ordering, Pickup and delivery problem, Many-to-many structure

The orienteering problem with time-dependent stochastic travel times

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This research compares two solution methods for the orienteering problem (OP) with time-dependent stochastic travel times (TDS-OP). In Orienteering problems an optimal combination of vertices needs to be selected and the routing between the vertices needs to be optimized, due to the limited available time. In this particular version the travel time are both dynamic and stochastic and are therefore modelled as a function of distributions. This specific problem formulation allows us to tackle congestion related issues in routing problems that deal with high uncertainty.

We mathematically define this problem and propose an evaluation function. Subsequently, two solution procedures are developed: the first solution method generates solutions to the (time-independent deterministic) OP using an iterated local search framework. The generated solutions are afterwards evaluated as TDS-OP solutions by the evaluation function. In the second method a problem instance is solved as a time-dependent orienteering problem by the ant colony optimisation approach developed in former research. For each arc in the network the time-dependent travel time corresponding to the 95\% percentile of its travel time distribution is used. Afterwards these solutions are evaluated as TDS-OP solutions.

A set of realistic problem instances was developed based on the realistic road network of Belgium, the Netherlands and Luxembourg, containing 425,479 vertices and 519,915 arcs with accurate 15 minute travel time distributions for each arc. Currently, both methods are being compared based on solution quality and computational performance.

Keywords: orienteering problem, time-dependent stochastic travel times, metaheuristics

Analysing and solving the joint route planning problem in a horizontal carrier cooperation context

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Severe competition in global markets and the heightened expectations of customers have caused profit margins of transport companies to shrink. In order to survive under the increasing pressure to operate more efficiently, they are obliged to adopt a collaborative focus. Carriers operating at the same level of the supply chain may cooperate horizontally to increase their productivity, improve their service level and enhance their market position. Analysis of existing scientific research on horizontal carrier collaboration reveals that the majority of logistics cooperation literature may be divided into two research streams: order sharing and capacity sharing. Our research focuses on one particular order sharing approach: joint route planning. Applying joint route planning, customer orders from all carriers are combined and collected in a central pool and efficient route schemes are set up for all requests simultaneously using appropriate routing techniques. The routing problem associated with horizontally cooperating carriers may be defined as a multi-depot pickup and delivery problem with time windows (MDPDPTW). Due to the complexity of the MDPDPTW, a meta-heuristic method has been developed to solve large problem instances. In addition, the effect of cooperation structure on the amount of collaborative savings is analysed. Both the influence of carrier size and relative geographic location is investigated.

Keywords: Horizontal cooperation, Vehicle routing, Meta-heuristics

On-line traveling salesman with duration and distance considerations

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We consider on-line traveling salesman problems in which the objective is to minimize a weighted sum of completion time and total travel distance. Requests are revealed over time, and thus only partial information on the problem is known at any time. The double objective based on time and distance captures both the customer-centric time-to-service performance measure and the carrier costs. We examine the properties of several on-line algorithms for this problem. We consider their competitive ratio, which is defined as the worst case ratio, on any problem instance, between the cost of the online algorithm, and the cost of an optimal offline algorithm which knew all information in advance, i.e. customer request locations and disclosure dates. The interplay between an adversary, playing to create the worst case instance, and the policy of some parameterized on-line algorithms is modeled as a min-max non-linear program. Solving this program leads to new interesting upper and lower bounds on the performance of the considered algorithms.

Keywords: Traveling salesman problem, Online optimization, Competitive ratio

A mix-integer programming formulation and hybrid metaheuristic for tactical planning in bike sharing systems

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Bike sharing has recently enabled sustainable means of shared mobility through automated rental stations. Spatio-temporal variation of bike rentals, however, leads to imbalances in the distribution of bikes causing full or empty stations.

The resource allocation problem (RAP) tackles imbalances at a tactical planning level by means of bike allocation and relocation. We propose a MIP formulation of an extended dynamic service network design model. The objective is to determine optimal fill levels at stations while minimizing the expected costs of relocation operations. The MIP formulation is hard to solve due to a high number of binary variables for relocations (stations times stations times periods).

We present a hybrid metaheuristic (HM) integrating a large neighborhood search (LNS) with exact solution methods provided by a solver. The LNS iteratively improves the solution by limiting and controlling possible relocation regimes by a fix-and-optimize strategy, i.e. a small subset of "free" binary relocation variables. The majority of remaining binary variables are tentatively fixed to zero leading to a fast solvable truncated MIP. Therefore, a commercial solver provides a local optimal value in a reasonable time. Results obtained indicate that the HM outperforms CPLEX for data from Vienna's bike sharing system "Citybike Wien".

Keywords: mixed integer program, hybrid metaheuristic, large neighborhood search, fix-and-optimize approach, resource allocation, bike sharing

A Pair-wise Heuristic Approach for Stochastic Time-dependent Service Network Design

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Service network design, as part of the tactical planning process in transportation systems, aims to ensure that the proposed services are performed as stated and customers' requirements are satisfied, while operating in a rational, efficient, and profitable way. This research looks at a stochastic, time-dependent, capacitated, multi-commodity service network design problem in which periodic, cyclic schedules are built. We find and illustrate the underlying structures of stochastic solutions by studying the optimal solutions to the stochastic network design problem and comparing them with deterministic counterparts. To achieve this, the following issues are addressed: Why does the solution select one particular route rather than others? What drives the solution to add/drop a service? Structural properties that characterize the stochastic solutions are found when addressing these issues and are then used to develop a pair-wise heuristic algorithm. The heuristic approach systematically increases the flexibility of the solution to hedge against demand uncertainty, and gradually nudges the solution towards having a more hedging and consolidation-based structure, which is more suitable in the stochastic environment.

Keywords: network design, stochastic programming, random demand, service network design, heuristic

Barge Convoy Voyage Optimization

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Container transportation on rivers and canals is mainly carried out by barges. Such barges have a capacity up to 200 TEU and the container positions are not restricted to dedicated slots as in sea ships. Typically the containers can be stacked in two or three layers. Yet, the number of layers is subject to the draught of the barge. The total mass of the barge should be high enough such that the draught allows the barge to pass underneath bridges during the voyage. Furthermore multiple barges can be towed or pushed by one towboat forming a convoy. During the execution of a voyage the convoy composition can change as a barge can be detached from or attached to the convoy. This implies that the capacity of the `vessel´ can change during the voyage and that the route for one container, which starts and ends at the pickup and delivery terminal, can be carried out by more than one vessel. Here we tackle this problem holding such interesting and challenging constraints. Our optimization method is tested and compared on real world data obtained by the container transport company BCTN Meerhout.

Keywords: Container, Transportation, Optimization

A combined station location and vehicle recharging problem

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We present a combined station location and vehicle recharging problem for electric vehicles, in which, two decisions are made simultaneously: 1) where to locate a limited number of stations, 2) where to recharge the electric vehicles so that they can complete the given trip chains without running out of battery. A trip chain consists of a series of linked short trips and is represented by a sequence of intervening stops along the trip chain. In this problem, a set of trip chains and a set of potential station locations are given. The objective is to locate a limited number of stations so that the number of trip chains that can be refueled is maximized. We formulated this problem as a mixed integer programming formulation and proposed a heuristic method for solving this problem. The proposed heuristic is tested on real data collected in Denmark. The computational results will be presented.

Keywords: Station location, Electric Vehicle Routing, Heuristic

Planning Pickup and Delivery Operations in Finished Vehicle Distribution

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We examine a real-world routing problem from a finished vehicle distribution background. A logistics provider operates specialized terminals that receive finished vehicles via ship or truck connections and sends them out to their dealer destinations exclusively by truck. Besides doing deliveries, these trucks also collect cars from the field and either directly move them to their destination or bring them to the terminal for consolidation with other volumes waiting for shipment.

We study the problem of planning these truck operations in terms of suggesting pickup and delivery trips that minimize the total driving and handling efforts while assuring that the contracted delivery times for the vehicles are met. We present two heuristic approaches to provide decision support to the problem and compare their runtime and solution quality on basis of real-world test instances of 300 to 800 transport orders.

Keywords: Finished Vehicle Distribution, Capacitated Vehicle Routing, Pickup and Delivery

Modelling logistics systems involving straddle carriers and quay cranes in container terminals

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The straddle-carrier systems in container terminals normally employ two types of equipment, i.e. straddle carriers (SCs) and quay cranes (QCs) to move containers between ships and container yard. As a consequence, the logistics problem involving the schedule of SCs and QCs and their coordination has a great impact on the whole operational efficiency for container terminals. This study proposes a new approach to determine the loading schedules of QCs and the dispatching rules of SCs. The SCs dispatching problem discussed in this study includes making decisions on the delivery sequences and transportation routes for each SC. We formulate this problem as a mixed integer programming model, aiming to minimise the loading element of the ship's berth time, which is the completion time that all containers are loaded from the container yard to the ship. Optimal solutions can be obtained in small sizes, however, large-sized problems are hard to solve optimally in a reasonable time. Therefore, the heuristic method, i.e. genetic algorithm is designed to solve the problem in large sizes. A series of numerical experiments are carried out to evaluate the effectiveness of the integration approach and algorithm.

Keywords: container terminal operations, straddle carriers, genetic algorithm, scheduling and routing

1L-CVRP Originated from Logistics Practice

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Routing problem with loading constraints combines the routing and packing problems, which are separately studied NP-hard problems by customary, however, the recent study of VRP with two and three dimensional loading constraints, abbreviated to 2L- CVRP and 3L-CVRP respectively, allows a better and practical solution of logistics targets. Accordingly, by dimensionality, where is 1L-CVRP?

In this paper, the one-dimensional situations of CVRP are investigated by cases from logistics practice. By the Cutting and Packing problem topology, loading of cargos into vehicle can be guided by wall-building or layering methods. Firstly, a milk-run pick-up routing problem of an engine plant is identified as a one-dimensional case of loading just along the longitudinal direction of the vehicle. The milk-run system must pick up different parts into vehicle with right route, however, each part has large quantity but quite small in size, they are loaded into vehicle just by group stacking. And by the wall-building approximation method, the three-dimensional loading is degraded into one-dimensional longitudinal loading, thus a 1L-CVRP model is formulated with dual capacity constraints of both weight and loading length. The 1L-CVRP problem with real data is solved, and some interesting results are examined.

Secondly, layering on the vertical direction, can be found in the case of plywood delivery. A plywood has the same 1219x2438mm sheet size but different thickness ranging from 2~30mm, the plywood demand of different customers must be loaded layer-on-layer into a mini-truck to generate a reasonable urban route, with objective of minimising the total transportation cost. A similar 1L-CVRP model and instance is also proposed in this case.

Therefore, our 1L-CVRP is introduced to enrich the routing problem logic with loading constraints of all dimensional scales, explicitly from 3, 2 to 1 and 0, while 0L-CVRP stands for traditional capacitated vehicle routing problem without loading constraints.

Keywords: Vehicle routing problem, loading constraints, packing problem, dimensions

A parallel matheuristic for solving a class of vehicle routing problems

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In this study we present a matheuristic approach for a class of Vehicle Routing Problems (VRP). Our approach couples the Ant Colony Optimization (ACO) with solving the Set Partitioning (SP) formulation of the VRP. As the ACO algorithm, we use a rank-based ant system approach. An agent level-based parallelization is implemented except for the multi depot VRP and heteregoneous VRP where the problem is solved in parallel for different type of depots and vehicles respectively. The interim solutions which correspond to single vehicle routes are collected in a solution pool. To eliminate the duplicate routes in the pool, we utilize an elimination rule based on an identification key . After a pre-determined number of iterations, the routes accumulated in the solution pool are used to solve the SP formulation of the problem subject to a time limit. Once the optimal solution is found or the time limit is reached, the solution obtained is fed back to ACO as an elite solution that can be used in the pheromone reinforcement procedure. Our experimental study using the well-known VRP benchmark instances shows that the proposed methodology provides promising results and improves some of the best-known solutions reported in the literature.

Keywords: Vehicle routing problem, Matheuristic, Ant colony optimization, Set partitioning

A literature review on reverse logistics of waste electrical and electronic equipment

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Reverse logistics of products has gained major importance in business environment as recovery and proper disposal of waste became main issues in production sector. This importance arises mainly from the facts that material resources for production are limited and non-environmental friendly disposal of products causes pollution and consequently, affects on health negatively. As a result, governments regulate these processes by legislations and complying with these legislations also drive businesses to pay attention to reverse logistics. Besides, consumers' positive behaviour about recycled products also motivates recovery. Importance of recovery of electrical and electronic equipment can be observed through the legislations specifically formed about these products. In this study, we examine the studies that focus on reverse logistics of waste electrical and electronic equipment (WEEE) and present a literature review. We aim to form a reference paper for companies to adjust their businesses and network structures regarding existing legislations and studies.

Keywords: Reverse logistics, Recovery, Waste electrical and electronic equipment

Barge Port-Hinterland Container Network Design

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The problem of barge operator that connects a set of inland with a set of seaport container terminals is considered. The barge operator has to schedule its barge services in a tactical level to accommodate container demand from the port to the hinterland. The barge services should be cost effective by employing economies of scale while achieving high frequencies at the inland corridors. The barge operator has to decide how many and which types of barges to employ, and then schedule their routing. The cost for barges consists of a fixed weekly leasing cost and a variable cost per trip. The utilization of barges can be assessed in two dimensions, first the load factor of a barge, and second, the number of trips per time period. The latter depends mainly on the circulation times of barges routes that consist of traveling times, handling times, and of possible delays. We formulate the above problem as an MIP problem and solve instances for the case of Brabant Intermodal, a major Barge operator in the Netherlands. Our results show the effect of economies of scale, number of calls per trip, and of service frequency on the total costs faced by the barge operator.

Keywords: Network design, Barge routing, Intermodal Transportation, Container

The Load-Dependent Vehicle Routing Problem and its Pick-up and Delivery Extension

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We examine a vehicle routing variant capable of generating sensible routing plans when the weight of the cargo transported significantly contributes to the gross vehicle weight. Contrary to the traditional objective which calls for the minimization of the total travel distance, the examined problem is aimed at minimizing the total product of the distance travelled and the gross weight carried along this distance. This objective is closely related to the energy consumption of the vehicle fleet, thus it represents a credible alternative when the environmental aspects of logistics activities need to be optimized. Two problem versions are examined: a) the first version considers delivery service, and b) the second version considers simultaneous pick-up and delivery service and is introduced for the first time in the present study. To solve the problem, we employ a local search algorithm using a novel computational scheme for evaluating the complex weight-distance objective changes in constant time. Extensive computational experiments are conducted to gain insight on the effect of the cargo weight on the solution structures and the role of three key problem characteristics, namely the deviation of customer demands, the cargo to tare weight ratio and the size of the available vehicle fleet.

Keywords: vehicle routing, cargo weight, energy requirements, local search

The Disrupted Vehicle Routing Problem with Vehicle Breakdown

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In this study, we focus on the Disrupted Vehicle Routing Problem with Vehicle Breakdown (DisVRP-VB). This problem arises when, during the execution of the optimal plan for the Capacitated VRP, one of the vehicles breaks down. In the DisVRP-VB, a set of 'active' vehicles start from a different position each and have to visit a preassigned set of customers before finishing at the depot. We assume that there is no extra vehicle available at the depot and that the orders are customer-specific. Each customer that was originally assigned to the broken-down vehicle has to be served by one of the active vehicles. Before visiting anyone among the broken-down vehicle's original customers, an active vehicle has to visit the broken-down vehicle, in order to load the goods ordered. Multiple visits to the broken-down vehicle are allowed. The goal is to construct a set of routes of minimum total distance, so that the relevant capacity and precedence constraints are satisfied. Different variants of the DisVRP-VB have been addressed in the literature and various formulations and algorithms have been proposed, most of them heuristics. Our research focuses on proposing a new formulation which can be used to find the exact optimal solution.

Keywords: Disrupted VRP, vehicle routing, vehicle breakdown, vehicle rescheduling problem, disruption management

A Branch-and-Price approach for the Capacitated Vehicle Routing Problem

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We address the capacitated vehicle routing problem (CVRP) where a set of customers with known demands have to be served by a set of homogenous fleet of capacitated vehicles. The objective is to build a minimum-cost set of routes that deliver the customers' demands while satisfying the vehicle capacity constraints. This problem is formulated as a set covering formulation that is solved by a branch-and-price approach.

First, we investigate the pricing problem that turns out to be a constrained elementary shortest path problem with negative cycles. We propose a new polynomial-size nonlinear mixed-integer programming model. We apply the Reformulation-Linearization Technique (RLT) to linearize the proposed model. Furthermore, we describe several algorithmic expedients that enable a quick convergence of the proposed branch-and-price algorithm. These expedients include preprocessing, upper bound computation, efficient solution of the LP relaxations, and stabilization procedures. We report the results of extensive computational experiments that provide evidence of the efficacy of the proposed branch-and-price approach.

Keywords: Capacitated Vehicle Routing Problem, Branch-and-Price, Column Generation

A Stochastic Location-Routing Model for Prepositioning and Distributing Emergency Supplies

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With the increasing number of natural or man-made disasters around the world, effective and efficient ways to manage emergency supplies become more and more indispensible. Currently, in some disaster-prone areas, prepositioning emergency supplies is a common tactic to prepare for potential disasters. But, the benefits of prepositioning activities are intertwined with the sequential distribution activities that are determined based on post-disaster situations. In this study, we model post-disaster situations as scenarios and propose a two-stage stochastic programming model to preposition and distribute emergency supplies. In the first stage, the model decides where to locate warehouses and how many quantities to stock in opened warehouses for prepositioning purposes. In the second stage, after the realization of a scenario, the model decides how many quantities to transport to demand sites and the corresponding routing. Furthermore, the issue of equitability is taken into consideration when distributing emergency supplies. A case study is provided to illustrate our stochastic programming model. Moreover, through comparing with other conventional models, the benefits of our model are demonstrated and some managerial insights are given.

Keywords: Emergency supplies, Location-routing, Stochastic programming