Workshop of the EURO Working Group on Vehicle Routing and Logistics optimization (VeRoLog)

2-5 Jun 2019
Seville
Spain

Table of contents

Handling Vehicle Relocation Through Layered graphs

Alain Quilliot * [1,2], Helene Toussaint [3]

[1] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Université Blaise Pascal - Clermont-Ferrand II, Université d'Auvergne - Clermont-Ferrand I, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France
[2] University Clermont Auvergne (UCA) – LIMOS UMR CNRS/UCA618, Laboratoire Informatique, Modélisation et Optimisation des Systèmes, UCACNRS – Campus des Cézeaux, Clermont-Ferrand, 63000, France, France
[3] Centre National de la Recherche Scientifique, France (CNRS) – Mines Saint-Etienne, Univ Clermont Auvergne, CNRS, UMR 6158 LIMOS, Institut Henri Fayol, F - 42023 Saint-Etienne, France – France

A *one-way vehicle-sharing* system involves *stations*, together with free access *vehicles* (bicycles or electric cars), that users may pick up and give back at different *stations*. *Carriers* (trucks, drivers...) periodically move *vehicles* from *excess* stations to *deficit* ones. The *Vehicle-Sharing Relocation* (*VSR*) problem is about the design of the routes followed by *carriers* when relocating *vehicles*. We suppose here that *relocation* is performed by multi-task drivers concurrently to the system activity, as soon as some unbalanced situation is detected. We distinguish *time* and *cost* notions, impose some threshold to the *makespan* of the process, and consider *carrier-number* and *vehicle-riding-time* (time during which *vehicles* become unavailable) as part of the performance, together with the *carrier-riding-cost*.
We cast both *non-preemptive* and *preemptive VSR* (*carriers* may exchange *vehicles*) into the multi-commodity flow framework while using *layered graphs*, which extend *time-expanded networks*, and handle it according to a 3-step *vehicle-driven* approach: we first deal with a 1-layer projection and compute elementary connections followed by *vehicles* sharing same *carriers*; next we lift those connections into the layered graph through a multi-processor scheduling algorithm; finally we solve the restriction of our model to the resulting arc subset through a math-heuristic. We turn any *preemptive* solution into a *non-preemptive* one by solving an auxiliary *min-cost* flow model.

We perform experiments in order to compute lower bounds, evaluate heuristics and estimate the gap *preemption/non-preemption*.

Gavalas.D, al.: Design&management of vehicle-sharing systems: a survey, *ArXiv e-prints*, (2015).
Gouveia.L, al.: Layered graph approaches for combinatorial optimization problems; *C.O.R*, (2018).

Keywords: Routing, Scheduling, Layered Graphs

*Speaker

Predictive dynamic relocations in carsharing systems implementing complete journey reservations

Martin Repoux * [1], Mor Kaspi [2], Burak Boyacı [3], Nikolas Geroliminis [1]

[1] Ecole Polytechnique Fédérale de Lausanne (EPFL) – EPFL ENAC IIC LUTS, Station 18 1015 Lausanne, Switzerland
[2] Department of Industrial Engineering, Tel Aviv University – Israel
[3] Lancaster University Management School, Department of Management Science, Centre for Transport and Logistics (CENTRAL) – Lancaster University Management School, Lancaster, LA1 4YX, United Kingdom

We study the operation of station-based one-way carsharing systems that enforce a complete journey reservation policy. Under such regulation, users are required to reserve both a vehicle at the origin station and a parking spot at the destination station during the booking time. Reservations can be made up to one hour in advance and users are not required to specify in advance the exact pick-up and drop-off times. These rental conditions are attractive to customers as they guarantee the availability of vehicles and parking spots at the start and end of the customers' journeys. Nevertheless, this policy may also result with inefficient use of resources due to long vehicle/parking spot reservation durations. From the operator's point of view, vehicle/parking spot reservations provide information about parking spots/vehicles that are about to become available. Integrating such information in the relocation decision process may improve the performance of the system significantly. In this work, we develop a single-station Markovian model that incorporates journey reservation information in the state representation and utilizes historical data to estimate expected near future demand loss at every station. The output of the model is integrated in a new proactive dynamic staff-based relocation algorithm that makes real-time relocation decisions. A collaboration with the Grenoble carsharing system has allowed us to test in field the proposed algorithm and compare it to other dynamic and static relocation approaches. The efficiency of the algorithm is further demonstrated through an extensive simulation experiment based on real transaction data obtained from the Grenoble system.

Keywords: simulation, Markov chain, carsharing

*Speaker

Comparing centralized and decentralized repositioning strategies for ride-sharing applications

Martin Pouls * [1], Katharina Glock [1], Anne Meyer [2]

[1] FZI Research Center for Information Technology (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany
[2] Technische Universität Dortmund – 44221 Dortmund, Germany

Ride-sharing services such as Lyft Line and UberPOOL offer a promising way of reducing urban traffic. One challenge faced by operators of these services is the repositioning of idle vehicles to anticipate future demand. In systems with independent drivers, this is generally achieved by providing incentives for drivers to reposition towards areas with a discrepancy between supply and predicted demand.
In this talk, we compare two approaches for solving the idle vehicle repositioning problem. Firstly, we present a novel way of modelling the problem, in which we aim to maximize coverage of forecasted demand locations by repositioning idle vehicles and minimize the travel duration for these repositioning movements. We compare this centralized strategy to a decentralized one. The latter consists of an agent-based approach, where drivers maximize their personal profit. Earning potential is increased in high-demand areas to incentivize drivers to reposition there. Both solution approaches are embedded into a framework for evaluating dynamic dial-a-ride-problems.
Based on real-world taxi trip records from New York City, we build a diverse set of test instances containing up to 400,000 trip requests per day. We evaluate our centralized and decentralized solution strategies on these instances regarding the number of rejected trip requests and the travel duration for repositioning movements. In addition, we compare them to solutions with a simple reactive repositioning approach and no repositioning at all. Lastly, for our forecast-based method we assess the impact of the forecast quality on the solution quality.

Keywords: dial a ride problem, ride sharing, mobility as a service, repositioning, dynamic

*Speaker

The pickup and delivery problem with online transfers, for the next generation of public transport

Paul Bouman [1], Gizem Ozbaygin * [2], Lucas Veelenturf [3]

[1] Erasmus School of Economics, Erasmus University – Rotterdam, Netherlands
[2] Faculty of Engineering and Natural Sciences, Sabanci University – Istanbul, Turkey
[3] Eindhoven University of Technology – Eindhoven, Netherlands

We introduce and study a new variant of the vehicle routing problem, which we call the pickup and delivery problem with online transfers (PDPOT), motivated by an innovative passenger transportation concept involving self-driving vehicles. These vehicles are designed in a way that they can couple/decouple while en-route and transfer passengers seamlessly towards more efficient capacity utilization and traffic management. Due to the potential reduction in fuel/energy consumption and travel costs, there are studies in the vehicle routing literature taking transfer opportunities into account within their framework. The most closely related vehicle routing problem to the one we consider in this study is the pick-up and delivery problem with transfers. However, the main difference and perhaps the most challenging aspect of the PDPOT is that when two or more vehicles couple, the passengers may transfer from one vehicle to another during the time the vehicles are traveling together as a single vehicle. Among the major contributions of our study are: (1) the development of an optimization based approach to solve a complex vehicle routing problem arising in an on-demand transportation system involving autonomous shared vehicles, (2) investigating the economic, social, and environmental benefits of the door-to-door shared mobility service with online transfers compared to private door-to-door rides and compared to shared mobility services with outside transfer possibilities.

Keywords: On demand shared mobility, pick up and delivery with online transfers, autonomous vehicles

*Speaker

Optimized real-time management for on-demand ride sharing services.

Zahra Ghandeharioun *† [1], Anastasios Kouvelas‡ [2]

[1] Institute for Transport Planning and Systems (IVT)- ETH Zurich – HIL F34.2, Stefano-Franscini-Platz 5, 8093 Zurich, Switzerland, Switzerland
[2] Institute for Transport Planning and Systems (IVT)-ETH Zurich – HIL F37.2, Stefano-Franscini-Platz 5, 8093 Zurich, Switzerland, Switzerland

Ridesharing on demand is considered nowadays an effective personal mobility service for reducing traffic congestion and pollutions. In the recent years by growing smartphone technologies and inexpensive cellular communications, a more individualized mode of transport in urban mobility has led companies like Uber, Lyft and Via to focus on developing demand responsive services, called Mobility on Demand (MoD). Furthermore, considering ride sharing benefits and its potential, the companies adjusted their services with sharing options. In the other hand with rising automated driving technologies, automated ride-sharing services would be an attractive mobility service in the near future. Optimization of ride-sharing services has attracted researchers to formulate it as vehicle-routing problem and dynamic pick-up and delivery problem. In the current work, we mainly focus to apply different optimization techniques to solve on-demand ridesharing services in a real-time framework. In addition, we evaluate various management strategies, by application of different decision variables and cost functions. Furthermore, the sensitivity of the strategies to different ride sharing capacities will be investigated. By developing an event-based simulation engine, we provide a real-time taxi ride-sharing search algorithm. The main task of the algorithm is to quickly decide between available taxi candidates, which satisfy both user inquiries and cost function constraints. Additionally, we validate the feasibility of the simulation engine by utilizing millions of real trip data from the New York City taxi dataset. Moreover, by variation of different parameters and implementing different cost functions, we study the result of various strategies.

Keywords: Capacitated ridesharing, Simulation, Mobility on demand

*Speaker
†Corresponding author: zahra.ghandeharioun@ivt.baug.ethz.ch
‡Corresponding author: anastasios.kouvelas@ivt.baug.ethz.ch

The effect of spatial and temporal flexibility on the profitability of one-way electric carsharing systems

Burak Boyaci *† [1], Konstantinos Zografos [1]

[1] Lancaster University Management School, Centre for Transport and Logistics (CENTRAL) – United Kingdom

Carsharing is an advanced car rental service, which allows its users to rent vehicles for a short period. One-way carsharing systems allow users to drop-off rented vehicles to different spots than where they are picked-up. Although one-way systems offer additional flexibility to their customers, i.e. using different pick-up and drop-off stations, the operators do not prefer because of the additional complexity that one-way option brings. To have an acceptable level of service, the vehicles and empty spots should be at the right place and time. One-way systems also experience demand imbalances between stations throughout the day. For these reasons, one-way systems require relocation of vehicles between stations. Either a group of personnel and/or the users (with positive incentives) execute relocations. One of the ways of decreasing relocations without compromising the service level could be providing spatial and temporal flexibility to users with incentives. If the operator can offer a pick-up time not very earlier/later, and origin and destination stations not very distant than the users asked for, with an incentive (i.e. discounted rental fee), the operator can serve its users with fewer relocations. For this reason, we developed a solution framework that decides on detailed relocation operations, and demand reject/accept (with alternative) decisions simultaneously. Experiments with real data have shown that 1km pick-up and drop-off location distance flexibility and 60 minutes pick-up time flexibility, increase the profit of the non-flexible system over 10% by increasing the number of demand served over 25% and decreasing the personnel cost by over 60%.

Keywords: one way carsharing, vehicle relocation optimization, integer programming, network flow, spatial and temporal flexibility

*Speaker

†Corresponding author: b.boyaci@lancaster.ac.uk

Dynamic Multimodal Freight Routing using a Co-Simulation Optimization Approach

Maged Dessouky * [1], Yanbo Zhao [2], Petros Ioannou [2]

[1] University of Southern California – Daniel J. Epstein Department of Industrial and Systems Engineering University of Southern California Los Angeles, CA 90089-0193, United States
[2] University of Southern California – United States

One of the challenges for freight transport efficiency arises from the fact that both freight and passenger traffic share the same infrastructure for
moving people in addition to freight goods which leads to non-homogeneous traffic. This non-homogeneity has a detrimental impact on urban
transport performance because of the differences of vehicle sizes and dynamics between passenger and freight vehicles. Without efficient management
of the freight transport, the whole transportation network will face severe capacity shortages, inefficiencies, and load imbalances.
However route decision-making in a dynamical and complex urban multi-modal transportation environment aims to minimize a certain objective cost
relying on the accurate prediction of traffic network states and estimation of route costs that are not readily available. We introduce a hierarchical
routing system to solve the formulated freight routing problem when hard vehicle availability and capacity constraints exist. The simulation layer
provides the state and cost estimation and prediction for the upper optimization layer in which we use a COSMO (CO-Simulation Optimization)
approach to solve the formulated freight routing problem based on iteratively rebalancing the freight loads. A simulation testbed consisting of a road
traffic simulation model and a rail simulation model for the Los Angeles/Long Beach Port regional area has been developed and applied to
demonstrate the efficiency of the proposed approach.

Keywords: Logistics, Routing, Load Balancing

*Speaker

A Large Multiple-Neighborhood Search for Order Management in Attended Home Deliveries

Jarmo Haferkamp *† [1], Jan Fabian Ehmke [1], Tino Henke [1]

[1] Otto-von-Guericke University Magdeburg – Germany

In recent years, more and more online retailers offer deliveries within tight customer time windows. Customers typically select a delivery time window within the checkout process, and online retailers engage logistics service providers to carry out the deliveries. As a result, logistics service providers have to decide quickly whether they can fulfil a particular delivery request. In order to ensure their economic success, logistics service providers need to maximize the number of accepted deliveries while guaranteeing feasibility for a limited number of delivery vehicles. This problem can be modelled as a Dynamic Vehicle Routing Problem with Time Windows. In recent years, the focus for solving such problems has been on complex anticipatory approaches. These approaches require a predictable environment as well as a sufficient amount of historical data. Since this is not always given, we examine whether and under which conditions a myopic approach can compete with anticipation methods. We propose a Large Multiple-Neighborhood Search and, as a benchmark for perfect anticipation, implement a hindsight approach based on an Adaptive Large Neighborhood Search. The evaluation and comparison of these approaches is based on extensive computational simulation using the historical order data of a large German online retailer.

Keywords: Large Multiple Neighborhood Search, Dynamic Vehicle Routing Problem with Time Windows, Attended Home Deliveres

*Speaker

†Corresponding author: jarmo.haferkamp@ovgu.de

Booking of loading/unloading areas

Andrea Mor * [1], M. Grazia Speranza [2], José M. Viegas [3]

[1] Department of Economics and Management, University of Brescia – Italy
[2] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy
[3] CERIS, Instituto Superior Técnico, Universidade de Lisboa – Portugal

City distribution usually requires vehicles to temporarily stop at roadside to allow for the driver to perform the last leg of the delivery by foot. The stops take place in designated areas, called loading/unloading (L/U) areas. In this chapter the introduction of a booking system for the management of the L/U areas in a city center is studies as a way to eliminate double parking. Two booking management system and the arising routing problems are presented. The first booking management proposed in the one where distributors book in sequence, accounting for the reservations that have already been placed. The second considers a centralized system that collects all the required stops at L/U areas and finds a reservation for each distributor. The optimization problems arising in each of the two approaches are presented. The solutions provided by the two booking systems are discussed and compared with a representation of the current use of the L/U areas, where the distributors do not consider the availability of a parking spot and resort to double if none is available.

Keywords: Booking, loading and unloading, routing

*Speaker

An Enhanced Branch and Price Algorithm for the Time-Dependent Vehicle Routing Problem with Time Windows

Gonzalo Lera Romero * [1], Juan Jose Miranda Bront [2,3], Francisco Soulignac [3,4,5]

[1] Instituto de Investigación en Ciencias de la Computación (ICC), CONICET-Universidad de Buenos Aires (ICC) – Argentina
[2] Universidad Torcuato Di Tella – Argentina
[3] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) – Argentina
[4] Departamento de Ciencia y Tecnología, Universidad Nacional de Quilmes – Argentina
[5] Departamento de Computación, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires – Argentina

In this paper we implement a branch and price (BP) algorithm for a time dependent vehicle routing problem with time windows in which the goal is to minimize the total route duration (DM-TDVRPTW). The travel time between two customers depends on the departure time and, thus, it need not remain fixed along the planning horizon. We propose several improvements to the exact labeling algorithm by Dabia et al. (Branch and price for the time-dependent vehicle routing problem with time windows, Transp. Sci. 2013; 47(3):380–396) for solving the pricing problem, while we provide a tailored implementation for the dominance tests that relies on efficient data structures for storing the enumerated labels. Computational results show that the proposed techniques are effective for accelerating the column generation step. The obtained BP algorithm is able to solve benchmark instances with up to 100 customers, being able to solve all the instances with 25 customers. Furthermore, heuristic adaptations are able to find good quality solutions in reasonable computing times, showing its potential to be applied in practice.

Keywords: vehicle routing problem, time windows, time dependent travel times, branch and price, dynamic programming

*Speaker

A Branch-and-Price Solution Approach for Electric Vehicle Routing Problems with Time Windows

Ece Naz Duman *† [1], Duygu Tas‡ [2], Bülent Çatay§ [1]

[1] Sabanci University – Faculty of Engineering and Natural Sciences, Istanbul, Turkey
[2] Duygu Taş – Turkey

We study the Electric Vehicle Routing Problem with Time Windows (EVRPTW) where electric vehicles (EVs) with limited driving range may need to recharge their batteries en-route in order to complete their tours. Recharging may take place at any battery state of charge and at any station, and its duration is linearly proportional to the amount of energy transferred. We address two variants of the problem where the stations are equipped with single and multiple charging technologies. We solve these problems by employing a branch-and-price method based on a column generation algorithm. We develop a modified version of the *ng-route* algorithm to solve the pricing subproblem of the column generation method, which corresponds to the Elementary Shortest Path Problem with Resource Constraints (ESPPRC). A two-stage label correcting algorithm based on *ng-route* algorithm is implemented to solve the ESPPRC. The *ng-route* algorithm is then improved by applying the state-of-the-art acceleration techniques including a heuristic column generator and a bounding procedure. In addition, we reduce the size of the transportation digraph by eliminating the dominated stations and merging station nodes with customer nodes, which further speeds up the algorithm. The performances of the proposed methods are tested by conducting an extensive computational study using well-known benchmark instances from the literature.

Keywords: Electric Vehicles, Vehicle Routing, Branch and Price, Ng route Algorithm, Partial Charging

*Speaker
†Corresponding author: ecenazduman@sabanciuniv.edu
‡Corresponding author: duygu.tas@mef.edu.tr
§Corresponding author: catay@sabanciuniv.edu

Optimizing Omni-Channel Fulfillment with Store Transfers

Joydeep Paul * [1], Niels Agatz [1], Martin Savelsbergh [2]

[1] Rotterdam School of Management, Erasmus University Rotterdam (RSM) – Netherlands
[2] School of Industrial and Systems Engineering [Georgia Tech] (ISyE) – H. Milton Stewart School of Industrial and Systems Engineering Georgia Institute of Technology 765 Ferst Drive, NW Atlanta, Georgia 30332-0205, United States

The presence of different distribution channels in omni-channel retail makes the fulfillment process challenging. When consumers can buy online and pick up their purchased goods at a store, the stores are often visited by a vehicle that supplies the pick-up points (PUPs) and by a vehicle that replenishes the store's inventory. We study the benefit of exploiting any spare capacity in the vehicles replenishing store inventories to reduce online order fulfillment cost by transferring online orders to these vehicles at one or more of the stores visited. This involves choosing transfer locations and the set of stores whose online orders are transferred at these locations so as to minimize the online order fulfillment cost. To enable feasible transfers at a transfer location, a vehicle from the online channel must visit the transfer location before the store replenishment vehicle. At a given transfer location, we can only transfer online orders of stores which are visited by the store replenishment vehicle after the transfer location in its route. We introduce the Shared Capacity Routing Problem with Transfers to minimize the transport cost of online order fulfillment in an omni-channel retail environment. We present a mixed integer linear programming model as well as an effective and efficient heuristic for solving this problem. An extensive computational study shows that a significant reduction in transport cost and store-visits can be achieved by sharing capacity across the two channels.

Keywords: Transportation, Routing, Capacity sharing, Store transfers, Omni, channel retail, Heuristics

*Speaker

Approximate dynamic programming for multi-period taxi dispatching

Felix Goetzinger * [1], Anne Meyer [2], Martin Pouls [3]

[1] Barkawi Management Consultants – Baierbrunner Str. 35 81379 Munich, Germany
[2] Technische Universität Dortmund – 44221 Dortmund, Germany
[3] FZI Research Center for Information Technology (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany

300,000 to 500,000 cab rides arise every day in New York. Conducted by roughly 30,000 taxi drivers and mostly allocated by taxi dispatchers. To allocate and to reposition the taxis, the future positions of the cabs and the expected value of these future positions needs to be considered. The target is to create an automated method, which provides decision support in real-time and incorporates stochastic information and expectations.
In this talk we define and solve the taxi dispatching problem as a stochastic dynamic resource allocation problem (SDRAP). Due to the large number of states, results, and actions we use an approximate dynamic programming approach (ADP). Our solution strategy is sampling-based and solves network flow problems as LP for each discrete point in time. Using the duals of the underlying LP solutions, we estimate concave value functions via reinforcement learning techniques within the simulation to predict future revenue and incorporate these functions into the model.
We perform evaluations on historical taxi trip records from Manhattan provided by the New York City Taxi and Limousine Commission. In our experiments, we compare different value function approximations, parameter settings and instance sizes. Compared to myopic policies our method leads to an increase of roughly 60% in revenue due to a higher utilization of cabs and roughly 90% less waiting cabs. In addition, we estimate well performing value functions and transfer them into heat maps. All in all, the optimization and decision support can be realized in real-time for realistic taxi data instances.

Keywords: Transportation, Logistics, Approximate Dynamic Programming

*Speaker

The electric fleet transition problem

Samuel Pelletier * [1], Ola Jabali [2], Jorge Mendoza [1], Gilbert Laporte [1]

[1] HEC Montréal – 3000 Chemin de la Côte-Sainte-Catherine, Montréal, QC H3T 2A7, Canada
[2] Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano – Piazza Leonardo da Vinci, 32 20133 Milano, Italy

The incorporation of electric vehicles in city logistics has become a topical issue in the last few years. Several companies and municipalities, either voluntarily or to comply with legal requirements, will need to transition to greener fleets in the next decades. Such transitions are often established by temporal targets, which dictate the number of electric vehicles that should be in the fleet by a given time period. In this research we introduce optimization-based decision making tools to support this transition. More precisely, we present a fleet replacement problem which allows organizations to determine vehicle replacement plans that will respect their fleet electrification targets in a cost-effective way. We refer to this problem as the electric fleet transition problem (EFTP). The EFTP incorporates several features that have not been considered in previous fleet replacement studies for electric vehicles, notably: temporal electrification targets, decisions regarding charging infrastructure-related investments and costs, and aggregated task assignment decisions. We formulate the EFTP as an integer linear program, and we conduct computational experiments in order to draw managerial insights regarding the impact of several features on optimal transition plans.

Keywords: fleet replacement, stochastic optimization, electric vehicles, city logistics

*Speaker

Heuristic approach to solve a tandem truck-dron logistic delivery problem

Pedro L. Gonzalez-R * [1], José L Andrade [2], David Canca Ortiz * [1], Marcos Calle-Suárez [1]

[1] Industrial Engineering and Management Science, School of Engineering, University of Seville – Spain
[2] Robotics, Vision and Control Group (GRVC) – Spain

Nowadays a great development and applications in unmanned aerial vehicles (UAVs) have succeeded. Probably, in a few years, these applications will be fully integrated into our lives and we will see them as something usual, as happened recently with the use of mobile phones or internet. The practical application and use of UAVs implies a series of problems that are of a different dimension to the technological component. Among them, the problems derived from the use of UAVs in logistics distribution tasks, in the so-called "last mile" delivery problems, stand out. In the present work we focus on the resolution of the truck-drone tandem routing problem.

The problems of tandem routing have a complex structure and have only been partially addressed in the literature. The use of UAVs raises a series of restrictions and considerations that did not appear previously. The aspects such as the autonomy of the batteries used by the UAVs and the definition of replacement points can be highlighted. This casuistry limits their mathematical modelling and resolution to small-size cases.

We propose an iterated greedy heuristic based on the iterative process of destruction and reconstruction of solutions. This process is orchestrated by a global optimization scheme using a simulated annealing algorithm. The obtained results are quite promising when comparing with the modelling and exact resolution from previous research

Keywords: unmanned aerial vehicle routing problem, UAVs scheduling, Iterated Greedy, Heuristics

*Speaker

An Exact Algorithm for a Rich Vehicle Routing Problem with Private Fleet and Common Carrier

Said Dabia* [1], David Lai †‡ [2], Daniele Vigo [3]

[1] VU University Amsterdam – VU University Amsterdam De Boelelaan 1105 1081 HV Amsterdam The Netherlands, Netherlands
[2] VU Amsterdam – Netherlands
[3] University of Bologna – Italy

The Vehicle Routing Problem with Private Fleet and Common Carrier (VRPPC) is a generalization of the classical Vehicle Routing Problem in which the owner of a private fleet can either visit a customer with one of his vehicles or assign the customer to a common carrier. The latter case occurs if the demand exceeds the total capacity of the private fleet or if it is more economically convenient to do so. The owner's objective is to minimize the variable and fixed costs for operating his fleet plus the total cost charged by the common carrier. This family of problems has many practical applications, particularly in the design of last mile distribution services, and has received some attention in the literature, where some heuristics were proposed. We extend here the VRPPC by considering more realistic cost structures that account for quantity discounts on outsourcing costs and by considering time windows resulting in a Rich VRPPC (RVRPPC). We present an exact approach based on a branch-and-cut-and-price algorithm for the RVRPPC, and test the algorithm on instances from the literature.

Keywords: Vehicle Routing Problem

*Corresponding author: s.dabia@vu.nl
†Speaker
‡Corresponding author: david.lai@vu.nl

Vehicle Routing Problem with Flexible Drones

Ilke Bakir *† [1], Gizem Ozbaygin‡ [2]

[1] University of Groningen (RuG) – 9712 CP Groningen, Netherlands
[2] Sabanci University – Tuzla 34956 İstanbul, Turkey

The use of unmanned aerial vehicles (UAVs), or *drones*, in conjunction with drone-launching trucks/vans for customer deliveries is currently being explored by numerous corporations. We study the *vehicle routing problem with flexible drones*, where the drones are not dedicated to certain vehicles. Rather, they can switch between vehicles in order to further increase the parallelization of delivery operations. We demonstrate the performance improvements provided by this flexibility compared to the more widely studied variant of this problem, where the drones must come back to the vehicle they were launched from. We model this problem using a time-expanded network, and provide optimal solutions for benchmark problem instances adapted from the traveling salesman problem with drone (TSPD) literature, as well as larger problem instances. To solve large problem instances, for which solving the fully time-expanded network MIP is impractical, we present a dynamic discretization discovery (DDD) algorithm (Boland et al. 2017), which iteratively refines the time-expanded network via computing lower and upper bounds. This way, the optimal solution is found without generating the fully time-expanded network, by only solving a series of much smaller MIPs compared to the fully time-expanded network MIP. We present an extensive computational study that demonstrates *(i)* the benefits provided by using drones in commercial delivery settings, *(ii)* makespan improvements obtained by flexible, rather than dedicated, drones, ***(iii)*** the solution performance of DDD in comparison to commercial solver(s), and ***(iv)*** the practical performance of DDD when stopped after a time/iteration limit, rather than proof of optimality.

Keywords: vehicle routing, drones, time expanded network, iterative refinement, dynamic discretization discovery

*Speaker
†Corresponding author: i.bakir@rug.nl
‡Corresponding author: ozbaygin@sabanciuniv.edu

The generalized vehicle routing problem with time windows

Yuan Yuan *† [1], Diego Cattaruzza‡ [1], Maxime Ogier§ [1], Frédéric Semet¶ [1], Daniele Vigo‖ [2]

[1] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) - UMR 9189 (CRIStAL) – Ecole Centrale de Lille, Institut National de Recherche en Informatique et en Automatique, Institut Mines-Télécom [Paris], Université de Lille, Centre National de la Recherche Scientifique : UMR9189 – Bâtiment M3, Université Lille 1, 59655 Villeneuve dÁscq Cedex FRANCE, France
[2] University of Bologne – Italy

Global e-commerce sales are estimated to hit $4.5 trillion in 2021. This poses huge challenges for last mile delivery services. Currently deliveries are performed at customer's home/workplace where customers wait to get orders. Recently, companies developed locker delivery. Customers choose a nearby locker as their pickup location for orders. In the past two years, trunk delivery has been proposed: orders can be delivered to the trunks of cars. Trunk delivery is different from the former two since the car may be in different locations during the day. Thus, synchronization between cars and couriers is required to perform the delivery.
This work studies a last-mile system that combines home/workplace, locker and trunk delivery services. We call the resulting problem the generalized vehicle routing problem with time windows (GVRPTW).

We describe the GVRPTW with a set covering model. The solution is obtained by solving this model on a restricted route pool, subset of all feasible routes. The route pool is first filled using construction heuristic: first pivots customers are selected, then next inserted customers are selected based on a regret paradigm. Finally routes are re-optimized with a labeling algorithm. The route pool is iteratively enriched 1) with routes obtained by exploiting the dual information retrieved by the resolution of the linear relaxation of the set covering model; 2) with new routes obtained by intensification of the research around feasible solutions via a local search procedure. The algorithm is tested on benchmark instances from the literature.

Keywords: Generalized vehicle routing problem, time windows, trunk delivery

*Speaker
†Corresponding author: yuan.yuan@inria.fr
‡Corresponding author: diego.cattaruzza@inria.fr
§Corresponding author: maxime.ogier@centralelille.fr
¶Corresponding author: frederic.semet@centralelille.fr
‖Corresponding author: daniele.vigo@unibo.it

Dynamic Service Area Sizing for Same-Day Delivery Routing

Marlin Ulmer * [1], Alan Erera [2], Martin Savelsbergh [2]

[1] Technische Universität Braunschweig – Germany
[2] Georgia Institute of Technology – United States

We consider a dynamic same-day delivery routing problem. Customers order goods over the course of the day and are served by a fleet of delivery vehicles. The vehicles perform several delivery tours from a depot to customers over the course of the day. The provider promises timely delivery, for example, within two hours. The delivery deadlines are occasionally violated, especially, when customer demand is high. Deadline violations result in customer dissatisfaction. To avoid customer dissatisfaction, the provider dynamically controls customer demand by changing the size of the service area. Same-day delivery service is only offered to customers within the service area. The provider's goal is to maximize the number of customers served while avoiding customer dissatisfaction. Dynamically sizing the service area is challenging. First, the size of the service area should depend on the current workload and the expected future customer demand. Second, a current sizing decision impacts the fleet's potential to serve customers in the future. We present two steps to address these challenges. First, we derive a functional dependency between workload and suitable service area size. Second, to anticipate future demand, we parametrize the function differently for different times of the day. The parametrization is determined by value function approximation (VFA). The VFA uses simulation to estimate the value of having a certain parametrization at a certain time of day. We show that our method allows serving many customers without significant deadline violations.

Keywords: Dynamic Vehicle Routing, Delivery Routing, Service Area Sizing, Value Function Approximation

*Speaker

A column generation approach for the driver scheduling problem with staff cars

Shyam Sundar Govindaraja Perumal * [1,2], Jesper Larsen [1], Richard Lusby [1], Morten Riis [2], Tue Christensen [2]

[1] Technical University of Denmark – Denmark
[2] QAMPO ApS – Denmark

Given a set of timetabled bus trips, transport companies are faced with the challenge of finding feasible driver schedule that covers all trips and abides by various labor union regulations. The regulations are concerned with providing sufficient breaks for the drivers during the day. Practical limitations in city networks enforce drivers to travel by cars between bus stops to have breaks. Transport companies have a limited number of cars, known as staff cars, which have to be returned to its depot at the end of the day. The simultaneous scheduling of drivers and staff cars is known as the driver scheduling problem with staff cars (DSPSC). It is estimated that the DSPSC accounts for 60% of a company's operational expense, and a column generation approach is proposed that attempts to minimize operational expense. The column generation method iterates between a master problem, a subproblem for generating driver variables and a subproblem for generating staff car variables. The subproblem related to the drivers is formulated as a resource constrained shortest path problem, which is solved by a dynamic programming approach. The proposed method is tested on eight real-life instances from seven Northern European companies. A comparison with a state-of-the-art mixed integer programming solver and an adaptive large neighborhood search heuristic indicate that the column generation method provides improved solutions for six instances and the average improvement is 1.45%.

Keywords: Transportation, Driver scheduling problem, Column generation

*Speaker

An Exact Solution Framework for Multi-Trip Vehicle Routing Problems with Time Windows

Rosario Paradiso [1], Roberto Roberti *† [2], Demetrio Laganà [1], Wout Dullaert [2]

[1] University of Calabria – Italy
[2] VU Amsterdam – Netherlands

Multi-Trip Vehicle Routing Problems (MTVRP) generalize the well-known VRP by allowing vehicles to perform multiple trips per day. MTVRPs have received a lot of attention lately because of their relevance in real-life applications, e.g., in city logistics and last-mile delivery. Several variants of the MTVRP have been investigated in the literature, and a number of exact methods have been proposed. Nevertheless, the computational results currently available suggest that MTVRPs with different side-constraints require ad-hoc formulations and solution methods to be solved. Moreover, solving instances with just 25 customers can be out of reach for such solution methods. In this talk, we propose an exact solution framework to address four different MTVRPs proposed in the literature. The exact solution framework is based on a novel formulation that has an exponential number of variables and constraints. It relies on column generation, column enumeration, and cutting plane. We show that this solution framework can solve instances with up to 50 customers of four MTVRP variants and outperforms the state-of-the-art methods from the literature.

Keywords: multitrip vehicle routing, time windows, column generation, exact methods, dynamic programming

*Speaker
†Corresponding author: r.roberti@vu.nl

An exact solution method to the pollution routing problem

Magnus Stålhane * [1], Troels Range [2], Marielle Christiansen [3]

[1] Norwegian University of Science and Technology [Trondheim] (NTNU) – NO-7491 Trondheim, Norway
[2] Sydvestjysk Sygehus – Denmark
[3] Norwegian University of Science and Technology, Trondheim, Norway – Norway

The pollution routing problem was proposed by Bektas and Laporte (2011) and extends the well-known vehicle routing problem, by minimizing speed- and load-dependent fuel costs on the vehicle routes, rather than the distance travelled. To solve this problem, we present a novel branch-price-and-cut algorithm, where the problem is decomposed into one sub problem generating vehicle routes, and one master problem selecting the optimal subset of these routes. The sub problem may be formulated as an elementary shortest path problem with resource constraints and speed optimization (ESPPRC-SO), and is solved using a labeling algorithm. For the ESPPRC-SO the challenge of applying this approach is to find a valid and efficient dominance step, since both the time and cost resource is dependent on the speed on each arc traversed on a (partial) path. We present a sufficient dominance criteria for the SPPRC-SO by, which handles the time-cost dependencies by approximating the cost function for given points in time, and then uses the relation between the cost values and points to discard dominated paths in the labeling algorithm. Computational results show that our method can solve benchmark instances of up to 50 customers to optimality within one hour.

Keywords: VRP, Branch, and, Price, Pollution routing

*Speaker

ng-Memory Based Capacity Cuts

Ymro Hoogendoorn *† [1], Kevin Dalmeijer [1]

[1] Econometric Institute, Erasmus University Rotterdam – Netherlands

We present new valid inequalities for the capacitated vehicle routing problem (CVRP), called the *ng*-capacity cuts (*ng*-CCs). These valid inequalities are stronger than the rounded capacity cuts, but still have the attractive property that they are robust when the *ng*-route relaxation is used in a branch-price-and-cut (BPC) algorithm. That is, including the duals of the *ng*-CCs in the pricing problem, a shortest path problem with resource constraints, does not require extra resources.
In this paper, we formalize the concept of *ng*-robustness and we present the first *ng*-robust valid inequalities, the *ng*-CCs. This framework can facilitate the search for new *ng*-robust counterparts of known valid inequalities. Furthermore, we introduce different separation techniques for separating the *ng*-CCs and compare these numerically. We show that the separation of these cuts is equivalent to separating rounded capacity cuts on a modified graph. We present results on including the robust *ng*-CCs in a BPC-framework for solving CVRP benchmark instances, compared to using rounded capacity cuts. We also investigate for which types of problems these new valid inequalities outperform the rounded capacity cuts.

Keywords: CVRP, Column Generation, Branch Price and Cut, Valid Inequalities, ng Route Relaxation

*Speaker
†Corresponding author: y.n.hoogendoorn@ese.eur.nl

Route relaxations for the pickup and delivery problem with time windows

Luciano Costa *† [1], Claudio Contardo [2], Guy Desaulniers [1]

[1] Ecole Polytechnique de Montréal and GERAD – Canada
[2] ESG-UQAM and GERAD – Canada

The pickup and delivery problem with time windows (PDPTW) aims at finding routes to satisfy a set of requests, each associated with pickup and delivery points. Like several other vehicle routing problems, the leading technique to solve the PDPTW is column generation (CG). In the literature, all the CG based algorithms developed to solve the PDPTW consider a set-partitioning formulation at the master and rely on a pricing problem to generate feasible routes. The inconvenient associated with this strategy is that, due to the pairing and precedence relations arising by the PDPTW definition, devising an efficient CG algorithm to solve this problem may be a challenging task. In this work, we investigate the impact of not directly addressing the pairing and precedence constraints in the CG pricing problem. Instead, we exploit the underlying structure induced by PDPTW feasible routes and solve a relaxed pricing problem by disregarding partially (or completely) pairing and precedence constraints. We introduce a new set of variables representing commodity paths from each origin point to its destination to ensure that the precedence and pairing constraints are met, at the master problem level. These new variables along with additional constraints incorporated into the master problem make the new formulation valid. Even if the proposed method may yield degradation of the lower bounds achieved, the also less restrictive dominance rules allow for gains in the overall running times. Preliminary computational experiments are presented to assess the validity and efficiency of the proposed methodology.

Keywords: column generation, pricing problem relaxation, pickup and delivery problem.

*Speaker
†Corresponding author: luciano.costa@gerad.ca

Exact column generation for the electrical vehicle scheduling problem

Axel Parmentier * [1], Rafael Martinelli [2], Thibault Vidal [2]

[1] Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique (CERMICS) – École des Ponts ParisTech (ENPC) – 6 et 8 avenue Blaise Pascal Cité Descartes - Champs sur Marne 77455 Marne la Vallée Cedex 2, France

[2] Pontifical Catholic University of Rio de Janeiro (PUC) – Rua Marques de Sao Vicente, 225-Gavea, Rio de Janeiro, 22451-900, Brazil, Brazil

Green and electrical routing problems attract a growing attention. We consider the electrical Vehicle Scheduling Problem (eVSP). A set of trips must be operated by a fleet of electrical vehicles. Each trip is scheduled between an origin and a destination at a given time. Vehicles have a limited battery capacity. Inbetween two trips, a vehicle can go to a station to charge its battery. Costs are associated to vehicle use and distance traveled. The objective is to build a sequence of trips and recharge followed by each vehicle in order to operate all trips at minimum cost. We propose an exact column generation approach to the eVSP. Numerical benchmark on instances of the literature demonstrate the efficiency of our approach. Our pricing algorithm, and more precisely the way it encodes energy consumption information in an ad-hoc algebraic structure, plays a key role in the efficiency of our column generation.

Keywords: Electrical Vehicle Scheduling Problem, Column Generation, Resource Constrained Shortest Path Problem

*Speaker

Branch-Cut-and-Price for Scheduling Deliveries with Time Windows in a Direct Shipping Network

Timo Gschwind *† [1], Stefan Irnich [2], Christian Tilk [1], Simon Emde [3]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz – Jakob-Welder-Weg 9, D-55128 Mainz, Germany
[2] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Jakob-Welder-Weg 9, D-55128 Mainz, Germany
[3] TU Darmstadt – Germany

In a direct shipping (or point-to-point) network, individual deliveries are round trips from one supplier to one customer and back to either the same or another supplier, i.e., a truck can only visit one customer at a time before it has to return to a supplier. We consider the multiple sources, multiple sinks case, where a given set of direct deliveries from a set of suppliers to a set of customers must be scheduled such that the customer time windows are not violated, the truck fleet size is minimal, and the total weighted customer waiting time is as small as possible. Direct shipping policies are, for instance, commonly employed in just-in-time logistics (e.g., in the automotive industry) or in humanitarian logistics. We present an exact branch-cut-and-price algorithm for this problem, which is shown to perform well on instances from the literature and newly generated ones. We also investigate under what circumstances bundling suppliers in so-called supplier parks actually facilitates logistics operations under a direct shipping policy.

Keywords: direct deliveries, branch, cut, and, price, weighted customer waiting times, just, in, time logistics

*Speaker
†Corresponding author: gschwind@uni-mainz.de

Stabilized Branch-Price-and-Cut for the Commodity-constrained Split Delivery Vehicle Routing Problem

Timo Gschwind* [1], Nicola Bianchessi [2,3], Stefan Irnich † [4]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz – Jakob-Welder-Weg 9, D-55128 Mainz, Germany
[2] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University – Jakob-Welder-Weg 9, D-55128 Mainz, Germany
[3] Dipartimento di Informatica, Università degli Studi di Milano – Via Celoria 18 - 20122 Milano, Italia, Italy
[4] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

In the commodity-constrained split delivery vehicle routing problem (C-SDVRP), customer demands are composed of sets of different commodities. The C-SDVRP asks for a minimum-distance set of vehicle routes such that all customer demands are met and vehicle capacities are respected. Moreover, whenever a commodity is delivered by a vehicle to a customer, the entire amount requested must be provided. Different commodities demanded by one customer, however, can be delivered by different vehicles. Thus, the C-SDVRP is a relaxation of the capacitated vehicle routing problem and a restriction of the split delivery vehicle routing problem. For its exact solution, we propose a branch-price-and-cut algorithm that employs and tailors stabilization techniques that have been successfully applied to several cutting and packing problems. More precisely, we make use of (deep) dual-optimal inequalities which are particularly suited to reduce the negative effects caused by the inherent symmetry of C-SDVRP instances. One main issue here is the interaction between branching and cutting decisions and the different classes of dual inequalities. Extensive computational tests on existing and extended benchmark instances show that all stabilized variants of our branch-price-and-cut are clearly superior to the non-stabilized version. On the existing benchmark, our algorithm is significantly faster than the state-of-the-art algorithm and provide several new optima for instances with up to 60 customers and 180 tasks. Lower bounds are reported for all tested instances with up to 80 customers and 480 tasks, improving the bounds for all unsolved instances and providing first lower bounds for several instances.

Keywords: routing, vehicle routing, dual, optimal inequalities, column generation, discrete split delivery

*Corresponding author: gschwind@uni-mainz.de
†Speaker

Column selection by machine learning in exact branch-and-price algorithms

Guy Desaulniers *† [1], Mouad Morabit [1], Andrea Lodi [2]

[1] Polytechnique Montreal and GERAD – Canada
[2] Polytechnique Montreal, GERAD, CERC in Data science for real-time decision making – Canada

Branch-and-price is the leading solution methodology for several classes of vehicle routing and crew scheduling problems. For certain problems where the restricted master problem (RMP) consumes a large proportion of the total computational time, it is important to add a limited number of columns to the RMP at each iteration. These columns are usually selected based on their reduced cost. In this paper, we propose a new selection procedure that relies on a machine learning tool which relies on a graph convolutional network. This tool tries to identify the generated columns that would take a positive value in the solution to the RMP if all columns were added. The columns identified as such are added to the RMP, together with a small subset of the remaining ones. Preliminary tests on some vehicle and crew scheduling problems show that speedups of up to 40% of the computational time can be achieved.

Keywords: Branch, and, price, machine learning, column selection, vehicle routing, crew scheduling

*Speaker
†Corresponding author: guy.desaulniers@gerad.ca

Exact method for bi-objective vehicle routing problems

Estèle Glize [1], Nicolas Jozefowiez [2], Sandra Ulrich Ngueveu * [1]

[1] Laboratoire d'analyse et d'architecture des systèmes [Toulouse] (LAAS) – Centre National de la Recherche Scientifique : UPR8001, Institut National des Sciences Appliquées - Toulouse, Institut National Polytechnique [Toulouse] – 7 Av du colonel Roche 31077 TOULOUSE CEDEX 4, France
[2] Laboratoire de Conception, Optimisation et Modélisation des Systèmes (LCOMS) – Université de Lorraine : EA7306 – LCOMS EA7306, Université de Lorraine, Metz 57000, France, France

This paper presents an original and generic column generation-based exact method to solve bi-objective vehicle routing problems.The talk will first provide a quick overview of exact methods on bi-objective problems and in particular on vehicle routing problems. Then mathematical formulations for these problems will be introduced, either with two explicit objectives or with ϵ-constraint linearization. Theorems on the structure of bi-objective vehicle routing problems will be presented, and based on them, new rules to explore the solution space will be introduced. The resulting exact method takes advantages of different techniques to discard some insignificant columns and save the current state of column generation. Numerical results on the two following case-studies show the efficiency of the approach with regards to the state-of-the art: bi-objective vehicle routing with time windows and with two integer costs and on bi-objective team-orienteering problem with time windows

Keywords: combinatorial optimization, column generation, biobjective optimization, vehicle routing problems

*Speaker

A meta-heuristic approach for the Vehicle Routing Problem with occasional drivers

Raúl Martín Santamaría * [1], Ana Dolores López-Sánchez [2], J. Manuel Colmenar† [1], María Luisa Delgado Jalón [1]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[2] Pablo de Olavide University – Spain

The Vehicle Routing Problem with Occasional Drivers (VRPOD) is a Vehicle Routing Problem (VRP) variant where a company has a fleet of capacitated identical vehicles but is able to hire a set of private or occasional drivers (ODs) who use their own vehicle to provide a single service of a customer. This service is given since the ODs obtain a compensation, and they are usually hired when the customer's location is not too far from the OD's location. This problem is very well connected to the current trends in logistics in low-density regions, where the cost of developing a fleet of vehicles could be high in relation to the actual volume of sales. The objective of this problem is to minimize the total cost, which is computed as the sum of the costs incurred by the routes performed by the fleet of vehicles and the compensation paid to the ODs. In this work we propose a meta-heuristic approach to tackle the VRPOD. This approach is able to find very good results in shorter computation times in relation to the state of the art.

Keywords: Occasional drivers, Meta, heuristics, Vehicle Routing Problem

*Speaker
†Corresponding author: josemanuel.colmenar@urjc.es

A branch-and-cut algorithm for the soft-clustered vehicle routing problem

Katrin Hessler * [1], Stefan Irnich [1]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

The soft-clustered vehicle routing problem is a variant of the classical capacitated vehicle-routing problem (CVRP) in which customers are partitioned into clusters, and all customers of the same cluster must be served by the same vehicle. In contrast to the non-soft variant, a cluster must not be served completely before the next cluster is served, but visits to customers of the same cluster can be interrupted by visits to customers of another cluster. We introduce a new two-index formulation of the problem and solve it with a branch-and-cut algorithm. In addition to problem-specific cutting planes for clusters, known valid inequalities for the CVRP can be adapted, e.g., MTZ-based subtour-elimination constraints, capacity cuts etc. We compare different model formulations and separation procedures. Computational results on benchmark instances show the usefulness of the new branch-and-cut.

Keywords: Soft clustered vehicle routing problem, branch and cut

*Speaker

Heuristic for the dynamic scheduling of a fleet of drones for sport filming in a wide field of operations

David Sanchez-Wells* [1], José L. Andrade-Pineda † [2,3], Pedro L. Gonzalez-R [1], Jose M. Leon-Blanco [1]

[1] Industrial Engineering and Management Science, School of Engineering, University of Seville – Spain
[2] Robotics, Vision and Control Group (GRVC) – Spain
[3] Group of Robotics, Vision and Control (GRVC) – Spain

We study the use of a fleet of unmanned aerial vehicles (UAVs) for covering sport filming in a very extensive area, so that the audio-visual producer is given the images of a set of participants (henceforth, the targets) whose different trajectories are known. The goal is the definition of a coordinated task assignment in order to provide both spatial and temporal coverage for the variety of points of interest (PoIs) marked at each target. We have to consider heterogeneity of UAVs regarding to their initial position and the charge of their batteries. Moreover, owing to the huge field of operations, every UAV in the fleet would require of battery replacements. Hence, the inherent problem that arises is a multi-trip capacitated vehicle routing problem.

Our assumption is that the planners require of a decision-support tool to clearly identifying the feasibility of the scheduling decisions with the safe operation of the fleet, particularly, to avoid the risk due to crossing trajectories among UAVs.
We have designed a decision-making procedure to generate plans according to a multi-criteria optimization problem, in which the total distance travelled by UAVs (to be minimized), the number of PoIs uncovered (to be minimized) and the number of risky crossing among the trajectories planned for the used UAVs (to be minimized) are jointly considered. Given the position and the time-windows for recording every PoI, we apply a sequential task assignment heuristic coded in Python to find the dynamic scheduling of the different UAVs in the fleet.

Keywords: unmanned aerial vehicles routing problem, UAV scheduling for persistent sport filming, multi, trip VRP, task assignment heuristic

*Corresponding author: dvswells@gmail.com
†Speaker

A matheuristic for the inventory routing problem with divisible pickup and delivery

Henrik Andersson [1], Magnus Stålhane [1], Simen Vadseth *† [1]

[1] Norwegian University of Science and Technology [Trondheim] (NTNU) – NO-7491 Trondheim, Norway

This paper considers an inventory routing problem with divisible pickup and delivery (IRP-DPD). A customer may have both delivery and pickup demand in this problem type and is allowed to have separate servings for pickup and delivery. The last part is contrary to what is common and is what constitutes a so-called divisible option. A single depot with a fleet of homogeneous vehicles is considered. The vehicles are restricted by capacity and a maximal duration for a route. An arc-flow formulation of the problem, formulated as a mixed integer linear program, is proposed as an exact solution approach. The formulation is strengthened with valid inequalities and an extended branch and cut algorithm is suggested. The branch and cut algorithm dynamically adds subtour cuts for each strong component of the solution that violates subtour elimination constraints. To solve larger instances, a matheuristic with a two-phase construction approach followed by an improvement search is proposed. To construct a solution the matheuristic decomposes the problem into an inventory problem and a routing problem. The constructed solution is further improved with a set of operators. The matheuristic embeds the construction and the improvement operators into an iterative scheme. When the iterative loop is terminated, a final improvement search is suggested. The matheuristic gives solutions with lower dual gaps than the exact method for all larger instances. It also finds good solutions faster and produces feasible solutions for instances where the exact method does not.

Keywords: IRP, divisible, IRP, DPD

*Speaker

†Corresponding author: simen.t.vadseth@ntnu.no

An inventory routing problem with prioritized deliveries

Paulina Avila * [1], Nancy Arratia Martínez *

1

[1] Universidad de las Américas [Puebla] (UDLAP) – Sta. Catarina Mártir. Cholula, Puebla. C.P. 72810. México, Mexico

In this paper we consider a vehicle routing problem in a producer and distributor company of gases with three main products; the company plan their deliveries daily for the north region of Mexico.

Their main costumers are industry and hospitals, which have a time window of service. The company has gas trucks with the same capacity.

Demand and travel time are considered deterministic. The inventory level is monitored to establish the amount of product to deliver.

The problem that we study here wants to garantee the minimum inventory level of the costumer prioritizing hospitals for federal regulation. A mathematical model based on the Inventory Routing Problem (IRP) is presented and the main objective is to minimize the distribution cost. Finally, some preliminary results and the future work are presented

Keywords: Inventory Routing Problem, Prioritized deliveries

*Speaker

Fair collaboration scheme for firms operating dial-a-ride services in a city network

Valentina Morandi * [1], Enrico Angelelli [2], M. Grazia Speranza [2]

[1] Freie Universität Bozen (LUB) – Piazza Università 1 Bolzano, Italy
[2] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy

Standard DARP problem consists in finding minimum-cost routing in a complete graph guaranteeing that all requests are satisfied and several variants of DARP have been proposed in the literature such as heterogeneity, multiple depots, multiple loads, transfers between different vehicles, soft time windows, multi-objective DARP, with stochastic or dynamic information. In literature very few works on collaboration in DARP problem and, in particular, considering different firms operating in dial-a-ride transport services on the same city network. Usually, the firm collects all the requests in advance and runs a DARP model in order to find the best routing in terms of pay-off. Sometimes, customers are located in such a way there is a small convenience in servicing it. The basic idea is that the firm would share customers with other firms that have more convenience in servicing them. The main issue related to sharing customers is that each firm wants to be advantaged by joining the cooperative, and hence, particular attention has to be given when revenues have to be shared among different firms. In this talk, two different MILP formulations to solve the Collaboration in DARP (shortly CDARP) are presented, each one corresponding to a different scheme able to share customers between firms fairly. Since the problem is NP-Hard, a reliable and fast ALNS algorithm is also provided. Both exact and heuristic methods have been tested on real road networks.

Keywords: collaboration, DARP, alns

*Speaker

Integrating Dial-a-Ride with Mode Choice

Xiaotong Dong *† [1], David Rey [1], S.travis Waller [1]

[1] University of New South Wales [Sydney] (UNSW) – High StKensington, Sydney, NSW 2052, Australia

The classical Dial-A-Ride Problem (DARP) aims at designing the minimum-cost routing that accommodates all requests under a set of constraints. The current trend of research on the DARP is to incorporate additional real-life characteristics to extend the scope of its applications. In this work, we propose to incorporate travellers' mode choice decisions within the original DARP formulation. Specifically, we consider that two travel modes are available: a shared mobility service (dial-a-ride) and a private travel option. We assume that travellers' utility for the shared mobility service depends on the collective choice of travellers whereas travellers' utility of private travel is fixed. We integrate these utility functions in a rich DARP formulation. Assuming that travellers are rational and seek to maximize their trip utility, we introduce variables and constraints to track users' mode choice and optimize the route and the schedule of the shared mobility service accordingly. Specifically, the shared mobility service must accommodate the requests of all travellers which have a higher utility for this mode compared to their private travel alternative. We explore the behaviour of the proposed integrated DARP with mode choice constraints formulation by conducting sensitivity analyses on the parameters of the utility functions and present a new solution algorithm for this rich DARP. Computational experiments are conducted on traditional DARP benchmark instances and numerical results are presented to show the effectiveness of the algorithm.

Keywords: Dial, a, Ride Problem, mode choice, shared mobility services

*Speaker

†Corresponding author: xiaotong.dong@unsw.edu.au

Integrating the use of public transport in dial-a-ride services

Yves Molenbruch* [1,2], Kris Braekers † [1], Patrick Hirsch [3], Marco Oberscheider [3]

[1] Hasselt University – Belgium
[2] Research Foundation - Flanders (FWO) – Belgium
[3] University of Natural Resources and Life Sciences, Vienna – Austria

In many Western countries, governments are currently implementing an innovative demand-driven mobility policy. Providers of collective door-to-door transport, called dial-a-ride services, are increasingly invoked to replace unprofitable public transport in rural areas. This requires an integrated mobility system in which a user's trip may consist of a combination of dial-a-ride services and regular public transport.
In order to optimally integrate both systems from an operational point of view, dial-a-ride providers need to solve a challenging routing problem which integrates the opportunity to use public transport in the classical dial-a-ride problem. Dial-a-ride routes should be synchronized to the timetables of the public transport services, while the optimal selection of the users' transfer terminals depends on the actual structure of the dial-a-ride routes.

This paper introduces a metaheuristic routing algorithm, based on Large Neighbourhood Search, to solve this integrated routing problem. An exact scheduling procedure is embedded to enforce the synchronization between dial-a-ride routes and public transport.
Experiments, performed on a new artificial benchmark data set with realistic characteristics, clearly indicate that considerable operational benefits are obtained by integrating dial-a-ride services and public transport. The resulting distance savings for the dial-a-ride vehicles are shown to depend on the operational characteristics of the system, the geographical distribution of the demand, and the ability to flexibly assign transfer terminals to user requests.

Keywords: Dial, a, ride, routing with synchronization, passenger transportation, meta, heuristics, integrated routing problem

*Corresponding author: yves.molenbruch@uhasselt.be
†Speaker

Approximate Linear Programming for Dynamic Fleet Management

David Sayah * [1], Martin Pouls [1]

[1] FZI Research Center for Information Technology (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany

In dynamic fleet management, a company operates a fleet of vehicles to provide transportation services between given locations, while customers request trips randomly over time. Each vehicle can transport one customer at a time. The fleet operator may dispatch a loaded vehicle, i.e., service a request, or an empty vehicle, i.e., reposition it at a cost for possible future demand. The optimization problem at hand essentially consists in finding a dynamic dispatching strategy so as to maximize total expected profit. The problem has applications, for instance, in taxi routing and in full truckload services. It can be cast as Markov decision problem (MDP). The corresponding value function, however, is intractable due to a high-dimensional state space. The latter fact motivated previous works to tackle this MDP by approximating the value function, also known as approximate dynamic programming (ADP). We devise a new value function approximation for the dynamic fleet management MDP based on linear programming. That is, we employ an affine approximation scheme to derive a relaxation. The relaxed model is a large-scale LP that can be solved via column generation. As a result, we obtain an affine approximation of the original value function. To evaluate our approach, we use real-world taxi trips from the well-known New York City taxi data set. We present numerical results that are concerned with the computational efficiency of our approximation procedure and with the quality of dispatching policies which can be derived from this affine value function approximation.

Keywords: dynamic fleet management, approximate dynamic programming, column generation

*Speaker

An Optimization Framework for Dynamic Multi-Skill Workforce Scheduling and Routing Problem

Onur Demiray * [1], Eda Yucel† [2], Gultekin Kuyzu‡ [2,3], Mert Parçaoğlu§ [2]

[1] Koç University – Rumelifeneri Yolu, 34450 Sarıyer-İstanbul, Turkey
[2] TOBB University of Economics and Technology [Ankara] – Turkey
[3] MIT-Zaragoza International Logistics Program, Zaragoza Logistics Center (ZLC) – Spain

In workforce scheduling and routing problems (WSRPs), personnel having different skills are required to be assigned to set of geographically distributed tasks that arise at different time instants and have different priority levels and skill requirements. Due to dynamic nature of the problem, a significant portion of tasks is unknown at the beginning and new tasks show up dynamically as time passes. Since new tasks may be urgent, the personnel task plan (PTP) must be re-evaluated as more tasks become known, and may be re-optimized, if needed. In practice, when re-optimizing the PTP, a portion of it within a time interval called frozen period is kept unchanged. The tasks in the frozen period (i.e., frozen tasks), personnel-task skill consistency, and task priorities should be considered during re-optimization. To address the described dynamic multi-skill WSRP, we propose an optimization framework that is triggered whenever a predetermined number of new tasks arrive. The framework first identifies frozen tasks and determines the first available time and location of the personnel, and then re-optimizes the subsequent PTP with the objective of minimizing the total weighted completion time of all tasks. For the route redesign phase of the framework, we develop both a mathematical model and a heuristic algorithm. We test the performance of both approaches on realistic instances obtained from an energy distribution company that faces the problem on a daily basis. Through computational experiments, we analyze the effect of the redesign frequency and length of the frozen period on the solution quality.

Keywords: Dynamic Workforce Scheduling and Routing, Mixed Integer Programming, Heuristic Methods

*Speaker
†Corresponding author: edatyucel@gmail.com
‡Corresponding author: gkuyzu.etu@gmail.com
§Corresponding author: mertparcaoglu@gmail.com

The Dynamic Orienteering Problem

Enrico Angelelli [1], Claudia Archetti [1], Carlo Filippi *† [1], Michele Vindigni [1]

[1] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy

We study a real-time decision problem defined on a directed graph where a travel cost is associated with each arc and a prize is associated with each node. The nodes are partitioned in mandatory and optional. Along a certain request-time horizon, mandatory nodes will certainly request a visit that must be satisfied; optional nodes will originate a request with a given time-dependent probability, and such a request can be accepted or not. During a following limited travel-time horizon, a server will start from a fixed origin, will visit both mandatory nodes and the optional nodes whose request has been accepted, and will end at a fixed destination. The profit of the server is the difference between the total collected prize and the total travel cost. The problem consists in finding a policy for accepting/rejecting optional requests during the request-time horizon in order to maximize the expected server profit while respecting the travel-time horizon limitation. We discuss the relevance of the problem and we derive a recursive formula for the expected profit optimization. Given the intractability of the recursion, we design several heuristic policies, based on combination of simple myopic rules, Monte Carlo simulation, and heuristic solution of the static counterpart of the dynamic problem, i.e., the Probabilistic Orienteering Problem. We set up a simulation framework where instances with up to 100 nodes are considered under different probabilistic assumptions and different widths of the travel-time horizon. The results of extensive computational tests are discussed.

Keywords: Real, time decisions, Orienteering Problem, Probabilistic VRPs

*Speaker

†Corresponding author: carlo.filippi@unibs.it

An Electric Vehicle Routing Problem with Flexible Time Windows

Duygu Taş *† [1]

[1] MEF University – Department of Industrial Engineering, Huzur Mah. Maslak-Ayazaga Cad. No.4, Sariyer 34396, Istanbul, Turkey

This paper studies the Electric Vehicle Routing Problem with Flexible Time Windows (EVRPFTW). In this problem, EVs are permitted to serve customers outside their original time window boundaries with respect to a given tolerance. This relaxation brings a penalty cost as time window violations negatively affect the customer satisfaction. The objective of the EVRPFTW is to minimize the total cost including the traveling costs, the costs of using electric vehicles and the penalty costs. We propose a solution procedure based on column generation where the pricing subproblem corresponds to an elementary shortest path problem with resource constraints. An integer solution is generated by solving an integer programming problem using the routes constructed by the column generation algorithm. A linear programming model is then solved to compute the optimal times to start service at each customer for the selected routes. We conduct our computational experiments for a number of well-known benchmark instances and evaluate the operational gains obtained by employing flexible time windows.

Keywords: Routing, Electric vehicles, Time windows, Column generation

*Speaker

†Corresponding author: duygu.tas@mef.edu.tr

Electric Arc Routing

Elena Fernández [1], Markus Leitner [2], Ivana Ljubic [3], Mario Ruthmair *† [4]

[1] Barcelona Tech-UPC, Department of statistics and operations research (BcnTech-UPC EIO) – C/ Jordi Girona 1-3, 08034 Barcelona, Spain
[2] VU University Amsterdam – De Boelelaan 1105, 1081 HV Amsterdam, Netherlands
[3] ESSEC Business School – ESSEC Business School – 3 Avenue Bernard Hirsch, 95021 Cergy-Pontoise, France
[4] University of Vienna – Oskar-Morgenstern-Platz 1, 1090 Vienna, Austria

In company fleets (battery) electric vehicles (EVs) impose additional challenges due to their limited range enforcing time-demanding charging breaks during service in case of long trips and since their energy consumption heavily depends on the driving speed (among other factors).
We study the use of EVs in the context of arc routing. Given a street network including a set of required arcs, the electric arc routing problem (eARP) proposed in this work asks for a set of energy-feasible routes that visit all required arcs with minimal total travel time. While the use of EVs in arc routing has not been studied before, related works in node routing with EVs typically use several simplifying assumptions with respect to the energy consumption and / or charging functions. We address several of these shortcomings by considering speed dependent energy consumption values and nonlinear charging functions that depend on the battery state and the charging time. Additionally, we study the possibility of inductive (wireless) charging along roads while driving. We introduce the new problem and describe an integer linear programming formulation with an exponential number of constraints solved by a branch-and-cut algorithm. Furthermore, several heuristics based on a labeling algorithm are presented. In a computational study we analyze the performance of the algorithms and compare the solutions for different battery sizes, speed and charging options.

Keywords: arc routing, electric vehicles, speed dependent energy consumption, nonlinear charging functions, integer linear programming, labeling algorithm

*Speaker
†Corresponding author: mario.ruthmair@univie.ac.at

Electric Vehicle Routing Problem with Time Windows and Stochastic Waiting Times at Recharging Stations

Merve Keskin *† [1], Gilbert Laporte [2], Bülent Çatay [3]

[1] Warwick Business School – The University of Warwick Coventry CV4 7AL, UK, United Kingdom
[2] HEC Montréal – 3000 chemin de la Cote-Sainte-Catherine, Montreal H3T 2A7, Canada
[3] Sabanci University – Faculty of Engineering and Natural Sciences, Istanbul, Turkey

The Electric Vehicle Routing Problem with Time Windows (EVRPTW) and Stochastic Waiting Times at Recharging Stations is an extension of the EVRPTW where the EVs may wait in the queue before the recharging service starts due to limited number of available chargers at the recharging stations. Since the customers and the depot have time windows, long waiting times at the stations in addition to the recharging times may cause disruptions in logistics operations. In this study, stations are equipped with single chargers and partial recharging is allowed. We use an queuing system to model the waiting times. We model this problem as a two-stage stochastic program with recourse using scenarios and propose a simheuristic method to solve it effectively. The proposed method is based on Adaptive Large Neighborhood Search and uses well-known mechanisms from the literature with adaptations for the problem as well as a new adaptive mechanism developed for the problem. To calculate the probabilities and the expected costs, simulation is used. We perform an experimental study using both small and large instances from the literature to investigate the performance of the proposed method and the influence of the stochastic waiting times at stations on routing decisions and costs. The results show that the simheuristic provides good solutions in both quality and computational time, and the uncertainty in waiting times may have significant impact on route plans.

Keywords: electric vehicle routing problem, simheuristics, adaptive large neighborhood search

*Speaker
†Corresponding author: Merve.Keskin@wbs.ac.uk

Benchmarking dispatching approaches for a fleet of urban autonomous delivery vehicles by solving the EVRPTW minimizing tardiness

Anne Meyer * [1], Boris Amberg [2], Dominik Colling [3], Katharina Glock [4]

[1] TU Dortmund University (TUD) – Leonhard-Euler-Straße 5, 44227 Dortmund, Germany
[2] FZI Forschungzentrum Informatik (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany
[3] Karlsruher Institut für Technologie (KIT) – Gotthard-Franz-Str. 8, 76131 Karlsruhe, Germany
[4] FZI Forschungzentrum Informatik (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany

The performance of fleets of electric automated guided vehicles (AGVs) in intralogistics systems depends on good recharge strategies when making dispatching decisions. For fleets of electric delivery robots for urban areas this is even more the case as the distances to travel are longer and the loading infrastructure is sparser. For benchmarking recharging strategies, good or even exact solutions for the static problem variant, in which all orders are known in advance, are valuable. In this talk, we propose a column generation (CG) based approach for solving the EVRPTW minimizing the tardiness of the jobs served by a fleet of electric delivery robots with a capacity of one. The objective value corresponds to the goal of dispatching approaches of serving jobs as early as possible to be available for future unknown demand. As in literature, the CG pricing problem is modelled as a variant of the elementary shortest-path problem with resource constraints and solved by dynamic programming using a labelling algorithm. To incorporate the minimum tardiness objective as well as multiple and partial recharging options per route, we propose tailored resource extension functions to compute efficiently minimum and maximum costs of (partial) paths. Based on solutions for different scenarios for urban delivery robots we identify patterns for successful recharging strategies, applicable to central or decentral dispatching strategies.

Keywords: Delivery Robots, Electric Vehicles, Recharging Decisions, Column Generation

*Speaker

Stronger bounds for the asymmetric traveling salesman problem

Safa Ben Salem *† [1], Ali Balma [2], Mehdi Mrad [3], Talel Ladhari [1]

[1] Université de Tunis, Tunis Business School, Business Analytics and Decision Making (BADEM) – P.O.Box 65, Bir El Kassaa, 2059, Tunis, Tunisia
[2] Université de Tunis, Ecole Nationale Supérieure d'Ingénieurs de Tunis (ENSIT) – Avenue Taha Hussein, 1008 Tunis, Tunisia
[3] Raytheon Chair of Systems Engineering , Advanced Manufacturing Institute (RCSE) – King Saud University, Riyadh 11421, Saudi Arabia

In our study, we propose novel compact formulations of polynomial size for the asymmetric traveling salesman problem (ATSP) by using the Reformulation Linearization Technique (RLT) which allowed to obtain a stronger formulation than the best state-of-the-art models. In fact, we are looking for a polyhedron that is as close as possible to the convex hull of integer solutions to ATSP. Furthermore, we improve the best compact formulations of ATSP due to (Sherali, Sarin and Tsai, 2006)-known so far as being the strongest ones- by eliminating the redundant constraints and showing that they are equivalent and reducing them to a more compact equivalent formulation of smaller size. Moreover, we elaborate new dominance relationships between the newly devised formulations and the existing models. In addition to that, we perform some projections into the subspace defined by (Sherali, Sarin and Tsai, 2006) and derive new formulations, which turned out to be stronger also than the state-of-the-art models. We extend our work to the variant of the ATSP with precedence constraints. Computational experiments conducted on the benchmark instances TSPLIB confirm the better quality of the relaxations provided by our proposed formulation as the relative deviation between the lower bound and the optimal solution did not exceed 0.5%, whereas that of (Sherali, Sarin & Tsai, 2006) is about 1.5%.

Keywords: Traveling Salesman, Reformulation, Linearization Technique, Compact formulations, projections.

*Speaker
†Corresponding author: safabensalem9@gmail.com

A Periodic Multi-Vehicle Arc Routing Problem

Demetrio Laganà * [1], Rosario Paradiso [2], Francesca Vocaturo [3]

[1] Department of Mechanical, Energy and Management Engineering (DIMEG) – University of Calabria, Italy
[2] Department of Mathematics and Computer Science – University of Calabria, Italy
[3] Department of Economics, Statistics and Finance "Giovanni Anania" – University of Calabria, Italy

We deal with a periodic arc routing problem on mixed graphs, in which some links require to be serviced a given number of times over a finite and discrete time horizon. A fleet of homogeneous vehicles is available at the depot to perform the services in each period of the time horizon. Moreover, each vehicle has a maximum length (expressed in terms of time or distance) to be traveled. In practical applications, a required link represents a street in which a given service is regularly planned (e.g., inspection of power lines or of water and gas underground pipelines) or irregular services arise (e.g. inspection of road networks where the traffic conditions sensibly change during the week). The aim is to design several sets of minimum-cost routes, one for each period of the time horizon, that satisfies the service requirements. We refer to this problem as the Periodic multi-vehicle Arc Routing Problem (PARP). For the PARP, an extended set partitioning based formulation is proposed and an exact algorithm is designed. In addition, preliminary results are presented

Keywords: Routing, Periodic Arc Routing Problem, Mixed Graph, Exact Algorithm

*Speaker

A Branch-and-Price Algorithm for a Vehicle Routing-allocation Problem

Mohammad Reihaneh * [1], Ahmed Ghoniem [2]

[1] IÉSEG School Of Management [Paris] – IÉSEG School of Management [Paris] – France
[2] University of Massachusetts [Amherst] (UMass Amherst) – 300 Massachusetts Ave, Amherst, MA 01003, United States

We investigate a variant of the Vehicle Routing-Allocation Problem that arises in the distribution of pallets of goods by a food bank to a network of relatively distant nonprofit organizations. Vehicles are routed to selected intermediate delivery sites to which the nonprofit organizations travel to collect their demand. The logistical cost is shared and the objective is to minimize a weighted average of the food bank vehicle routing cost and the travel cost of the nonprofit organizations. This study develops an effective branch-and-price algorithm for this food bank vehicle routing problem. The pricing subproblem is solved, exactly or heuristically, using a specialized labeling type dynamic programming (DP) algorithm. The computational efficacy of this DP approach stems primarily from the inclusion of preprocessing routines that enhance the label extension scheme by iteratively eliminating dominated (partial) solutions. The proposed exact DP algorithm, and five proposed heuristic variants, significantly reduce the computational time associated with the solution of the pricing subproblem. The resulting speedup enables the implementation of a branch-and-price algorithm that greatly outperforms the use of CPLEX over a test-bed of 60 problem instances.

Keywords: Vehicle Routing Allocation, Branch, and, Price

*Speaker

A Branch and-Cut Algorithm for the Distance Constrained Close-Enough Arc Routing Problem

Miguel Reula Martín *† [1], Angel Corberán [1], Isaac Plana [1], José Maria Sanchis [2]

[1] Universidad de Valencia (UV) – Spain
[2] Universitat Politecnica de Valencia (UPV) – Spain

Arc routing problems consist of finding one or several routes traversing a given set of arcs and/or edges that must be served. The Close-Enough Arc Routing Problem (CEARP), also known as Generalized Directed Rural Postman Problem, considers that each costumer is not located in a specfic arc, but can be served whenever the vehicle traverses any arc of a prefixed subset. The idea is that each customer is served when the vehicle gets closer than a certain distance. Some examples of real-life applications include routing for meter reading. A vehicle with a receiver travels through a series of neighborhoods. If the vehicle gets within a certain distance of a meter, the receiver can record the consumption. Therefore, the vehicle does not need to traverse every street, but only a few, in order to be close enough to each meter. In this paper we deal with an extension of this problem, the Distance-Constrained Close Enough Arc Routing Problem, in which a fleet of vehicles is available. The vehicles have to leave from and return to the depot, and the length of their routes must not exceed a maximum distance.
We propose a formulation for this problem and study a relaxation of its associated polyhedron. We present some families of valid inequalities that we use in the implementation of a branch-and-cut algorithm for solving the problem. Computational experiments have been performed on a set of benchmark instances and the results are compared with those obtained with the algorithms proposed in the Literature.

Keywords: Close Enough Arc Routing Problem, Generalized Directed Rural Postman Problem, distance constraints, branch and cut algorithm

*Speaker
†Corresponding author: miguel.reula@uv.es

Improved branch-and-cut algorithm for the inventory routing problem

Jørgen Skålnes *† [1], Magnus Stålhane [1], Henrik Andersson [1], Guy Desaulniers [2]

[1] Norwegian University of Science and Technology [Trondheim] (NTNU) – NO-7491 Trondheim, Norway
[2] Groupe d'études et de recherche en analyse des décisions (GERAD) – HEC Montréal 3000, chemin de la Côte-Sainte-Catherine Montréal (Québec) Canada H3T 2A7, Canada

The inventory routing problem is a problem that arises in a vendor managed inventory context. Each customer has an inventory with a maximum holding capacity and a periodic demand. The decision maker has to make sure the customers have enough products in their inventories to satisfy demand in each time period of the planning horizon. Thus, the decision maker has to decide which customers to serve in which time periods, how much to deliver of a product once a customer is visited and how to route the fleet of vehicles in order to minimize transportation cost and inventory holding cost. We propose an improved branch-and-cut algorithm combining the current state-of-the-art valid inequalities with new families of valid inequalities using the concept of delivery patterns. A delivery pattern contains information about which periods a customer is visited. Based on this we can calculate tighter upper and lower bounds on the quantity delivered to a customer given a certain delivery pattern. Preliminary results show that the new algorithm increases the lower bound considerably and on average reduces the solution times. A full computational study on how the different valid inequalities impact the lower bounds and solution times will be presented.

Keywords: Branch and cut, Inventory routing, Valid inequalities

*Speaker
†Corresponding author: jorgen.skalnes@ntnu.no

A Branch-and-Check Approach for a Tourist Trip Design Problem with Rich Constraints

Vu Duc Minh * [1], Yannick Kergosien [2], Jorge Mendoza [3], Pierre Desport [4]

[1] Laboratoire dÍnformatique Fondamentale et Appliquée de Tours (LIFAT) – Université François Rabelais - Tours – 64, Avenue Jean Portalis, 37200 Tours, France
[2] Laboratoire d'Informatique de l'Université de Tours (LIFAT) – Université François Rabelais - Tours : EA6300 – 64, Avenue Jean Portalis, 37200 Tours, France
[3] HEC Montréal – 3000 Chemin de la Côte-Sainte-Catherine, Montréal, QC H3T 2A7, Canada
[4] Laboratoire d'Informatique Fondamentale et Appliquée de Tours (LIFAT) – Université François Rabelais - Tours – 64, Avenue Jean Portalis, 37200 Tours, France

The Tourist Trip Design problem is an extension of the Orienteering Problem applied to tourism. The problem consists in selecting a subset of locations to visit, among a larger set, while maximizing the benefit for the tourist. The latter is given by the sum of the *rewards* collected at each visited location. We consider a variant of the problem dealing not only with "typical" constraints such as budget, opening time hours (i.e., time windows on the locations), and maximum trip duration, but also other practical constraints such as mandatory visits, limits on the number of locations of each type (e.g., no more than X castles, or Y museums), subsets of exclusive locations (e.g., if A is visited then B cannot be visited), subsets locations that must be visited together (e.g., if A is visited, then B must be visited), subsets locations that must be visited in order (e.g. if A, B are both visited, then A must be visited before B).
To solve this complex problem, we propose a branch-and-check approach. In our approach, the master problem selects a subset of locations verifying all constraints but time-related constraints. Then the subproblem checks that a feasible trip can be built. We propose and compare different formulations for the master problem. We also explore different types of valid inequalities aiming to tighten the master problem. The latter are dynamically generated during the execution of the algorithm. We also propose intensification strategies to further improve the performance of the algorithm. We report the experimental results and compare the performance of the proposed algorithm with the state-of-art Mixed Integer Programming solver CPLEX 12.8.

Keywords: Tourist Trip Design, Branch and check, Orienteering Problem, exact method

*Speaker

The Multi-period Multi-trip Containers Drayage Problem with Due and Release Dates

Ornella Pisacane *† [1], Maurizio Bruglieri [2], Simona Mancini [3], Roberto Peruzzini [4]

[1] Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche – Via Brecce Bianche 12, 60131 Ancona, Italy
[2] Dipartimento di Design, Politecnico di Milano (POLIMI) – Via Durando, 38/a, 20158 Milano, Italy
[3] University of Cagliari – Italy
[4] Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche – Via Brecce Bianche 12, 60131 Ancona, Italy

We introduce the *Multi-trip Multi-period Containers Drayage Problem with Due and Release Dates* (MM-CDP-DRD) aimed at routing a fleet of trucks, based at a common terminal, to serve all customers, minimizing the total distance. A trip starts/ends from/to the terminal, serving a sub-set of customers, each requiring either picking a container up or delivering a container. Moreover, according to the International Standards Organization, containers are of several sizes although 20ft and 40ft are more frequent. A truck can carry up to two 20ft containers or one 40ft container. The planning horizon is divided into periods in each one a truck can perform more than one trip until a maximum duration (T1) is not exceeded. Moreover, a truck cannot travel longer than T2 in two consecutive periods and T3 in the whole horizon. Due and Release Dates (DRDs) are associated with each customer, denoting, respectively, the first and the last period for service. Therefore, a feasible trip must respect capacity, duration and DRDs constraints while it is dominated if a shorter trip serving the same customers exists. We address MM-CDP-DRD by firstly generating all feasible non-dominated trips and then, solving a Trip-based Integer Linear Programming (T-ILP) model. We also design a Combinatorial Benders' Cuts method (CBC) where the T-ILP model is divided into a master that guarantees only the customers' coverage while the duration constraints are dropped and a slave that checks the solution feasibility regarding the dropped constraints. The results of CBC are compared with those of T-ILP model.

Keywords: Set Partitioning, Multi trip Vehicle Routing, Multi period Vehicle Routing, Combinatorial Benders' Cuts

*Speaker
†Corresponding author: pisacane@dii.univpm.it

Exact formulation for the dial a ride problem with transfers

Jacopo Pierotti *† [1], Theresia Van Essen‡ [1]

[1] Delft Institut of Applied Mathematics (DIAM) – PO Box 5031 2600 GA Delft The Netherlands, Netherlands

Automated vehicles are becoming a reality. The introduction of AVs on public roads will alter the current transportation system tremendously. Expectations are that AVs will ultimately transform personal mobility from privately owned assets to an on-demand service (car pooling, ride sharing, etc. are rapidly grown in popularity). This transformation will also enhance the possibility of sharing trips, leading to Shared AVs (SAVs). Such a futuristic scenario will result in a paradigm shift in conventional mobility mentality: vehicles will be owned by transport companies and will be used to satisfy on-demand services. The aim of this presentation is to lay foundations for fast and efficient algorithms to be used in such new driving conditions. These algorithm must solve the dial a ride problem with transfers (DARP-T), hence efficiently assigning passengers to vehicles and routes, allowing ridesharing and transfers. We have developed two integer linear models (and their 'extensions'), one in continuous time and the other in discrete time, to solve the a posteriori DARP-T and test their usefulness on benchmark instances. Since the models are linear, standard branch-and-bound methods can be directly applied. Our models take into account all the aspects of the standard DARP-T and also convenient parking, service times, constraints on maximum route time-span, unserved requests, preferred arrival and departure time, and non-constant travel times. In addition, they optimize routing costs and quality of service. Our results are the starting point to validate performances of forthcoming, ad hoc metaheuristics to be used in real-life scenarios.

Keywords: DARP, DARPT, exact method, shared autonomous vehicles (SAVs), green logistics

*Speaker
†Corresponding author: J.Pierotti@tudelft.nl
‡Corresponding author: J.T.vanEssen@tudelft.nl

Decomposition approach for the distributionally robust vehicle routing problem with time window assignments

Maaike Hoogeboom* [1], Yossiri Adulyasak † [2], Wout Dullaert [1], Patrick Jaillet [3]

[1] VU University Amsterdam – De Boelelaan 1105, 1081 HV Amsterdam, Netherlands
[2] HEC Montréal (HEC Montréal) – Canada
[3] Massachusetts Institute of Technology (MIT) – 77 Massachusetts Ave, Cambridge, MA 02139, United States

We present a solution framework for the robust vehicle routing problem with time window assignments under travel time uncertainty. The objective of the routing and time window decisions is to simultaneously determine routes and time window assignments such that the expected travel time and the risk of violating the time windows are minimized. The exact distributions of the uncertain travel time is not known whereas some statistics including the mean, minimum and maximum travel time are available. We extend the robust framework based on the requirements violation index and derive new subgradient cuts for the reformulation, which is solved by a branch-and-cut algorithm. Computational experiments were performed to demonstrate the performance of our approach and present the trade-off between expected travel time and risk of violating the time windows.

Keywords: Distributionally robust optimization, vehicle routing, time window assignments, convex optimization

*Corresponding author: m.hoogeboom@vu.nl
†Speaker

An exact algorithm for the agile earth observation satellite scheduling with time-dependent profits

Guansheng Peng *† [1], Pieter Vansteenwegen [1]

[1] Catholic University of Leuven (KU Leuven) – Oude Markt 13 - bus 5005, 3000 Leuven, Belgium

The Agile Earth Observation Satellite (AEOS) is a new generation system equipped with imaging instruments who can rotate to observe targets. In this study, we focus on a single orbit scheduling of an AEOS, that is to schedule a subset of observation tasks during a given orbit to maximize profits, subject to operational constraints. This problem shares some similarities with the Orienteering Problem with Time Windows (OPTW) where the collected profit is determined by the selection of tasks, and each task is constrained by a time window.
Some crucial new characteristics are taken into account. Firstly, for each pair of two consecutive tasks, a transition time is required to maneuver the look angle of the imaging instrument. Since different observation start times have different look angles, the transition time depends on the observation start times. Secondly, the quality of an image, i.e. the profit of an observation, also depends on the observation start time.

We develop an exact algorithm for this problem, based on a label setting algorithm and decremental state space relaxation (DSSR). For each label, we define an accumulated profit function. An improved calculation of the transition times is incorporated into the extension of the labels. Furthermore, we propose a new strategy of inserting critical vertices, based on the current optimal path at each iteration.
Unfortunately, no algorithm to compare with is published for the problem. Nevertheless, results show that our algorithm can solve the instances with 100 vertices to optimality in only 15 seconds on average.

Keywords: Orienteering problem, time, dependent transition time, time, dependent profit, label setting algorithm, decremental state space relaxation

*Speaker
†Corresponding author: guansheng.peng@student.kuleuven.be

Valid Inequalities and a Branch-and-Cut Algorithm for multi-depot vehicle routing problems

Michiel Uit Het Broek *† [1], Albert Schrotenboer [1], Bolor Jargalsaikhan [1], Kees Jan Roodbergen [1], Leandro Coelho [2,3]

[1] Department of Operations, Faculty of Economics and Business, University of Groningen – Netherlands
[2] CIRRELT and Université Laval, Québec – Canada
[3] Canada Research Chair in Integrated Logistics – Canada

We present a generic branch-and-cut framework for solving routing problems with multiple depots and asymmetric cost-structures, which consist in finding a set of cost minimizing (capacitated) vehicle tours in order to fulfill a set of customer demands. The backbone of the branch-and-cut framework is a series of valid inequalities, and accompanying separation algorithms, exploiting the asymmetric cost-structure in directed graphs. We derive three new classes of so-called DK inequalities that can eliminate subtours, enforce tours to be linked to a single depot, and impose bounds on the number of allowed customers in a tour. In addition, other well-known valid inequalities for solving vehicle routing problems are generalized and adapted to be valid for routing problems with multiple depots and asymmetric cost-structures. The resulting branch-and-cut framework is tested on four specific problem variants, for which we develop a new set of large-scale benchmark instances. The new DK inequalities are able to reduce root node optimality gaps by up to 67.2% compared to existing approaches in the literature. The overall branch-and-cut framework is effective as, e.g., Asymmetric Multi-Depot Traveling Salesman Problem instances containing up to 400 customers and 50 depots can be solved to optimality, for which only solutions of instances up to 300 customer nodes and 60 depots were reported in the literature before.

Keywords: Branch, and, Cut, Valid Inequalities, Asymmetric, Multi, Depot, Vehicle Routing

*Speaker
†Corresponding author: a.j.uit.het.broek@rug.nl

Criterion space search methods for a bi-objective facility location problem in the presence of uncertainty

Najmesadat Nazemi *† [1], Sophie Parragh [1]

[1] University of Linz – Austria

To cope with uncertainty in optimization problems, many different approaches have been presented in the literature. The most widely used ones are stochastic optimization including concepts such as the expected value, chance constraints or risk measure, and robust optimization, including prominent concepts such as minmax robustness or adaptive robust optimization. This paper aims at investigating bi-objective modeling frameworks for an uncertain location-allocation model to design a last mile food aid delivery network in a disaster relief chain. In order to find an efficient and reliable methodology to solve the problem, we use different approaches to model demand uncertainty: scenario-based two-stage stochastic optimization, minmax robustess and adaptive robust optimization. To cope with the bi-objective nature of the problem, all three approaches are embedded into criterion space search methods, namely the well-known e-constraint method and the recently introduced balanced box method. We compare the different approaches on data sets derived from a real world case study.

Keywords: Bi objective optimization, criterion space search method, uncertainty, facility location problem, humanitarian logistics

*Speaker

†Corresponding author: najmesadat.nazemi@jku.at

The Bi-objective p-Center and p-Dispersion problem

Sergio Pérez-Peló * [1], Jesús Sánchez-Oro† [2], Ana Dolores López-Sánchez [3], Abraham Duarte [1]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[2] Universidad Rey Juan Carlos (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[3] Pablo de Olavide University – Spain

Location problems are strategically solved to place facilities having into account a set of customers that require a supply. Vehicle routing problems deal with design of routes among facilities and customers that must be served. The overall cost can be reduced if facilities are properly located even when both problems have been addressed independently. In this work, we address a bi-objective location problem whose aim is to place a set of p facilities. Note that we name p as open facilities and n-p as closed facilities. On the one hand, the p-Center problem seeks to locate p facilities in order to minimize the maximum distance between each closed facility and its assigned open facility. On the other hand, the p-Dispersion problem aims to maximize the minimum distance between all pairs of open facilities in order to achieve the maximum diversity among them. When both objectives are simultaneously tackled we are solving the bi-objective p-Center and p-Dispersion problem (BpCD). To solve the BpCD an Iterated Greedy (IG) heuristic is implemented. IG builds an initial set of efficient solutions using a greedy algorithm. Since we are addressing a bi-objective optimization problem, two different greedy functions are considered and the output is the set of non-dominated solutions or efficient solutions instead of the optimal solution. Then, the IG destroys a percentage of each efficient solution, that will be subsequently reconstructed and three local searches are applied to each reconstructed in order to improve them. Results show the performance of the algorithm.

Keywords: PDispersion, PCenter, Multiobjective, Facility Location, Iterated Greedy

*Speaker
†Corresponding author: jesus.sanchezoro@urjc.es

The Vehicle Routing Problem with Private and Shared Delivery Locations

Simona Mancini * [1]

[1] University of Cagliari – Italy

In this work a new Rich Vehicle Routing Problem arising in parcel delivery for e-commerce, the VRP with Private and Shared Delivery Locations (VRP-PSDL) is introduced and formalized. In the VRP-PSDL deliveries can be perfomed directly at customer location within a short time-windows provided by the customer or, with a small compensation for the customer, they can be carried out at shared delivery locations (SDL) accessible 24/7 where customers may pick-up their goods at anytime. Each SDL can receive a limited number of deliveries. Each customer gives a list of the SDL in which he is willing to collect its order. The goal of the problem is to minimize total cost given by the sum of vehicle usage fixed costs, travel costs and compensations. A mathematical model and an effective Iterative Local Search based matheuristic are proposed. The matheuristic works as follows. Firstly, an intial solution is computed by running the model with a short timelimit. Then, at each iteration of the local search, p customers are randomly selected and they are assigned to the same SDL they were assigned in the current solution (or they are directly served if they were directly served in the current solution). This overconstrained version of the model is run for a short timelimit. The best solution obtained is kept as current best. After k noimpoving iterations a perturbation is applied randomly closing one of the SDL. Computational test show how this delivery system is strongly more cost effective respect to traditional delivery systems.

Keywords: Shared Delivery Locations, Ecommerce, Matheuristic, Iterated Local Search

*Speaker

A Branch-and-Cut-and-Price algorithm for the Two-Echelon Capacitated Vehicle Routing Problem

Guillaume Marques * [1,2,3], Ruslan Sadykov [2,3], François Vanderbeck [2,3], Jean-Christophe Deschamps [1], Rémy Dupas [1]

[1] Laboratoire de líntégration, du matériau au système (IMS) – Université Sciences et Technologies - Bordeaux 1, Institut polytechnique de Bordeaux, Centre National de la Recherche Scientifique : UMR5218 – 33405 TALENCE CEDEX, France
[2] Institut de Mathématiques de Bordeaux (IMB) – CNRS : UMR5251, Université Sciences et Technologies - Bordeaux I, Université Victor Segalen - Bordeaux II, Université Sciences et Technologies Bordeaux I, Université Victor Segalen – Bordeaux II – 351 cours de la Libération 33405 TALENCE CEDEX, France
[3] RealOpt (INRIA Bordeaux - Sud-Ouest) – Université Sciences et Technologies - Bordeaux I, INRIA – 200 avenue de la Vieille Tour 33405 Talence, France

The two-echelon capacitated vehicle routing problem aims to deliver goods to customers by processing and consolidating goods through intermediate depots. The problem involves two different fleets of homogeneous vehicles. The first fleet ships goods from the distribution center to the intermediate depots. The second fleet picks the goods at intermediate depots and delivers them to the customers. To solve exactly the problem we base our work on an efficient Branch-Cut-and-Price algorithm which combines the best techniques proposed recently for vehicle routing problems. Our contributions include a new path-based formulation of the problem without the need to use additional flow variables, a new family of valid inequalities, and a new branching strategy. Using the improved Branch-Cut-and-Price algorithm we were able to solve all classic instances of the problem with up to 10 intermediate depots and 200 customers. Thus we double the size of instances solved to optimality. Computational results for new instances with up to 15 intermediate depots will also be presented.

Keywords: Branch Cut and Price algorithm, valid inequalities, two echelon vehicle routing problem, column generation

*Speaker

Estimation of Disaggregated Freight Flows via a Real-Valued Genetic Algorithm

Javier Rubio-Herrero * [1], Jesús Muñuzuri [2]

[1] St. Mary's University – Engineering Department, 1 Camino Santa Maria San Antonio, TX, 78228, United States
[2] Universidad de Sevilla – Escuela Técnica Superior de Ingeniería, Camino de los Descubrimientos, S/N 41092, Sevilla, Spain

This presentation introduces a method for estimating indirectly the interregional transportation of certain commodities in those cases where their flows are not readily available and only aggregated flows per origin-destination (OD) pair are provided. Our method involves the use of a classical doubly-constrained gravity model embedded into an optimization problem that aims at finding an OD matrix of aggregated flows that is as similar as possible to the available data, in the sense of the standardized root mean square error (SRMSE). Different deterrence functions within the gravity model are put to the test and each of them is used in conjunction with a real-valued genetic algorithm in order to determine the option that yields the best fit. In turn, the genetic algorithm employs a combination of global and local searches to find the best set of parameters for each deterrence function under study in the gravity model.

Throughout this presentation, this methodology is applied directly to the case of estimating the disaggregated flows of ten different products among the fifteen regions of peninsular Spain between 2007 and 2016. Data are retrieved from the Spanish National Institute of Statistics and, amongst the different functions tested, we conclude that a gravity model with an exponential deterrence function provides a good fit for most of the routes and is as effective as other more complex options.

Keywords: Transport modeling, Metaheuristics, Logistics, Spatial models

*Speaker

A two-stage solution approach for the directed rural postman problem with turn penalties

Carmine Cerrone* [1], Benjamin Dussault [2], Xingyin Wang † [3], Bruce Golden [4], Edward Wasil [5]

[1] University of Molise [Campobasso] - Department of Biosciences and Territory (UNIMOL) – Via Francesco De Sanctis, 1, Campobasso, Italy
[2] End-to-End Analytics, LLC, – United States
[3] Singapore University of Technology and Design - Engineering Systems and Design – Singapore
[4] University of Maryland - Department of Decision, Operations and Information Technologies Robert H. Smith School of Business – College Park, MD 20742-1815, United States
[5] American University - Department of Information Technology – United States

In this paper, we consider the Directed Rural Postman Problem with Turn Penalties (DRPP-TP). A solution to the DRPP-TP is a tour that traverses all required arcs of the graph. The cost of the solution is the sum of the lengths of the traversed arcs plus the penalties associated with the turns made at the nodes. The DRPP-TP arises from real-world applications. For example, truck drivers prefer going straight as far as they can because turning left or even right can be dangerous and time consuming. U-turns are not possible for long trucks.
One solution approach involves transforming the arc routing problem into an equivalent node routing problem. An alternative direct approach without graph transformation has been proposed in the literature. The direct approach has two stages. First, the turn penalties are ignored and the problem is solved as a rural postman problem to obtain an Eulerian graph. Second, an end-pairing algorithm is used to generate an Eulerian tour taking the penalties of the turns into consideration. The first part of our paper investigates the applicability of the direct approach. We identify several characteristics of the input instances that make this approach effective and present several limitations of this approach.
In the second part of this paper, we improve the direct approach using an integer linear program in the first stage and a local search algorithm in the second stage to solve the DRPP-TP. This combination produces high-quality solutions in a reasonable amount of computing time.

Keywords: Arc routing, Heuristic, Greedy algorithm, Rural postman problem, Turn penalties

*Corresponding author: carmine.cerrone@unimol.it
†Speaker

Optimizing routing and delivery patterns with multi-compartment vehicles

Manuel Ostermeier *† [1], Markus Frank [2], Alexander Hübner [1], Andreas Holzapfel [3], Heinrich Kuhn [4]

[1] Technical University of Munich (TUM) – Germany
[2] Catholic University Eichstätt-Ingolstadt – Germany
[3] Geisenheim University – Germany
[4] Catholic University Eichstaett Ingolstadt – Germany

This paper addresses a periodic vehicle routing problem for the determination of delivery patterns (DPs) using multi-compartment vehicles. The presented problem happens in grocery distribution.

Store delivery policies and the resulting vehicle routes for supplying stores from distribution centers reveal a significant saving potential. Retailers usually apply repetitive weekly DPs for the supply of stores. DPs define the number of visits for each customer in which the complete weekly demand is satisfied. In grocery distribution, stores demand different product categories from different temperature zones. The demand for each category has to be fulfilled and therefore individual DPs need to be defined. Nowadays, retailers have the option of using multi-compartment vehicles. They enable the joint transportation of different temperature zones as their loading space can be split in compartments. The joint delivery directly affects the weekly DPs. For instance, instead of a separate delivery of a single product category twice per week, stores can receive this segment jointly with the daily deliveries of fresh products. This impacts both the delivery frequencies and the daily routing. These decisions are highly interrelated and need to be solved simultaneously. We therefore derive decision-relevant costs and propose a Periodic Multi-Compartment Vehicle Routing Problem (PMCVRP).

The PMCVRP is solved using a specialized heuristic. It combines an adaptive search for the determination of delivery patterns with a large neighborhood search for the routing. In numerical tests and a case study, we show the effectiveness of our approach and the impact of the use of MCVs on DPs.

Keywords: Retail, vehicle routing, heuristic, multi temperature logistics, multi compartment vehicles

*Speaker
†Corresponding author: manuel.ostermeier@tum.de

A Kernel Search Heuristic for the Multi-Vehicle Inventory Routing Problem

Claudia Archetti [1], Gianfranco Guastaroba *† [1], Diana Lucia Huerta-Muñoz [1], M. Grazia Speranza [1]

[1] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy

We study an inventory routing problem in which it has to be determined an optimal distribution plan to replenish a set of customers, by routing a limited fleet of capacitated vehicles over a discrete planning horizon. Each customer consumes a per period quantity of products and have a maximum inventory capacity. Products can be distributed by a supplier to the customers in advance compared to their consumption, provided that their inventory capacity is not violated. The goal is to minimize the total distribution cost, that comprises the routing and the inventory costs. We develop a novel matheuristic approach to solve this problem. The algorithm is based on Kernel Search (KS), a heuristic framework that has been shown to find high-quality solutions for a number of combinatorial optimization problems. The basic idea of KS is to identify subsets of the decision variables and then solving, using a general-purpose solver, a sequence of Mixed-Integer linear Programs, each one restricted to a subset of variables. Extensive computational experiments are conducted on a very large set of benchmark instances. The results show that KS outperforms state-of-the-art algorithms, finding 51 new best-known solutions out of 640 small-size instances, and 102 new best-known solutions out of 240 large-size instances.

Keywords: Inventory Routing, Vehicle Routing, Matheuristic, Kernel Search Framework

*Speaker

†Corresponding author: gianfranco.guastaroba@unibs.it

Make it Quick: Speed-up Techniques for Solving the TSP

Maša Avakumović * [1], Martin Josef Geiger† [1]

[1] Helmut Schmidt University [Hamburg] – Germany

The main goal of our work is to investigate speed-up techniques and implement them in the high-quality solution method for approximating the Traveling Salesman Problem (TSP) that arises numerous times when solving the Vehicle Routing Problem (VRP). In VRPs, partitioning customers in disjoint sets (i.e. routes) becomes especially problematic when the given constraints restrict not only the vehicle's capacity, but also the maximum travel distance permitted for a single vehicle, as is the case in the VeRoLog Challenge 2019. Due to this maximal traveled distance constraint, each time a set of customers in a single route is modified (e.g. by one inter-route operator), a new TSP for this route has to be solved in order to check if the the upper bound is exceeded.
In our approach, we used the logic of the Iterated Local Search (ILS) with adequate initialization methods and efficient implementation techniques. This techniques allowd us to exclude low-quality solutions before performing any further transformation and therefore contribute to the faster convergence towards the optimal solution. We mainly focused on enhancing the time efficiency of the well-known local search method 2-opt by calculating upper and lower bounds. Our experiments carried out on instances from the TSLIB show that more than 90% of the moves can be omitted by implementing our checks.
An independent assessment and comparison with other implementation methods was carried out on the optil.io platform, where we reached the top of the optil.io ranking in the ongoing TSP challenge.

Keywords: heuristic, local search, TSP, speed, up techniques

*Speaker
†Corresponding author: m.j.geiger@hsu-hh.de

Avoidance of unnecessary demerging and remerging logistics flows

Zhiyuan Lin* [1], Raymond Kwan †‡ [2]

[1] Alliance Manchester Business School, University of Manchester – United Kingdom
[2] School of Computing, University of Leeds – United Kingdom

Many routing and logistics optimisation problems can be modelled as multi-commodity flow. When flows merge, peak demands could be satisfied; and demerging allows more efficient use of resources in periods of lower demands. Optimization models may need additional controls over how flows merge/demerge. In particular an unacceptable situation in practice is the demerging of some merged flows only to recombining them into different, but equivalent in terms of total merged flow values, combinations of merged flows again. The additional controls may be modelled by means of binary fixed charge variables, but they would increase the computational burden tremendously. The problem of unnecessary coupling/decoupling in train unit scheduling based on integer multicommodity flows is one example. This deficiency could be overcome by fixed-charge variables, but the practicality of this approach is restricted for medium/large instances. Based on previous research, we present a further heuristic branching method for removing unnecessary coupling/decoupling without using fixed-charge variables. Based on flow potentials, this method heuristically removes candidate arcs that are "underutilized", such that the number of unnecessary coupling/decoupling operations is reduced. It can deal with non-interchangeable units and unbalanced arcs, compared with our previous research. Moreover, a train station sub-model is also proposed to further enhance the solutions. Computational experiments based on real-world instances have shown the usefulness of the proposed methods, which may have application for other problems in routing and logistics optimisation.

Keywords: Logistic flow, Train unit scheduling, Unnecessary coupling/decoupling, Heuristic branching, Fixedcharge network flow

*Corresponding author: zhiyuan.lin@manchester.ac.uk
†Speaker
‡Corresponding author: R.S.Kwan@leeds.ac.uk

Local search for the container relocation problem

Dominique Feillet [1], Sophie Parragh [2], Fabien Tricoire * [2]

[1] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – Campus Georges Charpak Provence, F-13451 Gardanne, France, France
[2] Johannes Kepler Universität Linz – Austria

The unrestricted block relocation problem is an important optimization problem encountered at terminals, where containers are stored in stacks. It consists in determining the minimum number of container moves so as to empty the considered bay following a certain retrieval sequence. A container move can be either the retrieval of a container or the relocation of a certain container on top of a stack to another stack. The latter types of moves are necessary so as to provide access to containers which are currently not on top of a stack. They might also be useful to prepare future removals. In this paper, we propose the first local search type improvement heuristic for the block relocation problem. It relies on a clever definition of the state space which is explored by means of a dynamic programming algorithm so as to identify the locally optimal sequence of moves of a given container. Our results on large benchmark instance reveal unexpectedly high improvement potentials (up to 50%) compared to results obtained by state-of-the-art constructive heuristics.

Keywords: container relocation, dynamic programming, local search, shortest path

*Speaker

Mining frequent patterns to drive the exploration of high-order neighborhoods

Florian Arnold * [1], Thibaut Vidal [2], Italo Gomes Santana [2], Kenneth Sörensen [1]

[1] University of Antwerp – Belgium
[2] Pontifical Catholic University of Rio de Janeiro (PUC-Rio) – 1PUC-Rio – Pontificia Universidade Catolica do Rio de Janeiro Caixa Postal 38097 Rio de Janeiro, RJ, Brazil, Brazil

Pattern mining is a well-established technique to discover frequently-occurring substructures in datasets. These substructures can be used to infer general knowledge about the underlying data, e.g., "if a customer buys milk, he is likely to also buy bread and coffee". This idea can be easily translated into the routing domain to obtain statements such as "a visit to customer A is likely to be followed by visits to customers B, C and D in good vehicle routing solutions".

In this work, we use pattern mining to make a controlled exploration of high-order neighborhoods in a local search (LS). We maintain a limited number of most-frequent patterns in elite solutions. Then, during the LS, each pattern serves to define one move in which 1) incompatible edges are disconnected, 2) the edges defined by the pattern are reconnected, and 3) the remaining route fragments are optimally reconnected. Each such move is accepted only in case of improvement. This "pattern injection" local search (PILS) finds useful high-order local search moves which would not be detected with traditional operators. Our first experiments indicate that this technique can thereby complement and improve existing state-of-the art heuristics with a limited implementation effort, and can potentially be applied to a wide range of combinatorial optimization problems.

Keywords: Vehicle routing, pattern, mining, local search, heuristics

*Speaker

Enhancing Local Search Through Machine Learning: a Case Study on the Vehicle Routing Problem

Daniele Vigo * [1], Luca Accorsi [1], Michele Lombardi [2], Michela Milano [2]

[1] DEI, University of Bologna – Italy
[2] DISI, University of Bologna – Italy

Local search is one of most popular optimization techniques used to effectively solve hard combinatorial optimization problems (COPs) and in particular large scale ones, for which exact solution approaches are prohibitive.Local search is indeed the main engine of all modern metaheuristics which perform hundreds of thousands of iterations exploring the neighborhoods of given solutions.
Practical algorithms typically exploit a relatively small set of simple local search operators and use them to optimize a solution until a local optimum is reached.
A common example of such apporaches is the Variable Neighborhood Descent (VND), in which the neighborhood defined by each operator is completely examined before moving to the next operator.
Up to now, little attention has been given to the orderings in which operators are examined; common orderings usually consists in prefixed static or dynamic randomly ordered operators examination.
This work we study whether in a VND setting, using Machine Learning techniques to identify the most promising operator (or knowing that none of them will be able to improve a given solution) enables computational savings that could be used to perform a more fruitful search.
In particular, as a case study, we focused on the (capacitated) vehicle routing problem, and we train an Artificial Neural Network for raking operators at search time.

Keywords: Vehicle Routing, Machine Learning, Heuristics

*Speaker

The Consistent Vehicle Routing Problem for a Food Distribution Firm

Hernán Lespay *† [1], Karol Suchan [1]

[1] Universidad Adolfo Ibáñez [Santiago] – Diagonal Las Torres 2640, Santiago, Región Metropolitana, Chile

In this work, we present a heuristic for solving The Consistent Vehicle Routing Problem (ConVRP), which is motivated by a real-world application in a distribution center of a food company. The problem is characterized by a set of customers that vary from day to day, as well as their demand. Additionally, each customer requires that their orders be delivered within a certain time window. The main difficulty of the problem comes from the large size of instances and high demand variability.
We propose a new heuristic for solving the ConVRP for the food company. For evaluating the performance of the heuristic, we used the benchmark instances generated for the ConVRP from the literature. The results confirm the good performance of the implemented heuristic, outperforming several instances. Finally, for the food company, we obtain significant improvements in terms of generating a better consistent service.

Keywords: consistent vehicle routing, heuristics, logistics

*Speaker
†Corresponding author: hlespay@alumnos.uai.cl

Picking location metrics for order batching on a unidirectional cyclical picking line

Flora Hofmann *† [1], Stephan Visagie [2]

[1] Department of Logistics [Stellenbosch] – Van der Sterr Building, Bosman Street Stellenbosch, 7600., South Africa
[2] Department of Logistics [Stellenbosch] – Van der Sterr Building, Stellenbosch, 7600., South Africa

Order batching is extended to a picking system with the layout of a unidirectional cyclical picking line. The objective is to minimise walking distance expressed as the number of cycles traversed by pickers in the picking line. The set up of the picking system shows similarities to unidirectional carousel systems, if the store keeping units are viewed as moving relative to a static picker.

As a first step, three order-to-route closeness metrics are introduced to approximate distance. All metrics are based on the picking location describing when a picker has to stop at a bay to collect the items for an order. These metrics comprise a number of stops, a number of non-identical stops and a stops ratio measurement.
Besides exact solution approaches, four greedy heuristics and six metaheuristics are applied to combine similar orders in batches.

All metrics are tested using real life data of 50 sample picking lines in a distribution centre of a prominent South African retailer. The capacity of the picking device is restricted, thus the maximum batch size of two orders per batch is allowed. The best combination of metric and solution approach is investigated. The significance of metric and cycles traversed is determined by a Welch-ANOVA, while the additional impact of the algorithms is investigated in a two-way ANOVA. Results show that the combination of stops ratio metric and greedy random heuristic generate the best results in terms of minimum number of total cycles traversed as well as computational time to find the solution.

Keywords: order batching, picking location metrics, unidirectional cyclical picking line, carousel

*Speaker
†Corresponding author: 20304269@sun.ac.za

Heuristics for the multi row facility layout problem considering facilities of equal length

Nicolás Rodríguez Uribe [1], J. Manuel Colmenar* [1], Alberto Herrán [1], Abraham Duarte † [1]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain

The Multi Row Facility Layout Problem considering facilities of equal length (MREFLP) is a particular case of the family of Floor Layout Problems. The most generic problem is Multi Row Facility Layout Problem, and the difference between them is that in the first one, it can be assumed that the facilities have the same width. The best-known is the Corridor Allocation Problem (also called Space-Free Double Row Facility Layout Problem), which is a particular case of this one, considering only two rows, and with no space between the facilities. The objective is minimising the cost obtained as the product between the distance of each pair of facilities and the associated weight of the same pair of facilities. The result is n facilities in m rows. There are several applications of this problem, most of them related to industry like assembly lines, chip design, manufacturing systems, arrangement of facilities and so on. This problem has been studied in the past with exact approaches. These exact approaches perform better in the case where the number of facilities is lower or equal to 20. For grater values, it cannot reach the optimal value in their time limit. Also, the smallest the m, the better the results. We propose a new heuristic approach for this problem where we have obtained promising results in comparison with the state of the art.

Keywords: Multi Row Facility Layout Problem, Heuristics, Meta, heuristics

*Corresponding author: josemanuel.colmenar@urjc.es
†Speaker

A new approach to solve the demand weighted vehicle routing problem

Raúl Martín Santamaría [1], José Ignacio González Méndez [1], J. Manuel Colmenar *† [1], Ana Dolores López-Sánchez [2]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[2] Pablo de Olavide University – Spain

The demand weighted vehicle routing problem (DWVRP) is a variant of the capacitated vehicle routing problem that models bus shuttle services. In this problem, bus shuttles run from the demand points (bus stops) to the depot or hub (that could represent, for instance, a hotel, the airport, the university, a train station, downtown, etc.) and vice versa. Specifically, shuttle buses always perform a complete route and passengers are picked up from the demand points to the hub or from the hub back to the demand point. Of course, shuttle buses have a capacity and the problem seeks to minimize the distance traveled by the buses weighted by the number of passengers on the routes. Note that, in the DWVRP, passengers travel along the entire route, instead of just travelling from the hub to the bus stop location, that is, just a portion of the route.

The interest of the DWVRP arises in many real-world situations in which public or private companies provide a transportation service to their customers picking them up at several locations placed far away from the hub. The shuttle bus runs frequently performing routes starting and finishing at the hub.

In this work, we present a new metaheuristic method to tacke this problem in an efficient way. Our results are promising in relation to the current state of the art.

Keywords: Capacitated VRP, Heuristics, Metaheuristics, Bus transportation

*Speaker

†Corresponding author: josemanuel.colmenar@urjc.es

A Learning Large Neighborhood Search for the Dynamic Electric Autonomous Dial-A-Ride Problem

Claudia Bongiovanni *† [1], Mor Kaspi [2], Jean-François Cordeau [3], Nikolas Geroliminis [1]

[1] Ecole Polytechnique Federale de Lausanne (EPFL) – Switzerland
[2] Tel Aviv University (TAU) – Israel
[3] HEC Montréal – Canada

The dynamic electric Autonomous Dial-a-Ride Problem (e-ADARP) extends the dynamic dial-a-ride problem by considering the employment of electric autonomous vehicles (e-AVs). The problem maximizes the number of served demand and minimizes a cost function composed of the total operational cost and user inconvenience. The operation of e-AVs introduces new opportunities that must be taken into account in real-time planning processes. That is, differently from human-driven vehicles, e-AVs operate non-stop and offer more flexibility to modify vehicle plans in real-time. The operation of e-AVs also introduces new challenges that need to be tackled on-line. Namely, the planning process needs to continuously re-optimize the vehicle battery levels, decisions regarding detours to charge stations, recharge times, together with the classic dial-a-ride features. In this work, we propose a two-phase heuristic approach to solve the dynamic e-ADARP. The first phase consists of an insertion heuristic that efficiently modifies both vehicle routes and schedules with the arrival of new transportation requests. The second phase introduces a new Learning Large Neighborhood Search (LLNS) algorithm to re-optimize both vehicle plans and schedules through intra- or inter-route customer exchanges. The LLNS utilizes multiple neighborhoods defined from problem-specific characteristics. We formulate the choice of the operator by a classification problem, where the operator represents a class and selected characteristics of the problem instances or solutions represent the features. Numerical results are produced from an event-based simulation based on existing benchmark instances and real-world data from ride-hailing services.

Keywords: dial a ride problem, dynamic, electric autonomous vehicles, metaheuristics, machine learning

*Speaker
†Corresponding author: claudia.bongiovanni@epfl.ch

The Bi-objective p-Median and p-Dispersion problem

Juan David Quintana Pérez * [1], Jesús Sánchez-Oro† [1], Ana Dolores López-Sánchez‡ [2]

[1] Universidad Rey Juan Carlos (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[2] Pablo de Olavide University – Spain

In the logistic field is crucial to locate in an accurate way a set of facilities since this is going to optimize the routing cost among facilities and customers.

In general, in any location problem the aim is to place p facilities out of a candidate set of n facilities, where p is smaller than n. From now on, we refer to p as open facilities and n-p as closed facilities. Depending on the objective function that we want to optimize and the constraints that we include (capacitated or uncapacitated, discrete or continuous, among others), we can solve a wide variety of location problems.

As is well-known the p-Median problem seeks to determine the locations of p facilities in order to minimize the total distance between open facilities and their nearest closed facilities. The p-Dispersion problem aims to maximize the minimum distance between all pairs of open facilities in order to achieve the maximum diversity among the open facilities.

The bi-objective p-Median and p-Dispersion problem (BpMD) combines both objectives that are in conflict, being the goal to search for the set of non-dominated solutions or efficient solutions instead of the optimal solution.

To solve the BpMD we have implemented a Greedy Randomized Adaptive Search Procedure (GRASP) to construct the initial set of efficient solutions and then, we have combined the GRASP with Path Relinking in order to improve the set of efficient solutions. Computational results show the quality of our proposal.

Keywords: facility location, pdispersion, Maxmin diversity, pMedian partitioning, grasp, path relinking

*Speaker
†Corresponding author: jesus.sanchezoro@urjc.es
‡Corresponding author: adlopsan@upo.es

Consistent-DARP

Oscar Tellez [1], Samuel Vercraene *† [1], Fabien Lehuédé [2], Olivier Péton [2], Thibaud Monteiro [1]

[1] Décision et Information pour les Systèmes de Production (DISP) – Institut National des Sciences Appliquées de Lyon – Campus LyonTech La Doua,INSA Lyon Bât Léonard de Vinci, 21 avenue Jean Capelle, 69621 Villeurbanne Cedex, France
[2] Institut de Recherche en Communications et en Cybernétique de Nantes (LS2N) – École Nationale Supérieure des Mines - Nantes, IMT anlantique – 1, rue de la Noë BP92101 44321 Nantes Cedex 03, France

We investigate a multi-period Dial-A-Ride Problem in the context of passengers with disabilities. The problem integrates an objective related to cost as well as an objective on the consistency of passengers schedules. This consistency is defined as the number of significantly different pickup times in a one week long planning. The problem is modeled as a route based mathematical model. This set partitioning formulation is combined with a large neighborhood search in an epsilon constraint algorithm. The method is evaluated on a benchmark of the literature and some managerial insights are derived on real instances.

Keywords: Multiperiod DARP, Time consitecy, Matheuristic

*Speaker
†Corresponding author: samuel.vercraene@insa-lyon.fr

A Large Neighborhood Search for the Active-Passive Vehicle Routing Problem

Biljana Roljic * [1], Fabien Tricoire [2], Karl Doerner [3]

[1] University of Vienna, Faculty of Business, Economics and Statistics – Oskar-Morgenstern-Platz 1, 1090 Vienna, Austria
[2] Johannes Kepler University, Institute of Production and Logistics Management – Altenberger Straße 69, 4040 Linz, Austria
[3] University of Vienna, Faculty of Business, Economics and Statistics – Oskar-Morgenstern-Platz 1, 1190 Vienna, Austria

The active-passive vehicle routing problem (APVRP) is a variant of the vehicle routing problem in which pickup-and-delivery requests require a joint operation of two types of transport resources, namely, passive and active means of transport. The passive means are used for holding the cargo, representing a single unit that is to be shipped from pickup to delivery locations. The active means haul the passive means and carry them from one location to another. The contribution of our work is twofold. First, we investigate the classical APVRP and provide a fast metaheuristic able to address very large benchmark instances. We design our method such that we realize more opportunities for optimization by allowing the transshipment of passive means among active means during the fulfillment of single pickup-and-delivery requests. Second, we introduce an extended version of the APVRP, where passive means of transport can hold multiple units up to a maximum capacity. This extension is motivated by a real-world problem setting in integrated steel production, concerning the task of intra-facility steel slab routing. We report computational results for the classical APVRP and show that our metaheuristic provides competitive performance on benchmark data sets. As for the extended APVRP, we create new instance sets conforming to the specific problem characteristics. Our contributions are completed by a thorough analysis of the possibilities and limitations of transshipments within the scope of the classical and extended APVRP.

Keywords: Large neighborhood search, Route synchronization, Combined routing, Pickup and Delivery

*Speaker

The PDP with alternative locations and overlapping time windows

Alina-Gabriela Dragomir * [1], Karl Doerner [1], Tom Van Woensel [2]

[1] University of Vienna – Vienna, Austria
[2] Eindhoven University of Technology – Netherlands

Sending and receiving parcels can be a nuisance in both a B2C and C2C settings. Public post services or commercial shipping companies are not very accommodating for private mail by enforcing personal visits at pickup or drop off points, or simply by maintaining rigid schedules. Courier services on the other hand are often too expensive. None of these options are sufficiently accommodating. Therefore we propose the PDP with alternative locations and overlapping time windows. The transportation requests have to be served by a fleet of homogeneous capacitated vehicles, and each request may have multiple alternative pickup locations throughout the day with non-overlapping time windows (since the product cannot be in two places at once). Request may also have multiple alternative delivery locations, since the parcel is no longer delivered to a single specific person, but rather to a 'household'. A household consists of multiple persons in different locations that can be available simultaneously. Household members can accept the parcel at multiple locations throughout the day whether they are at work or at home.
We propose a solution approach combining a genetic algorithm and large neighbourhood search with problem specific operators to solve the pickup and delivery problem with alternative locations. Preliminary computational results are discussed and a comparison with already existing literature is provided.

Keywords: PDP, Genetic algorithm, Large Neighborhood Search

*Speaker

A solution method for k-mldp and some comparatives.

Nancy Arellano Arriaga* [1,2], Julián Molina † [1], Iris Martínez-Salazar [2], Elisa Schaeffer [2], Ada Alvarez [2]

[1] Universidad de Málaga [Málaga] – Avda. Cervantes, 2 29071 MÁLAGA, Spain
[2] Universidad Autónoma de Nuevo León - UANL (MEXICO) (UANL) – Ave. Universidad s/n Ciudad Universitaria, San Nicolás de los Garza, Mexico

We introduce a bi-objective problem which considers a fleet of k uncapacitated vehicles to visit a set of clients waiting for a service. In this problem we optimize an economic objective as well as a service-quality objective simultaneously by minimizing the total travel distance of the fleet while also minimizing the total waiting time of the clients to be visited. All agents depart from a known depot and return to it at the end of the day. Each of the clients is visited exactly once and all agents must be active.
This combination of objectives seeks to satisfy the requests of the clients as fast as possible by minimizing their total waiting time while the agents travel the minimum distance to perform the visiting. We call this problem as k-Minimum Latency-Distance Problem ({k}-{mldp}), and in this talk we present a novel heuristic approach to approximate its Pareto fronts. We call this methodology as Evolutionary algorithm with Intelligent Local Search (EiLS). It is based on the classical Pareto ranking scheme with crowding distance, which was originally proposed by Deb et al (2000) in their NSGA-II algorithm, but to produce offsprings EiLS employs an efficient random-shake crossover and an intelligent local search over various neighborhoods as a substitute for a classical mutation process. EiLS exploits {k}-{mldp} structure and selects the neighborhood with the best ratio of success, to maintain a high quality of the produced fronts. We show comparisons between a classical multi-objective solution algorithm and EiLS.

Keywords: Multiple Traveling Salesman Problem, Multiple Traveling Repairman Problem, Biobjective Optimization

*Corresponding author: nancy.arellanoarg@uanl.edu.mx
†Speaker

The Clustered Heterogeneous Vehicle Routing Problem with relaxed priority rules

Tan Doan * [1], Nathalie Bostel [2], Hoang Ha† [3]

[1] Laboratoire des Sciences du Numérique de Nantes (LS2N) – Université de Nantes, IMT Atlantique Bretagne-Pays de la Loire – Université de Nantes – faculté des Sciences et Techniques (FST)2 Chemin de la HoussinièreBP 92208, 44322 Nantes Cedex 3, France
[2] Laboratoire des Sciences du Numérique de Nantes (LS2N) – Université de Nantes – Université de Nantes – faculté des Sciences et Techniques (FST)2 Chemin de la HoussinièreBP 92208, 44322 Nantes Cedex 3, France
[3] ORlab (ORlab) – ORLab, VNU University of Engineering and Technology, E3 building, 144 Xuan Thuy, Cau Giay, Ha Noi, Vietnam

Vehicle Routing Problem (VRP) is one of the most studied topics in Operations Research. Among the numerous variants of the VRP, this research addresses the Clustered Heterogeneous Vehicle Routing Problem with relaxed priority rules in which customers are assigned to several priority groups and customers with the highest priorities typically need to be visited before lower priority ones. Some rules are additionally imposed to control the trade-off between priority and efficiency (traveling cost). The problem has important applications in the context of logistics of commercial products as well as humanitarian relief operations. We propose a Mixed Integer Linear Programming (MILP) model to formulate the problem and solve small-size instances. An adaptive large neighborhood search (ALNS) algorithm with problem-tailored components is then designed to handle the problem at larger scale. The results obtained on a set of instances with different priority assignment appoaches that simulate natural disasters and commercial logistics show the robusness of the problem model and the performance of the proposed methods.

Keywords: Vehicle Routing Problem, Priority, Order of Demand Fulfillment, d, relaxed rule, Mixed Integer Programming, ALNS, Humanitarian relief

*Speaker
†Corresponding author: minhhoangha.vth@gmail.com

Production and delivery problem with late departure and tardiness penalties

Hugo Chevroton * [1], Yannick Kergosien [1], Jean-Charles Billaut [1]

[1] Laboratoire dÍnformatique Fondamentale et Appliquée de Tours (LIFAT) – Université de Tours : EA6300, Polytech'Tours – 64, Avenue Jean Portalis, 37200 Tours, France

The context of supply chain imposes a high-level of coordination between the production and the delivery of types of good that cannot be stored for a long time. (drugs, foods).
We study an integrated production and delivery problem where commands of such type of good have to be produced and delivered to various customers. Each customer has a specific localization and an expected due date. Each command is produced on a flow shop with permutation production chain. In order to build the delivery plan, the commands are grouped in batches and assigned to a dedicated vehicle among a homogeneous fleet. A vehicle can start as soon as all the commands of the batch are completed in order to serve customers.

A solution ensures the production and the delivery of commands minimizing several costs. A storage cost is taken to account when a product on the production chain is not in process on a machine or when the product is finished and waiting for its vehicle departure. A fixed cost is taken into account for each vehicle used. A routing cost is considered and a penalty must be paid to customers for any tardiness related to his command.
A heuristic method is proposed to solve this global problem. From a production sequence, a linear model is solved to minimize the inventory costs. The batches are determined using a clustering method. An original approach, based on local search, is designed to optimize a batch delivery with uncertainty on the departure date.

Keywords: Production, delivery, matheuristique, modelization

*Speaker

A Method for 1-M-1 Pickup and Delivery Problem with Robust Paths

Islam Altin *† [1], Aydin Sipahioglu [1], Ahmet Yazici [1]

[1] Eskisehir Osmangazi University (ESOGU) – Meselik Campus, 26480, Eskisehir, Turkey

1-M-1 Pickup and Delivery Problem (1-M-1 PDP) can be defined as pickup and delivery of materials between warehouse and customers. There are four kinds of solution models for 1-M-1 PDP in the literature. One of them is Hamiltonian solution model that allows simultaneously pickup and delivery at the same time. As the objective of this problem is minimizing total travel cost, routes should be designed by considering shortest paths without exceeding capacity of vehicles. However, especially in-plant logistics, some paths may not be available for vehicles due to the various reasons such as traffic congestion or temporarily blockage of a road. Therefore, paths to be used by vehicles should be determined dynamically based on the changing road conditions. Especially, if Autonomous Robots or AGVs are used in-plant logistics, the convenience of these roads is essential in terms of completing the tours. In this case, the shortest travel time is much more important than the shortest path. Hence, obtaining reliable path by considering the shortest travel time can be called robust path. In this study, a method is suggested to find robust paths for the 1-M-1 PDP using Simulated Annealing algorithm. Different test problems are generated to evaluate the performance of the proposed method. The computational results show that the proposed method is efficient to obtain robust paths for this problem. **Acknowledgement:** This work is supported by the Scientific and Technical Research Council of Turkey (TUBITAK), Contract-No 116E731, project-title: "Development of Autonomous Transport Vehicles and Human-Machine/Machine-Machine Interfaces for Smart Factories"

Keywords: 1, M, 1 Hamiltonian Pickup and Delivery Problems, Robust Paths, Simulated Annealing Algorithm

*Speaker

†Corresponding author: ialtin@ogu.edu.tr

Home Chemotherapy Planning: An Integrated Production Scheduling and Multi-Trip Vehicle Routing Problem

Yasemin Arda [1], Diego Cattaruzza * [2], Véronique François [1], Maxime Ogier [2]

[1] HEC Liege - Management School of the University of Liege – Belgium
[2] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) – Ecole Centrale de Lille – Cité Scientifique - CS 20048 59651 Villeneuve d'Ascq cedex, France

Home chemotherapy (HC) services aim to assist cancer patients enabling them to remain comfortable at home. This is currently a rising trend, and it should be encouraged
when the patient's conditions are favorable. HC services imply both the production and the administration of drugs to patients. These activities are run in parallel and must be carefully
synchronized due to short lifespan of drugs and limited resources.
In order to efficiently plan these activities at the operational level, two well known and hard problems, scheduling and routing, need to be solved as a whole, rising challenging
synchronization issues to be addressed.

We consider a set of patients that must be visited by a set of nurses for administration of a personalized drug. Nurses are allowed to come back to the hospital and get new produced drug
thus performing multiple serving trips. The drug is produced right before delivery by a set of the technicians in the hospital pharmacy.

We propose to use a large neighborhood search heuristic that iteratively removes and reinserts production and/or drug administration operations to create new solutions.
Three destroy and recreate operators are considered: 1) production operations are removed and reinserted 2) drug administration operations are removed and reinserted 3) both types of operations are
removed and reinserted to modify the complete solution.
Ad-hoc mathematical programming based operators are developed to re-optimize the current solution.
The algorithm is tested on new instances created based on discussion with Belgium hospitals.

*Speaker

Keywords: Home chemotherapy, Meta, heuristic, Integrated problems

A Hybrid Solution Method for the Vehicle Routing Problem with Locker Boxes

Jasmin Grabenschweiger * [1], Karl Doerner [2], Richard Hartl [3], Martin Savelsbergh [4]

[1] University of Vienna – Vienna, Austria
[2] University of Vienna – Vienna, Austria
[3] University of Vienna – A-1210 Wien, Austria, Austria
[4] School of Industrial and Systems Engineering [Georgia Tech] (ISyE) – H. Milton Stewart School of Industrial and Systems Engineering Georgia Institute of Technology 765 Ferst Drive, NW Atlanta, Georgia 30332-0205, United States

As a consequence of the online shopping trend, people tend to receive a lot of parcels nowadays, which brings new challenges for delivery companies. Customer convenience and logistic efficiency play a role when competitive strategies have to be found. To account for both aspects, we introduced the Vehicle Routing Problem with Locker Boxes. Customers can be serviced at their home address, but only within a certain time window. Apart from that, the parcels can also be brought to so called locker boxes, that are accessible 24/7 and close to the customer's home address or any other suitable place. The service aspect appears as a requirement on the minimum number of home deliveries. Efficiency of a routing plan is measured in terms of total travelled distance. A collaborative hybrid solution method is developed to solve the problem. In a first step Adaptive Large Neighborhood Search is used to solve the problem as a Vehicle Routing Problem with Time Windows, where the locker box stations are neglected. Then, some customers are taken out of the pure home delivery plan, and moved to locker boxes. At the locker box stations slots of different size are available and a bin-packing model is used to decide about the assignment of parcels to slots. The current capacity requirements of the locker boxes are returned to the routing algorithm to improve the selection of the locker box customers and the resulting routing problem is re-solved in an iterative procedure. The algorithm is applied to real-world inspired instances.

Keywords: Hybrid solution method, vehicle routing problem with locker boxes

*Speaker

Optimizing the Location of Incident Response Vehicles for Congestion Mitigation

Güşta Dilaver * [1], Eda Yucel [1], Mahir Yildirim [2]

[1] TOBB University of Economics and Technology [Ankara] – Turkey
[2] Istanbul Bilgi University [Istanbul] – Turkey

In this research, we study the location routing problem of incident response vehicle fleet in urban areas. The most studied objective in the literature is minimizing the response time in case of incidents. However, we present possible scenarios where this objective function is shown to disregard the overall time spent in congestion by the drivers. With this motivation, our objective is minimizing the expected total traffic congestion caused by the incidents. Given the traffic flow between any two nodes of the highway network for a certain time horizon, an incident occurring on a road segment that is not responded quickly blocks the traffic flow on the former road segments to a certain level and the number of road segments affected by the incidence and their congestion levels increase as the delay in incident response increases. We first provide a scenario-based multi-period stochastic formulation that determines the locations of the response vehicles at each period with the aim of minimizing the expected total traffic congestion over all possible scenarios, where each scenario, specifying a number of incidents with their location and occurrence time information, has a probability of occurrence. As the number of possible scenarios is extremely large for a real road network, we propose a Tabu Search heuristic that evaluates candidate solutions over a sample of scenarios. We apply our methods on a case study of Istanbul, one of the most congested cities in the world.

Keywords: Location Routing, Heuristic Algorithm, Accident Management, Accident Responder Vehicles

*Speaker

Managing Election Campaign with the Power of Analytical Modeling and Heuristics

Masoud Shahmanzari * [1], Deniz Aksen [1], Said Salhi [2]

[1] Koç University – Rumelifeneri Yolu 34450 Sariyer Istanbul Turkey, Turkey
[2] University of Kent – Centre of Logistics and Heuristics Optimisation (CLHO) Kent Business School, University of Kent, Canterbury, CT2 7PE, United Kingdom, United Kingdom

Campaign planning is one of the important decisions to make while dealing with determining routes, schedule of the activities, and accommodation planning. The campaign planner is required to plan the schedule of the visits to the customers, to satisfy time constraints, and to organize activities at its best with a proper decision on the scheduling and routing. In this paper, we analyze the problem of election logistic arising in campaign planning. The goal is to schedule the campaigner's daily tours throughout the entire campaign period and to propose an activity plan for each day. In other words, the problem seeks to maximize the net benefit accrued by a party leader during a fixed campaign period. We introduce a new hybrid metaheuristic algorithm, called granular skewed variable neighborhood tabu search (GSVNTS). It consists of a Granular Tabu Search which is embedded in a Skewed Variable Neighborhood Search algorithm. The problem is tackled efficiently by adapting analytical model, scenario analysis, and metaheuristics. The proposed approach is tested on a case study involving 81 cities and 12 towns in Turkey. Using effective analytical models and metaheuristics, we show that promising results can be obtained to hopefully assist campaign planners in their strategic decision making.

Keywords: Campaign planning, Election logistics, Variable neighborhood search, Mixed, integer linear programming

*Speaker

A Trilevel r-Interdiction Selective Multi-Depot Vehicle Routing Problem

Deniz Aksen *† [1], Mir Ehsan Hesam Sadati [2], Necati Aras [3]

[1] Koç University (KU) – Rumelifeneri Yolu 34450 Sariyer Istanbul Turkey, Turkey
[2] Istanbul Kültür University (İKÜ) – İstanbul Kültür Üniversitesi Ataköy Yerleşkesi E5 Karayolu üzeri Bakırköy 34158 İstanbul, Turkey
[3] Department of Industrial Engineering, Bogazici University (BOUN) – Boğaziçi University Department of Industrial Engineering 34342, Bebek, Istanbul, Turkey, Turkey

We introduce a trilevel optimization problem for the determination of the most critical depots in a multi-depot vehicle routing network. The problem is modelled as a 'defender-attacker-defender' game from the perspective of the defender who needs to protect a limited number of depots on an existing network against interdiction by an adversary agent whom we designate as the attacker. The attacker's objective is to inflict the maximum disruption on this network by annihilating a certain number of unprotected depots beyond repair. We call this problem the trilevel r-interdiction selective multi-depot vehicle routing problem (3LRI-SMDVRP). The defender is the decision maker in the upper level problem (ULP) who decides which depots to protect. In the middle level problem (MLP), the attacker chooses r depots to interdict among the unprotected ones. Finally, in the lower level problem (LLP), the decision maker is again the defender who optimizes the vehicle routes and thereby selects which customers are to be served in the wake of depot interdictions. All three levels of the problem have an identical objective function comprised of three cost components. (i) Operating cost of the vehicles. (ii) Traveling cost. (iii) Outsourcing cost due to unsatisfied demand. The defender aspires to minimize this objective function while the attacker tries to maximize it. As a solution approach, we resort to smart exhaustive enumeration for the ULP and MLP. For the LLP we implement a hybrid method combining Variable Neighborhood Descent and Tabu Search heuristic techniques adapted to the SMDVRP.

Keywords: Trilevel Programming, Protection, Interdiction, Outsourcing, Selective Multi, Depot Vehicle Routing Problem, Variable Neighborhood Descent, Tabu Search

*Speaker
†Corresponding author: daksen@ku.edu.tr

The p-k-median location problem: clustering data with respect to several patterns within each cluster.

Carlos Martín *† [1], Justo Puerto [1]

[1] Departamento de Estadística e Investigación Operativa (DESTIO) – Spain

This paper introduces a new location problem with application in clustering data using more than one representative pattern. We assume to be given a set of demand points (set of data) and we wish to locate p configurations of k points each, in order to minimize the overall sum of distances of the demand points to the k points in their closest configuration.
We consider the continuous and discrete versions of this problem. In the continuous case, the p configurations can be placed anywhere in a continuous space endowed with an lp-norm. The discrete version assumes that the feasible locations for the configurations must belong to a given finite sets of points, from where the model has to choose the p configurations. The first problem can be formulated as a mixed integer non-linear programming problem whereas the second one is a mixed integer linear program. These problems generalize several well-known facility location problems as the p-median and round trip location problem.
We study some properties of these models and give solution approaches to obtain their solutions. We present preliminary computational results, implemented in MOSEK, on several databases having in mind their application to cluster data with respect to k representative patterns rather that with respect to only one, as in the p-mean or p-median models.

Keywords: k, median, prototype based clustering, facility location, conic programming

*Speaker
†Corresponding author: carlosvalverdemartin@gmail.com

Optimizing Onboard Catering Loading Locations and Plans for Airlines

Seren Bilge Yilmaz * [1], Eda Yucel [1]

[1] TOBB University of Economics and Technology [Ankara] – Turkey

Airlines serve complimentary or for-purchase in-flight meals that vary depending on the length of flight. These meals are prepared by airline caterers and are ideally loaded just before the flight. However, as it is costly to have correct amount of meal at the departure airport just before each flight, airline companies carry out meal loading at predetermined airports. In general, the loading sites (airports) are two types as normal or cross. At normal loading sites catering can be loaded directly to the aircraft with a loading cost, whereas at cross loading sites before loading catering should be transported from a normal loading site with an additional transportation cost. Although flight plan changes dynamically, airlines determine meal loading sites before each season based on the established flight plan and estimated amount of meal consumed at each flight. In this study, given flight plan for a specified planning horizon and estimated demand for each meal type, we address the problem of determining normal and cross loading sites. The objective is to minimize total operational costs including fixed costs of opening loading sites, loading costs, transportation costs for cross loading and aircraft fuel costs. The aircraft meal capacity and life time for each meal should be considered. We develop a mathematical model and a tabu search algorithm for the problem. We analyze their performance on realistic problem instances obtained from a well-known airline company in Turkey.

Keywords: Airline Applications, Metaheuristics, Facility Location

*Speaker

Optimizing workforce scheduling and routing problem with electric vehicles

Seray Cakirgil * [1], Eda Yucel† [2], Cağri Koç‡ [3]

[1] TOBB University of Economics and Technology (TOBB ETU) – Sogutozu Caddesi No:43, Soğutozu, Ankara, 06560, Turkey
[2] TOBB University of Economics and Technology [Ankara] – Turkey
[3] Department of Business Administration, Social Sciences University of Ankara (ASBU) – Turkey

Motivated by a real-life technician routing and scheduling problem that a company in energy distribution sector faces on a daily basis, in this study, we work on a workforce scheduling and routing problem (WSRP) that involve dispatching of a number of multi-skilled personnel to a set of geographically distributed tasks having multi-skill requirements, different priority levels, and precedence relationships. These days, electric vehicles are preferred by such service companies instead of conventional vehicles due to environmental considerations and cost reductions. The WSRP addressed in this study differs from the traditional problems in this domain by use of electric vehicles to perform tasks and consideration of the charging needs of these vehicles. The objective is to minimize total weighted completion time of all tasks, where the tasks that cannot be performed in the current planning horizon (shift) are assumed to be completed during the upcoming shift. We develop a mathematical formulation to address the problem. As the computational effort grows for realistic size instances, we propose a metaheuristic based on a variable neighborhood search. We analyze the performance of the proposed solution approach through computational analysis on instances derived from literature.

Keywords: Service operations, Electric VRPs, Workforce scheduling and routing, Metaheuristics

*Speaker
†Corresponding author: edatyucel@gmail.com
‡Corresponding author: cagri.koc@asbu.edu.tr

Weekly planning in the broth and cream industry with several channels

Joaquin Pacheco * [1], JosÉw RubÉn GÓmez * † [1], Silvia Casado‡ [1], Manuel Laguna§ [2]

[1] University of Burgos – Spain
[2] University of Colorado at Boulder – Spain

This paper deals with a real planning problem of a company in the food sector. This company produces mainly fresh cheese, broths, creams, vegetable desserts and soy products among other products. The company has a production line for each family of these products. The problem refers to the soy dessert line, but it can be generalized to the others. Normally the process consists of uperization (UHT), filling tetra – briks, and boxing (filling boxes with tetra-briks). Each line consists of two identical channels. Each request (order) can be made on one channel or both. Specifically, the problem consists in establishing the weekly planning of the orders, that is, production order and the channels that it occupies each order. The objective is to maximize weekly production and reduce production time. It takes into account the setups times between the different orders, maximum time and maximum production between cleaning operations, etc. A formulation of the problem is proposed. The model has similarities with route problems although it also has some notable differences. A Multi-Start tabu search method is proposed. This heuristic method is compared with commercial software (CPLEx and Localsolver) in real and pseudoreal instances.

Keywords: scheduling, several chanels, tabu search, MIP

*Speaker
†Corresponding author: jrgomez@ubu.es
‡Corresponding author: scasado@ubu.es
§Corresponding author: laguna@colorado.edu

On the Ground Transportation Process and Costs within the Bi-Objective Insular Traveling Salesman Problem

Pablo A. Miranda *† [1], Javier Maturana-Ross [2], Carola Blazquez [1], Guillermo Cabrera-Guerrero [3], Carlos Obreque [4]

[1] Universidad Andrés Bello [Santiago] (UNAB) – Santiago, Chile
[2] University of Liverpool – Liverpool L69 3BX, United Kingdom, United Kingdom
[3] Pontificia Universidad Católica de Valparaíso (PUCV) – avenida Brasil 2950, Valparaiso, Chile
[4] Universidad del Bio Bio [Concepción] (UBB) – Av. Casilla 5-C - Collao 1202, Concepción, Región del Bío Bío, Chile

Insular Vehicle Routing Problems have been recently introduced in the literature, in which visit sequences and port/node selection for a set of island or isolated regions to be served must be simultaneously optimized. The ground transportation process inside the islands and the related costs are relevant distinctive features of these problems, in contrast to similar works in related literature, such as the Generalized Vehicle Routing Problems. This research analyzes alternative formulations for the ground transportation process inside the islands, exploring different related assumptions. Moreover, this paper aims at analyzing the results regarding solution quality and structure, and computational performance.

Keywords: Insular Vehicle Routing Problems, Bi, Objective Insular Traveling Salesman Problem, Ground Transportation Costs, Exact and Approximated Models.

*Speaker
†Corresponding author: pablo.miranda@unab.cl

Exact solution methods for the multi-period vehicle routing problem with due dates

Homero Larrain * [1], Leandro Coelho [2], Claudia Archetti [3], M. Grazia Speranza [4]

[1] Pontificia Universidad Católica de Chile (PUC) – Chile
[2] Laboratoire CIRRELT Université Laval Quebec (CIRRELT) – Université Laval Pavillon Palasis-Prince, bureau 2642 2325, rue de la Terrasse Québec (Québec) G1V 0A6 CANADA, Canada
[3] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy
[4] University of Brescia, Department of Quantitative Methods – C.da S. Chiara n. 50, Brescia, Italy, Italy

We study the multi-period vehicle routing problem with due dates. A supplier has to determine a distribution plan to visit a set of customers over a given planning horizon. Each customer is associated with a release date and a due date, that is, the date at which the goods required by the customer become available at the supplier's depot, and the date by which the customer has to be visited, respectively. A fleet of capacitated vehicles is available at the depot to perform the distribution, and the objective is to minimize the distribution costs and the costs related to delayed deliveries. New families of valid inequalities are presented that allow us to improve a branch-and-bound algorithm from the literature. The new branch-and-bound algorithm reduces to 5.1% the optimality gap, which is 12.1% for the known branch-and-bound on instances with one vehicle. A variable MIP neighborhood descent (VMND) algorithm is also presented, which speeds up the search for high quality solutions through a local search heuristic embedded in the branch-and-bound algorithm. Computational tests are performed to assess the quality of the VMND algorithm against the new branch-and-bound algorithm. The computational results show that the VMND algorithm improves 35 out of 80 solutions on instances with one vehicle, reducing the average optimality gap from 5.1% to 3.6%. It further matches the performance of the new branch-and-bound algorithm on another 35 instances. On instances with two and three vehicles the average optimality gap obtained by the VMND algorithm is 5.5% and 5.6%, respectively.

Keywords: Routing, due dates, heuristic, local search, exact algorithm, hybrid algorithm, VMND

*Speaker

The Urban Transit Network Design Problem

Alicia De Los Santos Pineda *† [1], David Canca Ortiz [2], Alfredo García Hernández-Díaz [3], Eva Barrena [3]

[1] Department of Statistics, Econometrics, Operational Research, Management Science and Applied Economics, University of Cordoba – Spain
[2] Industrial Engineering and Management Science, School of Engineering, University of Seville – Spain
[3] Deparment of Economic, Quantitative Methods and Economic History, University of Pablo de Olavide, Spain – Spain

In this work we consider the problem of simultaneously designing the infrastructure of a urban bus transportation network and its set of lines while minimizing the total travel time of all passenger willing to travel in the network. As main differences with respect to other works in the bus transportation design field, we do not consider an a priori line pool, but we design the set of lines from square one, presenting a detailed description of the travel time (which incorporates the time spent in transferring along the passengers paths) and we jointly determine the transit assignment accordingly to the users' minimum trip time. Most authors incorporate transfers into the computation of the travel time as a penalty term considering only the number of transfers. In this work we are interested in introducing a detailed description of the transfer time. To this end, we consider two layers: the first one affecting the off-board passengers movement (pedestrian layer) and the second one corresponding to the road infrastructure over which buses can run along (road-infrastructure layer). In a realistic way, we can distinguish two types of transfers: transfers at the same stop and transfer between different stops. Obviously, the second type requires an extra-time to walk between stops over the pedestrian layer and therefore, a greater discomfort for passengers.We present a mathematical programming model for solving the problem on the directed graph that results when superimposing both layers. We illustrate the problem with some computational experiments over several networks.

Keywords: bus, network design, line planning, mathematical model

*Speaker
†Corresponding author: aliciasantos@uco.es

A Heuristic Algorithm for the Undirected Capacitated General Routing Problem with Profits

Annarita De Maio *† [1], Demetrio Laganà [1], Francesca Vocaturo [2]

[1] Department of Mechanical, Energy and Management Engineering, University of Calabria – Arcavacata di Rende (CS), Italy
[2] Department of Economics, Statistics and Finance "G. Anania", University of Calabria – Arcavacata di Rende (CS), Italy

We study the Undirected Capacitated General Routing Problem with Profits. The class of problems with profits has become very popular in the last decades due to their capability to model several real cases. Our problem is defined on an undirected graph where customers are represented by sets of vertices and edges. A non-negative demand and a given profit are associated to each of them. We consider a fleet of homogeneous capacitated vehicles located at the depot to service the customers. The aim is to maximize the difference between the total collected profit and the traveling cost. A feasible solution is represented by a subset of customers that are selected according to their net profit, that is the difference between the profit and the additional traveling cost to serve them. The problem is NP-hard. We propose a heuristic algorithm based on a local search technique. First, a set of feasible routes servicing a subset of customers is iteratively built by considering both the distance from the depot and the collected profit. Second, we use tailored moves embedded into a local search scheme to improve the initial solution. An in-depth analysis is conducted in order to investigate the effectiveness of each move. Preliminary computational results are presented.

Keywords: General Routing Problem, Local Search, Profits.

*Speaker
†Corresponding author: annarita.demaio@unical.it

The on-demand bus routing problem: the importance of bus stop assignment

Lissa Melis * [1], Kenneth Sörensen [1]

[1] University of Antwerp – Prinsstraat 13 2000 Antwerp, Belgium

Even though public bus transport is still largely bound to fixed routes and fixed timetables, technology would allow for a large-scale shift to on-demand public transport in the near future. In such an on-demand system, buses would drive along routes completely determined by the demand of passengers. To support the routing of on-demand buses we define a new optimization problem: the on-demand bus routing problem (ODBRP), which combines the dial-a-ride problem (DARP) with bus stop selection, introduced in the school bus routing problem. Given a set of requests for transportation, indicating a passenger's departure and arrival location, as well as his/her preferred arrival time, the aim of the problem is to (1) assign each passenger to a departure and arrival bus stop within walking distance, and (2) develop a set of bus routes, picking up passengers at their departure stop and delivering them to their departure stop before their preferred arrival time. The first decision is called bus stop assignment. The goal is to group customers so that the bus can avoid extra stops and detours. This way there is more flexibility for the routing and the efficiency of the system increases. In this talk, we present the ODBRB and we investigate the positive impact of bus stop assignment on the solution quality, using a straightforward heuristic. Further, we determine the parameters (number of requests, fleet size, number of stations, etc.) most influencing this impact.

Keywords: Public transport, Metaheuristics, Vehicle routing

*Speaker

The Airport Shuttle Problem: A Formulation and Metaheuristic Algorithm

Cağri Koç *† [1], Nihat Öner [2], Hakan Gültekin [3]

[1] Department of Business Administration, Social Sciences University of Ankara (ASBU) – Turkey
[2] Department of Industrial Engineering, TOBB University of Economics and Technology (TOBB ETU) – Turkey
[3] Department of Mechanical and Industrial Engineering, Sultan Qaboos University (SQU) – Oman

Airport shuttle services transfer passengers from or to the airport and city center which must be completed in a specific time. After the service, new passengers can be assigned to the vehicle or the vehicle can return to the next location with no passenger for the next service. The vehicle services, which has no service for a while, can wait in a location which was determined before. All transfer operations continue in accordance with the constraints until the accepted passenger demands are satisfied during the day. Transportation of some customers can be rejected which brings no extra cost. Hence, the demand of some passengers cannot be satisfied. Each passenger transfer must begin within the time window. We may group passengers and assign them to the same vehicle. These passengers can be in different flights and are ready to transfer in different times. The main objective is to maximize the profit while satisfying the limited seat capacity, the predefined flight times, and the number of passengers constraints. Such considerations give rise to a people transportation variant of the pickup and delivery problems. This study introduces the airport shuttle problem, presents a mixed integer programming formulation, and develops a metaheuristic for its solution. Extensive computational experiments have shown that the metaheuristic is highly effective on the problem.

Keywords: Airport shuttle service, vehicle routing problem, scheduling, metaheuristic

*Speaker
†Corresponding author: cagri.koc@asbu.edu.tr

The pickup and delivery problem with time windows, multiple-stacks, and handling operations

Marilène Cherkesly * [1,2,3], Timo Gschwind [4]

[1] Université du Québec à Montréal - UQAM (CANADA) (UQAM) – Canada
[2] École des sciences de la gestion Université du Québec à Montréal (ESG UQAM) – Canada
[3] GERAD – Canada
[4] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

We introduce, model and solve the pickup and delivery problem with time windows, multiple-stacks and handling operations (PDPTWMS-H). In the PDPTWMS-H, a fleet of vehicles based at a depot is used to complete a set of requests which consist of transporting items from a pickup location to a delivery location. The vehicles have multiple compartments operated using last-in-first-out (LIFO) loading which requires the vehicle to be rear-loaded and items can only be unloaded if they are closest to the back door. In the PDPTWMS-H, handling operations are allowed, and an additional handling time might be incurred when delivering items (by unloading and reloading items). Several handling policies are investigated. The problem consists of determining the number of vehicles and the vehicle routes needed to complete the set of requests at minimal cost while respecting the handling policy. We model the PDPTWMS-H with a set-partitioning formulation and resort to branch-and-price for its solution. In branch-and-price, solving the pricing problem is typically the most time-consuming part. In the PDPTWMS-H, the pricing problems are variants of elementary shortest path problems with capacity constraints, time windows, multiple-stacks and handling operations. These can be solved using labeling algorithms where dominance criteria are needed to eliminate unpromising labels. When re-handling is allowed, there are many possibilities for unloading and reloading items which creates several symmetrical labels making its resolution challenging. We derive a labeling algorithm that models information about on-board items in a way that symmetry is reduced. Computational results will be presented.

Keywords: Branch, and, price, elementary shortest path problem with resource contraints, labeling algorithm, LIFO loading, handling time, multiple stacks

*Speaker

Branch-cut-and-price algorithms for the vehicle routing problem with backhauls

Eduardo Queiroga* [1], Yuri Frota [1], Ruslan Sadykov †‡ [2,3], Anand Subramanian [4], Eduardo Uchoa§ [1], Thibaut Vidal [5]

[1] Universidade Federal Fluminense (UFF) – Brazil
[2] Institut de Mathématiques de Bordeaux (IMB) – CNRS : UMR5251, Université Sciences et Technologies - Bordeaux I, Université Victor Segalen - Bordeaux II, Université Sciences et Technologies Bordeaux I, Université Victor Segalen – Bordeaux II – 351 cours de la Libération 33405 TALENCE CEDEX, France
[3] RealOpt (INRIA Bordeaux - Sud-Ouest) – Université Sciences et Technologies - Bordeaux I, INRIA – 200 avenue de la Vieille Tour 33405 Talence, France
[4] Universidade Federal da Paraíba (UFPB) – Departamento de Engenharia de Produção, Centro de Tecnologia, Campus I - Bloco G, Cidade Universitária, João Pessoa-PB, 58051-970, Brazil
[5] PUC-Rio – Brazil

This work deals with the vehicle routing problem (VRP) with backhauls (VRPB), a classical VRP variant with two types of customers: linehaul (delivery) and backhaul (pickup) ones. The linehaul customers have a delivery demand that is loaded at the depot and the backhaul customers have a pickup demand to be transported to the depot. A route must visit at least one linehaul customer and may visit backhaul ones. After visiting a backhaul customer, linehaul customers cannot to be visited. At any moment vehicle capacity should be respected. Despite the large number of works on heuristics for the VRPB, we were able to identify only a couple works on exact algorithms for the problem published in the 1990s. We thus propose two branch-cut-and-price (BCP) algorithms for the VRPB. The first of them follows the classic approach with one pricing subproblem. The second one exploits the linehaul/backhaul customer partitioning and defines two pricing subproblems. The algorithms incorporate elements of state-of-the-art BCP algorithms, such as rounded capacity cuts, limited-memory rank-1 cuts, strong branching, route enumeration, arc elimination using reduced costs and dual stabilization. Computational experiments show that the proposed algorithms are capable of obtaining optimal solutions for all existing benchmark instances with up to 200 customers, many of them for the first time. In addition, the approach involving two pricing subproblems is more efficient than the classic one. New instances for the problem are also proposed.

*Corresponding author: eduardovqueiroga@hotmail.com
†Speaker
‡Corresponding author: Ruslan.Sadykov@inria.fr
§Corresponding author: uchoa@producao.uff.br

Keywords: Branch cut and price, column generation, vehicle routing with backhauls

Optimising drayage operations by combining column generation and branch-and-cut

Robin Pearce * [1,2], Mahboobeh Moghaddam [2]

[1] Vrije Universiteit Amsterdam [Amsterdam] (VU) – De Boelelaan 1105 1081 HV Amsterdam, Netherlands
[2] University of Queensland [Brisbane] (UQ) – Brisbane, St Lucia, QLD 4072, Australia

Port drayage operations account for between 20% and 80% of the total transportation cost for a shipping container, despite covering the shorter distances of the container's trip. In addition to being expensive, truck movements around urban areas are often blamed for increasing road congestion, environmental pollution, and road safety risks in the service area. Such factors make improvement of drayage operations desirable to port authorities. This has led to increased attention from researchers interested in solving such problems through optimisation models for drayage operations.

There are many studies which seek to optimise drayage operations, but many of these make simplifying assumptions which may impact the quality of solutions found. Some of these assumptions are one truck one container, homogeneous fleet of trucks, one container size, single shipping terminal, and live loading/unloading where a truck must stay with the container for all legs of a journey. We present a flexible request model that does not make any of the above assumptions. This allows us to find solutions of higher quality when compared to models with less flexibility.

We demonstrate that our model is capable of solving instances of reasonable size, and discuss our current work where we implement an *a priori* column generation method for finding solutions to larger and more difficult instances. This method involves generating portions of feasible routes and connecting them together in a branch-and-cut framework.

Keywords: Drayage, Pickup and Delivery, Integer programming, Branch and cut

*Speaker

A New Modeling of the Transportation Constraints in the RCPSP with Routing: Application to Healthcare Problems

Marina Vinot *† [1], Philippe Lacomme‡ [2]

[1] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Université Clermont Auvergne, Institut d'Informatique, Centre National de la Recherche Scientifique - CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France

[2] Laboratoire d'Informatique, de Modélisation et d'Optimisation des Systèmes (LIMOS) – Université Clermont Auvergne : UMR6158, Centre National de la Recherche Scientifique : UMR6158 – Bât ISIMA / Campus des Cézeaux BP 10025 / 63173 Aubière Cedex, France

The Resource-Constrained Project Scheduling Problem with Routing (RCPSPR) problem is an integrated problem that extends the Resource-Constrained Project Scheduling Problem. This extension is based on the assertion that the resources used by the activities must be transported by vehicles. The challenge of this paper is to introduce a new modeling of the problem to generalize the transport in the RCPSPR.

The originality of this work rests on the resolution of a 1-to-n transport problem, i.e. a vehicle can simultaneously transport resources requested by different activities. A question then arises on the resources transported but not necessary for the realization of the destination activity. Two behaviors are possible for these resources: 1) to be pickup by a vehicle at the end of the activity with the released resources, 2) to be pickup at any time since they are not necessary for the progress of the activity. These resources must be differentiated from the resources needed and used by each activity in the modeling. The use of a specific flow graph makes it possible to answer this problem.

The proposed approach to solve the RCPSPR problem with these new constraints is based on a new flow graph and on a split algorithm to define the routes of vehicles in the solution. Local search tools are also set up, including pattern recognition within the solutions. The first results are promising since they allow the cost of some solutions to be reduced by almost 15% by considering only the makespan.

*Speaker

†Corresponding author: marina.vinot@gmail.com

‡Corresponding author: placomme@isima.fr

Keywords: RCPSP, Routing, VRPPD

Solution strategies for the vehicle routing problem with backhauls

Anand Subramanian * [1], Eduardo Queiroga [2]

[1] Universidade Federal da Paraíba (UFPB) – Brazil
[2] Universidade Federal Fluminense (UFF) – Brazil

In the VRP with backhauls (VRPB) there are two sets of customers: linehaul and backhaul. The first one has delivery demands, while the second has pickup demands. The objective is to design a set of least-cost routes satisfying the following constraints: (i) each customer must be visited exactly once; (ii) a non-empty route must contain at least one linehaul customer; (iii) backhaul customers can only be served after all linehaul customers have been visited in a particular route; and (iv) the capacity of the vehicle cannot be exceeded. The problem can be seen as a special case of the asymmetric VRP with mixed backhauls (AVRPMB). We tackle the VRPB by: (i) directly applying a state-of-the-art AVRPMB matheuristic for the problem, in which a VRPB instance is transformed into an AVRPMB instance, i.e., the infeasible VRPB arcs (from backhaul to linehaul customers, and from the depot to backhaul customers) are penalized; and (ii) by adapting the same matheuristic for the VRPB itself. Such adaptation mainly consists of preventing infeasible moves to be unnecessarily evaluated during the local search and also by only allowing feasible solutions to be explored in all steps of the algorithm, as opposed to the first solution strategy. Both approaches were capable of obtaining all best-known solutions for the traditional benchmark instances and the result of one instance was improved. We also compared the scalability of both methods for instances with up to 1000 customers.

Keywords: backhauls, matheuristics, local search

*Speaker

A bilevel approach for the collaborative and integrated transportation planning

Maria Santos *† [1,2], Eduardo Curcio [2], Pedro Amorim [1], Alexandra Marques [2], Margarida Carvalho [3]

[1] Faculdade de Engenharia [Porto] (FEUP) – Rua Dr. Roberto Frias, s/n 4200-465 Porto, Portugal

[2] INESC TEC [Porto] – INESC TECFEUP campusRua Dr. Roberto Frias4200 - 465 PortoPortugal, Portugal

[3] Department of Computer Science and Operations Research [Montreal] – Université de Montréal Pavillon André-Aisenstadt CP 6128 succ Centre-Ville Montréal QC H3C 3J7, Canada

This work addresses the collaborative and integrated transportation planning problem, considering collaboration between a shipper (e.g., manufacturer) and a third party logistics provider (3PL). This problem is analogous to a Vehicle Routing Problem with Selective Backhauls (VRPSB), which considers a transportation network composed of a depot (manufacturer), a set of customers that receives products from the depot and a set of suppliers that sends raw-materials to the depot. All customers demand must be satisfied in a single visit, by a single vehicle, whereas backhauls routes are optional. Thus, an integrated route is created if it is more cost-effective than a dedicated inbound route. The selection of which suppliers to visit, if any, is determined by the 3PL, as it will only agree to perform an integrated route if the incentive offered by the manufacturer is sufficient to compensate the cost increase in distance (or other metric used by the 3PL).

The VRPSB is formulated as a bilevel mixed integer programming (MIP), where the upper level describes the problem of the manufacturer, which aims to minimize the total costs, and the lower level describes the problem of the 3PL, which aims to maximize the total profits. A reformulation technique reduces the problem to a single-level, which is solved with an exact method.

This work aims to evaluate the benefits of our approach and compare it with a non-collaborative problem and with a full collaboration approach (assuming that the 3PL always accepts the incentives offered by the manufacturer).

Keywords: Vehicle Routing Problem with Selective Backhauls, collaboration, bilevel optimization

*Speaker

†Corresponding author: mjsantos@inesctec.pt

A mixed integer program for capacitated asset protection during escaped wildfire

Delaram Pahlevani *† [1], John Hearne [1], Babak Abbasi [1], Andrew Eberhard [1]

[1] RMIT University [Melbourne] – GPO Box 2476 Melbourne VIC 3001 Australia, Australia

Despite worthwhile efforts to implement wildfire prevention programmes, Australia is still suffering the impacts of wildfire due to human activities and climate change. Wildfire is a common natural phenomenon in many parts of world such as Australia, USA, Canada, New Zealand and South Africa in which communities and assets are impacted and destructed. In the past few years, many scholars focused on proposing evacuation plans (Haynes et al. 2010), (Shahparvari et al. 2016) and studied asset protection operations during wildfire (Roozbeh et al. 2018). Due to the complexity of the problem and operational challenges that incident management teams are dealing with, finding more effective solutions still needs further investigation. To this end, we formulated a model aimed at protecting as many assets as possible during an escaped wildfire. The model is a mixed integer linear programming model that determines the optimal set of routes for fleets of protection vehicles during wildfire subject to various constraints such as time windows, vehicle synchronisation and the capacity of vehicles to make it closer to real life operation. We also considered the possibility of refilling during the tour once vehicles can not fulfil the expected demand. This feature enables vehicles to accomplish more tasks in a single trip, rather than returning back to the depot to refuel. The computational results suggest that the proposed model will be a useful decision-aid incident managers.

Keywords: asset protection, wildfire, VRP

*Speaker

†Corresponding author: delaram.pahlevani@rmit.edu.au

Asset protection problem with uncertain time of wind change

Iman Roozbeh *† [1], John Hearne [1], Babak Abbasi [2], Melih Ozlen [1]

[1] School of Science, RMIT University, Melbourne, Australia – Australia
[2] School of Business IT Logistics, RMIT University, Melbourne, Australia – Australia

Wildfires are natural disasters capable of damaging community assets and claiming human lives. In the case of extreme wildfires incident managers plan protection tasks at key assets, according to their special requirements. Decision makers working under severe time constraints need to take into account uncertainties involved in wildfires. A situation that frequently arises is that it is known a significant change in wind direction will occur in a few hours but the precise time is uncertain. During bushfires, all assets are often cannot be serviced due to the time constraint and limited resources, which is similar to the vehicle routing problem with profit. Thus, the asset protection protection problem can be counted as a variant of the vehicle routing problem with profit that aims to maximise the total profit collected. In our study, we develop a two-stage stochastic approach for the asset protection problem. The model handles existing complexities and the timing uncertainty along with other attributes of the problem. This stochastic program considers different wildfire scenarios and assign fire trucks to protective tasks in the first stage to achieve the maximum total expected value of assets being protected at all stages. In this paper, a case study is presented and solved using CPLEX. To validate our approach, we perform extensive experiments. Results are compared to the dynamic rerouting approach. The computational testing reveals that our approach can achieve better solutions and realistic sized problems can be solved using CPLEX in times suitable for operational purposes.

Keywords: Asset protection, Wildfire, Stochastic programming, Disaster management

*Speaker
†Corresponding author: iman.roozbeh@rmit.edu.au

Consistent Vehicle Routing and Its Influence on Priority-Based Pickup Decisions: The Case of Junior Soccer Player Training Transfers

Christian Jost * [1], Alexander Döge [2], Sebastian Schiffels [1], Rainer Kolisch [1]

[1] Technical University of Munich (TUM) – Arcisstrasse 21, D- 80333 München, Germany
[2] BASF SE, CoE Excellence Innovations, Advanced Analytics in Procurement – Carl-Bosch-Strasse 38, 67063 Ludwigshafen am Rhein, Germany

In the multibillion-dollar soccer business, rising player transfer cost make the promotion of young talents a key factor for the soccer clubs' long-term success. German first division club TSG 1899 Hoffenheim (TSG) runs one the most renowned soccer training academies in Germany. As a service, they provide a van transfer for around 100 youth players on each training day. Currently, the manual assignment of players to tours is a complex and time-consuming task, which leaves many players unserved. Our approach increases the rate of served players by up to 21 %.

Given limited van capacities, players are prioritized according to their age group (U12-U19); the closer to professional soccer, the higher the priority. The objective is to find tours that maximize the priority sum of served players. However, a tradeoff exists with TSG's organizational and safety requirements aiming for players to be picked up by the same driver each day they request a transfer. Without this consistency requirement, driver-player assignments would vary significantly, given the different daily training schedules.

To maximize the sum of collected priorities while warranting highly consistent driver-player assignments, we design a two-stage heuristic framework based on Tabu Search: (1) We derive a template driver-player assignment, valid for the entire season and adhering only to a small subset of players. (2) We solve each daily routing problem, maximizing collected priorities, while enforcing assignment consistency for the subset of players from the template.

Results suggest that high assignment consistency can be reached at low pickup priority losses.

Keywords: ConVRP, Consistency, Team Orienteering, Passenger Transportation

*Speaker

Decentralized dynamic task allocation and route planning for autonomous delivery vehicles in urban areas

Katharina Glock *† [1], Anne Meyer [2], Martin Pouls [1]

[1] FZI Research Center for Information Technology (FZI) – Haid-und-Neu-Strasse 10-14 76131 Karlsruhe, Germany
[2] Technische Universität Dortmund – 44221 Dortmund, Germany

We address the problem of assigning and executing orders for a fleet of autonomous electric delivery vehicles operating in urban areas. The vehicles are equipped with storage units, allowing them to transport several packages at the same time. Material handling equipment supports the automatic exchange of loads at mechatronic post-boxes. Together, this leads to a new form of last mile logistics, reducing traffic volume and pollution in cities. Related applications in intralogistics, where automated guided vehicles (AVG) are already widely used for material handling, often use decentral control systems for deciding on task assignment and routing. In our talk, we investigate whether these control concepts can be transferred to urban vehicle fleets in the light of changing operational factors, e.g., the ratio of driving time to service time, the fact that several orders can be transported simultaneously, and the impact of traffic and congestion. To this end, we propose a multi-agent system (MAS), where orders are allocated via sequential auctions. We evaluate this system based on a discrete-event simulation. The quality of the decentral control strategies are compared with central solution approaches to the corresponding static vehicle routing problem with pickup and deliveries.

Keywords: autonomous vehicles, dynamic vehicle routing, multi, agent system, discrete, event simulation, urban logistics

*Speaker
†Corresponding author: kglock@fzi.de

The Team Orienteering Problem with Overlaps: an Application in Cash Logistics

Christos Orlis [1], Nicola Bianchessi [2], Roberto Roberti* [1], Wout Dullaert † [1]

[1] Vrije Universiteit, Amsterdam – Netherlands
[2] University of Milan – Italy

The Team Orienteering Problem (TOP) aims at finding a set of routes subject to maximum route duration constraints that maximize the total collected profit from a set of customers. Motivated by a real-life Automated Teller Machine (ATM) cash replenishment problem that seeks for routes maximizing the number of bank account holders having access to cash withdrawal, we investigate a generalization of the TOP that we call the Team Orienteering Problem with Overlaps (TOPO), in which the total gathered profit can be strictly lower than the sum of the individual collected profits. We present exact solution methods based on column generation and a metaheuristic based on large neighborhood search to solve the TOPO. An extensive computational analysis shows that the proposed solution methods can efficiently solve synthetic and real-life TOPO instances. Moreover, the proposed methods are competitive with the best algorithms from the literature for the TOP. In particular, the exact methods can find the optimal solution of 371 of the 387 benchmark TOP instances, 33 of which are closed for the first time.

Keywords: team orienteering, cash distribution, routing with profits, column generation, metaheuristic

*Corresponding author: r.roberti@vu.nl
†Speaker

Optimisation of vessel routing for offshore wind farm maintenance tasks

Toby Kingsman *† [1], Burak Boyaci‡ [2]

[1] STOR-i Centre for Doctoral Training, Lancaster University (STOR-i) – Lancaster, LA1 4YR, United Kingdom

[2] Lancaster University Management School, Department of Management Science, Centre for Transport and Logistics (CENTRAL) – Lancaster University Management School, Lancaster, LA1 4YX, United Kingdom

The rapid growth expected in the offshore wind sector means there is an increasing opportunity to find savings from conducting operations and maintenance activities more efficiently. The predicted increase in the size and quantity of offshore wind farms means mathematical tools for scheduling maintenance activities will be necessary to exploit economies of scale fully.

Maintenance tasks must be worked on by a specific combination of technicians, equipment and vessel support for a set duration of time. A heterogeneous fleet of vessels is responsible for transporting technicians around the wind farm and conducting personnel transfers. Vessel movements must satisfy any limitations in wind turbine accessibility imposed by offshore weather conditions and the need to return all resources back to port by the end of the shift.

In this research, we propose a mathematical model capable of determining the most cost effective routes for vessel movements and the ideal times to undertake crew transfers. The model incorporates a one-to-one pickup and delivery structure between the port and the wind farm and a many-to-many structure within the wind farm. We allow for selective task completion to model instances with restricted resources.

We conduct experiments on a mix of simulated and real-life instances from an offshore wind farm. We examine the impact of various instance characteristics such as the task profiles, weather conditions and technicians available on the vessel routes and crew transfer plans.

Keywords: offshore wind

*Speaker

†Corresponding author: t.kingsman1@lancaster.ac.uk

‡Corresponding author: b.boyaci@lancaster.ac.uk

A New Distribution Paradigm: Delivery of Medicines by Drone

Tânia Ramos * [1], André Conceição [2], Daniele Vigo [3]

[1] Centro de Estudos de Gestão, Instituto Superior Técnico, Universidade de Lisboa (CEG-IST) – Av. Rovisco Pais, 1049-001 Lisboa, Portugal
[2] Centro de Estudos de Gestão, Instituto Superior Técnico, Universidade de Lisboa (CEG-IST) – Portugal
[3] DEI, University of Bologna – Italy

This work analyses a new paradigm imposed by the integration of unmanned aerial vehicles (UAV), commonly referred to as drones, in logistics and distribution processes. This work is motivated by a real case-study, where the company Connect Robotics, the first drone delivery provider in Portugal, wants to implement drone deliveries in a pharmacy located at a rural region. This pharmacy delivers medicines to five nursing homes every day. However, this is a service that causes some problems in the drugstore's daily operations considering it requires an available vehicle, as well as an employee leaving their station. Moreover, rural road networks do not always enable a fast delivery and, unfortunately, car accidents are not unprecedented either. Therefore, drone deliveries came as a potential answer to these issues, but it requires tackling some logistics challenges brought by the drones' characteristics. From the literature, the parallel drone scheduling travelling salesman problem (PDSTSP) was considered the most similar to the problem at hand since its formulation considers the drone integration concurrently with a road vehicle. Therefore, this work proposes the parallel drone scheduling vehicle routing problem (PDSVRP), which is based on the PDSTSP but allows for multiple road vehicle routes. Two variants of this problem were modelled: (1) the daily delivery operations and (2) single delivery operation, with two objectives: cost and time minimization. The MILP models were implemented with real data and the results obtained suggest that it is possible to obtain savings in the cost and transportation time of the pharmacy's deliveries.

Keywords: drone deliveries, unmanned aerial vehicles, drones, last mile deliveries, vehicle routing problem

*Speaker

A Decision Support System for Attended Home Services

Bruno P. Bruck * [1], Filippo Castegini [2], Jean-François Cordeau [3], Manuel Iori [2], Tommaso Poncemi [4]

[1] Universidade Federal da Paraíba (UFPB) – Centro de Informática - Rua dos Escoteiros, s/n - Mangabeira, João Pessoa - PB, 58055-000, Brazil
[2] Università degli Studi di Modena e Reggio Emilia [Reggio Emilia] (UNIMORE) – Via Amendola 2, 42122 Reggio Emilia, Italy
[3] HEC Montréal – Canada
[4] Iren SpA, External and Metering Operations – Italy

This work presents a decision support system to address a practical attended home services problem faced by Gruppo Iren, an Italian distributor of electricity, gas and water. The company operates in several regions across Italy and must optimize the dispatch of technicians to customer locations where they carry out installation or maintenance activities within time slots chosen by the customers. The system uses historical data and helps managers to divide regions into clusters based on the minimum travel time among towns, to create weekly time slot tables for each cluster and evaluate them dynamically within a rolling horizon approach, and to simulate and visualize optimal technician routing plans in order to analyze results under different scenarios. The system uses a previously developed integer linear programming tool to specify the amount of resources allocated to each region in each time slot and to route technicians in a cost-effective way. This tool has been modified to fit new quality of service constraints and to design an automated instrument for solving multiple-tasks problems. Computational experiments carried out on data provided by the company confirm the efficiency of the proposed methodology.

Keywords: Attended home services, time slot management, routing, decision support system, simulation

*Speaker

A Branch-and-Price Algorithm for a Delivery Network Using Autonomous Robots

Stefan Schaudt *† [1], Nicklas Klein [2]

[1] Department of Transport Logistics (ITL) – Leonhard-Euler-Strasse 2, 44227 Dortmund, Germany
[2] Technical University Dortmund (TUDo) – Emil-Figge-Strasse 50, 44227 Dortmund, Germany

The growth rate in Courier Express Parcel markets presents a major challenge for the logistics industry worldwide.
Innovative approaches and solutions are needed. For densely populated areas, so-called delivery robots are a promising alternative to traditional trucking.
Delivery robots represent a rather new technology, capable of transporting small goods autonomously on sidewalks.
These robots drive at walking speed and are equipped with the same technology used for autonomous driving.
One advantage of these robots is that a delivery time, chosen by the customer, can be realized more easily compared to traditional trucking.

In this study, the goal is to maximize the number of customers served within their pre-specified time windows with a given fleet of robots, while observing battery restrictions.
This problem can be modeled as a team orienteering problem with time windows and battery constraints, which is solved exactly using a branch-and-price algorithm.
The pricing problem is implemented by solving a resource constrained elementary shortest path problem. This path is caluclated with a dynamic program based on a labeling algorithm.
First tests were carried out with the branch-and-price algorithm and an alternative mixed integer program.
Comparing these two approaches, it turned out that our algorithm outperforms the alternative formulation.

Keywords: Branch and price, Column Generation, Delivery robots, Team Orienteering, Green Vehicle Routing

*Speaker
†Corresponding author: schaudt@itl.tu-dortmund.de

Vehicle Routing Problem under Safe Distance Separation Constraints

Hyunseop Uhm *† [1], Young Hoon Lee [1]

[1] Yonsei University – South Korea

The multi-depot vehicle routing problem is considered with the constraint that vehicles may travel with at least certain distance separation from each other for the safety purpose. This kind of instance can be found in the multi drone operation for delivery or the vehicles operation for hazardous material transportation. It is assumed that safety can be achieved if the vehicles travel apart at any time with at least safety distance predetermined. Vehicles may visit customers for service which are distributed on the two dimensional space with Euclidean distance. Customers have their own demand and vehicle may visit customers whose total demands are within the vehicle's capacity. Vehicles may travel with same speed, i.e., traveling time is proportional to the distance, and may not stop during the trip until returning to the depot, but may delay the departure from the depot for the purpose of the safety distance separation on the trip. The objective is to find the vehicle's traveling routes with the minimal total time to complete customer's demand under the safety distance separation. Mathematical formulation is suggested with the mixed integer linear programming. Meta-heuristics of tabu search algorithm is also suggested with the 2-opt procedure. The performance of the suggested algorithm is evaluated for the randomly generated instances and compared with optimal solutions by the mixed integer programming for small size instances. Computational experiment shows that it can be applied to the practical cases with the reasonable computation time.

Keywords: Multi depot vehicle routing problem, Safe distance separation constraints, Mixed integer linear programming, Tabu search

*Speaker

†Corresponding author: uhs0730@yonsei.ac.kr

Fleet sizing and composition in grocery retailing

Sara Martins *† [1], Ayse Akbalik [2], Christophe Rapine [2]

[1] INESC TEC and Faculty of Engineering, Universidade do Porto – Portugal
[2] Université de Lorraine – LCOMS, Université de Lorraine – France

In grocery retailing, due to the management of products with distinct temperature requirements (ambient, chilled, frozen), different distribution strategies can be performed depending on the available types of vehicles, namely single compartment vehicles (SCV) or multi-compartment vehicles (MCV). Each type imposes different costs, but also distinct limitations and impacts for both product quality and environment. For these reasons, grocery retailers need to carefully select the types of vehicles to use to perform the distribution of the products. Single compartment vehicles can only transport one type of product at a time, while multi-compartment vehicles allow for joint distribution of different product types. However, the costs associated with each type of vehicle are very different and trade-offs between costs and operational requirements need to be analyzed to select the best fleet size and composition. In addition, retail sites and products have different time windows associated and, usually, site-dependency restrictions which limit the distribution planning. Although there is literature on fleet sizing, none of them portrays these challenges found in grocery retail distribution. Therefore, this work aims to analyze how to define the best distribution fleet in grocery retailing, considering different types of products and heterogeneous vehicles, including compartment-based vehicles.

Keywords: Fleet sizing, VRP, multi, compartment, multi, commodity, heterogeneous vehicles

*Speaker
†Corresponding author: sara.martins@fe.up.pt

A Template-based ALNS for the Consistent E-VRP with Backhauls and Charging Management

Pamela Nolz * [1], Nabil Absi [2,3], Dominique Feillet [3]

[1] AIT Austrian Institute of Technology – Giefinggasse 4, 1210 Vienna, Austria
[2] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – CNRS : UMR6158 – F-13541 Gardanne, France
[3] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – Campus Georges Charpak Provence, F-13451 Gardanne, France, France

We consider the delivery and collection of parcels to business customers over a predefined time horizon. In order to enable the sustainable delivery and collection of parcels, electric vehicles are used. A backhauling policy is followed, i.e., all delivery operations in a vehicle route are performed before collection of parcels is started. Each tour has a maximum length given on the one hand by the allowed working time of drivers and on the other hand by the battery range of the electric vehicles. Between the delivery tour and the collection tour vehicles return to the depot, where recharging is possible. Since fast charging slots are a limited resource, delivery and collection tours have to be optimized in combination with the scheduling of the recharging operations. In addition, business customers rely on regular delivery times and familiar delivery personnel. Therefore, consistency when visiting customers for delivery and collection is also to be maintained, implying that the same person should visit the same customer at approximately the same time every day. We aim at identifying a set of consistent delivery and collection tours for electric vehicles, considering the limited autonomy of vehicles and the recharging planning, and optimizing a combination of criteria: vehicle fixed cost, operating time of each vehicle (including waiting time for recharging and recharging time), time consistency, driver consistency. We propose a metaheuristic approach based on efficient and effective operators for the recharging management while respecting consistency requirements. These operators are embedded in a Template-based Adaptive Large Neighborhood Search.

Keywords: electric VRP, consistency, delivery and collection, charging management

*Speaker

Routing drones in the interior of a factory using a new version of the VRP

Ivan Derpich * [1], Daniela Miranda [2]

[1] Departamento de Ingeniería Industrial, Universidad de Santiago de Chile [Santiago] (USACH) – Av. Libertador Bernardo O'Higgins 3363, Santiago, Región Metropolitana, Chile
[2] Departamento de ingeniería ndustrial, Universidad de Santiago de Chile (USACH) – Ave. Ecuador 2769, Estación Central, Santiago de Chile, Chile

In this paper we analyze the feasibility of using drones in a manufacturing factory that requires multiple transports from the warehouse to the workstations. Considering low cost drones it is understood that they have little autonomy and low load capacity. To minimize energy consumption a mathematical model of vehicle routing type is used, in three dimensions, which is a new formulation of the VRP and it is solved using an optimization method. The problem is complex because is a new problem named VRP min takeoff and it is a NP-hard problem, like the VRP, moreover the routes must be planned in order to avoid collisions, therefore they must follow time windows in the deliveries.

Keywords: drones, vrp, heuristic, LHS

*Speaker

Multiple vehicle synchronisation in a full truck-load pickup and delivery problem: a case-study in the biomass supply chain

Ricardo Soares *† [1,2], Alexandra Marques [1], Pedro Amorim [1,2]

[1] Institute for Systems and Computer Engineering, Technology and Science (INESC TEC) – Rua Dr. Roberto Frias 4200-465 Porto, Portugal
[2] Faculty of Engineering of the University of Porto (FEUP) – Rua Dr. Roberto Frias 4200-465 Porto, Portugal

The search for higher efficiency in transportation planning processes in real life applications is challenging. The synchronisation of different vehicles performing interrelated operations can enforce a better use of vehicle fleets and decrease travelled distances and non-productive times, leading to a reduction of logistics costs. In this work, the full truck-load pickup and delivery problem with multiple vehicle synchronisation (FT-PDP-mVS) is presented. This problem is motivated by a real-life application in the biomass supply chain "hotsystem", where it is necessary to simultaneously perform chipping and transportation operations at the forest roadside. The FT-PDP-mVS consists in determining the integrated routes for three distinct types of vehicles, which need to perform interrelated operations with minimum logistics costs. We extend existing studies in synchronisation of multiple routes by acknowledging several synchronisation aspects, such as operations and movement synchronisation. A novel mixed integer programming model (MIP) is presented and a solution method approach is developed based on the fix-and-optimise principles under a variable neighbourhood decomposition search. Results of its application to 19 instances based on a real-world case-study demonstrate its performance. For a baseline instance, the synchronisation aspects tackled in this problem allowed for significant gains when compared to the company's current planning approach. Furthermore, the proposed approach can enhance planning and decision making processes by providing valuable insights about the impact of key parameters of biomass logistics over the routing results.

Keywords: pickup and delivery, synchronisation, OR in natural resources

*Speaker
†Corresponding author: ricardo.s@fe.up.pt

Routing in air cargo networks

Felix Brandt *† [1]

[1] FZI Research Center for Information Technology (FZI) – Haid-und-Neu-Strasse 10-14 76131 Karlsruhe, Germany

During the sales process for air cargo, an airline has to find valid (and not necessarily only the fastest) routes for the quoted cargo through its given network of scheduled flights. In todays air cargo market, where airlines operate multi-hub-networks and offer many direct connections between airports as well as road feeder services (trucks between airports) this becomes a non-trivial task. Besides, possible routes of the cargo heavily depend on shipment details (e.g., size, weight, dangerous goods?) and its transport requirements (e.g., urgency, temperature, supervision).
In this talk we introduce the problem how to find a set of valid routes through an air cargo network and highlight the related regulatory and operational requirements from practice. We present a new algorithm CSAir, derived from the connection scan algorithm (CSA) addressed to public transit networks, that incorporates many practical requirements and allows us to find valid air cargo routes extremely fast. Finally, we evaluate the performance of the algorithm on a set of real networks of different airlines.

Keywords: air cargo, timetable routing, multi criteria routing

*Speaker
†Corresponding author: brandt@fzi.de

Simheuristics for Stochastic Vehicle Routing Problems: a review and open challenges

Leandro Martins * [1], Angel Juan *

[1], David Raba [1], Rafael Tordecilla [1], Javier Panadero [1], Christopher Bayliss [1]

[1] Universitat Oberta de Catalunya – Spain

Many realistic vehicle routing problems need to consider uncertainty conditions, which typically also require from a reliability or risk analysis. Simheuristics extend metaheuristics by adding a simulation layer that allows the optimization component to deal efficiently with scenarios under uncertainty. This work reviews recent applications of simheuristics, mainly in the area of vehicle routing. It also discusses current trends and open research lines in this field.

Keywords: Stochastic VRPs, metaheuristics, simulation

*Speaker

The VeRoLog Solver Challenge 2019

Joaquim Gromicho* [1,2], Pim Van 't Hof † [1], Daniele Vigo [3]

[1] ORTEC B.V. – Netherlands
[2] VU University Amsterdam – De Boelelaan 1105, 1081 HV Amsterdam, Netherlands
[3] University of Bologna – Italy

The fourth edition of the VeRoLog Solver Challenge, organized by ORTEC, revolves around a challenging vehicle routing problem that is faced by ORTEC customers in practice, but has received little attention in the literature so far.
The problem of the challenge is the coordination of delivery and subsequent installation of equipment, such as vending machines. The goal is to satisfy all machine requests from customers within the given planning horizon, while minimizing the total cost. The machines (of different kinds) must be delivered to the customers from a central depot location within a customer-specific delivery window. After delivery, each machine must be installed by a technician. For every full day a machine is 'idle', i.e., delivered at the customer but not yet installed, a fixed penalty is charged. Each technician has a skill set that determines which kinds of machines he or she can install. Technicians, who are based at different locations, must adhere to a simple labor rule that limits the maximum number of consecutive days they can work. A comprehensive description of the problem is available on the challenge website https://verolog2019.ortec.com/.
The purpose of this talk is to give a detailed explanation of the problem, and share some interesting facts and figures about this year's VeRoLog Solver Challenge. The remainder of this special session is devoted to presentations by selected challenge finalists, who will report on their solution approach. The winners of the challenge will be announced during the conference dinner on June 4, 2019.

Keywords: vehicle routing, solver challenge, scheduling, optimization, transport

*Corresponding author: joaquim.gromicho@ortec.com
†Speaker

Dynamic Time Window Reassignment

Kevin Dalmeijer * [1], Remy Spliet [1], Albert Wagelmans [1]

[1] Econometric Institute, Erasmus University Rotterdam – Netherlands

We propose to improve customer satisfaction in delivery networks by dynamically reassigning time windows. Specifically, we consider delivering goods to customers within given time windows, and we improve customer satisfaction by giving the distributor the possibility to dynamically reassign the time windows of the customers when faced with uncertainty during the day. Time window reassignment in itself is not appreciated by the customer. However, being informed timely that a delivery will be made in a later time window is preferred to not being informed at all.

To the best of our knowledge, dynamically reassigning time windows to improve customer satisfaction has not been considered in the literature. In this paper, we assume that travel times and service times are stochastic, and that their value only becomes known after serving a customer or traveling an arc, respectively. This setting is relevant for, e.g., parcel delivery, retailer distribution, and repairmen scheduling.

We first consider the case where the route is fixed and we have to decide when to reassign which time window, and how much the time window is moved. We model customer satisfaction and we provide both exact and heuristic methods for reassigning time windows to maximize satisfaction. Next, we explore integrating customer satisfaction into the vehicle routing phase.

We present results comparing the optimal time window reassignment to multiple heuristics that are inspired by practice. Finally, we analyze the effect of including customer satisfaction in the vehicle routing phase.

Keywords: time window reassignment, customer satisfaction, dynamic programming, vehicle routing

*Speaker

A study on time window offerings in attended home delivery

Jean-François Côté * [1], Jacques Renaud [1], Ranya El Byaz [1]

[1] Laboratoire CIRRELT Université Laval Quebec (CIRRELT) – Université Laval
Pavillon Palasis-Prince, bureau 2642 2325, rue de la Terrasse Québec (Québec) G1V 0A6 CANADA, Canada

This work addresses the challenge of establishing delivery schedules for consumers who buy goods online or who buy furniture and appliances in a store. Home delivery companies have several challenges in managing their distribution network efficiently due to the high level of uncertainty of the future demand. The existence of a delivery schedule becomes essential to ensure customer satisfaction and to reduce the delivery costs. Several works have tackled this problem in the literature and most of them try to build a delivery schedule using a restricted set of time windows to increase the consolidation and reduce delivery costs. In this talk, we evaluate the current alternatives and propose new ones to increase the offering of time windows. Our evaluation scheme is a two-step procedure based on stochastic programming. The first step generates a set of delivery schedules without taking into account the future demand. Then, in the second stage, future customers are known and routes satisfying the first stage time windows are planned. The objective is to minimize the expected cost of the second stage. Both stages are solved using dedicated metaheuristics. The final delivery schedules are evaluated by a Monte-Carlo procedure that simulates the arrival of customers and the selection of a time window. The different alternatives are compared in terms of transportation cost, number of served customers and number of offered time windows.

Keywords: vehicle routing, time windows and attended home delivery

*Speaker

Solving order batching and picker routing, as a clustered vehicle routing problem

Babiche Aerts *† [1], Trijntje Cornelissens [1], Kenneth Sörensen [1]

[1] University of Antwerp – Prinsstraat 13 2000 Antwerp, Belgium

Order batching and picker routing are well-known problems in the warehouse management literature. Although these problems are interrelated, they are usually solved in isolation, using dedicated heuristics specifically aimed at a warehouse context. Mathematically, however, the integrated order batching and picker routing problem is the same as the clustered vehicle routing problem which groups customers into clusters that should be visited by the same vehicle. We test a two-level Variable Neighborhood Search (VNS) algorithm developed for the latter problem on instances for the former, and study the adaptations required to perform efficiently. Additionally, we test if the Hausdorff distance is a valid order batching criterion and compare this clustering metric to a commonly used batching criterion in warehouse literature, the minimal number of aisles visited. Concerning the pickers' routings, we compare the total travel distances resulting from the VNS algorithm to the distances obtained when routing heuristics are used dedicated to warehouse settings, including the s-shape, largest gap and combined heuristic, and define the optimality gap using the algorithm developed by Ratliff and Rosenthal (1983). The results indicate the Hausdorff distance is being outperformed by the minimal number of aisles visited-rule as a batching criterion. On average, a gap of 5,88% was measured between the total travel distances obtained by the two batching criteria. Given the batches composed with the presented batching criteria, the VNS algorithm obtains the optimal route for half of the instances. For the remainder of the instances, an optimality gap of less than 2% is observed.

Keywords: Warehouse, Vehicle Routing Problem, Order batching, Order picker routing

*Speaker

†Corresponding author: babiche.aerts@uantwerpen.be

On simple heuristics for the cumulative TSP

Mengke Wang *† [1], Vladimir Deineko [1]

[1] Warwick Business School (WBS) – Warwick Business School The University of Warwick Coventry CV4 7AL, UK, United Kingdom

Cumulative travelling salesman problem (CTSP) is a variant of classical travelling salesman problem (TSP) in which the objective is to minimize the sum of arrival times at customers, instead of the total travelling time. The cumulative objective arises in such important applications as humanitarian relief supply, data retrieval, and home delivery services. The CTSP is surprisingly different from the TSP: the small local changes in a tour can produce highly non-local changes. For this NP-hard combinatorial optimization problem, many papers have explored local search heuristics which combine several classical simple heuristics (usually 5 or 6!). Surprisingly, the experimental analyses and comparisons of simple heuristics for the CTSP have been neglected in the literature, especially when compared with the extensive efforts devoted to analysis of heuristics for the TSP. This paper provides detailed analyses and comparisons among various simple heuristics. Extensive computational experiments are performed on a set of instances ranging from 10 to 1000 cities, to evaluate the trade-off between the running time and solution quality. Several new heuristics based on dynamic programming paradigm are also analysed and compared with classical heuristics.

Keywords: cumulative objective in the TSP, heuristics, computational experiments

*Speaker
†Corresponding author: phd17mw@mail.wbs.ac.uk

Algorithms for the Pollution Traveling Salesman Problem

Valentina Cacchiani *† [1], Carlos Contreras Bolton [1], Luis Escobar-Falcón [2,3], Paolo Toth [1]

[1] DEI, University of Bologna (DEI) – Viale Risorgimento 2, 40136, Bologna, Italy
[2] Universidad Tecnológica de Pereira (UTP) – Colombia
[3] Universidad Libre Seccional Pereira – Colombia

The Pollution Traveling Salesman Problem (PTSP) is a generalization of the well-known Traveling Salesman Problem. It arises when environmental issues become important, as it happens nowadays, since it aims at reducing carbon emissions. More precisely, the PTSP calls for determining a Hamiltonian tour that minimizes a function of fuel consumption and driver costs, where the fuel consumption depends on the distance travelled, the vehicle speed and the vehicle load. We present a Mixed Integer Linear Programming (MILP) model for the PTSP, and propose an Iterated Local Search algorithm, a Genetic algorithm and a combination of the two algorithms. In order to evaluate the performance of the proposed metaheuristics, we developed a Cut-and-Branch algorithm, in which sub-tour elimination constraints are separated at the root node of the decision tree. The proposed algorithms are tested on instances with up to 200 customers.

Keywords: Pollution Traveling Salesman Problem, MILP model, Iterated Local Search, Genetic Algorithm

*Speaker
†Corresponding author: valentina.cacchiani@unibo.it

Methods for Solving Problems in Urban Air Mobility

Eric Oden *† [1], Bruce Golden‡ [2], Raghu Raghavan§ [3]

[1] University of Maryland - Department of Mathematics – College Park, MD 20742-1815, United States
[2] University of Maryland - Department of Decision, Operations and Information Technologies – College Park, MD 20742-1815, United States
[3] University of Maryland - Department of Decision, Operations and Information Technologies – United States

The vision of urban air taxis is edging closer to a reality, with many companies (Volocopter, Lilium, Aurora, etc.) actively developing prototypes of aircraft designed for intra-city transit. While many engineering and regulatory concerns must be addressed first, the concept of urban air mobility opens up many interesting problems for exploration. For instance, given that such aircraft will only land at specifically designed ports, where should these ports be placed throughout the city? Once these ports are placed, where should the air taxis travel to satisfy as many requested trips as possible? We must keep in mind the finite capacity of the aircraft and the ports, the finite battery life of the aircraft (as most prototypes in development are electrically powered), and the time windows for passengers requesting rides. Given such constraints, as well as a set of typical trip demand data throughout the day, where should the aircraft be scheduled to satisfy the most demand? Demand data is given in the form of origins, destinations, and time windows. With the goal of on-demand urban mobility, we explore routing customer trips dynamically. Given that flights are initialized to some schedule, how can the schedule be modified mid-day to include new customers? We have developed a set of mixed integer programs and heuristics for addressing these questions. The output can then be used to perform sensitivity analysis on the parameters that remain unknown, such as flight speed and aircraft capacity, and could inform engineering decisions as prototype aircraft are developed.

Keywords: Urban Air Mobility, VTOL, MIP, Heuristics

*Speaker
†Corresponding author: eoden@math.umd.edu
‡Corresponding author: bgolden@rhsmith.umd.edu
§Corresponding author: raghavan@rhsmith.umd.edu

Deadlock-free routing and scheduling of autonomously guided vehicles

Markó Horváth * [1], Márton Drótos [1], Péter Györgyi [1], Tamás Kis [1], Mária Prill [1]

[1] Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI) – H1111 Budapest, Kende str. 13-17, Hungary

We will present a novel approach to control a fleet of autonomously guided vehicles whose task is to process transportation requests arriving on-line. The main goal is to avoid deadlocks and to serve all requests without (much) delays. The vehicles work in a workshop, where there can be narrow corridors, gates, small and big halls. We define a graph representation of the layout of the operation area whose nodes are the crossing points, and the edges represent path segments that the vehicles must follow. The novelty of our approach is that by explicitly representing the schedule of the vehicles (considering each node and edge as a resource, and crossing them by jobs), we can guarantee a deadlock-free movement, and a suboptimal fulfillment of the transportation requests. However, it is not obvious how to obtain and keep up to date such a feasible schedule. For instance, when a new transportation request arrives, we have to choose a vehicle to process it, and then create a new route and insert it into the schedule. However, there can be idle vehicles at the target location or on the way of this vehicle. Such blocking vehicles must be given some route to some free, non-disturbing locations, and their movements to those locations must also be scheduled. Since the transportation requests have due dates, we bear in mind the minimization of the maximum tardiness during the insertion of the routes. We also apply a local search approach to improve the quality of the schedules.

Keywords: Vehicle Scheduling, Deadlock, free Routing, Pickup and Delivery

*Speaker

Routing, scheduling and fleet composition for municipal solid waste collection: Multiple types of waste and single compartment vehicles

Dušan Hrabec * [1], Jorge Oyola [2], Richard Hartl [3], Radovan Šomplák [4], Vlastimír Nevrlý [4]

[1] Tomas Bata University in Zlín (TBU in Zlín) – nám. T. G. Masaryka 5555, 760 01 Zlín, Czech Republic
[2] Universidad de Cordoba – Carrera 6 No. 76-103, 230002, Monteria, Colombia, Colombia
[3] University of Vienna – A-1210 Wien, Austria, Austria
[4] Brno University of Technology – Czech Republic

We consider a waste collection routing and fleet composition problem for a collection network with multiple types of waste. While each container (i.e., each waste type in each node) has assigned a weekly collection frequency, the collection schedule is to be optimized. The fleet composition decision is made over a set of heterogeneous single-compartment vehicles. The problem is formulated as a multi-trip multi-commodity heterogeneous fleet composition periodic vehicle routing problem with an overall aim to minimize the total operational costs. A general mathematical model of the problem is presented and a solution algorithm is proposed. Computational results are presented on an illustrative data sample (with regards of a future usage of the proposed approach on a real case study in the Czech Republic). The probem is solved by the developed heuristic method as well as by exact methods in order to test the suggested waste collection approach (i.e., model as well as proposed algorithm).

Keywords: waste collection, fleet size composition, multiple waste types, single compartment vehicles, multi trip VRP

*Speaker

Recyclable Waste Collection Routing Problem, formulation and solution

José Andrés Moreno Pérez *† [1,2], Airam Expósito-Márquez [2], Christopher Expósito-Izquierdo [2], Julio Brito-Santana [2], Dagoberto Castellanos-Nieves [2]

[1] University of La Laguna (ULL) – Spain
[2] Universidad de La Laguna – Spain

In this work we deal with a routing problem arising in recyclable waste collection. The problem motivated by a real application in the island of La Palma (Canary Islands). There is a fixed set of containers with the same capacity scattered in the island. From a large set of historic data we obtain a filling waste rate for each container (the average quantity of waste collected per day). The fill level of each container any given day is estimated using the filling rate and the number of filling days. The managers want to collect as much waste as possible avoiding overflowing of the containers to increase the recycling of waste. The problem consists of designing the optimal routes for a fleet of vehicles in a given horizon of days (typically from Monday to Friday). We formulate the problem by a series of MILP problems corresponding these days. The problems include the usual constraints that characterize a set of routes including capacity and time limitations for each route. Some additional constraints, like time windows or due containers, could be added for a few containers. In addition to the total distance or time, several objective functions appropriated for the purpose of the managers can be stated as linear functions, like the total waste collected or the number of overflowing of the containers. In addition to the multistage MILP, a GRASP is designed and tested to provide high quality solutions. The solutions are compared using the performance indicators provided by the waste managers.

Keywords: Recyclable Waste Collection Routing, GRASP, MILP

*Speaker
†Corresponding author: jamoreno@ull.edu.es

Waste Collection with Route Balancing Concerns: A real-world application

Ana Raquel De Aguiar *† [1], Tânia Ramos‡ [1]

[1] Centro de Estudos de Gestão, Instituto Superior Técnico, Universidade de Lisboa (CEG-IST) – Av. Rovisco Pais, 1049-001 Lisboa, Portugal

The optimization of waste collection typically focuses on the minimization of distance, route time or the maximization of profit while assuring a service level to the population. However, when dealing with real-world cases other concerns may arise. That was the case of a Portuguese waste collection company that covers a wide area of 7 000 km2. This area is highly heterogeneous, covering urban and rural territories, where some rural areas are characterized by a high degree of roughness (mountains and hills). Defining routes that minimize distance or maximize profit may result in unbalance routes from the human resources perspective, leading to a generalized dissatisfaction among the drivers. Moreover, the term "unbalance" could be measured in different ways. The drivers would prefer a routing plan where all routes visit the same number of waste bins, or have the same duration? Should the driving difficulties at rural roads be somehow incorporated? A literature review was conducted, and different ways of measure the balance/fairness of a routing plan were found, namely route workload, quantities transported, route length and route duration. In this work, we apply some of those measures to define a balanced routing plan to the company and compare the results among them. Moreover, a new measure is developed to account for the different characteristics of the territory. The problem is modeled as a CVRP with balancing concerns. The results show that the incorporation of a coefficient that translates the driving difficulties promotes a balanced routing plan from the driver's perspectives.

Keywords: Waste Management, Route Balancing, CVRP, Real Applications

*Speaker

†Corresponding author: a.raquel.aguiar@ist.utl.pt

‡Corresponding author: tania.p.ramos@tecnico.ulisboa.pt

The Cumulative Capacitated Arc Routing Problem

Juan Carlos Rivera* [1], Sergio Andrés Lenis † [1]

[1] Universidad EAFIT (EAFIT) – Carrera 49 No. 7 sur - 50. Medellín, Colombia

In this paper we propose a new variant of the Capacitated Arc Routing Problem (CARP). The objective function becomes a flow-based function, i.e. energy consumption minimization since it is computed by multiplying the travelled distance by the vehicle load. Kara et al. (2008) argue that the real cost of a vehicle traveling between two nodes depends on several conditions like the vehicle load, fuel consumption per kilometer, fuel price, time spent or distance travelled, depreciation of the tires and the vehicle, maintenance, driver wages, time spent on visiting all customers, total distance travelled, etc. Even though most of those attributes can be represented by a distance measure, others cannot, i.e. load of the vehicle, fuel consumption per kilometer, maintenance, depreciation of the tires and the vehicle. These attributes can be represented by the flow on the corresponding arcs and allow us to tackle problems related to garbage trucks, salt spreaders, school buses, etc. more efficiently. Here a mathematical model and a metaheuristic approach are proposed. The metaheuristic approach is based on the hybridization of three known procedures: GRASP, VND and Set covering model. The mathematical model and the metaheuristic are tested with some benchmark instances from CARP. The results allow to evaluate the performance with the different metaheuristic components and to compare the solutions with the classical objective function and the best found solutions by the mathematical model given a reasonable amount of time. **References**

Kara, Imdat, Kara, Bahar, & Kadri, M. 2008. Cumulative Vehicle Routing Problems. 85–98.

Keywords: Cumulative Capacitated Arc Routing Problem, MILP, Metaheuristics, GRASP, VND, Set covering

*Corresponding author: jrivera6@eafit.edu.co

†Speaker

An interactive method for multiobjective routing problems

Delgado-Antequera Laura * [1,2], Francisco Ruiz [2], Germán Gémar [2]

[1] Departamento de Economía Aplicada (Matemáticas), Universidad de Málaga – Spain
[2] UNIVERSIDAD DE MÁLAGA – Spain

The aim of most of the multi-objective routing problems is to design a meta-heuristic strategy capable of generating the most accurate approximation of the Pareto set in the shortest time. However, merely a few studies focus on how to deal with the decision making process afterwards. In real life situations, this becomes an additional problem, since the decision maker (DM) needs to select only one feasible solution, according to his/her preferences.
Several researches propose different approaches to build a solution taking into account the preferences of the DM within a Decision Support System. In recent years, Geographical Information Systems (GIS) have been incorporated to these strategies to enable the DM to actively participate on the construction phase. In this context, we propose a graphical user interface (GUI) that facilitates the information exchange between the analyst and the decision maker in a multi-objective vehicle routing problem, where a valid approach to the Pareto Set has been externally generated. This GUI incorporates a trade-off free interactive method that allows the DM to freely explore and learn along the process from the given set of feasible solutions. To conclude, we show the performance of this methodology for a multi-objective waste collection problem in Málaga, although it could perfectly apply for any other multi-objective VRP.

Keywords: Multiobjective VRP, Waste collection problem, Interactive method, GUI.

*Speaker

A two - steps heuristic for a multi-objective waste collection problem

Delgado-Antequera Laura [1], Jesús Sánchez-Oro* [2], Rafael Caballero† [1], J. Manuel Colmenar‡ [3], Rafael Martí §¶ [4]

[1] Departamento de Economía Aplicada (Matemáticas), Universidad de Málaga – Spain
[2] Universidad Rey Juan Carlos (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[3] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[4] Universidad de Valencia – Valencia, Spain

In the last few years, the application of decision making to logistic problems has become crucial for public organizations. In particular, waste management involves a set of economic, social, labor and environmental aspects, which implies a big effort from these companies that must provide a good service. In general, any real waste management scenario contemplates multiple criteria, to find, according to the decision maker's requirements, the most suitable solution. The dimension and complexity of real Waste Collection Problems (WCPs) recommends the use of metaheuristic strategies to find high quality solutions in short computational time. As it is customary in multiobjective optimization, we do not have a unique optimal solution, but we are seeking for a good approximation of the set of efficient solutions. In this paper, we formulate the WCP as a Capacitated Vehicle Routing Problem, with the following objectives: minimize the overall travel cost, balance the driven routes (in terms of distance and time), and minimize the number of routes. We propose a solution method based on the hybridization between Iterated Greedy and Variable Neighborhood Search. Additionally, it uses the Wierzbicki achievement scalarizing function to perform an efficient search of the multi-objective solution space. We explore different designs of our method and compare it with the well-known NSGA-II solver on a large set of public domain instances.

Keywords: Achievement scalarizing function, waste management, multiobjective

*Corresponding author: jesus.sanchezoro@urjc.es
†Corresponding author: r_caballero@uma.es
‡Corresponding author: josemanuel.colmenar@urjc.es
§Speaker
¶Corresponding author: rafael.marti@uv.es

Determining time-dependent minimum cost paths under several objectives

Hamza Heni *† [1,2,3,4], Leandro C. Coelho * ‡ [1,3,4], Jacques Renaud * § [1,2,4]

[1] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) – Canada
[2] Centre d'innovation en logistique et chaîne d'approvisionnement durable (CILCAD) – Canada
[3] Canada Research Chair in Integrated Logistics – Canada
[4] Faculty of Business Administration, Laval University – Canada

As the largest contributor to greenhouse gas (GHG) emissions in the transportation sector, road freight transportation is the focus of numerous strategies to tackle increased pollution. One way to reduce emissions is to consider congestion and being able to route traffic around it. In this paper we study time-dependent minimum cost paths under several objectives (TDMCP-SO), in which the objective function comprises GHG emissions, driver and congestion costs. Travel costs are impacted by traffic due to changing congestion levels depending on the time of the day, vehicle types and carried load. We also develop time-dependent lower and upper bounds, which are both accurate and fast to compute. Computational experiments are performed on real-life instances that incorporate the variation of traffic throughout the day, by adapting Dijkstra's label-setting algorithm according to different cost computation methods. We show that explicitly considering first-in, first-out (FIFO) consistency using time-varying speeds allows the efficient computation of tight time-dependent bounds. Our computational results demonstrate that the TDMCP-SO is more difficult to solve to optimality but the proposed algorithm is shown to be robust and efficient in reducing the total cost even for large instances in an environment of varying speeds, outperforming those based on the link travel time model and on the smoothing method according to each optimization objective, flexible departure times, and different load patterns.

Keywords: Time, dependent networksCongestionEmissionQuickest pathBoundsLabel, setting algorithmLink travel timeFlow speed model

*Speaker
†Corresponding author: hamza.heni@cirrelt.ca
‡Corresponding author: Leandro.Coelho@fsa.ulaval.ca
§Corresponding author: Jacques.Renaud@fsa.ulaval.ca

Time-dependent scheduling with replenishable resources

Steffen Pottel * [1], Asvin Goel *

1

[1] Kühne Logistics University (KLU) – Germany

In many real-life vehice routing problems, the time required to travel between locations varies depending on traffic levels. If electric vehicles are used, these variations in travel time can lead to higher or lower overall energy consumption, and, thus, the time when batteries must be recharged may vary as well. Similarly, if hours of service regulations must be complied with, variations in travel time can lead to variations in the timing of compulsory break or rest periods. In this contribution we study the problem of determining feasible schedules for routes in which travel times are time-dependent and resources required for driving, e.g. energy levels of batteries or alertness levels of drivers, must be replenished during the route. Because of the interaction of resource replenishments and time-dependent travel times, the first-in first-out property typically exploited in time-dependent routing and scheduling does no longer hold. In this contribution we propose an efficient methodology to solve time-dependent scheduling problems with resources that must be replenished while en-route.

Keywords: Time–dependent scheduling, Electric vehicles, Hours of service regulations

*Speaker

The Vehicle Routing Problem with Time Windows and Time-Dependent Road-Network Information

Hamza Ben Ticha [1,2], Nabil Absi [1,2], Dominique Feillet * [1,2], Alain Quilliot [3], Tom Van Woensel [4]

[1] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – CNRS : UMR6158 – F-13541 Gardanne, France
[2] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – Campus Georges Charpak Provence, F-13451 Gardanne, France, France
[3] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – CNRS : UMR6158, Université Clermont Auvergne – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France
[4] Eindhoven University of Technology – Netherlands

In the literature, most approaches proposed to solve time-dependent vehicle routing problems assume that for each pair of interest points (e.g., depot, customers...), a travel-time function is known. Almost no paper investigates how these functions can be computed from travel times in the underlying road network. Furthermore, most of them neglect the possibility that different paths could be selected in the road network depending on the compromises they offer between cost (distance) and travel-time. In this presentation, we propose the first exact solution approach for these problems that starts from travel-time function expressed at the level of the road network. Computational study carried out on realistic instances and on instances derived from a real road-network illustrate the important impact of the proposed modeling on solution values.

Keywords: vehicle routing, column generation, shortest path, road, network, time, dependent travel times

*Speaker

The Time-Dependent Shortest Path and Vehicle Routing Problem

Rabie Jaballah *† [1], Marjolein Veenstra [2], Leandro Coelho [1], Jacques Renaud [1]

[1] Laboratoire CIRRELT Université Laval Quebec (CIRRELT) – Université Laval Pavillon Palasis-Prince, bureau 2642 2325, rue de la Terrasse Québec (Québec) G1V 0A6 CANADA, Canada
[2] University of Groningen [Groningen] – PO Box 72 , 9700 AB Groningen, Netherlands

Many of today's logistics systems are based on variants of the well-known vehicle routing problem (VRP). In VRP one needs to answer a simple question: in which sequence should we visit a set of clients in order to minimize mainly the total distance. Advances in communications and real-time data acquisition technologies have made it possible to collect a huge amount of data on vehicles such as their driving speed and CO2 emission. This has led to what is known as the time-dependent VRP, in which the time (or cost) to move from one customer to another change depending on the starting time. In this work we integrate the time-dependent shortest path within the time-dependent VRP to create a more general and realistic problem called the time-dependent shortest path and vehicle routing problem (TDSPVRP). TDSPVRP effectively determines the path to take when visiting customers by considering both the real underlying street map and the real travel time to each them. We provide a mathematical formulation for the problem and also develop valid inequalities to strengthen this formulation which significantly improve the lower bounds. Given the size and difficulty of the problem, a heuristic based on the local search and simulated annealing is proposed. Finally, we provide a sensitivity analysis that highlights the importance of incorporating traffic in routing models and how ignoring traffic data can impose substantial delays.

Keywords: Time Dependent Shortest Path, Time Dependent Vehicle Routing Problem, Traffic and congestion, City logistics, Heuristic, Simulated annealing

*Speaker
†Corresponding author: rabie.jaballah.1@ulaval.ca

An enhanced lower bound for the Time-Dependent Traveling Salesman Problem

Emanuela Guerriero * [1], Gianpaolo Ghiani [2], Tommaso Adamo [2]

[1] Università del Salento - Dipartimento di Ingegneria dell'Innovazione – Lecce, Italy
[2] Università del Salento - Dipartimento di Ingegneria dell'Innovazione – Italy

Given a graph whose arc traversal times vary over time, the Time-Dependent Travelling Salesman Problem
amounts to find a Hamiltonian tour of least total duration. In this research work we define a new lower bounding

scheme whose parameters are determined by fitting the traffic data. Computational results show that, when

embedded into a branch-and-bound procedure, this lower bounding mechanism allows to solve to optimality a
larger number of instances than state-of-the-art algorithms.

Keywords: travelling salesman problem, time dependence, lower and upper bounds

*Speaker

The Mixed Capacitated General Routing Problem with Time-Dependent Demands

Chahid Ahabchane *† [1], Martin Trépanier [1], André Langevin [2]

[1] Polytechnique Montréal, Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Canada
[2] Polytechnique Montréal, Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Canada

The Mixed Capacitated General Routing Problem (MCGRP) is defined over a mixed graph, for which some nodes, arcs and edges must be serviced. The problem consists of determining a minimum cost that satisfy the demand. Some problem like snow plowing or salt spreading have a time dependent demand which was ignored in the previous studies, this variation of demand is due to the weather or traffic condition. This study presents two models without graph transformation and another with graph transformation to node routing, we use CPLEX to solve the small instances and we developed "Slack Induction by String Removals" metaheuristic for the large instances, The proposed model and metaheuristic were tested on problems derived from a set of classical instances of the MCGRP and CARP with some modification.

Keywords: Mixed Capacitated General Routing Problem, time dependent demand, metaheuristic

*Speaker
†Corresponding author: ahabchane.chahid@gmail.com

Efficient Constraint Programming Approaches for routing problem : a case study for the VRP

Bourreau Eric * [1], Philippe Lacomme *

[2,3], Gondran Matthieu *

3

[1] Laboratoire dÍnformatique de Robotique et de Microélectronique de Montpellier (LIRMM) – Université de Montpellier : UMR5506, Centre National de la Recherche Scientifique : UMR5506 – 161 rue Ada - 34095 Montpellier, France
[2] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Institut Français de Mécanique Avancée, Université Blaise Pascal - Clermont-Ferrand II, Université d'Auvergne - Clermont-Ferrand I, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France
[3] Laboratoire dÍnformatique, de Modélisation et dÓptimisation des Systèmes (LIMOS) – SIGMA Clermont, Université Clermont Auvergne : UMR6158, Centre National de la Recherche Scientifique : UMR6158 – Bât ISIMA / Campus des Cézeaux BP 10025 / 63173 Aubière Cedex, France

Numerous routing or scheduling problems encompass a lot of constraints including due date, time windows, precedence constraints or disjunctive constraints. Exact resolution based on linear formulation or heuristic based approaches should expect difficulties in finding a simple feasible solution. Strongly constraints optimization problems To face this challenge, some approaches based on constraint programming are of great interest taking advantages of the great number of constraints to satisfy and providing one solution in short computation first and capable of investagating new best solution in the neighborhood of one initial solution. In numerous problems conversions of well-know mixed integer programming (MILP) formulation to CP, lead to poor CP performances. Well-known custom-made CP formulation are required to obtain CP formulation of interest. The generality of the CP approach and its efficiency is demonstrated to a VRP where the MILP formulation conversion lead to a 150s resolution time and the well-known custom-made CP formulation provide a resolution in 0.8s. The generic appaoch for solving combinatorial otpimization problem with a CP paradigm is based on global constraints, enumeration technics, propagating technics ... to facilitate strong reduction of domain and a proper exploration of the search tree.

*Speaker

Keywords: VRP, Contraint programming

A Demon Algorithm for the Vehicle Routing Problem with Cross-Docking

Gültekin Kuyzu *† [1,2], Hakan Yurtdaş [3]

[1] TOBB University of Economics and Technology (TOBB ETU) – Department of Industrial Engineering, Ankara, Turkey
[2] Zaragoza Logistics Center (ZLC) – MIT-Zaragoza International Logistics Program, Zaragoza, Spain
[3] Gazi University (GU) – Graduate Program in Operations Research, Ankara, Turkey

We study the vehicle routing problem with cross-docking (VRPCD), which can be seen as a variant of the pickup and delivery problem with a required transfer point. In cross-docking, the goods picked up at supply points must be consolidated and reloaded to delivery vehicles at an intermediate facility (i.e. a cross-dock) before being delivered to demand points. In this setting, coordinated routing of the collection and delivery vehicles is crucial. The objective of the VRPCD is to identify a set of collection and delivery routes via a cross-dock with minimum total cost, given a set of supply and demand points with known demands, ensuring that the vehicle capacities are not exceed and each delivery vehicle departs only after all of the goods to be loaded to it are brought to the cross-dock. We propose a demon algorithm, which can be viewed as a generalization of simulated annealing, for solving the VRPCD. Our computational experiments on benchmark instances we found in the literature show that the demon algorithm can find high quality solutions very efficiently, outperforming previously proposed methods.

Keywords: vehicle routing, cross, docking, transfers, synchronization, demon algorithm, meta, heuristics

*Speaker
†Corresponding author: gkuyzu@zlc.edu.es

Constraint Programming approaches for the Inventory Routing Problem

Axel Delsol* [1], Christophe Duhamel [1], Philippe Lacomme † [1], Helene Toussaint [1]

[1] Laboratoire d'Informatique, de Modélisation et d'Optimisation des Systèmes (LIMOS) – Université Clermont Auvergne : UMR6158, Centre National de la Recherche Scientifique : UMR6158 – Bât ISIMA / Campus des Cézeaux BP 10025 / 63173 Aubière Cedex, France

The inventory routing problem (IRP) occurs in supply chains management when retailers' inventory levels are managed by the suppliers. The IRP consists of designing routes to replenish retailers' inventory level over a discrete time horizon. Quantities delivered are set by the supplier such that no stock-out occurs and retailers' demands are satisfied. The objective is to minimize transportation and inventory costs over the time horizon.
We consider a variant of the IRP where the supplier has a limited fleet of homogeneous vehicles (MIRP) for which we propose original Constraint Programming (CP) formulations. In each formulation, the replenish plan and the routing design are jointly defined such that subtours are implicitly forbidden. Moreover, our models use global constraints in order to prune infeasible solutions more efficiently in the CP propagation algorithm.
We use several well-known CP strategies to guide the variables domain exploration and improve constraints propagations. The numerical experiments have been carried out on the set of instances from (Archetti et al., 2007) and the results are compared with the matheuristic method of (Archetti et al., 2017). Our CP approach computes initial feasible solutions for instances with up to 50 customers over 3 periods in 2 seconds on average, which is significantly faster than most previous published methods. Our model also finds solutions for the largest instances of literature (200 customers, 6 periods, 5 vehicles) in 30 seconds. We are currently investigating the combination of CP with local searches and integer programming to quickly reach near-optimal solutions.

Keywords: Inventory Routing Problem, Constraint Programming, Modeling

*Corresponding author: axel.delsol@isima.fr
†Speaker

Multiple solve approaches applied to the Heterogeneous Vehicle Routing Problem

Gwénaël Rault *† [1,2], Flavien Lucas [1], Marc Sevaux‡ [1]

[1] Université de Bretagne Sud (UBS) – Lab-STICC UMR CNRS 6285, Brest – BP 92116 - 56321 Lorient cedex, France

[2] Mapotempo – Pôle Recherche et Developpement – 2, allée de l'innovation 64300 Biron, France

In the context of this presentation, we focus on Asymmetric HVRP where the shortest path between two customers nodes is vehicle dependent. Moreover, the distance matrices doesn't verify the triangular inequality. Case which is common when we consider a real road network at the fastest with the objective to minimize the total distance. The problem in itself contains a set of multiple vehicle types with a limit number on their usage, as well as a capacity limit at the parcels number they can load to deliver at the customers nodes.
At this purpose, the instances provided by C. Duhamel and al(2011) and named New real life Duhamel–Lacomme–Prodhon_HVRP instances (DLP_HVRP), based on realistic distances between french cities, are considered as the main comparison set.
The current approach use at first step a GRASP+ALNS metaheuristic, method known to provide good results in a short computation time. In a second step, a constraint programming model of the problem is used to shuffle the problem and provide an additional local search starting from the current solution. Data are exchanged iteratively in order to benefit from each solve step improvement.
The aim behind the use of multiple models is to expose the possible synergies between those methods. Multiple solve scenarios will be presented to discuss about the multiple layout available between the two previously mentioned solve steps and show their impact on the resolution.

Keywords: HVRP

*Speaker
†Corresponding author: gwenael.rault@mapotempo.com
‡Corresponding author: marc.sevaux@univ-ubs.fr

Branch-price-and-cut for the electric vehicle routing problem with stochastic travel times and battery consumption chance-constraints

Alexandre Florio * [1,2], Nabil Absi [3,4], Dominique Feillet [3,4]

[1] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – France
[2] Laboratoire dÍnformatique, de Modélisation et dÓptimisation des Systèmes (LIMOS) – SIGMA Clermont, Université Clermont Auvergne : UMR6158, Centre National de la Recherche Scientifique : UMR6158 – Bât ISIMA / Campus des Cézeaux BP 10025 / 63173 Aubière Cedex, France
[3] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – Campus Georges Charpak Provence, F-13451 Gardanne, France, France
[4] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – CNRS : UMR6158 – F-13541 Gardanne, France

In this talk, we present a novel branch-price-and-cut (BP&C) algorithm for solving an electric VRP with stochastic travel-times and energy consumption. Instead of working on the customer-based graph, we model and solve the problem directly on the road network graph. This is motivated mainly due to (i) the difficulty of properly dealing with stochastic travel times in the customer-based graph, as pointed out recently in the literature, and (ii) the possibility, in the road network, of representing all the relevant attributes that can affect energy consumption when traveling along a road link.
The first contribution is a method for generating time- and space-correlated speed scenarios. This technique makes use of speed average and speed variance profiles defined on each link, which are then used to generate a multivariate normal distribution that represents the traveling speed on every link and time period. In addition to space- and time-correlation, the technique also enables time-dependency, much common in urban scenarios due to e.g. peak traffic hours.
Next, we introduce a BP&C algorithm to solve the target problem. The main difficulty when designing such algorithm is to develop an efficient procedure for checking the feasibility of routes, since the battery consumption constraint is probabilistic. By drawing and evaluating scenarios, we are able to statistically infer the feasibility (or infeasibility) of routes. This procedure is incorporated into the pricing algorithm. Other components of the algorithm include capacity-based completion bounds and the separation of rounded capacity cuts. Preliminary results are reported.

*Speaker

Keywords: Electric VRP, Stochastic travel times, Column generation

Control of Autonomous Electric Fleets for Ridehail Systems

Nicholas Kullman * [1,2], Martin Cousineau [3], Justin Goodson [4], Jorge Mendoza [2,3]

[1] Laboratoire d'Informatique de l'Université de Tours (LIFAT) – Université de Tours : LIFATEA 6300, CNRS, ROOT ERL CNRS 7002 – 64 Avenue Jean Portalis, 37200 Tours, France

[2] Centre Interuniversitaire de Recherche sur les Réseaux dÉntreprise, la Logistique et le Transport (CIRRELT) – Pavillon André-Aisenstadt, bureau 3520 2920, Chemin de la Tour Montréal (Québec) H3T 1J4 CANADA, Canada

[3] HEC Montréal – 3000 Chemin de la Côte-Sainte-Catherine, Montréal, QC H3T 2A7, Canada

[4] Saint Louis University Richard A. Chaifetz School of Business (SLU) – 3674 Lindell Blvd, St. Louis, MO 63108, United States

Operators of ridehail platforms such as Lyft and Uber will likely be early-adopters of autonomous electric vehicles (AEVs), since AEVs promise to reduce costs, be safer, and more efficient. While studies on the operation of ridehail systems with AEVs exist, nearly all have ignored the need to recharge the vehicles during operation. We address this here in our work on the ridehail problem with AEVs (RP-AEV).

In the RP-AEV, a decision maker (DM) operates a fleet of AEVs that serve requests arising randomly throughout a region. The DM is responsible for assigning AEVs to requests, as well as repositioning and recharging AEVs in anticipation of future requests. We model the RP-AEV as a Markov decision process.

We compare classical approximate dynamic programming (ADP) solution methods with those of deep reinforcement learning (RL), which have garnered enthusiasm but achieved only limited success to date in operational problems. From ADP, we explore novel heuristic policies, both alone and combined with lookaheads. From RL, we build on the approach from Holler et al. (2018). We employ neural-networks (NNs) both to determine the state representation (with single-layer NNs) and to learn state-action value functions (with deep NNs) using Q-learning.

Additionally, we establish a dual bound to gauge the effectiveness of these approaches by calculating the expected value with perfect information. With perfect information, the RP-AEV may be decomposed so as to permit a solution via Benders decomposition, where the master problem assigns AEVs to requests, and the subproblem provides instructions for repositioning and recharging.

*Speaker

Keywords: AUTONOMOUS VEHICLES, ELECTRIC VEHICLES, MARKOV DECISION PROCESS, DEEP LEARNING, REINFORCEMENT LEARNING, APPROXIMATE DYNAMIC PROGRAMMING

A column generation approach for the joint order batching and picker routing problem

Olivier Briant* [1], Hadrien Cambazard† [1], Diego Cattaruzza‡ [2], Nicolas Catusse§ [1], Anne-Laure Ladier¶ [3], Maxime Ogier ‖** [2]

[1] Laboratoire des sciences pour la conception, lóptimisation et la production (G-SCOP) – Université Joseph Fourier - Grenoble 1, Institut Polytechnique de Grenoble - Grenoble Institute of Technology, Institut National Polytechnique de Grenoble, Centre National de la Recherche Scientifique : UMR5272, Université Grenoble Alpes – GSCOPLaboratoire des Sciences pour la Conception, lÓptimisation et la Production de GrenobleUMR 527246, avenue Félix Viallet - 38031 Grenoble Cedex 1 - France, France

[2] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) - UMR 9189 (CRIStAL) – Ecole Centrale de Lille, Institut National de Recherche en Informatique et en Automatique, Institut Mines-Télécom [Paris], Université de Lille, Centre National de la Recherche Scientifique : UMR9189 – Bâtiment M3, Université Lille 1, 59655 Villeneuve dÁscq Cedex FRANCE, France

[3] Décision et Information pour les Systèmes de Production – Institut National des Sciences Appliquées (INSA) - Lyon – France

Picking is the process of retrieving products from inventory. It is mostly done manually by dedicated employees called pickers and is considered the most expensive of warehouse operations. To reduce the picking cost, customer orders can be grouped into batches that are then collected by traveling the shortest possible distance.

This work presents an exponential linear programming formulation to tackle the joint order batching and picker routing problem. Variables, or columns, are related to the picking routes in the warehouse. Computing such routess is generally an intractable routing problem and relates to the well known traveling salesman problem (TSP). Nonetheless, the rectangular warehouse's layouts can be used to efficiently solve the corresponding TSP and take into account in the development of an efficient subroutine, called oracle. We therefore investigate whether such an oracle allows for an effective exponential formulation. In order to tackle the exponential number of variables, we develop a column generation heuristic with performance guarantee. The pricing problem approx-

*Corresponding author: Olivier.Briant@grenoble-inp.fr
†Corresponding author: hadrien.cambazard@grenoble-inp.fr
‡Corresponding author: diego.cattaruzza@ec-lille.fr
§Corresponding author: nicolas.catusse@grenoble-inp.fr
¶Corresponding author: anne-laure.ladier@insa-lyon.fr
‖Speaker
**Corresponding author: maxime.ogier@centralelille.fr

imates the distances, and when finding a solution the oracle is used to get the optimal distance of this solution. The performance of the proposed column generation is strenghten using stabilization techniques and a rich column set.

Experimented on a publicly available benchmark, the algorithm proves to be very effective. It improves many of the best known solutions and provides very strong lower bounds. Finally, this approach is applied to another industrial case to demonstrate its interest for this field of application.

Keywords: order batching, picker routing, column generation

Multi-period routing and battery charge scheduling for electric vehicles

Laura Echeverri* [1], Aurélien Froger† [2], Jorge E. Mendoza ‡ [3]

[1] Laboratoire dÍnformatique Fondamentale et Appliquée de Tours (LIFAT) – Université de Tours : EA6300, Polytech'Tours – 64, Avenue Jean Portalis, 37200 Tours, France
[2] Institut de Mathématiques de Bordeaux (IMB) – Université Bordeaux Segalen - Bordeaux 2, Université Sciences et Technologies - Bordeaux 1, Université de Bordeaux, Institut polytechnique de Bordeaux, Centre National de la Recherche Scientifique : UMR5251 – 351 cours de la Libération 33405 TALENCE CEDEX, France
[3] HEC Montréal (HEC Montréal) – Canada

Recent innovations on battery technology have significantly improved electric vehicle's (EVs) driving ranges. As a result, companies exploiting EVs for urban and semi-urban operations do not longer need to plan for mid-route battery charging and can restrict all charging operations to take place overnight (or between shifts) at the depot. However, the trivial policy of fully charging all vehicles every night can lead to poor fleet management decisions. First, this policy may simply be infeasible because of charging infrastructure constraints (e.g., grid contraints, maximum number of available chargers). Second, this practice has a great and negative impact in the lifespan of the batteries (the most expensive and ecologically unfriendly component of an EV). To solve these issues, routing and charge scheduling decisions must be simultaneously made over a planning periods of (at least) few days. In this talk, we present a set mixed integer programming models to tackle this problem. Our models explicitly take into account the impact of routing and charging decisions on the lifespan of the batteries and try to minimize it. The models are not trivial and they provide insight into how to include battery concern and continous-time charge scheduling decisions into multi-period electric vehicle routing problems. We also present a matheuristic approach tailored to solve large instances of the problem.

Keywords: Multi, period, electric vehicle routing, Matheuristics, battery degradation

*Corresponding author: laura.echeverriguzman@etu.univ-tours.fr
†Corresponding author: aurelien.froger@univ-tours.fr
‡Speaker

A contribution to the VeRoLog Solver Challenge 2019

Martin Josef Geiger * [1]

[1] Helmut-Schmidt-University, University of the Federal Armed Forces Hamburg – Germany

The talk describes our ideas for the VeRoLog Solver Challenge 2019. We propose a heuristic search algorithm that only uses a single, somewhat generalized neighborhood operator for Vehicle Routing Problems. While the algorithm as such is kept rather universal (it is non-adaptive and uses a single parameter only), a tailored, problem-specific implementation has been put forward for the current competition. This includes the proposition of a series of checks, speedups, and preprocessing techniques. In essence, we work on the core of what is, to us, of scientific interest: the very fast manipulation of data in memory, with the aim of finding an optimal/ satisfactory solution. Experiments have been conducted on the test instances published by the challenge organizers, i.e. the EURO VeRoLog Working Group and ORTEC. As far as we can tell, our approach exhibits a reasonable performance, both in short and in longer runs.

Keywords: VeRoLog Solver Challenge, multi period vehicle routing, implementation techniques

*Speaker

An Adaptive Large Variable Neighborhood Search for a Combined Vehicle Routing and Scheduling Problem

Benjamin Graf * [1]

[1] Osnabrück University (UOS) – Germany

The problem posed in the VeRoLog Solver Challenge 2019 requires the routing and scheduling of trucks and technicians to satisfy a given set of item deliveries and subsequent installations. At the core of the proposed solution method is a Variable Neighborhood Search (VNS) applying well-known operators such as 2-opt, Or-opt, inter-route relocate and inter-route exchange. All operators are either tailored towards the improvement of the truck or the technician tours. To escape local optima the VNS is embedded in an Adaptive Large Neighborhood Search (ALNS) combining multiple removal and insertion operators. Optimizing routes and schedules of trucks and technicians may be conflicting goals, due to the broad objective function, the scheduling constraints on technicians and the time window constraints on deliveries. Therefore, trucks and technicians are improved in two different modes, either respecting or ignoring their counterpart technicians and trucks respectively. In conjunction with a rather tight time limit it is required to focus on those aspects of a given problem instance that yield the largest improvements. To achieve that, the procedures and operators are organized in a dynamically weighted tree that guides the search process. In addition, certain sub-problems, e.g. the scheduling of technicians, the minimization of trucks and the distribution of truck tours over the trucks are achieved by embedded bin-packing and matching procedures.

Keywords: ALNS, VNS, Solver Challenge

*Speaker

Matheuristics for the 2019 VeRoLog Solver Challenge: MIPs and Bits

Caroline Jagtenberg *† [1], Andrea Raith [1], Michael Sundvick [1], Kevin Shen [1], Andrew Mason [1], Oliver Maclaren [1]

[1] University of Auckland (UoA) – 70 Symonds St Auckland 1010 New Zealand, New Zealand

We decompose the 2019 VeRoLog Solver Challenge problem into two parts: trucks and technicians. These are effectively two dependent VRPs. A feasible solution is obtained by first solving the more challenging technician problem and then using this solution as a constraint on the time windows for the truck problem. The technician problem has two main difficulties: there is no central depot, and there are rostering constraints. We use a heuristic to construct several feasible solutions for the technician problem. We combine these solutions, using all their routes as input for a generalized Set Covering Problem (SCP), solved using Gurobi's Mixed Integer Program (MIP) solver. We then take all routes in the solution of this SCP, and generate a neighbourhood of these promising routes. Rather than sequentially evaluating these neighbouring routes in a heuristic manner, we add these routes as columns to the MIP, which is solved again iteratively. We are thereby exploring the neighborhood of our solution in an exact way. The obtained set of technician routes are then heuristically assigned to days (without guarantee that a feasible solution can be obtained). To increase the likelihood of finding a feasible assignment, we add constraints limiting the total number of days each technician can work. The truck problem is solved similarly: we generate initial solutions using a sequential savings algorithm and use these as input for a SCP model followed by columnwise neighborhood search. Finally, we combine truck routes to reduce the number of trucks needed, using a bin packing algorithm.

Keywords: VRP, Solver Challenge, Set Covering Problem, columnwise neighborhood search, matheuristics

*Speaker

†Corresponding author: jagtenbe@cwi.nl

Using the Optaplanner solver

Raúl Martín Santamaría * [1]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain

Application of the Optaplanner solver for the given problem, using the Java programming language. Use a hard/soft score approach with customized score calculation to find viable solutions in the minimum possible time.

Keywords: Optaplanner, Heuristics, CVRPTW

*Speaker

An Arc Routing Problem with a fleet of drones

Isaac Plana *† [1], James Campbell [2], Angel Corberán [1], José Maria Sanchis [3], Paula Segura [1]

[1] Universidad de Valencia – Spain
[2] University of Missouri-St. Louis – United States
[3] Polytechnic University of Valencia – Spain

Here we present an arc routing problem where a fleet of drones is available and, considering that the autonomy of the drones is restricted, the length of the single routes is limited by a maximum distance. Some applications for drone arc routing problems include traffic monitoring by flying over roadways, infrastructure inspection such as by flying along power transmission lines, pipelines or fences, and surveillance along linear features such as coastlines or territorial borders. Unlike the vehicles in traditional arc routing problems, drones can travel directly between any two points in the plane without following the edges of the network. Therefore, a drone route may service only part of an edge, with multiple routes being used to cover the entire edge. For this problem, we propose a matheuristic algorithm and present an Integer Linear Programming formulation. A preliminary branch-and-cut algorithm is also introduced and some computational results are presented.

Keywords: drones, arc routing, distance constraints, matheuristic, branch and cut

*Speaker
†Corresponding author: isaac.plana@uv.es

Drone and truck deliveries: solving the parallel drone scheduling traveling salesman problem

Mauro Dell'amico [1], Roberto Montemanni * [2], Stefano Novellani [1]

[1] DISMI, Univesità di Modena e Reggio Emilia – via Amendola 2, 42122, Reggio Emilia, Italy
[2] Dalle Molle Institute for Artificial Intelligence (IDSIA-USI/SUPSI) – Galleria 2, 6928 Manno, Switzerland

In the last decades e-commerce has boomed and home deliveries have followed the same trend. Moreover, customers began expecting parcels delivery to be performed in a very short time after purchase. One of the proposed methods to deliver parcels to customers in a fast way is the use of unmanned areal vehicles (UAV), also known as drones.
In this work we consider the parallel drone scheduling traveling salesman problem (PDSTSP) defined by Murray and Chu [1], where a set of drones can serve the customers within a certain radius from the depot and deliver parcels in parallel with a vehicle. The authors proposed a MILP formulation and greedy heuristics for the problem. More recently, Mbiadou Saleu et al. [2] proposed an iterative two-step heuristic in which customers are firstly partitioned between the vehicle and the drones and then the routing optimization is performed.

In this work we propose a new formulation for the PDSTSP and we define some effective math-heuristic local searches that can be used to provide good quality solutions in a short computation time. Preliminary results on benchmark instances are very promising, allowing us to provide the optimal solution for most of them.

Murray, C.C. and Chu, A.G.: The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery. Transportation Research Part C:
Emerging Technologies, 54, 86-109, (2015).
Mbiadou Saleu, R.G., Deroussi, L., Feillet, D., Grangeon, N. and Quilliot, A.: An iterative twostep heuristic for the parallel drone scheduling traveling salesman
problem. Networks, 72(4), 459-474, (2018).

*Speaker

Keywords: TSP, Drones, MILP, math, heuristic

A prototype of truck-drone route optimization based on agent modelling and simulation

Jose M. Leon-Blanco *† [1], Marcos Calle-Suárez‡ [1], Pedro L Gonzalez-R§ [1], David Canca Ortiz¶ [1]

[1] Industrial Engineering and Management Science, School of Engineering, University of Seville – Spain

In recent times, the optimization of the use of unmanned aerial vehicles (UAVs) or drones in the last-mile delivery of goods is receiving increasing interest from the research community. In this work, we study the routing problem of finding the best time needed by a truck-drone tandem to visit a set of locations or customers to deliver a set of goods. Due to limitations in drone payload, each client will receive only one parcel.
This problem, like other routing problem is NP-Hard and we propose a multi-agent simulation methodology capable to find good quality solutions in polynomial time. This methodology has been little used in logistics. In our system, each location needed to be visited, is modelled as an agent, competing with others for the delivery of one parcel as soon as possible, with the constraints imposed by the environment.
Results obtained by our model and those obtained by exact resolution are compared. We have found good quality solutions in case of a high number of clients, but they are not as good in case of small problems, where an exact solution can be found in reasonable time. In addition to that, our method easily shows the real path of the tandem truck-UAV and simplifies sensitivity analysis, i.e., when new clients are added or removed from the mission, or there are closed or saturated roads

Keywords: UAVs, Agent, Modelling and Simulation, last mile delivery

*Speaker
†Corresponding author: migueleon@us.es
‡Corresponding author: mcalle@us.es
§Corresponding author: pedroluis@us.es
¶Corresponding author: dco@us.es

Heuristic and dynamic programming for Parallel Drone Scheduling with Multiple Drones and Vehicles

Mbiadou Saleu Gertrude Raïssa * [1], Dominique Feillet† [2,3], Alain Quilliot‡ [4,5], Laurent Deroussi§ [4], Nathalie Grangeon¶ [4]

[1] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Université Blaise Pascal - Clermont-Ferrand II, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France
[2] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – CNRS : UMR6158 – F-13541 Gardanne, France
[3] Ecole des Mines de Saint-Etienne (EMSE) – Ecole des Mines de Saint-Etienne – Campus Georges Charpak Provence, F-13451 Gardanne, France, France
[4] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Université Blaise Pascal - Clermont-Ferrand II, Université d'Auvergne - Clermont-Ferrand I, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France
[5] University Clermont Auvergne (UCA) – LIMOS UMR CNRS/UCA618, Laboratoire Informatique, Modélisation et Optimisation des Systèmes, UCACNRS – Campus des Cézeaux, Clermont-Ferrand, 63000, France, France

The growth of last-mile delivery and demand for next- and same-day service is pushing logistics beyond traditional transportation management and supply chain analytics. One recent evolution in urban logistics involves the usage of unmanned aerial vehicle (drones) in the delivery process. Delivery by drones offers new possibilities, but also induces new challenging routing problems.
The problem of parcel delivery with drone has received increasing attention these last years. We consider the problem of combining K vehicles and M drones without synchronization between the vehicles and drones (vehicles perform classical delivery tours from the depot, while drones make back and forth trips to the depot). The objective is to minimize the makespan. We propose a solution approach based on dynamic programming which consists in an iterative three-steps heuristic. The first step builds a giant tour visiting all customers. In the second step, the giant tour is split in order to determine a set of vehicles tours (each vehicle tour following the order defined by the giant tour) and a set of customers assigned to drones. Thirdly, an improvement step performs some moves of customers between vehicle/vehicle or vehicle/drone. To

*Speaker
†Corresponding author: feillet@emse.fr
‡Corresponding author: alain.quilliot@isima.fr
§Corresponding author: laurent.deroussi@uca.fr
¶Corresponding author: nathalie.grangeon@uca.fr

ensure execution time efficiency, some bounding and heuristic-based mechanisms for controlling labels in step two are introduced. A branch&cut procedure helping to obtain optimal solutions for small size instances is also provided. The results obtained are very promising. Experiments conducted confirm the efficiency of our heuristic and give some insights on this kind of drone delivery system.

Keywords: drone delivery, vehicle routing problem, city logistics, heuristic, MILP

TSP with one truck and one or multiple drones

Kilian Seifried *† [1]

[1] Business School, University of Mannheim – PO Box 103462 68131 Mannheim, Germany

We develop a novel mixed-integer programming (MIP) formulation for a traveling salesman problem with a truck-drone tandem that carries out a set of deliveries. Our model takes an approach different to other MIP formulations in the literature. Benchmarks show that it can compete with those as well as with purpose-built exact solution methods but has the advantage of being easily implementable with an off-the-shelf solver. Our model can be easily extended to include multiple drones, with only a minor impact on solution performance.

Keywords: drones, drone delivery, last mile, tsp

*Speaker
†Corresponding author: kilian.seifried@bwl.uni-mannheim.de

The Mothership and Drone Routing Problem with Obstacles

Stefan Poikonen * [1], Bruce Golden [2]

[1] University of Colorado Denver Business School – United States
[2] University of Maryland R.H. Smith School of Business – United States

The mothership and drone routing problem is a collaborative transportation model between a mothership (e.g., a ship, plane, or other large vehicle that can move by Euclidean distances) and a drone. We show that by combining second order cone programming with the branch-and-bound algorithm, we can find optimal solutions. Additionally, we show fast heuristics that use second order cone programming. We show that the second order cone program can be modified for other constraints. We then consider the case where there exist several polygonal obstacles (e.g., dry land, shallow waters, political boundaries) that restrict the motion of the mothership. These obstacles inject non-convexity into the feasible domain, which complicates the problem significantly. Our proposed solution method first finds a feasible solution. Afterwards, a sequential second order cone program is applied. This second order cone program contains a new set of constraints. Critically, we circumscribe the launch and landing locations of the drone from the previous iteration's solution with a circle of maximal radius, such that the circle does not intersect with any obstacle. The launch and landing locations of the current iteration are constrained within these circles. Thus, we are able to ensure that the chosen launch and landing locations do not intersect with land, but we are able to preserve the form of a second order cone program. We show that the sequential second order cone program tends to drift towards some local optimum.

Keywords: drones, UAV, VRP, drone

*Speaker

Integration of Vehicles and Drones in Last Mile Delivery

Necati Aras * [1]

[1] Department of Industrial Engineering, Bogazici University – Boğaziçi University Department of Industrial Engineering 34342, Bebek, Istanbul, Turkey, Turkey

Last mile delivery is an important aspect to be considered by logistics service providers.The increase in online shopping from e-commerce firms results in a boost in the number of home deliveries. If the logistics company does not offer a service that includes a specific time window agreed with the customers, the parcel may arrive the customer's address any time during the day and there is a high likelihood that the customer will not be home. In such cases, the parcel is brought back to the local store of the logsitcs service provider, and the customer is asked to retrieve the parcel from the store which creates customer dissatisfaction. One possible remedy is to ask the customer about his current location when he is not found at his address, and carry the parcel to the vehicle that performs drop offs at delivery addresses close to the current location of the customer. In this study, we assume that vehicles are equipped with drones and if a customer is not found at the delivery address, the parcel is transported by the drone to another vehicle that will make the delivery to the customer at the new location. To this end, we formulate a mixed-integer linear programming model to determine at which point the drone has to depart from one vehicle and at which point it has to land on another vehicle that will make the delivery to the customer's new address. The model is solved for randomly generated instances by a commercial solver.

Keywords: drone, synchronization, integer programming

*Speaker

A Large Neighborhood Search approach to integrate delivery options in last mile delivery

Dorian Dumez *† [1], Fabien Lehuédé [2], Olivier Péton [1]

[1] Ecole des Mines de Nantes (EMN/IRRCyN/SLP) – Ecoles Mines de Nantes – 1, rue de la Noë - BP 92101 - 44321 NANTES CEDEX 3, France
[2] LUNAM / Ecole des Mines de Nantes / IRCCyN (EMN) – Ecole des Mines de Nantes – 1, rue de la Noë - BP 92101 - 44321 NANTES CEDEX 3 - France, France

The growth of e-commerce is stressing last-mile delivery services. Some solutions are being developed to avoid delivery failures. Classically, parcels are delivered into mailboxes. They can also be delivered in shared locations such as shops or lockers boxes. During worktime, packages can also be delivered at work in some companies. We define the Vehicle Routing Problem with Delivery Options, which generalizes the VRP with time windows, integrating several delivery locations per request. Each location can be associated with a time window and a priority level, and called a delivery option. We consider several types of delivery locations, including lockers which may introduce some synchronization between routes due to their limited capacities. An overall service level is defined based on prorities. Consequently, the set of routes must serve all clients through exactly one option, respect the time windows and the synchronized resources constraints. To solve this problem, we design a LNS coupled with a set partitionning formulation. It integrates specific operators as well as operators adapted from the VRPTW. The method is evaluated on randomly generated instances and on the VRPTW benchmarks.

Keywords: LNS, matheuristic, city logistic, VRPTW, resource synchronization

*Speaker
†Corresponding author: dorian.dumez@imt-atlantique.fr

A Location-Routing Problem with Delivery Options and Time-Windows for the Last Mile Delivery of Fresh Products

Sonja Rohmer * [1], J.c. Gerdessen [1], G.d.h. Claassen [1]

[1] Wageningen University - Operations Research and Logistics (WUR - ORL) – Netherlands

This research presents a location-routing problem with delivery options for the last mile delivery of fresh products. Product delivery can occur either directly to the customer locations or indirectly to a customer pickup point, where they are stored until customer pickup takes place. Due to the fresh nature of the products, direct delivery requires customer attendance and is thus subject to tight time windows at the customer locations, whereas indirect delivery allows for more flexibility. However, pickup points are restricted in terms of capacity and require refrigeration, therefore incurring a cost related to the operation and cooling of the pickup facilities in use. The objective is to minimise the total transportation and storage cost. Formulating the problem as a mixed integer linear program and solving it by means of an adaptive large neighbourhood search, the research aims to investigate the potential benefits of implementing refrigerated pickup stations in last mile distribution systems for fresh products.

Keywords: Fresh Products, Alternative Delivery, Last Mile, City Logistics

*Speaker

Using Mobile Pick-up Stations for Last-Mile Deliveries

Tino Henke *† [1], Saba Pakdel [1], Trong Dai Pham [1], Thi Kim Nhung Phan [1], Jan Fabian Ehmke [1]

[1] Otto-von-Guericke University Magdeburg – Germany

Because of continuously growing e-commerce and increasing urbanization, many innovative last-mile delivery concepts have been introduced in recent years. One of such concepts considers the usage of mobile pick-up stations. Mobile pick-up stations contain several lockers for storing a limited number of parcels to be collected by customers. Moreover, each station can be moved to a different location on each day to enable convenient access for customers. However, for sparsely populated areas, conventional home deliveries may still be more efficient for the logistics service provider than operating with mobile pick-up stations. Thus, we regard an optimization problem in which a given set of customers needs to be partitioned into clusters served either by mobile pick-up stations or by home deliveries. Moreover, temporary locations for the pick-up stations as well as routes for home deliveries have to be determined such that total delivery costs can be minimized. In our presentation, we will discuss a sequential three-stage heuristic. Customer clusters are determined on the first stage, the best delivery option for each cluster is identified on the second stage, and a simulated annealing-based local search is performed on the last stage. Extensive numerical experiments evaluate the performance of the proposed heuristic and provide valuable managerial insights into the benefits of using mobile pick-up stations.

Keywords: Last Mile Deliveries, Location Planning, Vehicle Routing, Heuristics

*Speaker
†Corresponding author: tino.henke@ovgu.de

Optimal vehicle routing with autonomous devices for last-mile delivery

Laurent Alfandari [1], Ivana Ljubic *† [1], Marcos Melo [1]

[1] ESSEC Business School (ESSEC) – ESSEC Business School – France

In this work we study a variant of the Routing-Scheduling Problem in which autonomous devices are used for last-mile delivery. The problem aims at finding an optimal route for a vehicle carrying customer parcels from a central depot to selected facilities, from where autonomous devices like robots or drones are launched to perform last-mile deliveries. The objective is to minimize a lateness indicator, given customer delivery due dates. Depending on the preferences of the decision maker, three key objective functions are considered: min-max, min-sum and min-num, referring to minimizing the maximum tardiness, the total tardiness, and the number of late deliveries, respectively.

After providing a formal definition of the problem for various objective functions measuring lateness, we investigate their complexity and devise a (generic) Mixed Integer Programming (MIP) formulation based on multi-commodity network flows.

To deal with instances of realistic size, we propose a Benders Decomposition approach that can be implemented in a generic way for all three problem variants. Furthermore, we show how Benders cuts can be generated without resorting to linear programming to solve the Benders subproblems, and use a combinatorial approach instead.

Three variants of the proposed Benders decomposition are implemented and their performance is analyzed using adapted instances from the literature.

Numerical results show that the Benders approach with a tailored combinatorial algorithm for generating Benders cuts largely outperforms all other tested approaches.

Keywords: Vehicle Routing, Scheduling, Last Mile Delivery, Branch and Benders Cut

*Speaker

†Corresponding author: ljubic@essec.edu

The Last-mile Vehicle Routing Problem with Alternative Delivery Options

Christian Tilk *† [1], Stefan Irnich [1], Katharina Olkis [1]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

The ongoing rise in e-commerce comes along with an increasing number of first-time delivery failures due to the absence of the customer at the delivery location. Failed deliveries result in rework which in turn has a large impact on the carriers delivery cost. In this presentation, the vehicle routing problem with alternative delivery options is investigated. In contrast to the classical vehicle routing problem with time windows, in which each customer request has only one location and one time window describing where and when shipments need to be delivered, alternative delivery options imply that at least some requests allow the shipment to different locations and times. Furthermore, customers may favor some delivery options. The carrier must then decide for each request to which of the given alternative delivery options the shipment is sent such that the carriers overall costs are minimized and a certain service level regarding the customer preferences is achieved. Moreover, when delivery options share a common location (e.g., a locker), location capacities must be respected when assigning shipments.To solve the problem, we present a branch-price-and-cut algorithm. The resulting pricing problem is a shortest-path problem with resource constraints that is solved with a bidirectional labeling algorithm on an auxiliary network. We investigate two different modelling approaches for the auxiliary network and present optimal solutions for instances with up to 60 requests.

Keywords: City Logistics, Column Generation, VRP, Synchronization

*Speaker

†Corresponding author: tilk@uni-mainz.de

The tail routing problem in air transportation

Manuel Fuentes *† [1], Luis Cadarso‡ [1], Vikrant Vaze [2], Cynthia Barnhart [3]

[1] Universidad Rey Juan Carlos [Madrid] (URJC) – Calle Tulipán s/n. 28933 Móstoles. Madrid, Spain
[2] Dartmouth College – United States
[3] Massachusetts Institute of Technology (MIT) – 77 Massachusetts Ave, Cambridge, MA 02139, United States

Airline planning is a field rich in combinatorial optimization problems. Flights and airports make up the network where aircraft and passengers fly. In order to schedule aircraft, assignments of fleet types to flights and of aircraft to routes must be determined. The former is known as the fleet assignment problem while the later is known as the aircraft routing problem in the literature. Aircraft routing is usually addressed as a feasibility problem whose solution is needed for constructing crew schedules. Note that all these problems are usually solved from 4 to 6 months before the day of operations. Therefore, there is limited information regarding each aircraft's operational condition.
The tail routing problem, which has received limited attention in air transportation literature, is solved when additional information regarding operational conditions is revealed aiming at determining each aircraft's route for the day of operations accounting for the originally planned aircraft routes and crew schedules. Therefore, it is a problem to be solved the day before operations.

We propose a mathematical programming approach based on sequencing that captures all operational constraints and maintenance requisites while operational costs are minimized and schedule changes with respect to original plans are minimized.
Computational experiments are based on realistic cases drawn from a Spanish airline, which features a network with more than 1000 flights and more than 100 aircraft.

Keywords: Air transportation, tail assingment, aircraft routing

*Speaker
†Corresponding author: manuel.fuentes@urjc.es
‡Corresponding author: luis.cadarso@urjc.es

Considering Parking Areas in Route Planning for Truck Drivers

Frank Schulz * [1], Alexander Kleff [1], Christian Bräuer [1], Tim Zeitz [2], Valentin Buchhold [2], Dorothea Wagner [2]

[1] PTV Group – Haid-und-Neu-Str. 15, 76131 Karlsruhe, Germany
[2] Karlsruhe Institute of Technology (KIT) – Karlsruhe, Germany

We study extensions of the shortest-path problem in road networks: given a road network, a start and a destination location, determine the best path to drive from start to destination.

For truck drivers several additional constraints apply. For example, it is sometimes necessary or beneficial to stop and wait somewhere on the way from start to destination. Reasons for such a waiting stop include time-dependent driving bans and regulations on drivers' working hours. In reality, it is not possible to just wait anywhere in the road network and hence must be planned only where a parking area is available.

Further extensions for more realistic solutions are time-dependent driving times and the consideration of a sequence of planned stops at customers. The latter extension constitutes the main use-case our research is targeted on: typically when solving a VRP not all path constraints can be taken into account, but for tour execution a path that is as realistic as possible is desired.

We focus on allowing waiting only at designated parking areas and at customers. In the main approach that we present, time-dependent driving bans are considered, and we optimize two criteria, the arrival time and the driving time. Since waiting is not allowed everywhere the problem is NP-hard. Our heuristic approach returns multiple Pareto-optimal solutions. The algorithms are evaluated using real-world data.

Another approach combines designated parking areas and the regulations on drivers' working hours. It can deal also with planned intermediate stops at customers and time-dependent driving times.

Keywords: Time Dependent Shortest Path Problem, Drivers' Working Hours

*Speaker

A Dynamic Discretization approach to the integrated Service Network Design and Vehicle Routign Problem

Yun He [2,1], Fabien Lehuédé *† [1,2], Olivier Péton [1,3]

[2] Laboratoire des Sciences du Numérique de Nantes (LS2N) – Université de Nantes, Ecole Centrale de Nantes, Centre National de la Recherche Scientifique : UMR6004, IMT Atlantique Bretagne-Pays de la Loire – Université de Nantes – faculté des Sciences et Techniques (FST)2 Chemin de la HoussinièreBP 92208, 44322 Nantes Cedex 3, France

[1] IMT Atlantique (IMTA) – IMTA – 4 rue Alfred Kastler 44307 Nantes, France

[3] Laboratoire des Sciences du Numérique de Nantes (LS2N) – LS2N – 4, rue Alfred Kastler 44307 Nantes, France

The Service Network Design and Routign Problem (SNDRP) integrates long-haul and local transportation planning in a logistics hub network. Delivery paths are to be planned for a set of commodities, via a pre-defined set of routes in the service network. Each commodity has to be picked up and delivered in time, while the total transportation and consolidation cost should be minimized. We extend the Dynamic Discretization Discovery algorithm that has been recently proposed to solve the Service Network Design problem. We show that the SNDRP can be solved with a very thin time discrtization on a time-space network. A case study in the retail area is used to illustrate how our approach can help decision makers to design and operate collaborative transportation networks.

Keywords: Service network design, consolidation, synchronization, vehicle routing

*Speaker

†Corresponding author: fabien.lehuede@imt-atlantique.fr

Setting a Maximum Capacity Network and Sharing its Cost.

Andrés Caro * [1], Miguel Hinojosa [1], Diego Borrero [1]

[1] Pablo de Olavide University, of Seville (UPO) – Spain

Sometimes the solution of set a network connecting different places (agents) are provided by seeking higher capacity in their connections instead of lower cost or times. In those cases, the routes will be settled looking for certain capacity. In a maximum capacity network problem, it is assumed that the network to be built has minimum capacity requirements between the agents that will be connected. The capacity demands between each pair of agents are known and the minimum cost of establishing the capacity network is sought. The solution to this problem lays in the construction of a maximum cost spanning tree that connects all the agents with their required capacity. The objective of this work is not only to describe the trees which solve the problem but also to share the network cost between the agents. Thus, we present a set of algorithms that generate maximum cost spanning trees and produce different allocations of the costs. When these allocations are analysed from the point of view of Game Theory, it will be concluded that they are optimal both from the cooperative and the non-cooperative approach. As a consequence, using the introduced algorithms, a large set of solutions are achieved. And, in the Game Theory framework, these solutions are in the Core of a certain Cooperative Game and are Nash-Equilibrium of a related Non Cooperative Game.

Keywords: Maximum Capacity Network, Cooperative Games, Non, cooperative Games, Core, Nash, Equilibrium.

*Speaker

Enhanced Multi-Directional Local Search for the Bi-Objective Heterogeneous Vehicle Routing Problem with Multiple Driving Ranges

Majid Eskandarpour * [1], Djamila Ouelhadj† [2], Angel A. Juan‡ [3]

[1] IÉSEG School Of Management (LEM-CNRS 9221) – IÉSEG School Of Management (LEM-CNRS 9221) – France
[2] University of Portsmouth – Winston Churchill Avenue Portsmouth PO1 2U, United Kingdom
[3] Open University of Catalonia [Barcelona] – Spain

The transportation sector accounts for a significant amount of greenhouse gas emissions. To mitigate this problem, electric vehicles have been widely recommended as green vehicles with lower emissions. However, the driving range of electric vehicles is limited due to their battery capacity. In this paper, a bi-objective mixed-integer linear programming model is proposed to minimise total costs (fixed plus variable) as well as CO2 emissions caused by the vehicles used in the fleet for a Heterogeneous Vehicle Routing Problem with Multiple Loading Capacities and Driving Ranges (HeVRPMD). To solve the proposed model, an enhanced variant of Multi-Directional Local Search (EMDLS) is developed to approximate the Pareto frontier. The proposed method employs a Large Neighbourhood Search (LNS) framework to find efficient solutions and update the approximated Pareto frontier at each iteration. The LNS algorithm makes use of three routing-oriented destroy operators and a construction heuristic based on a multi-round approach. The performance of EMDLS is compared to MDLS, an Improved MDLS (IMDLS), non-dominated sorting genetic algorithm II (NSGAII), non-dominated sorting genetic algorithm III (NSGAIII), and the weighting and epsilon-constraint methods. Extensive experiments have been conducted using a set of instances generated from the Capacitated Vehicle Routing Problem benchmark tests in the literature. In addition, real data is utilised to estimate fixed and variable costs, CO2 emissions, capacity, and the driving range of each type of vehicle. The results show the effectiveness of the proposed method to find high-quality non-dominated solutions.

*Speaker
†Corresponding author: djamila.ouelhadj@port.ac.uk
‡Corresponding author: ajuanp@gmail.com

Keywords: Routing, Multi, objective, Multi, directional Local Search, Electric Vehicles, Multiple Driving Ranges

Internalizing Negative Externalities in the Vehicle Routing Problem

Adrian Serrano-Hernandez* [1,2], Luis Cadarso [3], Javier Faulin † [4]

[1] Rey Juan Carlos University (URJC) – Spain
[2] Institute of Smart Cities, Public University of Navarra (ISC-UPNA) – Spain
[3] Rey Juan Carlos University (URJC) – Spain
[4] Istitute of Smart Cities, Public University of Navarra (ISC-UPNA) – Spain

Road freight transportation includes various internal and external costs that need to be accounted for in the construction of efficient routing plans. Typically, the resulting optimization problem is formulated as Vehicle Routing Problem (VRP) in any of its variants. While the traditional focus of the VRP was the minimization of internal routing costs such as travel distance or duration, numerous approaches to include external factors related to environmental routing aspects have been recently discussed in the literature. However, internal and external routing costs are often treated as competing objectives. Instead, this work considers the internalization of external costs within the economic structure of the logistic company. Thus, not only the traditional approach of distance based internal costs of routing is considered but also the external costs are included in the objective function: that is, minimization of the full costs. Two protocols of internalizing are further analyzed and discussed: green taxes and green tolls. Numerical experiments with a biased-randomization savings algorithm show benefits of combining internal and external costs in delivery route planning. Consequently, the behavior of companies when internalizing external costs significantly changes. That means that they plan a different route in order to minimize their full costs, allowing for a noticeable reduction on emissions.

Keywords: vehicle routing problem, biased randomization, green logistics, negative road transportation externalities, internalization.

*Corresponding author: adrian.serrano@unavarrra.es
†Speaker

MILP formulations and Cutting Plane approaches for the Green Vehicle Routing Problem with Capacitated Alternative Fuel Stations.

Maurizio Bruglieri *† [1], Simona Mancini [2], Ornella Pisacane [3]

[1] Dipartimento di Design, Politecnico di Milano – Via Durando, 38/a, 20158 Milano, Italy
[2] Dipartimento di Matematica ed Informatica, Università di Cagliari – Italy
[3] Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche – Italy

We introduce the Green Vehicle Routing Problem with Capacitated Alternative Fuel Stations (GVRP-CAFS) aimed at routing Alternative Fuel Vehicles (AFVs), serving all customers at minimum total travel distance. A route starts/ends from/to a common depot where the AFVs are based at, serving a subset of customers, with possible intermediate stops at stations for being refueled. Unlike the GVRP, in the GVRP-CAFS, at most AFVs can be simultaneously refueled at each station, being the number of its refueling pumps. We consider both the scenario in which stations are owned by the transportation company and that one where they are public. In the latter case, refueling pumps can be reserved in advance for preventing unpredictable waiting times at stations during the routes. We propose both an Arc and a Path-based Mixed Integer Linear Programming (MILP) models where the latter is defined on only feasible non-dominated paths. Both are extended to model also multiple time windows associated with stations in the public scenario. We propose also two Cutting Plane approaches where the relaxations are obtained dropping the stations capacity constraints and the cuts are obtained in two different ways. In the first approach, at each iteration, we add a single cut that consists in restoring the capacity constraint violated by the current solution. In the second one, we add a pull of cuts consisting in capacity constraints that can be luckily violated in the next iterations. The solutions of both MILP models are compared with those of the Cutting Plane approaches.

Keywords: Vehicle Routing Problem, Mixed Integer Linear Programming, Cutting Planes, Fuel Station Reservation

*Speaker
†Corresponding author: maurizio.bruglieri@polimi.it

A Skewed VNS for solving a nonlinear optimization case: The Generalized Team Orienteering Problem

Adolfo Urrutia * [1], Gregorio Tirado [2], Alfonso Mateos Caballero [1]

[1] Universidad Politécnica de Madrid (UPM) – Edif. A.- Calle Ramiro de Maeztu, 7, Madrid, Spain
[2] Universidad Complutense de Madrid – Spain

This work approaches the Team Orienteering Problem (TOP), from a nonlinear optimization perspective. The Generalized Team Orienteering Problem (GTOP) extends the TOP, but keeps some features of the latter. In the GTOP, as in the TOP, a set of nodes which could potentially be visited is given, and the travel time between any pair of nodes, time budget, and the number of tours with starting and ending points, are known. The problem consists in finding a closed tour maximizing the scores of the visited nodes while not exceeding the time limit. The difference with the TOP is that each of the nodes is now associated with two or more scores, there is a vector of preferences that indicates the importance of each score in the final value, and the objective function that aggregates the values is nonlinear. To solve this optimization problem, we propose a skewed variable neighborhood search with a reduced number of local search operators. The metaheuristic evaluation is performed on 10 benchmarks, some of them already in the literature such as Tsiligirides' and Chaos'. In these cases, a linear objective function was used to enable the comparison with other techniques, and the results were encouraging. For that reason, we proceeded, from a nonlinear perspective, with new datasets based on real data from Spanish tourist cities. The results in this case are an interesting first approximation for the GTOP and future applications of the VNS to similar problems like the Tourist Trip Design Problem.

Keywords: Orienteering Problem, Variable Neighborhood Search, nonlinear optimization

*Speaker

New Steiner Travelling Salesman Problem Formulation and its multi-depot extension

Jessica Rodriguez-Pereira *† [1], Elena Fernández [2], Gilbert Laporte [1], Enrique Benavent [3], Antonio Martinez-Sykora [4]

[1] HEC Montréal – 3000 Chemin de la Côte-Sainte-Catherine, Montréal, QC H3T 2A7, Canada
[2] Technical University of Catalonia (UPC) – 1-3 Jordi Girona Street 08034 Barcelona, Spain
[3] Universidad de Valencia – Spain
[4] University of Southampton [Southampton] – University Road Southampton SO17 1BJ, United Kingdom

The purpose of this work is to present a new compact formulation and efficient exact solution algorithm for the Steiner Traveling Salesman Problem (STSP) on an undirected network and its multi-depot extension. The STSP is an uncapacitated node-routing problem looking for a minimum-cost route that visits a known set of customers with service demand, placed at vertices of a given network, which is assumed to be uncomplete. The multi-depot extension, MDSTSP, studies the case when there are several depots and the allocations of customers has to be decided as well. A compact integer linear programming formulation is proposed for each problem, where the routes are represented with two-index decision variables, and parity conditions are modeled using co-circuit inequalities. Exact branch-and-cut algorithms are developed for all formulations. Computational results obtained confirm the good performance of the algorithms. Instances with up to 500 vertices are solved optimally.

Keywords: Steiner Traveling Salesman Problem, integer linear programming, branch, and, cut

*Speaker
†Corresponding author: jessica.rodriguez-pereira@hec.ca

Supply vessel planning with uncertain demand and weather conditions

Kisialiou Yauheni [1], Irina Gribkovskaia *† [2], Gilbert Laporte [3]

[1] Molde University College (MUC) – Britvegen 2, 6410 Molde, Norway, Norway
[2] Molde University College - Specialized University in Logistics – Britvegen 2, 6410 Molde, Norway
[3] HEC Montréal – 3000 chemin de la Cote-Sainte-Catherine, Montreal H3T 2A7, Canada

Supply vessel planning problem arises in the upstream offshore oil and gas logistics, where supply vessels are the most expensive logistics resource. A fleet of supply vessels provides delivery of necessary materials and equipment to a set of offshore installations on a periodic basis from an onshore supply base. The challenge is that the performance of the vessel schedule is affected by both uncertain weather conditions and uncertain demand at installations. The objective is to define an optimal fleet composition and a least-cost weekly sailing plan used repetitively over a season. Uncertain weather conditions influence both sailing and service times leading to delays. Uncertain demand quite often leads to inability to deliver all the planned cargo on time due to insufficient vessels deck capacity. The uncertainty results in the rescheduling where in the worst case an extra vessel is hired at a higher cost. Rescheduling involves several recourse actions performed simultaneously in various combinations and aimed to ensure feasibility of the schedule. Logistics planners aim to create vessel schedules with minimized schedule's deterministic cost and the expected cost of recourse. We present an optimization-simulation methodology for the construction of supply vessel schedules. We develop a heuristic algorithm able to generate solutions with some reliability level against uncertain demand and weather for large real-life problem instances. The heuristic algorithm is combined with a discrete event simulation to assess the performance of the schedule and to compute the expected cost of recourse.

Keywords: Vehicle routing, energy logistics, optimization, simulation

*Speaker
†Corresponding author: Irina.Gribkovskaia@hiMolde.no

Scheduling of Intelligent and Autonomous Vehicles under pairing/unpairing collaboration strategy in container terminal: A branch-and-cut algorithm

Jorge Riera-Ledesma * [1], Shahin Gelareh [2,3]

[1] Departamento de Ingeniería Informática y de Sistemas, Universidad de La Laguna (DIIS, ULL) – Escuela Superior de Ingeniería y Tecnología, Apartado de correos 456, Universidad de La Laguna, 38200 La Laguna, Spain
[2] Shahin Gelareh – Université d'Artois : EALGI2A – Faculté des Sciences Appliquées - LGI2A Technoparc - Zone Futura - 62400 Béthune, France
[3] LGI2A – Université d'Artois : EALGI2A – UArtois, LGI2A (EA 3926), F-62400, Bethune, France, France

A new class of Intelligent and Autonomous Vehicles (IAVs) has been designed in the framework of Intelligent Transportation for Dynamic Environment (InTraDE) project funded by the European Union. This type of vehicles has the ability of pairing/unpairing enabling a pair of units to join, transport bigger containers and disjoin again.
We study a scheduling problem associated with this new family of vehicles. This scheduling problem aims at transporting a set of different size containers among different areas in the port platform using a fleet of IAVs. In this problem, each vehicle represents a configurable processor, and moving a container from a location to other represents a job, whose processing might require the synchronized configuration of some specific processors (vehicles). This optimization problem looks for a sequence of settings for each processor, to minimize the makespan.

Previous studies have approached this problem using algorithms based on a Mixed Integer Programming model that linearizes the synchronization constraints by the big-M method. We propose an alternative model which manages the synchronization constraints by combinatorial cuts that remove minimum infeasible subsets detected by exploring its associated dual problem. Its associated branch-and-cut algorithm has shown to be competitive behavior in extensive computational experience.

Keywords: Synchronization, branch and cut, job scheduling

*Speaker

Heterogeneous resource scheduling and routing with order acceptance

Meryem İlbeği * [1], Eda Yucel [1]

[1] TOBB University of Economics and Technology [Ankara] – Turkey

In this research, we study the resource scheduling and routing problem that is motivated by a service company that provides hourly machinery leasing services with and without machinery operators. Given a heterogeneous fleet of machinery, a set of operators with different machinery capabilities, and a set of work orders with their location and soft service time window information and their machinery type and operator requirements, the goal is to assign resources to the work orders in accordance with their competence and determine their routing, where a portion of the work orders might be rejected due to limited resources. The objective is to minimize total operational costs consisting of the traveling cost of the resources, overtime cost of the operators, and order latency and rejection costs. We develop a mixed integer programming formulation for the problem. As the computational effort grows rapidly with the problem size, a variable neighborhood search heuristic is proposed to provide solutions for realistic size instances. The performance of the proposed heuristic is analyzed through realistic problem instances obtained from the machinery leasing company that faces the problem on a daily basis.

Keywords: resource routing and scheduling, order acceptance, variable neighborhood search

*Speaker

Interdependent Home Health Care and Social Care Problems

Jésica De Armas *† [1], Helena Ramalhinho [1]

[1] Universitat Pompeu Fabra [Barcelona] (UPF) – Spain

In home health care (HHC) services, professional caregivers are dispatched to patients' homes to provide medical care services, such that each patient can stay at home to be treated periodically. In an increasingly aging world, many of these patients usually need additional cares, such as Social Care (SC). Very often public medical institutions and public social services attend these patients, and both services present a certain degree of interdependency, e.g., a patient should be helped to get up, groom, and eat, before being seen by a doctor; or a patient needs help to organize the pills and doses after a doctor's visit.
Since the coordination of both services is relevant in a large number of patients, the aim of this work is to propose a realistic mathematical model and solving method considering the synchronization of both services and the particularities of each of them. The HHC problem consists of the medical staff rostering problem (NRP) and the vehicle routing problem with time windows (VRPTW), both of which are NP-hard problems. Additionally, the SC problem presents similar composition. Thus, the joint solution of both problems considering synchronization is a complex challenge but that can bring a huge social and economic benefit.

We propose a Mixed Integer Program (MIP) model and a metaheuristic method to solve this synchronized rostering and routing problem. Through experiments, we show the effectiveness of our approach and the benefits of this integration proposal.

Keywords: Home Health Care, Social Care, Scheduling and Routing, Combinatorial Optimization

*Speaker
†Corresponding author: jesica.dearmas@upf.edu

Robust Crew Recovery in Air Transportation: Reserve-Crew Scheduling to Mitigate Risks

Evrim Ursavas * [1]

[1] Department of Operations, Faculty of Economics and Business, University of Groningen – Netherlands

Due to a significant growth in air traffic, airports are becoming increasingly congested. Consequently, efficient and effective disruption management is becoming more crucial for hub-and-spoke airlines. The airline's capability to deal with inevitable disruptions such as crew absenteeism and sudden aircraft unavailability depends predominantly on the flexibility of an airline's (reserve) crew schedule. We hereby study a novel airline crew recovery problem in which regular and reserve-crew schedules are jointly determined in a robust way. Besides repairing a disrupted schedule in a cost-efficient way, flexibility is maintained in order to cope with additional future disruptions. The flexibility in reserve crew usage is explicitly considered through evaluating the expected shortfall of an airline's underlying reserve crew schedule based on a Markov chain formulation. We propose a set-covering formulation for, the Robust Crew Recovery Problem (RCRP), which encapsulates this flexibility notion for reserve crew usage. A tailored branch-and-price algorithm is developed for solving the problem to optimality where the pricing problems are solved by a pulse algorithm. Experiments on real-life data from a medium-sized Dutch carrier show that the RCRP outperforms traditional recovery models in delivering a more stable schedule for the day of execution, which leads to a reduced amount of last-minute crew alterations (and subsequent delays) and even a reduced amount of cancellations due to lack of crew. This is especially important for a carrier operating in a hub-and-spoke network, in which the reserve crew members are located at the main hub from which the aircraft rotations are departing.

Keywords: Airline Operations, Disruption Management, Branch, and, Price Algorithm, Reserve Crew, Robust

*Speaker

Managing stochastic supply and demand in an inventory routing problem

Aldair Alvarez *† [1], Jean-François Cordeau [2], Raf Jans [2], Pedro Munari [3], Reinaldo Morabito [3]

[1] Federal University of São Carlos – Brazil
[2] HEC Montréal – Canada
[3] Federal University of São Carlos – Brazil

In this work, we address a stochastic inventory routing problem under supply and demand uncertainty. In this problem, a supplier must simultaneously determine the visit schedule, the replenishment quantities, and the vehicle routes to perform those deliveries while taking uncertainty into consideration and minimizing the total cost of the system. We consider the problem with a single product in a discrete and finite multi-period planning horizon, where the distribution network consists of a single supplier and multiple customers. We introduce several two-stage stochastic programming formulations for different recourse actions, such as lost sales, backlogging, and extra supply under a capacity reservation contract setting. In the first case, the supplier incurs a lost sales penalty each time a customer demand is not fully satisfied. In the second case, we allow demand backlogging, which permits the supplier to recover from previous failures. Finally, in the capacity reservation setting the supplier can contract a supplementary external provider such that any amount of a reserved capacity is ready when required. To solve this problem, we present a branch-and-cut algorithm as well as a hybrid method based on the combination of the progressive hedging method and an iterated local search metaheuristic. We perform extensive computational experiments to provide managerial insights into the behavior of the solutions provided by the formulations under different conditions. We also show that our hybrid method is able to provide good feasible solutions within reasonably running times.

Keywords: inventory routing, stochastic supply, stochastic demand, mathematical formulation, hybrid method.

*Speaker
†Corresponding author: aldair@dep.ufscar.br

Solution Approaches for the Consistent Stochastic Inventory Routing Problem

Emilio Jose Alarcon Ortega * [1], Karl Doerner [1]

[1] University of Vienna – Vienna, Austria

In the last decades, companies developed a growing interest in dealing with problems that occur in different levels of the supply chain. Among all research directions within the supply chain, the Inventory Routing Problem (IRP) is recently one of the most studied in the literature. In this paper, we present an IRP that aims to minimize the total cost of elaborating efficient replenishment and delivery plans considering several characteristics. We introduce the Consistent Stochastic Inventory Routing Problem with Time Windows (CSIRPTW). Each period over a finite planning horizon, customers face a stochastic demand given by a probability distribution. Moreover demands present continuous consumption rates within the periods that, in the later, create the possibility of incurring in stock out situations within the periods. Customers can also demand consistency in delivery times in order to anticipate the deliveries and present different time windows related to opening times. After formulating the CSIRPTW we propose three different solution approaches for the problem. The first solution approach consist on a matheuristic solution approach that integrates an ALNS with a Sample Average Estimator, in order to evaluate the efficiency of the algorithm. The second solution approach is an adaptation of the Branch-and-Regret heuristic for stochastic and dynamic vehicle routing problems. The last method is a multiple scenario approach that evaluates different demand realizations and creates efficient routes to minimize average costs. In the last step, we present computational comparisons between the proposed methods and managerial insights using an adapted benchmark set of instances.

Keywords: IRP, Time Windows, Consistency, Stochastic

*Speaker

Sequential approaches to solve a multi-commodity transportation planning problem

Wenjuan Gu *† [1], Claudia Archetti [2], Diego Cattaruzza [1], Maxime Ogier [1], Frederic Semet [1], M. Grazia Speranza [2]

[1] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) – Ecole Centrale de Lille – Cité Scientifique - CS 20048 59651 Villeneuve d'Ascq cedex, France

[2] Department of Economics and Management - University of Brescia (DEM) – Contrada S. Chiara 50 - 25122 - Brescia, Italy

We address a transportation planning problem with three sets of stakeholders: suppliers, distribution centers and customers. Different commodities have to be sent from suppliers to customers, using multiple distribution centers for consolidation.
Commodities are compatible and can be mixed inside the vehicles as long as the vehicle capacity is respected. Multiple visits to a customer are allowed to reduce transportation costs. However, a single commodity has to be delivered at once for the convenience of customers.

The operations are as follows: suppliers transport commodities to distribution centers with direct trips, while a fleet of homogeneous vehicles distributes commodities to customers. The problem concerns both collection and delivery operations. However, the objective is to optimize these two operations jointly. Note that collection decisions (which quantity of each commodity is delivered to which center) impact delivery operations. Thus, collection and delivery must be determined jointly.

In order to solve the whole problem, we consider two sequential solution approaches: first collection then delivery or first delivery then collection. In both cases, the solution of the first subproblem determines the quantity of each commodity that is required at each distribution center. The second subproblem takes this information and deals with delivery or collection accordingly. To solve the first subproblem, we propose several strategies in order to take into account the impact on the second subproblem.
A case study on a fresh local vegetable supply chain is studied. Results will be presented and analyzed for two types of clients: school catering and supermarkets.

*Speaker

†Corresponding author: wenjuan.gu@inria.fr

Keywords: multicommodity, routing problem, collection, delivery, supply chain, sequential solving

A branch-price-and-cut algorithm for the inventory routing problem with time windows

Gizem Ozbaygin [1], Esra Koca * [2], Hande Yaman [3]

[1] Faculty of Engineering and Natural Sciences, Sabanci University – Istanbul, Turkey
[2] Faculty of Engineering and Natural Sciences, Sabanci University – Istanbul, Turkey
[3] Faculty of Economics and Business, KU Leuven – Leuven, Belgium

The inventory routing problem is an integrated inventory and transportation planning problem that jointly determines the replenishment plans of the retailers and routing decisions of the supplier. Although the supplier is the central decision maker in such a system, the retailer should have some power on manipulating the delivery times in practice (consider, e.g., the food distribution of the companies to the supermarket chains). With this motivation, we study the inventory routing problem with time windows where the retailers can be visited only within specific time intervals. We develop a mathematical model involving both arc and route-based variables. Since the number of routes and the number of capacity constraints in our model are exponentially many, we employ column and cut generation to solve the LP relaxation at each node of the branch-and-bound tree, i.e., we propose and devise a branch-price-and-cut algorithm to solve the problem. To improve our formulation, we use some valid inequalities originally derived for the lot sizing problem. We also adopt several techniques to enhance the performance of our algorithm such as heuristic pricing, early pruning, and hierarchical branching. We generate a set of test problems based on the well-known Solomon benchmark instances, and perform computational experiments to evaluate the benefits of our algorithmic enhancements as well as to provide insights into the effect of various parameter choices on the difficulty of the problem.

Keywords: inventory routing, time windows, branch price and cut

*Speaker

Author Index