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BOOK OF ABSTRACTS

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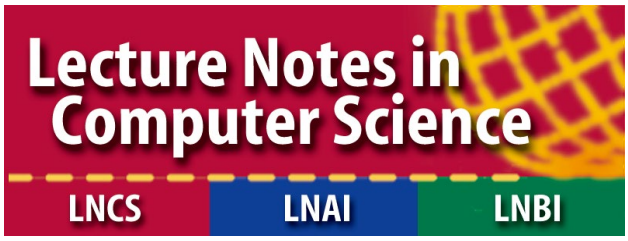

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Mobility

Monday, Sept. 27, 13:30-15:00

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Monday, Sept. 27, 13:30-15:00; Session: Mobility

Smart City: A Perspective of Observations and Scenarios on Advanced Public Transport in Hamburg

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Abstract. Recently, the smart city concept has been drawing research attentions in an increasing manner. Mobility is a central aspect in smart cities and an indicator of the progress of such cities (Shi et al., 2020) both in the scenario of business-as-it-is, in the scenario of emergency and in the scenario of deploying future technologies. Many cities around the world are now enacting no-driving zones for eliminating the negative impact of pollutants from motor vehicles. In addition to that, urban areas are modified to become more efficient, more connected and more environment-friendly applying advanced technologies.

An important component of mobility is local public transport, which is often operated in cities by public transport associations. Through extensive networking among all transport service actors (public ones, private ones, and public-private partnerships) in the ecosystem, public transport-related activities are expected to be communicated with precision timing in the overall smart city concept.

Based on that, a growth scenario needs to be further investigated, i.e., more people might be willing to use public transportation given effective policy measures in the field of public transport. In order to further motivate the willingness of using public transport service and increase demands accordingly, it is necessary to deploy advanced technological implementations, such as digital offerings, dynamic routing, and ticketing, among others.

In this research, based on customer surveys organized within the case of the city of Hamburg, Germany, a feasibility analysis on various scenarios is carried out to determine the current critical

issues. Central aspects include, but are not limited to, 1) views of society, 2) industry, and 3) logistical feasibility. In the case of Hamburg, several bus lines, Line 5, Line 143 and Line 149 are used to collect feedbacks on the designed customer surveys. It needs to be noted that the goal of the feasibility analysis is to demonstrate to what extent these three components have impacts on each other and to which extent they can be realized.
Last but not least, this research would also contribute to the perspective of cargo logistics in the smart city, though this perspective is not yet the focus of this paper and related integration is also judged as controversial. Such a contribution mainly relies on the fact that public transport interacts with cargo logistics through infrastructure investment and network sharing (Shi and Vanelslander, 2010). On the one hand, in order to build up a base to further investigate the mentioned interaction, we need to better understand the residents'/passengers' viewpoints. On the other hand, the operational planning of the associated vehicles including driverless shuttles in a specific area, i.e. the Hafen City area (Halleerback et al, 2018), regular bus services, bus repair and maintenance services are similar with the classical cargo logistics problem, too. While surveys are conducted and related results are presented, we imply future research directions, indicating to which extent an integration is reasonable and possibly accepted.

Keywords: Smart City, Public Transport, Feasibility Analysis, Customer Surveys

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Analysis of Schedules for Rural First- and Last-Mile Microtransit Services

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Abstract. Low and infrequent demand in rural areas poses a problem for public transport providers to run cost-effective services and individual car use is usually the main means of transportation. We investigate how microtransit services can be integrated with existing public transport solutions (bus, train) as a flexible shared mobility alternative in rural areas and how to make them attractive alternatives to individual car use. We combine large neighborhood search with agent-based modeling and simulation to validate generated schedules for a microtransit service in terms of vulnerability to tardiness in passenger behavior or service provision. This includes the study of how disturbances, such as delays in service provision or late arrivals of passengers affect the stability of a transport schedule concerning a reliable timely delivery to transfer stops. We explore how simulation can be utilized as a means to fine-tune provider policies, e.g., how long vehicles may wait for late passengers before they depart.

Keywords: Mobility, Agent-Based Simulation, Ride-Sharing

Monday, Sept. 27, 13:30-15:00; Session: Mobility

Online Order Dispatching and Vacant Vehicles Rebalancing for the First-Mile Ride-Sharing Problems using Autonomous Vehicles

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Abstract. The first-mile ride-sharing problem (FMRSP), which refers to the design of ride-sharing transport services for passengers to reach their nearby transit station, has attracted growing attention recently.
In our problem setting, we have a set of customers, a set of vehicles and one station, which is the destination of all the customers. The problem consists of dispatching and rebalancing the available fleet simultaneously. Order dispatching decisions assign customers to vehicles in order for them to reach the station within their desired arrival time. Rebalancing decisions assign vehicles to selected locations in order to prepare for future customer requests. We propose an online optimization process, which means that we divide the operating hours into small planning periods and re-optimize dispatching and rebalancing decisions for each planning period in light of updated information, such as customer requests and vehicle positions. We formulate the re-optimization problem for each planning period using a Mixed-Integer Linear Programming model. The model ensures that customers that had already been accepted during a previous re-optimization, but have not yet been picked up, will be assigned to a vehicle. On the other hand, the model may reject new customer requests incurring a corresponding penalty. Finally, the model optimizes the dispatch of empty vehicles to rebalancing centers. We assess different methods to generate rebalancing locations based on historical data as well as different ways of rewarding rebalancing activities. The efficiency of the model and the result of different rebalancing

strategies are evaluated in a simulation process. Extensive numerical experiments are conducted to analyze the efficiency of the model as well as compare different methods for obtaining rebalancing points and rewarding rebalancing activities.
In conclusion, in this talk we discuss a new MILP model to optimize the order dispatching and vacant vehicle rebalancing process in a first-mile ride-sharing problem. The model, and different rebalancing strategies are extensively tested in a simulation experiment based on real-world data.

Keywords: Online Optimization, First-Mile, Ride-Sharing, Order Dispatching, Rebalancing Autonomous Vehicles

Allocation

Monday, Sept. 27, 13:30-15:00

1 **A Branch-and-Cut Algorithm for Aircraft Routing with Crew Assignment for On-Demand Air Transportation** · *Rafael Campos, Thiago Vieira, Pedro Munari*

2 **Branch-and-Price-and-Cut Algorithm for the Capacitated Single Allocation Hub Location Routing Problem** · *Yuehui Wu, Ali Gul Qureshi, Tadashi Yamada*

3 **Vaccine Allocation to Prioritize the Vulnerable Population in Mexico** · *Linda Martinez-Fantini, Fabiola Regis-Hernandez*

Monday, Sept. 27, 13:30-15:00; Session: Allocation

A Branch-and-Cut Algorithm for Aircraft Routing with Crew Assignment for On-Demand Air Transportation

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Abstract. We address the aircraft routing problem with crew assignment in the context of on-demand air transportation. This problem involves the design of least-cost routes for an aircraft set in order to service private flight requests, considering the customer preferences, fleet characteristics and maintenance events. Additionally, a crew team has to be assigned to each route while satisfying the crew legislation, including duty time limitations and minimum rest times. Despite its practical relevance, integrated aircraft routing and crew assignment has been barely explored in the literature addressing on-demand air transportation. In this paper, we propose a tailored branch-and-cut algorithm to effectively solve the addressed problem, which resorts to a strategy based on dynamic programming to separate cuts that guarantee the feasibility regarding crew legislation. In computational experiments carried out using real-life data provided by a company, the method obtained optimal solutions for all instances in less than five minutes. Moreover, these solutions indicate a potential improvement of around 23% in the operational cost when compared to the routes designed by the company, which highlights the benefits of using the proposed approach in practice.

Keywords: Aircraft Routing, Crew Assignment, On-Demand Air Transportation

Monday, Sept. 27, 13:30-15:00; Session: Allocation

Branch-and-Price-and-Cut Algorithm for the Capacitated Single Allocation Hub Location Routing Problem

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Abstract. Hub-and-spoke networks are employed in various many-to-many network systems, such as airline systems and postal service systems. When applied to less-than-truckload (LTT) systems, direct connections between hubs and non-hub nodes are often replaced by local tours for the sake of a lower operating cost. In this situation, the number and location of hubs, the allocation between non-hub nodes and hubs, and the visiting sequence of local tours should be decided jointly, resulting in a hub location routing problem (HLRP, Karimi (2018)).

In this study, we focus on a variant of HLRP for the design of an intra-city express system, where parcel flows are collected at origin branch offices, routed via capacitated hubs, and distributed at destination branch offices. Local tours, operated by a fleet of capacitated vehicles, are designed to collect and distribute flows at branch offices, through which collection and distribution processes are handled simultaneously. Each branch office should be served by exactly one local tour, while each local tour can serve multiple branch offices. With these considerations, the problem is named as single-allocation hub location routing problem (CSAHLRP). To our best knowledge, CSAHLRP has never been solved to optimality, and therefore, we propose a branch-and-price-and-cut algorithm to exactly solve this problem for the first time.

We first formulate the problem as a mixed-integer programming problem and then decompose the formulation into a master problem (MP) and a pricing subproblem via the column generation technique. The MP is enhanced by some newly introduced valid inequalities as well as by ones adapted from literature. The pricing subproblem is solved by a bidirectional labeling algorithm, which

is accelerated by some acceleration techniques (such as dominance rules and heuristics pricing). Finally, we present the branching strategies to complete the algorithm.
To test the proposed algorithm, we conducted numerical experiments on instances with up to 40 non-hub nodes generated from the Australian Post dataset, and the results were compared with those obtained by CPLEX. A computational time limit of 10800s was imposed on both our algorithm and CPLEX. Outcomes of the computational studies reveal that the proposed algorithm outperforms CPLEX on all the instances in both solution quality and computational time. In fact, the algorithm yielded the optimal solutions for instances with up to 35 non-hub nodes and found high-quality solutions for the remaining instances, whereas the CPLEX could only solve the smallest instances. Also, a sensitivity analysis was conducted to investigate the influence of the unit inter-hub transportation cost on the algorithm, which indicates that the problem becomes harder to handle when the unit inter-hub transportation cost is high.

Keywords: Intra-City Express, Single Allocation Hub, Location Routing Problem, Mixed-Integer Programming, Branch-and-Price-and-Cut

References:

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Monday, Sept. 27, 13:30-15:00; Session: Allocation

Vaccine Allocation to Prioritize the Vulnerable Population in Mexico

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Abstract. The frequency and severity of disasters have increased in the last decade, and forecasts suggest that this trend will continue. Disasters are sudden devastating events that disrupt the functioning of a community causing human, economic or environmental losses that exceed the community's ability to cope with its resources. Disasters are characterized by a high level of complexity, uncertainty, and pressure to save people's lives. One type of recurrent natural disaster throughout history is pandemics, which are massive outbreaks of infectious diseases that rapidly increase morbidity and mortality worldwide. The most recent one started in December 2019 when the novel virus SARS-COV-2 appeared, causing COVID-19 disease. Due to the rapid spread, in January 2020, the World Health Organization declared the outbreak a Public Health Emergency of International Concern. Months later, Mexico ranked among the top 10 countries with the highest number of confirmed cases and within the top 5 in deaths. Due to these indicators, alongside the increased demand for hospitalization, the need for a vaccine became one of the Mexican government's primary concerns.

Moreover, immunization and prior involved activities require complex decision-making, which shall be both efficient and equitable. Therefore, this research focuses on addressing the vaccine allocation problem when these resources are insufficient to cover the entire population. The work proposes a two-phase methodology to prioritize the Mexican entities with higher levels of vulnerability and risk of hospitalization, based on the individual's specific comorbidities. The linear programming model presented aims to minimize the non-vaccinated vulnerable population's risk of exposure to the virus. The case study considers

the 32 Mexican entities. Their population density is considered a risk factor that helps to prioritize the population to assign the vaccines. The model integrates a vulnerability index per entity obtained through data analytics of a Mexican open database and considers a two-dose vaccination program with a monthly time horizon. The problem is solved in Gurobi Optimizer commercial software, which provides a solution in 0.07 secs. The results showed that the first vaccine lots are assigned to Mexico City, the entity with the highest risk of exposure. The results reveal that by immunizing the population with a two-dose vaccination program, after 6 months, 65% of the population can reduce the risk of hospitalization by having the first dose.

Keywords: Data Analytic, Vulnerability, Risk, Equity, Optimization

Data-Driven Maritime Operations

Monday, Sept. 27, 13:30-15:00

1 **Simulation of an AIS System for the Port of Hamburg** · *Pierre Bouchard, Adriana Moros Daza, Stefan Voß*

2 **Destination Prediction of Oil Tankers Using Graph Abstractions and Recurrent Neural Networks** · *Búgvi Benjamin Magnussen, Nikolaj Bläser, Rune Møller Jensen, Kenneth Ylänen*

3 **Predictive Inland Waterway Transportation Using Machine Learning and RIS Data** · *Peter Wenzel, Rudy Negenborn, Frederik Schulte*

Monday, Sept. 27, 13:30-15:00; Session: Data-Driven Maritime Operations

Simulation of an AIS System for the Port of Hamburg

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Abstract. This paper shows that the prediction of vessel arrival times with AIS (Automatic Identification System) is increasing the number of vessels a port can handle without additional superstructure. The Port of Hamburg is used as a case study to show the difference between the as-is situation and one with the integrated information system. The simulation shows improvements with two different risk levels to prove the concept. The simulation uses simplified versions of an algorithm that assigns vessels to free berths without disrupting the normal terminal usage. It was possible to clear up to 44% more ships each day just with an additional system that utilises already existing data for achieving more efficiency within the port.

Keywords: Smart Port, AIS, Berth Allocation

Monday, Sept. 27, 13:30-15:00; Session: Data-Driven Maritime Operations

Destination Prediction of Oil Tankers Using Graph Abstractions and Recurrent Neural Networks

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Abstract. Predicting the destination of vessels in the maritime industry is a problem that has seen sustained research over the last few years fuelled by an increase in the availability of Automatic Identification System (AIS) data. The problem is inherently difficult due to the nature of the maritime domain. In this paper, we focus on a subset of the maritime industry - the oil transportation business - which complicates the problem of destination prediction further, as the oil transportation market is highly dynamic. We propose a novel model, inspired by research on destination prediction and anomaly detection, for predicting the destination port- and region of oil tankers. In particular, our approach utilises a graph abstraction for aggregation of global oil tanker traffic and feature engineering, and Recurrent Neural Network models for the final port- or region destination prediction. Our experiments show promising results with the final model obtaining an accuracy score of 41% and 87.1% on a destination port- and region basis, respectively. While some related works obtain higher accuracy results - notably 97% of port destination prediction accuracy - the results are not directly comparable, as no related literature found deals with the problem of predicting oil tanker destinations on a global scale specifically.

Keywords: Oil Tankers, AIS, Destination Prediction, Graph Abstraction, Recurrent Neural Networks

Predictive Inland Waterway Transportation Using Machine Learning and RIS Data

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Abstract. With data availability in the European River Information System (RIS), the authors propose a new approach towards predictive Inland Waterway Transportation (IWT). Predictive IWT addresses the main challenges of waterborne transportation, such as unreliability and unexpected waiting times, by proposing novel traffic prediction methods as already applied on the roads. Prediction methods have changed from classical statistical approaches to machine learning methods. Researchers have developed classical models when traffic systems were less complex and fewer big data sets were available. Due to the development of computational power and the availability of data volume, the more recent work focuses on machine learning methods for traffic forecasting (Cui et al., 2020).

In this work, we analyse the data structure of the European RIS the potential usage of upcoming machine learning techniques. We propose to adopt the concept of Spatio-Temporal Graph Neural Network (STGNN) for IWT. The presented STGNN can predict the Estimated Times of Arrival (ETA) and suggest alternative routes.

Initial computational results show that predictive IWT can significantly improve short-term, mid-term, and long-term planning for skippers, ports, and authorities. The proposed methods can be implemented in existing software for short-term navigation, inland waterway planning or strategic waterway infrastructure. The proposed machine learning techniques offer reliable and fast results for practical planning scenarios. Potential limitations may occur regarding data privacy and the quality of calculation methods for route and traffic flow predictions. Predictions will help to increase the acceptance of IWT in

comparison to other transportation modes. More acceptance may lead to more freight and, therefore, will strengthen the saving of emissions.

Keywords: Inland Waterway Transportation(IWT), Predictive Planning, Machine Learning, Graph Neural Networks, River Information Systems (RIS), Automatic Identification System(AIS), AIS Data

Plenary Talk I:

Recent and Future Developments in Supply Chain Coordination

Prof. Iris Vis

Abstract. Logistics networks evolve more and more towards fully open and connected physical internet networks. Developments as the sharing economy, platform technology, and self-organizing concepts start to play a role in supply chains. In this presentation, the vision of the Physical Internet (PI) will be introduced in more detail and new interdisciplinary research ideas will be discussed.
In the second part of the presentation, several scientific insights will be shared related to various research projects on the concept of the physical internet. Specifically, results will be presented from the NWO/TKI Dinalog project 'Towards Virtual Ports in a Physical Internet' that aimed to develop models and tools to support ports and businesses in hinterland networks in their decision making related to participation in PI networks.

Ride Sharing

Monday, Sept. 27, 16:30-18:00

1 **The Share-A-Ride Problem with Integrated Routing and Design Decisions: The Case of Mixed-Purpose Shared Autonomous Vehicles** · *Max van der Tholen, Breno Beirigo, Jovana Jovanova, Frederik Schulte*

2 **Real-Time Dispatching with Local Search Improvement for Dynamic Ride-Sharing** · *Martin Pouls, Katharina Glock, Anne Meyer*

3 **Algorithms for the Design of Round-trip Carsharing Systems with a Heterogeneous Fleet** · *Pieter Smet, Emmanouil Thanos, Federico Mosquera, Toni Ismael Wickert*

The Share-A-Ride Problem with Integrated Routing and Design Decisions: The Case of Mixed-Purpose Shared Autonomous Vehicles

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Abstract. The shared autonomous vehicle (SAV) is a new concept that meets the upcoming trends of autonomous driving and changing demands in urban transportation. SAVs can carry passengers and parcels simultaneously, making use of dedicated passenger and parcel modules on board. A fleet of SAVs could partly take over private transport, taxi, and last-mile delivery services. A reduced fleet size compared to conventional transportation modes would lead to less traffic congestion in urban centres. This paper presents a method to estimate the optimal capacity for the passenger and parcel compartments of SAVs. The problem is presented as a vehicle routing problem and is named variable capacity share-a-ride problem (VCSARP). The model has a MILP formulation and is solved using a commercial solver. It seeks to create the optimal routing schedule between a randomly generated set of pick-up and drop-off requests of passengers and parcels. The objective function aims to minimize the total energy costs of each schedule, which is a trade-off between traveled distance and vehicle capacity. Different scenarios are composed by altering parameters, representing travel demand at different

times of the day. The model results show the optimized cost of each simulation along with associated routes and vehicle capacities.

Keywords: Shared Autonomous Vehicles, Share-a-Ride Problem, Design Decisions, Capacity Optimization, Vehicle Routing Problem

Real-Time Dispatching with Local Search Improvement for Dynamic Ride-Sharing

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Abstract. Dynamic ride-sharing services such as UberPool or MOIA are becoming increasingly popular as they offer a cheap and flexible mode of transportation and reduce traffic compared to traditional taxi and ride-hailing services. One key optimization problem when operating ride-sharing services is the assignment of trip requests to vehicles to maximize the service rate while minimizing operational costs. In this work, we propose a real-time dispatching algorithm capable of quickly processing incoming trip requests. This dispatching algorithm is combined with a local search that aims to improve the current routing plan. Both algorithms are embedded into a planning and simulation framework for dynamic ride-sharing and evaluated through simulation studies on real-world datasets from Hamburg, New York City, and Chengdu. The results show that the local search improvement phase can improve the request acceptance rate as well as vehicle travel times. We achieve an average reduction of the request rejection rate by 1.62 percentage points and a decrease in vehicle travel time per served request of 6.5 %. We also study the influence of pre-booked rides and show that the local search yields even larger benefits when part of the trip requests are known in advance.

Keywords: Vehicle Routing, Ride-sharing, Dial-a-Ride-Problem

Monday, Sept. 27, 16:30-18:00, Session: Ride Sharing

Algorithms for the Design of Round-Trip Carsharing Systems with a Heterogeneous Fleet

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Abstract. Carsharing has become a viable mode of transport which not only contributes to improving the environment and traffic congestion, but is often also cheaper for its users. It is a challenging task for carsharing providers to design an effective system which meets user demand while at the same time limiting expenses. This paper introduces an integer programming formulation and a simulated annealing metaheuristic to optimize the location of vehicles for round-trip systems with a heterogeneous fleet. An extensive computational study is carried out to understand the impact of fleet heterogeneity, request generality and the number of possible vehicle locations on the algorithms' performance. Problem instances derived from a case study are shown to be edge cases in terms of fleet heterogeneity and request generality, for which the proposed integer programming formulation performs exceptionally well. Finally, solutions of the case study are analyzed to demonstrate the effect of spatial flexibility on the system's costs.

Keywords: Carsharing, Vehicle Location, Integer Programming, Simulated Annealing

Supply Chain Management

Monday, Sept. 27, 16:30-18:00

1 **Smarter Relationships? The Present and Future Scope of AI Application in Buyer-Supplier Relationships** · *Anna-Maria Nitsche, Markus Burger, Julia Arlinghaus, Christian-Andreas Schumann, Bogdan Franczyk*

2 **The Effect of Sparse Data on the Performance of Machine Learning Techniques for Supply Chain Visibility** · *Isabelle M. van Schilt, Jan Kwakkel, Alexander Verbraeck*

3 **An Analysis of an Optimization Model Incorporating Risk into a Stochastic Supply Chain Applied to an Energy System** · *Yajaira Cardona Valdés, Krystel Castillo-Villar, Esteban Andres García Granados*

Monday, Sept. 27, 16:30-18:00, Session: Supply Chain Management

Smarter Relationships? The Present and Future Scope of AI Application in Buyer-Supplier Relationships

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Abstract. The last decade has seen rapid developments in the area of artificial intelligence (AI). While research focuses on technical challenges and enablers of AI, the number of publications examining application approaches at the buyer-supplier interface is increasing. To accelerate the related discussion and to add clarity and richness to this fragmented research field, a systematic overview of the existing comprehensive body of literature is essential. We contribute to the academic debate by applying a combined systematic literature review with a text mining and machine learning-based literature review. Thus, we categorize and cluster different research streams and analyze the application of AI at the buyer-supplier interface. Subsequently, we identify gaps resulting from the comparison of the technology and the application domain and derive the main points of discussion from the literature. As a result, we present ten central questions outlining future requirements and research opportunities in the field of AI application at the buyer-supplier interface.

Keywords: Artificial Intelligence, Machine Learning, Buyer-Supplier Relationship, Literature Review

The Effect of Sparse Data on the Performance of Machine Learning Techniques for Supply Chain Visibility

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Abstract. In recent years, there has been a trend towards increasing supply chain resilience by improving supply chain visibility. Supply chain visibility is the ability of tracking parts, components, or products in transit from supplier to customer through relevant data of stakeholders. Machine learning techniques are often applied to improve supply chain visibility. These techniques are data-hungry and often assume availability of big data with high quality. A supply chain consists of three main flows of which relevant data may be collected, namely the goods flow, the information flow, and the financial flow. More specifically, time-based data of each flow is considered. For example, arrival times of the goods, inventory levels, orders, and money transfers.

However, data about supply chain functioning is often sparse. Actors within a supply chain are reluctant to share (correct) data for various reasons such as competitive position, high costs of data solutions, or because of illegal behavior in case of criminal supply chains. There is little insight into the effect of sparse data on the performance of machine learning techniques for supply chain visibility.

Therefore, this research compares the performance of various machine learning techniques for enhancing supply chain visibility given increasing degree of data sparseness, such as Bayesian inference, genetic algorithms, and data assimilation. To test these techniques, we use a simulation model of a stylized supply chain as ground truth. We extract data from this model, systematically increase the degree of sparseness of this data, and assess the extent to which the various machine learning techniques can still reconstruct the underlying supply chain. We find that most

machine learning techniques do not perform well under a high degree of data sparseness. Approximate Bayesian Computation seems to be one of the most promising techniques for enhancing supply chain visibility with sparse data.

Keywords: Supply Chain Visibility, Machine Learning, Sparse Data Simulati

An Analysis of an Optimization Model Incorporating Risk into a Stochastic Supply Chain Applied to an Energy System

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Abstract. Decision makers should consider the multiple sources of uncertainties when designing and planning a supply chain network. Particularly, for location-allocation problems, two-stage stochastic programming has been a powerful technique to address such problems (Birge and Louveaux 2011; however, this technique is risk-neutral since it considers only the expected cost or profit in the objective function. Ahmed (2006) as well as Ruszczyński and Shapiro (2006) studied risk-neutral approaches and point out some inefficiencies in those approaches when just expectation is considered in the objective function. To overcome this, the incorporation of the Conditional Value-at-Risk (CVaR) is an effective and well-behaved risk measure that provides more robust solutions compared with risk-neutral approaches. Filippi et al. (2020) presents the general concept of CVaR and its application in optimization modelling including several applications different from financial optimization, such as supply chain management, scheduling, networks, energy, and healthcare.

In this work, we present a supply chain network design to produce biofuel, which incorporates biomass quality uncertainties and risk aversion using an approach that reformulates the two-stage stochastic programming problem with the CVaR measure on the total cost as a large scale linear programming problem, named mean-CVaR model where the mean risk function is minimized (Schultz and Tiedemann 2004, Noyan 2012, Soleimani and Govindan 2014, and Rahimi et al. 2019).

The problem consists of a two-echelon supply chain that considers suppliers and biorefineries. The suppliers provide switchgrass as

raw material, which is used to produce biofuel at the biorefineries. The switchgrass exhibits key uncertain characteristics (moisture and ash contents) that affect the conversion process from biomass to biofuel. These biomass quality characteristics vary by county and type of biomass. We consider that the moisture affects the quantity of switchgrass provided by suppliers (by using humid instead of dry tons), so this quantity is also uncertain. The uncertainty will be modeled through a set of scenarios. At biorefineries, the production capacity is known, also the total biofuel demand is known.

In the two-stage stochastic problem, the first stage decision variables (independent scenario variables) consist in deciding between a set of potential locations which biorefineries to open, their capacity size and the biomass conversion technology to be installed. The second stage decision variables (dependent of scenario variables) consist in determining for each scenario the biomass quantity that will be sent from suppliers to biorefineries (wet biomass), and the biomass quantity before preprocessing (dry biomass). The mean risk function to be minimized measures the trade-off between the expected cost (investment and logistic costs) and the CVaR. This trade-off is controlled by the parameter λ that is a non-negative coefficient representing the exchange rate of mean cost for risk ($\lambda \geq 0$). The level of risk aversion is controlled by the parameter α that represents the confidence level ($0 \leq \alpha \leq 1$). To do that some variables are added to the formulation, the Value-at-Risk (VaR) variables and those variables that measure the positive difference between the cost of each scenario and VaR, these variables are minimized in the CVaR objective function depending on α.

The modeling approach is tested and exemplified using a realistic case study of the Texas State USA of a biofuel supply chain network. By varying the two parameters in the mean risk function we analyze their effect on the two measures involved in the objective function and make observations ofthe tactical and strategical decisions taken within the supply chain by considering the biomass quality variability and the risk of investment.

Keywords: Risk-Averse, Supply Chain Network Design, Conditional Value-at-Risk, Stochastic Optimization

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Seaside Logistics

Monday, Sept. 27, 16:30-18:00

1 **An Integrated Planning, Scheduling, Yard Allocation and Berth Allocation Problem in Bulk Ports: Model and Heuristics** · *João Luiz Marques de Andrade, Gustavo Campos*

2 **The Multi-Port Berth Allocation Problem with Speed Optimization: Exact Methods and a Cooperative Game Analysis** · *Bernardo Martin-Iradi, Dario Pacino, Stefan Ropke*

3 **A Collaborative Berth Planning Model in Response to Disruptions** · *Xiaohuan Lyu, Frederik Schulte*

Monday, Sept. 27, 16:30-18:00, Session: Seaside Logistics

An Integrated Planning, Scheduling, Yard Allocation and Berth Allocation Problem in Bulk Ports: Model and Heuristics

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Abstract. Integrating operational and logistic processes is fundamental to ensure a port terminal's efficient and productive operation. This article deals with the integration of planning, scheduling, yard allocation, and berth allocation in dry bulk export port terminals. The integrated problem consists of planning and sequencing the flow of products between arrival at the terminal and the berths, allocating the products to the storage yards, and determining the sequence, berthing time, and position of each vessel. A mixed-integer linear programming formulation is proposed, connecting the problems and incorporating tidal time windows and non-preemptive scheduling. To solve the integrated problem more efficiently, we developed an algorithm based on a combination of a diving heuristic with limited backtracking, two relax-and-fix heuristics, a local branching heuristic, a rolling horizon heuristic, and a variable-fixing strategy. The mathematical formulation and proposed algorithm are tested and validated with large-scale instances. The computational results show that the proposed algorithm is effective in finding strong upper bounds.

Keywords: Integrated Planning, Scheduling, Berth Allocation, Yard Allocation, Matheuristics

Monday, Sept. 27, 16:30-18:00, Session: Seaside Logistics

The Multi-Port Berth Allocation Problem with Speed Optimization: Exact Methods and a Cooperative Game Analysis

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Abstract. The total shipping's CO2 emissions have increased by 9.6% in the period 2012-2018. Yet, world maritime trade keeps growing at an annual average of 3%. Given this trend, the need for more efficient and sustainable operations in maritime transport logistics is essential. One of the most critical operations in container terminal logistics is the berth allocation, which is formulated mathematically as the berth allocation problem and aims at assigning incoming ships to berthing positions along the terminal's quay.

In this presentation, we consider a variant of the berth allocation problem—i.e., the multi-port berth allocation problem—that extends the berth allocation problem to cover multiple container terminals simultaneously. This variant involves optimizing vessel travel speeds between multiple ports, thereby exploiting the potentials of a collaboration between carriers (shipping lines) and terminal operators. The objective of the problem aims at minimizing the operational costs of both carriers and terminal operators.

Using a graph representation of the problem, we reformulate an existing mixed-integer problem into a generalized set partitioning problem, in which each variable refers to a sequence of feasible berths in the ports that the vessel visits.

We integrate column generation and cut separation in a branch-and-cut-and-price procedure, and compare it with a commercial solver in a set of 34 benchmark instances and a set of 16 self-generated larger instances. Within 5.5 minutes, our proposed method achieves an average optimality gap of 0.03% across all 50 instances compared to a 1.87% gap achieved by the commercial solver. This gap is further reduced to less than 0.01% within 3.3

hours for our method compared to a gap of 1.33% for the commercial solver. The tight bound achieved at the root node allows our method to find optimal and sub-optimal solutions for all instances in short computational times.
In addition, we apply two cooperative game theory methods, the Shapley value and the equal profit method, to efficiently distribute the savings resulting from a potential collaboration and show that both carriers and terminal operators would benefit from collaborating. The results of the cooperative game show that all instances have a non-empty core and all players achieve significant savings with both methods. With the Shapley value, carriers and terminal operators achieve 1.5-3.1% and 5.8-14.1% in average relative savings, respectively. With the equal profit method, carriers and terminal operators achieve 3.1-4.4% and 3.2-4.4% in average relative savings, respectively.

Keywords: Freight Transportation, Maritime Logistics, Exact Methods, Container Terminal, Berth Allocation Problem, Speed Optimization, Cooperative Game Theory

Monday, Sept. 27, 16:30-18:00, Session: Seaside Logistics

A Collaborative Berth Planning Model in Response to Disruptions

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Abstract. Berths and quay cranes are both scarce resources and their capacity limits the efficiency of port operations. Generally, terminal operators form a weekly berthing plan before the calling of vessels. This plan involves when and where to load or discharge containers for the calling vessels. However, disruption incurred by unforeseen events impedes the implementation of the initial plan, for example, arrival delays, equipment breakdowns, tides, or extreme weather. Thus, uncertainties cannot be ignored, and a well-functioning berthing plan should incorporate both efficiency and resilience [1].

Researchers deal with uncertainties in two main perspectives, namely proactive and reactive. This paper studies reactive strategies that aim to make quick and effective responses to disruptions. Looking through the literature on reactive strategies, researchers tend to prioritize larger vessels in response to disturbances [2], but they ignore the implied transhipment connections between vessels. Containers that are unloaded from one vessel and then loaded on another vessel may delay the transhipment because of the uncoordinated berth planning. Moreover, during major disruptions, some calling vessels have to wait a long time until the berths and quay cranes are idle. One way for reducing the waiting time is to ally different terminals to share berthing resources by allowing the calling vessels to transfer to other terminals, and it is a win-win strategy for both collaborative terminals [3].

The berth allocation problem is an NP-hard problem, so researchers generally apply heuristics to find acceptable solutions. We devise the Squeaky Wheel Optimization heuristic to find solutions for large-scale problems, and then we conduct

computational experiments to show that the proposed model functions well in obtaining a trade-off between service level and service cost for the disrupted terminals. To sum up, the main contribution of this study is (1) proposing the reactive berth allocation and quay crane assignment problem, which considers both transhipment connections between vessels and the collaboration among terminals; (2) formulating a Mixed-Integer Linear Programming (MILP) model for the proposed problem; (3) developing an efficient and effective SWO-based heuristic to solve large-scale problems; (4) supporting terminal operators to better respond to disruptions.

Keywords: Collaborative Berth Panning, Berth Planning, Disruptions, Mixed-Integer Program, Metaheuristic

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Drone-Assisted Transport

Tuesday, Sept. 28, 10:30-12:30

1 **Exact Separation Algorithms for the Parallel Drone Scheduling Traveling Salesman Problem** · *Tobias Klein, Peter Becker*

2 **A VNS Algorithm for the TSP-D with Energy Constraints** · *Giovanni Campuzano, Eduardo Lalla-Ruiz, Martijn Mes*

3 **Last-Mile Relief Distribution with Trucks and Drones under Uncertainty** · *Robert van Steenbergen, Martijn Mes*

Exact Separation Algorithms for the Parallel Drone Scheduling Traveling Salesman Problem

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Abstract. The joint delivery of parcels by trucks and drones is a futuristic scenario that already started. As a result of this development, new optimization problems are defined and studied. In this paper, exact separation algorithms for the Parallel Drone Scheduling Traveling Salesman Problem are presented. Known separation algorithms for subtour elimination constraints and 2-matching inequalities are modified and applied to the new context. In addition, a new valid inequality for an invalid drone-truck subtour is given. For this inequality, a simple separation algorithm with a runtime of O(n^2) for n nodes (customers) is presented. It is shown that this problem-specific separation algorithm reduces the total runtime of problem instances more effectively compared to modified TSP approaches, especially for instances with a large number of customers that can be served by a drone. These separation algorithms are used to solve instances with up to 127 customers by a branch-and-cut algorithm.

Keywords: Parallel Drone Scheduling, Traveling Salesman problem, PDSTSP, Branch-and-Cut Separation Algorithm, Integer Programming

A VNS Algorithm for the TSP-D with Energy Constraints

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Abstract. The Traveling Salesman Problem (TSP) is a well-known optimization problem with a wide range of extensions and applications in delivery systems. In this paper, we consider a recent extension of the TSP where a truck in collaboration with a single drone should visit a set of customers while minimizing the transportation times. We propose a Variable Neighbourhood Search (VNS) and a Multi-Start VNS (MS-VNS) algorithm, develop new neighbourhood structures, and compare the solutions against an existing mixed-integer linear programming (MILP) formulation. We take a set of instances based on existing benchmarks from the related literature. Results point out that the new neighbourhood structures substantially improve the performance of the VNS algorithms. Furthermore, results also show that the exact method is only able to find competitive solutions for small sets of instances, whereas our MS-VNS approach reaches better solution quality for large instances.

Keywords: Traveling Salesman Problem, Drones, UAV, Last-Mile delivery, Multi Start, Variable Neighbourhood Search

Last-Mile Relief Distribution with Trucks and Drones under Uncertainty

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Abstract. Logistics applications of Unmanned Aerial Vehicles (UAVs), or drones, have received an increasing amount of interest from both academia and practice, regarding their potential role in same-day deliveries, urban logistics, internal transport and also humanitarian logistics (Otto et al., 2018). Drones have the benefit to deliver goods directly to the required location regardless traffic or infrastructure conditions. Several reviews, among others Otto et al. (2018), present a substantial number of contributions in the field of drone delivery and routing. Authors encourage to develop approaches to deal with data uncertainty, for example aspects as travel times, weather conditions, energy consumption, or customer requests. In the survey of Anuar et al. (2021) about vehicle routing optimisation for humanitarian operations, the authors state that real-world problems demand addressing the dynamic and stochastic elements. They also emphasize that that dynamic and stochastic information can be naturally addressed by modelling them as Markov Decision Processes (MDPs).

In this presentation, we focus on humanitarian logistics using trucks and drones. For the trucks, we incorporate uncertain travel times resulting from the impact of a disaster. We consider a single depot, a fleet of trucks and drones, and a set of locations with a demand for a single-commodity relief good (e.g., food, shelter, or first aid kits). The vehicles deliver independently from each other the relief goods from the depot to the locations in the area. The locations and demand are known beforehand. The disaster impact on the road network is yet uncertain, but can be estimated based on impact expectancy maps. The actual impact of the disaster on the road network becomes known over time. This incoming information on specific travel times between locations can be used to adapt the logistics operations accordingly.

We first model a deterministic version of the problem using a mixed-integer linear programming (MILP) model. This type of model is still applied in the majority of studies on drone deliveries as well as humanitarian logistics. Next, we formulate the problem as an MDP, and propose various heuristic methods to solve it. We benchmark our heuristics by comparing them with the MILP solutions being applied in stochastic environments. This demonstrates the relevance of modelling the problem as a MDP and solving it with a heuristic approach, both regarding the stochastic elements and the computational complexity. For our experiments, consider theoretical problem instances that are adapted from the Solomon instances as well as historical disaster scenarios. By modelling extreme events in these cases, we aim to provide approaches that are valuable for humanitarian logistic practices and research about uncertainty within vehicle routing methods.

Keywords: Vehicle Routing, Drones, Unmanned Aerial Vehicles, Uncertainty, Last Mile, Disaster Response, Humanitarian Logistics

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Inventory and Production

Tuesday, Sept. 28, 10:30-12:30

1 **Production Scheduling with Stock- and Staff-Related Restrictions** · *Carlo S. Sartori, Vinícius Gandra, Hatice Çalik, Pieter Smet*

2 **New Valid Inequalities for a Multi-Echelon Multi-Item Lot-Sizing Problem with Returns and Lost Sales** · *Franco Quezada, Céline Gicquel, Safia Kedad-Sidhoum*

3 **The Craft Beer Game and the Value of Information Sharing** · *Joshua Grassel, Alfred Craig Keller, Alessandro Hill, Frederik Schulte*

4 **Interactive Multi-Objective Optimization in Lot Sizing with Safety Stock and Safety Lead Time** · *Adhe Kania, Juha Sipilä, Bekir Afsar, Kaisa Miettinen*

Production Scheduling with Stock- and Staff-Related Restrictions

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Abstract. Effective production scheduling allows manufacturing companies to be flexible and well-adjusted to varying customer demand. In practice, production scheduling decisions are subject to several complex constraints which emerge from staff working hours and skills, delivery schedules, stock capacities, machine maintenance and machine setup. This paper introduces a novel production scheduling problem based on the real-world case of a manufacturing company in Belgium. Given a set of customer requests which may only be delivered together on one of the provided potential shipment days, the problem is to select a subset of these requests and schedule the production of the required item quantities subject to the aforementioned restrictions. All decisions must be taken for a time horizon of several days, leading to a complex problem where there may not be enough resources to serve all requests. We provide an integer programming formulation of this novel problem which is capable of solving small-scale instances to proven optimality. In order to efficiently solve large-scale instances, we develop a metaheuristic algorithm. A computational study with instances generated from real-world data indicates that the metaheuristic can quickly produce high-quality solutions, even for cases comprising several days, requests and limited stock capacities. We also conduct a sensitivity analysis concerning characteristics of the schedules and instances, the results of which can be exploited to increase production capacity and revenue.

Keywords: Production Scheduling, Stock Levels, Integer Programming, Metaheuristics

New Valid Inequalities for a Multi-Echelon Multi-Item Lot-Sizing Problem with Returns and Lost Sales

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Abstract. This work studies a multi-echelon multi-item lot-sizing problem with remanufacturing and lost sales. The problem is formulated as a mixed-integer linear program. A new family of valid inequalities taking advantage of the problem structure is introduced and used in a customized branch-and-cut algorithm. The provided numerical results show that the proposed algorithm outperforms both the generic branch-and-cut algorithm embedded in a standard-alone mathematical solver and a previously published customized branch-and-cut algorithm.

Keywords: Production Planning, Lot-Sizing, Remanufacturing, Mixed-Integer Linear Programming, Valid Inequalities

The Craft Beer Game and the Value of Information Sharing

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Abstract. The craft beer supply chain in the USA differs from the supply chain of macro breweries in its structure, handled volumes and product shelf-life. In this work, we study how these smaller craft breweries can benefit from transparency in their supply chain. We consider additional information sharing of orders and inventories at downstream nodes. The levels that we investigate grant the brewery incremental access to distributor, wholesaler, and retailer data. We show how this knowledge can be incorporated effectively into the brewery's production planning strategy.

Extending the well-known beer game, we conduct a simulation study using real-world craft beer supply chain parameters and demand. We quantify the impact of information sharing on the craft brewery's sales, spoilage, and beer quality. Our model is designed to directly support the brewery when evaluating the value of downstream information and negotiating data purchases with brokers.

Through a computational analysis, we show that the brewery's benefits increase almost linearly with every downstream node that it gets data from. Full transparency allows to halve the missed beer sales, and beer spoilage can even be reduced by 70% on average.

Keywords: Craft Beer Industry, Supply Chain Management, Information Sharing, Production Planning, Simulation

Interactive Multi-Objective Optimization in Lot Sizing with Safety Stock and Safety Lead Time

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Abstract. In this paper, we integrate a lot sizing problem with the problem of determining optimal values of safety stock and safety lead time. We propose a probability of product availability formula to assess the quality of safety lead time and a multiobjective optimization model as an integrated lot sizing problem. In the proposed model, we optimize six objectives simultaneously: minimizing purchasing cost, ordering cost, holding cost and, at the same time, maximizing cycle service level, probability of product availability and inventory turnover. To present the applicability of the proposed model, we consider a real case study with data from a manufacturing company and apply the interactive NAUTILUS Navigator method to support the decision maker from the company to find his most preferred solution. In this way, we demonstrate how the decision maker navigates without having to trade-off among the conflicting objectives and could find a solution that reflects his preference well.

Keywords: Inventory Management, Uncertain Demand, Uncertain Lead Time, Interactive Decision Making, NAUTILUS Navigator

Container Loading

Tuesday, Sept. 28, 10:30-12:30

1 **Designing a Physical Packing Sequence Algorithm with Static Stability for Pallet Loading Problems in Air Cargo** · *Philipp Gabriel Mazur, No-San Lee, Detlef Schoder, Tabea Janssen*

2 **Vertical Stability Constraints in Combined Vehicle Routing and 3D Container Loading Problem** · *Corinna Krebs, Jan Fabian Ehmke*

3 **Analysis of the Impact of Physical Internet on the Container Loading Problem** · *Ana Rita Ferreira, Galrão Ramos, Elsa Silva*

4 **Models and Methods for the Multi-Drop Container Loading Problem with Soft Unloading Constraints** · *Guillem Bonet Filella, Alessio Trivella, Francesco Corman*

Designing a Physical Packing Sequence Algorithm with Static Stability for Pallet Loading Problems in Air Cargo

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Abstract. Large amounts of airfreight are loaded on pallets and containers for transport every day. Especially in the air cargo sector, fast and efficient pallet loading is crucial for smooth operations. Recently, scholars have proposed AI-optimized solutions for the pallet loading problem that include strongly heterogenous cargo. However, finding packing sequences that determine item loading order, receive scant attention in literature. In this research, we develop a design to solve the physical packing sequence problem that comprises requirements, features, and fitness criteria to equip an algorithm that automatically finds a physical packing sequence for a given cargo arrangement. We derive our algorithm based on previous findings and practical insights from a collaboration with a major cargo carrier. Also, we provide an integration design in combination with optimization heuristics. Our approach is implemented in a prototype, demonstrated, and evaluated on a set of real-world cargo data. Our findings reveal both the ability to find packing sequences in reasonable time and the ability to identify improvement potential with respect to stability.

Keywords: Pallet Loading Problem, Loadability, Physical Packing Sequence, Genetic Algorithm

Vertical Stability Constraints in Combined Vehicle Routing and 3D Container Loading Problems

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Abstract. The vertical stability of the cargo is one of the most important loading constraints, since it ensures parcels from falling to the ground. However, frequently considered constraints either lead to unstable positions, are too restrictive or have a high complexity. This paper focuses on the evaluation of different vertical stability constraints, analyses corner cases and introduces a new improved constraint. For the first time, constraints based on the science of statics are considered in the context of the combined Capacitated Vehicle Routing Problem with Time Windows and 3D Loading (3L-VRPTW).
All constraints are embedded in an established hybrid heuristic approach, where an outer Adaptive Large Neighbourhood Search tackles the routing problem and an inner Deepest-Bottom-Left-Fill algorithm solves the packing problem. For the computational tests, we use a well-known instance set enabling a comparison w.r.t. the number of customers, the number of items and the number of item types. Based on the impact on the objective values and on the performance, we give recommendations for future work.

Keywords: Vehicle Routing Problem, 3D Loading, Vertical Stability

Analysis of the Impact of Physical Internet on the Container Loading Problem

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Abstract. In the Physical Internet supply chain paradigm, modular boxes are one of the main drivers. The dimension of the modular boxes has already been subject to some studies. However, the usage of a modular approach on the container loading problem has not been accessed. In this work, we aim to assess the impact of modular boxes in the context of the Physical Internet on the optimization of loading solutions. A mathematical model for the CLP problem is used, and extensive computational experiments were performed in a set of problem instances generated considering the Physical Internet concept. From this study, it was possible to conclude for the used instances that modular boxes contribute to a higher volume usage and lower computational times.

Keywords: Physical Internet, Modular Boxes, Container Loading Problem

Models and Methods for the Multi-Drop Container Loading Problem with Soft Unloading Constraints

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Abstract. Motivated by a collaboration with a logistics company, we study a variant of the container loading problem (CLP) with multi-drop shipments, i.e. multiple customers to serve in a given order, and soft unloading constraints. Our goal is to maximize the total value of the cargo loaded into a truck (as commonly done in the CLP) while penalizing unnecessary relocations of boxes during unloading operations. In other words, the cargo should be initially packed by considering the subsequent delivery phases and limiting the "obstacle boxes", defined as boxes that require being relocated during the unloading process as they belong to customers served later. Such relocations are indeed time consuming, and hence costly for the company.

In the literature, unloading constraints have been incorporated in the CLP as hard constraints, which considerably limit the flexibility to optimize the packing and utilize the vehicle capacity. The only exception to this is a recent work in which obstacle boxes are allowed, but each unloading constraint violation is considered equivalent (Gajda et al. 2021). In contrast, we propose a significantly more general approach to model soft unloading constraints and capture the real impact of dealing with obstacle boxes. We do this by modeling obstacle boxes by means of penalties in the objective function that depend on the volume and weight of the boxes to move as well as the type of move.

To tackle this problem, we derive a mixed-integer programming formulation that covers the case of linear penalty functions, but that is hard to solve in practice for large-scale instances. We thus propose a heuristic framework based on a randomized extreme-point constructive phase and a subsequent improvement phase. The latter phase iteratively destroys regions in the packing space

with a high "penalty density", and reconstructs them by using potentially different sets of boxes. Extensive computational experiments with different penalties show that our approach runs in a few seconds and significantly outperforms: (i) the hard unloading constraints used in the literature, and (ii) a sequential heuristic that neglects the obstacle boxes first and evaluates the penalties afterwards. Our findings underscore the relevance of accounting for soft unloading constraints in the CLP.

Keywords: Container Loading Problem, Multi-Drop Shipments, Unloading Constraints, Mixed-Integer Programming, Improvement Heuristic

References:

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Deep Reinforcement Learning

Tuesday, Sept. 28, 13:30-15:00

1 **Tackling Uncertainty in Online Multimodal Transportation Planning using Deep Reinforcement Learning** · *Amirreza Farahani, Laura Genga, Remco Dijkman*

2 **Deep Reinforcement Learning with a Combinatorial Action Space for Solving Stochastic Crowd Shipping Last-Mile Delivery problems** · *Marco Silva, Joao Pedro Pedroso, Ana Viana*

3 **Deep Reinforcement Learning for Routing and Allocation Decisions in Logistics** · *Fabian Akkerman, Martijn Mes, Willem van Jaarsveld*

Tackling Uncertainty in Online Multimodal Transportation Planning using Deep Reinforcement Learning

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Abstract. In this paper we tackle the container allocation problem in multimodal transportation planning under uncertainty in container arrival times, using Deep Reinforcement Learning. The proposed approach can take real-time decisions on allocating individual containers to a truck or to trains, while a transportation plan is being executed. We evaluated our method using data that reflect a realistic scenario, designed on the basis of a case study at a logistics company with three different uncertainty levels based on the probability of delays in container arrivals. The experiments show that Deep Reinforcement Learning methods outperform heuristics, a stochastic programming method, and methods that use periodic re-planning, in terms of total transportation costs at all levels of uncertainty, obtaining an average cost difference with the optimal solution within 0.37% and 0.63%.

Keywords: Optimization, Deep Reinforcement Learning, Online Planning under Uncertainty, Multimodal Transport

Deep Reinforcement Learning with a Combinatorial Action Space for Solving Stochastic Crowd Shipping Last-Mile Delivery Problems

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Abstract. We consider a setting in which a company not only has a fleet of capacitated vehicles and drivers available to make deliveries but may also uses the services of occasional drivers (ODs) who are willing to make deliveries using their vehicle in return for a small compensation. Under such a business model, a.k.a crowd shipping, the company seeks to make all the deliveries at the minimum total cost, i.e., the cost associated with their vehicles and drivers plus the compensation paid to the ODs. Due to its impact on customer satisfaction and cost, last-mile delivery has prompted companies to seek creative and innovative solutions such as crowd shipping. Besides, in the case of individuals sharing their vehicles on a journey, they would do anyway, crowd shipping can lead to a reduction in polluting emissions, energy consumption, and traffic congestion.

Crowd shipping gives rise to new variants of the routing problem. It has been addressed in the literature as an extension of the classical vehicle routing problem or the traveling salesman problem, being modeled under different deterministic, stochastic, and/or dynamic optimization approaches. These approaches, in general, lead to reformulations that are hard to solve, especially for large problem instances.

We consider a dynamic and stochastic last-mile delivery environment in which delivery orders, as well as ODs willing to make deliveries, arrive randomly throughout the day. The decision of assigning a delivery order to a vehicle route or an available OD is made dynamically.

We present a novel deep reinforcement learning approach to the problem that can deal with large real-life problem instances, with a concern on the quality of the solution provided. To provide good solutions, a challenge associated with the design of our deep reinforcement learning approach concerns the action space, due to its combinatorial nature. Reinforcement learning algorithms typically require an action space that is small enough to enumerate or is continuous. We present a different approach where we formulate the action selection problem from each state as a mixed-integer program. We combine the combinatorial structure of the action space with the neural architecture of the learned value function, involving techniques from machine learning and integer optimization.
We evaluate our approach against defined baselines on random instances. The baselines are two-stage data-driven stochastic optimization approaches, where each vehicle route or the order of visiting the customers is defined in the first stage and different recourse actions are defined in the second stage. We show that the reinforcement learning approach solves larger instances and can provide better solutions (less total cost) because, among others, the greater flexibility to define routings at each decision stage when compared to the recourse actions.

Keywords: Last-Mile Delivery, Crowd Shipping, Deep Reinforcement Learning, Mixed-Integer Optimization

Tuesday, Sept. 28, 13:30-15:00, Session: Deep Reinforcement Learning

Deep Reinforcement Learning for Routing and Allocation Decisions in Logistics

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Abstract. The field of transportation and logistics spans a wide variety of complex operational problems often dealing with (some of) the three curses of dimensionality: large decision spaces making it hard to find optimal decisions, too large state spaces to evaluate value functions, and large outcome spaces rendering it difficult to calculate expectations of the future [5]. A class of methods that could overcome these curses of dimensionality is called reinforcement learning, also referred to as approximate dynamic programming or neuro-dynamic programming [1]. Reinforcement learning has already been successfully applied to logistics problems, e.g, the application to synchromodal freight transport, allocating shipments to different modalities using value-based learning [4], learning to solve several different routing problems with a policy gradient method [3], and the application of value-based learning with neural networks to a variant of the nomadic trucker problem [2].

We show the results of several case studies for which we apply deep reinforcement learning to routing as well as allocation decisions. We compare the results of both policy-based and value-based deep reinforcement learning in a model-based setting. For the routing problem,we show how multiple agents work together to pick up freights that appear randomly during the day. The allocation problem encompasses the choice of modality for container dispatching from a terminal. We show how policy-based methods work well for instances with small event spaces, and show the performance of a value-based method for larger event- and decision spaces. The reinforcement learning model learns autonomously, without expert knowledge as input. Our contribution is the comparison of different types of reinforcement

learning models applied to the most common classes of transportation problems. We compare the results of our methods with heuristics and discuss the opportunities for further research in deep reinforcement learning for logistics and transportation problems.

Keywords: Deep Reinforcement Learning, Routing, Allocation

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Multi-Agent Systems

Tuesday, Sept. 28, 13:30-15:00

1 **Automated Negotiation for Supply Chain Finance** · *Alexandra Fiedler, Dirk Sackmann*

2 **A Hybrid Local Search for the Trailers Waiting Time Minimization in Warehouse Logistics** · *Alexey Ratushny, Yury Kochetov*

3 **Formal Methods to Verify and Ensure Self-Coordination Abilities in the Internet of Vehicles** · *Vahid Yazdanpanah, Enrico Gerding, Sebastian Stein*

Tuesday, Sept. 28, 13:30-15:00, Session: Multi-Agent-Systems

Automated Negotiation for Supply Chain Finance

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Abstract. The growing importance of supply chain finance and the possibility of digital descriptions for goods and services increase the urgency of providing sophisticated solutions for automating negotiations in this area. Multi-agent systems technology plays an essential role in this regard. This paper highlights the specics of automated negotiations and describes financial supply chain actors as agents. It also describes the complexity of possible supply chain finance solutions. A scenario for automated decision making for the best financing option is explained and the negotiation flow of a multi-agent system implemented in Java Agent Development Framework is demonstrated. The negotiations, in the form of an auction, are aimed at minimizing the capital costs of the supply chain. Here, it is important to weigh up whether internal financing via an investor within the supply chain or external financing via the capital market is more advantageous. The different roles of the supply chain finance agents capital demander, investor and capital market are described in detail. The use of so-called HelperAgents for the negotiating participants capital demander and investor as negotiating agents within a supply chain finance negotiation protocol is also explained.

Keywords: Automated Negotiation, Supply Chain Finance, Multi-Agent System

A Hybrid Local Search for the Trailers Waiting Time Minimization in Warehouse Logistics

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Abstract. We study the following scheduling problem for warehouse management. A warehouse consists of several buildings. Each building has locations (rooms) with known capacities. Each room can contain only one type of product. Each building has two gates. One gate is for the loading/unloading trailers. Another gate is for two forklifts from a central zone. The central zone is a production line. It produces some products which have to be placed into one of the buildings. We know how the central zone works during each day, i.e. how many pallets (units) and when they will be ready for being putaway. Outbound trailers come to pick some pallets of the products from the warehouse. Inbound trailers come to put away some units of the products into the warehouse. Inbound/outbound order consists of one product. We know the arriving time for each inbound/outbound trailer and its unloading/loading time. We assume that only one forklift can work in each building due to safety regulations. In other words, it is impossible to service any trailer at the second gate when a forklift from the central zone is working. Exactly one forklift can service inbound/outbound trailers. Our goal is to assign all trailers to buildings and find the schedule for all the inbound/outbound trailers with minimal total waiting time (i.e. with the minimal total sum of the differences between the starting time of service and the arrival time for all trailers).
In our model, we replace the central zone with a sequence of virtual trailers working by the no-wait rule. It means that a batch of produced units is unloaded to a building as soon as ready. We design a mixed-integer linear program for the case all non-virtual

trailers are serviced by the rule First In, First Out (FIFO) for each building and known starting time for all virtual trailers. Under this assumption, Gurobi software can find the optimal solutions for small instances. For real-world instances, we design a multi-agent system, a randomized heuristic with three types of agents: I, G, and M. The I-agents are free trailers that need to be scheduled, whereas the G-agents are groups of trailers already assigned to buildings. The I- and G-agents are driven by their goals (own waiting time). The M-agent acts as the system's manager of the independent intelligent agents and uses local search heuristic with swap and move neighborhoods to improve the current solution. We apply this multi-agent system in our genetic algorithm with a simple encoding scheme based on the virtual trailers' assignment to the buildings. Thus, we generate such assignments first and use the multi-agent system to complete this partial schedule to a feasible solution for all inbound/outbound trailers. A crossover operator combines the parent's assignments to produce offspring. For preliminary computational experiments, we use the real data of a Dutchlogistics company. We discuss our results for 10 test instances with 6 buildings, 18 products, and 90 trailers. Approximately 40% of the trailers are virtual ones and represent the central zone. We run the hybrid genetic algorithm for 10 minutes on the PC with a 2.5GHz Intel Core i5 processor and 8GB of memory. We compare the results with the local search heuristic where the starting solution is generated by an hour computation of Gurobi software. We show some advantages of the results obtained for all test instances.

Keywords: Genetic Algorithm, Multi-Agent System, Warehouse Logistic

Tuesday, Sept. 28, 13:30-15:00, Session: Multi-Agent-Systems

Formal Methods to Verify and Ensure Self-Coordination Abilities in the Internet of Vehicles

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Abstract. The emerging Internet of Vehicles (IoV) is a distributed multiagent network that utilises the potentials for collaboration of vehicles with the aim to improve the reliability and safety of transportation and logistic systems. IoV systems require operational methods to reason about the capacity of the involved (human and artificial) agents to form strategically capable coalitions as a means to ensure safety. In this work, we (1) develop a logic-based machinery to represent and reason about strategic abilities in IoV systems, (2) provide a process to verify whether a given IoV system is capable to safely self-coordinate, and (3) introduce a mechanism to ensure such an ability in a temporal, strategic, and normative setting.

Keywords: Multiagent Systems, Computational Logic, Smart Logistics, Self-Coordination, Internet of Vehicles, Formal Reasoning

Drilling Operations

Tuesday, Sept. 28, 13:30-15:00

1 **Scheduling Drillships in Offshore Activities** · *Rafael Gardel Azzariti Brasil, Marco Aurelio de Mesquita, Dario Ikuo Miyake, Tiago Montanher, Debora Pretti Ronconi*

2 **The Robust Rig Routing with Drilling Time Uncertainty** · *Igor Kulachenko, Polina Kononova*

3 **Collaborative Decision Making for a Multi-Actor Platform – A Case of an Offshore Drilling Operation** · *Juan M. Pulido, Xiaoning Shi*

Tuesday, Sept. 28, 13:30-15:00, Session: Drilling Operations

Scheduling Drillships in Offshore Activities

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Abstract. This paper addresses the scheduling of offshore oil well construction using drilling vessels. Drilling costs constitute a substantial part of the total development costs for an offshore field, thus planning the efficient use of drilling rigs is crucial to ensure economic feasibility of oil and gas exploration and production (E&P) projects. The objective of this study is to minimize the completion time of all operations involved in the development of subsea wells considering the availability of the drilling rigs. These activities are drilling and completion of the well, and maintenance activities. Technical constraints and availability of the drilling vessels and release dates and precedence constraints of the activities are considered. In addition, vessel eligibility restrictions are respected. A mixed-integer linear programming model was developed cosidering the goals and constraints above. Numerical experiments using instances based on real-world situations show adequate behavior, which demonstrates that it faithfully represents the situation portrayed and can be used, combined with more advanced optimization techniques, to achieve better results.

Keywords: Oil Wells, Offshore Activities, Mixed-Integer Linear Programming

The Robust Rig Routing with Drilling Time Uncertainty

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Abstract. The real-world Drilling Rig Routing Problem (DRRP) in an uncertain environment is considered. There is a set of customers that are exploration sites requiring work on drilling wells. For each customer, we know the number of wells that need to be drilled within a given time interval, and it is allowed to partition the set of wells so that several drilling rigs perform the required work. However, the work on a well is unsplittable and should be performed by only one rig. After completion of its work plan, a rig does not have to return to the depot it started from. This problem is close to an open uncapacitated multi-depot split delivery vehicle routing problem with time windows.

Yet in the real world, unforeseen circumstances can affect drilling time, and that, if disregarded, can lead to a disruption of the work plan. Thus, in this problem, we maximize the norm of deviations of drilling times from expected values when there is still a set of routes for a fleet of drilling rigs to perform all well-drilling requests in time with total traveling costs no more than a given threshold. It is a so-called threshold robustness

In this research, we propose a MILP model for the DRRP with uncertainties and a method based on Adaptive Large Neighborhood Search (ALNS). The destruction and reconstruction operators used in the algorithm are working either at the route, customer, or visit level. A POPMUSIC approach is also applied, which uses the decomposition of the original problem into smaller subproblems that can be solved (optimally or sub-optimally) through MILP models. Computational results for the algorithm and Gurobi solver show the dominance of the ALNS scheme for the medium-size instances and the ability of the

POPMUSIC method to sufficiently improve results obtained by ALNS.

Keywords: Logistics, Threshold Robustness, Uncapacitated Vehicles, Split deliver, Time windows, Metaheuristics

Collaborative Decision Making for a Multi-Actor Platform – A Case of an Offshore Drilling Operation

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Abstract. Offshore drilling is a highly specialized and complex operation comprising a wide variety of actors in a capital-intensive scenario and complex logistics frameworks around the world. The complexity of the offshore drilling operations includes, but is not limited to, 1) just-in-time supplies of materials, 2) speed control of the associated Offshore Support Vessels (OSV), 3) synchronization of heterogeneous transportation services, and 4) incentives and moments of providing to-be-shared data and/or information to the platform. There also exist multiple actors, who are involved in this operation, i.e., the oil & gas company group (operator and dominating actor), oil & gas service companies, multiple vendors and oilfield equipment providers, multi-modal transportation companies (international and domestic), logistics service providers, maritime agents, port (shore base) and port-related services, warehousing, yards, OSVs, helicopter transportation, and the Mobile Offshore Drilling Units (MODUs) including a wide variety of sub-services on board. The afore-mentioned players act according to a pre-established master equipment list, Authorization for Expenditure (AFE), and the drilling program.

On one hand, these players mainly provide heterogenous transportation services with most probably collaborative decision-making perceptions, though they make decisions on their own, respectively. Hence, the design of the platform would be different from that of the platform designed for a homogenous-players setting (Shi et al., 2020, Shi and Voß, 2008), e.g., using a Stackleberg model. The design of the platform for heterogenous

players will focus more on the complementary and sequential processes. On the other hand, any minor change, update or deviation in the drilling program or logistics operation could affect the overall logistics chain because that associated data and/or information needs to be updated and retransmitted by the originator to multiple actors working in a multi-level relationship due to the different roles and the technical-based segregation of each of the nodes or actors in the operation.

This research investigates a case study mainly from the perspective of the oil & gas company who carries out a one-well operation under the traditional system and search for improvements of the logistics system, changing from the traditional logistics system where the flow of information and data collection is not efficient, to a model where the flow of information is centralized and n-bidirectional. All players interact with a unique interface system, i.e., the platform to manage the state-of-art operations and collect the large amount of data that is generated, not properly recorded, and underutilized in terms of understanding the logistics performance of the oil company (dominating player) and its service providers (multi actors and followers).

At the current stage, the available data used in this case study includes:

- Drilling time: P50 scenario 73 days – Port Call Frequency: P50 scenario 1.0 or 1.5 per week per vessel
- Specification, cost structure and categorized consumption of Marine Gas Oil (MGO) according to the operational status of the vessels, transit speeds (base case and optimized) and travel distance (240NM) for one leg. Estimated emissions i.e., CO2, CH4 and N2O based on MGO consumption
- Platform Supply Vessels (PSV) and drilling rig technical specifications

Based on the available data at current stage, some preliminary computational results are shown as follows:

- The consumptions of the drilling operation, i.e., Marine Gas Oil (MGO) can be saved, and it achieved 26% decrement for overall sailing operations
- The emission can be saved, and it achieved 24.8%, 24.6% and 29.8% decrement for three OSVs, respectively
- The overall operational duration gets longer; however, that is because of the deployment of the Just-in-time (JIT)

concept. Through the application of JIT Arrival, the overall length or duration of the voyage in this case study is not impacted and remains the same. Instead, the voyage overall is optimized – the ship may spend more days sailing, but the aim is to minimize and preferably eliminate waiting time and enable sailing at a speed which means reduced fuel consumption per mile steamed.

Finally, further research aspects are planned.

A) the timestamp of identifying speeds of the vessels and rig does not yet interact with the overall operational plan. In other words, the operational plan discussed in this case is rather stable. We might need to consider dynamic or rolling horizon planning as one of the necessary functions of the platform.

B) this case does not face the time limits when considering JIT concept. However, when an emergency or disruption occurs, some time limits might be enforced, which need to be reflected in the design of the platform.

Keywords: Collaborative Decision Making, Logistics Platform, Offshore Drilling, Game Theory

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Plenary Talk II:

Dynamic Optimization Algorithms for Same-Day Delivery Problems

Prof. Manuel Iori

Abstract. In this talk, we will concentrate on dynamic vehicle routing problems where stochastic customers request urgent deliveries characterized by restricted time windows. The most important problem in this class is known as the same-day delivery problem and requires maximizing the number of served requests, breaking ties by minimizing traveled distance. The problem is of high importance because it models several real-world applications, including the delivery of online purchases, and has received large attention in recent years.

After a general introduction on dynamic vehicle routing, we will present a set of dynamic solution approaches for the same-day delivery problem, ranging from simple reoptimization heuristics to sophisticated branch-and-regret ones in which sampled scenarios are used to anticipate decisions. We will also discuss how to embed adaptive large neighborhood search in the dynamic approaches to optimize the routing plans, and how to use consensus functions to select routing plans for implementation. The effectiveness of the methods in comparison with recent literature is proved by extensive experiments.

We will finally discuss ways to adapt the proposed methods to solve other dynamic problems that we are currently facing together with companies, as the routing of Automated Guided Vehicles within an industrial plant, and the transportation of patients within a hospital.

Sustainability

Tuesday, Sept. 28, 16:30-18:00

1 **Machine Learning for Promoting Environmental Sustainable Container Terminals** · *Meead Mansoursamaei, Mahmoud Moradi, Rosa Gonzalez, Eduardo Lalla-Ruiz*

2 **Bi-objective Optimization for Joint Production Scheduling and Distribution Problem with Sustainability** · *Ece Yağmur, Saadettin Erhan Kesen*

3 **Optimization of Green Pickup-and-Delivery Operations in Multi-Depot Distribution Problems** · *Alejandro Fernández Gil1, Eduardo Lalla-Ruiz, Martijn Mes, Carlos Castro*

Tuesday, Sept. 28, 16:30-18:00, Session: Sustainability

Machine Learning for Promoting Environmental Sustainable Maritime Shipping and Port Logistics

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Abstract. Maritime-based freight transportation is one of the essential drivers of the global economy as it enables both lower transportation costs and faster intermodal operations across multiple forms of transportation. On the other hand, global warming, air pollution, and greenhouse gas emissions are all having a detrimental influence on the environment and will most likely continue to do so for future generations. Hence, the maritime and port sectors are facing increasing pressure to promote environmental sustainability practices and reduce the negative impacts of their operations. This implies requirements that may be addressed through technologies that are now available, such as the internet of things, sensors, autonomous vehicles, and artificial intelligence (Lalla-Ruíz et al., 2019; Ystmark Bjerkan and Seter, 2019). As a strategic node on global transport chains, maritime ports are key stakeholders to promote more sustainable practices in the industry.

The application of machine learning techniques as one of the main subdomains of artificial intelligence support the advances in green activities in maritime shipping and port logistics, by providing analytical tools to aid a more efficient and sustainable utilization of resources. Accordingly, we present the results of a systematic literature review of recent literature on machine learning for

promoting environmentally sustainable maritime shipping and ports. We categorize the identified papers based on their main focus and technical approaches implemented to support maritime shipping, port-related operations and hinterland transport to identify the main scope in which the use of machine learning has been implemented to aid more sustainable operations. Furthermore, we identify gaps in the literature and provide directions for future research lines.

Keywords: Maritime Shipping, Port Logistics, Machine Learning, Sustainability, Analysis

Tuesday, Sept. 28, 16:30-18:00, Session: Sustainability

Bi-Objective Optimization for Joint Production Scheduling and Distribution Problem with Sustainability

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Abstract. This paper considers a joint production and distribution planning problem with environmental factors. While the production phase of the problem consists of a job shop production environment running under Just-In-Time (JIT) philosophy, the distribution phase involves a heterogeneous fleet of vehicles with regards to capacity and fuel consumption rate. Therefore, we tackle two well-known problems in Operations Research terminology which are called machine scheduling and vehicle routing problems. The joint problem is formulated as a bi-objective structure, the first of which is to minimize the maximum tardiness, the second of which aims to minimize the total amount of CO2 emitted by the vehicles. Orders are required to be consolidated to reduce the traveling time, distance, or cost. An increase in the vehicle capacity results in a higher possibility of consolidation, but in this case, the amount of CO2 emission that the vehicle emits into the air will also increase. Having shown that two objectives are conflicting in an illustrative example, we formulate the problem as a mixed-integer programming (MIP) formulation and use an Augmented Epsilon Constraint Method (AUGMECON) for solving the bi-objective model. On randomly generated test instances, the applicability of the MIP model through the use of AUGMECON is reported.

Keywords: Joint Production and Distribution, Scheduling, Vehicle Routing, Job Shop, Sustainability, Heterogeneous Fleet, Mixed-Integer Model

Optimization of Green Pickup-and-Delivery Operations in Multi-Depot Distribution Problems

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Abstract. In this work, the Multi-Depot Green VRP with Pickups and Deliveries (MDGVRP-PD) is studied. It is a routing optimization problem in which the objective is to construct a set of vehicle routes considering multiple depots and one-to-one pickup-and-delivery operations that minimize emissions through fuel consumption, which depends on weight and travel distance. In one-to-one problems, goods must be transported between a single origin and its single associated destination. Practical considerations imply addressing the pickup and delivery of customers from multiple depots, where a logistics service company can efficiently combine its resources, thus reducing environmental pollution. To tackle this problem, we develop a mathematical programming formulation and matheuristic approach based on the POPMUSIC (Partial Optimization Metaheuristic under Special Intensification Conditions) framework. The results show that if the weight carried on the routes as part of the fitness measure is considered, our matheuristic approach provides an average percentage improvement in emissions of 30.79%, compared to a fitness measure that only takes into account the distances of the routes.

Keywords: Multi-Depot, PDVRP, Green VRP, Matheuristics

Multi-Objective Optimization

Tuesday, Sept. 28, 16:30-18:00

1 **A Multi-Objective Biased Random-Key Genetic Algorithm for the Service Technician Routing and Scheduling Problem** · *Ricardo Damm, Débora Ronconi*

2 **Solving a Multi-Objective Vehicle Routing Problem with Synchronization Constraints** · *Briseida Sarasola, Karl F. Doerner*

3 **Robust Multi-Objective Gate Scheduling at Hub Airports Considering Flight Delays: A Hybrid Metaheuristic Approach** · *Abtin Nourmohammadzadeh, Stefan Voß*

Tuesday, Sept. 28, 16:30-18:00, Session: Multi-Objective Optimization

A Multi-Objective Biased Random-Key Genetic Algorithm for a Service Technician Routing and Scheduling Problem

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Abstract. Every day many service companies need to plan the tasks that will be carried out by its field staff. Maintenance service technicians have to perform a set of jobs at different locations in a city or state. This problem can be defined as the Service Technician Routing and Scheduling Problem in which tasks have different priorities and time windows, and technicians have different skills and working hours. Scheduling must account for technicians' lunch breaks, which must be respected. Each task is performed by only one technician. To ensure quality customer service and consumer rights are upheld, a novel approach is proposed: to address the problem in a multi-objective context aiming to execute the priority tasks and, simultaneously, to serve the customers at the beginning of their time windows. A Multi-objective Biased Random-Key Genetic Algorithm (BRKGA) was customized to tackle this NP-hard optimization problem and then compared with the Non-dominated Sorting Genetic Algorithm II (NSGA-II). The analyzed methods showed similar performance for small instances, but for medium- and large-sized instances the proposed method presented superior performance and more robust results.

Keywords: Multiple Objective Programming, Routing and Scheduling Technicians, Time windows, Biased Random-Key Genetic Algorithm, NSGA-II

Tuesday, Sept. 28, 16:30-18:00, Session: Multi-Objective Optimization

Solving a Multi-Objective Vehicle Routing Problem with Synchronization Constraints

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Abstract. In this paper, we solve a multi-objective vehicle routing problem with synchronization constraints at the delivery location. Our work is motivated by the delivery of parcels and consumer goods in urban areas, where customers may await deliveries from more than one service provider on the same day. In addition to minimizing travel costs, we also consider a second objective to address customer preferences for a compact schedule at the delivery location, so that all deliveries to a customer happen within a non-predefined time interval. To determine the Pareto fronts, three metaheuristic methods based on large neighborhood search are developed. The results on small instances are compared with an epsilon-constraint method using an exact solver. Results for large real-world instances are also presented.

Keywords: Vehicle Routing Problem, Synchronization, Multi-Objective Optimization

Robust Multi-Objective Gate Scheduling at Hub Airports Considering Flight Delays: A Hybrid Metaheuristic Approach

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Abstract. Regarding the large number of flights that a hub airport usually has to serve and the competitiveness in the aviation industry, optimal scheduling of limited and expensive airport resources such as gates is really vital. This work focuses on the efficient scheduling of airport gates to achieve a balance between three important goals, namely reducing the walking distance of passengers, decreasing the number of flights assigned to the gates different from their reference gates as well as widening the total shopping area passed by passengers while walking to, from or between the gates. A set of different scenarios is considered for the arrival of flights regarding the possible delays. Robust multi-objective optimisation is followed through an exact solution approach according to the weighted sum method by the Baron solver as well as a metaheuristic method consisting of the hybridisation of multi-objective particle swarm optimisation (MOPSO) and the multi-objective simulated annealing (MOSA). The sets of Pareto-optimal solutions obtained by these two methods along with those of the pure MOPSO, MOSA and a tabu search algorithm from the literature are compared based on some evaluation metrics and with the aid of a statistical test.

Keywords: Airport Gate Scheduling, Robust Optimisation, Multi-Objective Optimisation, Multi-Objective Particle Swarm Optimisation (MOPSO), Multi-Objective Simulated Annealing (MOSA)

Maritime Transport

Tuesday, Sept. 28, 16:30-18:00

1 **Solving a Real-Life Tramp Ship Routing and Scheduling Problem with Speed Profiles** · *Lucas Louzada, Rafael Martinelli, Victor Abu-Marrul*

2 **Optimizing Maritime Preparedness under Uncertainty - Locating Tugboats along the Norwegian Coast** · *Julie Louise Musæus, Håkon Nøstvik, Henrik Andersson, Peter Schütz*

3 **Designing the Hydrogen Supply Chain for Maritime Transportation in Norway** · *Šárka Štádlerová, Peter Schütz*

Solving a Real-Life Tramp Ship Routing and Scheduling Problem with Speed Profiles

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Abstract. Shipowners seek to increase their profits by optimizing the operation of their available fleet, increasing its capacity, and reducing costs while meeting the customers' demands. Ship routing stands out as a relevant topic of study, especially for tramp shipping companies, due to the high competitivity on this market, which highlights the importance of providing reliable and price-competitive services. This work presents a mixed-integer programming formulation to maximize the profit of an actual tramp shipping company. The studied problem considers pick-up-and-delivery for different cargoes, partial contract orders, time window restrictions, heterogeneous fleet, cargo split, varying navigation speeds, and guaranteed transit time terms. We perform computational experiments with real data from the studied company, comparing the achieved solutions with those developed by the company following their current planning process. The mathematical formulation improves the existing solutions in all tested cases with total costs up to 7% smaller, including fuel, port, and operational shipcosts.

Keywords: Ship Routing, Mixed-Integer Programming, Tramp shipping, Speed Profiles

Tuesday, Sept. 28, 16:30-18:00, Session: Maritime Transport

Optimizing Maritime Preparedness under Uncertainty - Locating Tugboats along the Norwegian Coast

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Abstract. We study the strategic problem of locating tugboats along the Norwegian coast to optimize maritime preparedness. The problem is formulated as a two-stage stochastic program. In the first-stage, we locate the tugboats such that nominal coverage requirements are satisfied, whereas we deploy the located tugboats in the second stage in order to assist vessels in distress. The objective is to minimize the sum of the total tugboat chartering and operating costs and the expected penalty costs due to insufficient preparedness. We solve the problem using Sample Average Approximation in combination with a self-developed heuristic. Our results indicate that we can achieve a sufficient preparedness level with six tugboats.

Keywords: Maritime Preparedness, Set Covering Problem, Uncertainty

Designing the Hydrogen Supply Chain for Maritime Transportation in Norway

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Abstract. We study the problem of locating hydrogen facilities for the maritime transportation sector in Norway. We present a multi-period model with capacity expansion to obtain optimal investment and expansion decisions and to choose optimal production quantities and distribution solutions. The objective is to minimize the sum of investment, expansion, production, and distribution costs while satisfying the demand in each period. Hydrogen production costs are subject to economies of scale which cause non-linearity in the objective function. We model long-term investment and expansion costs separately from short-term production costs. The short-term production costs depend on the installed capacity and production quantities. We analyze two models that differ in investment decision flexibility and two demand scenarios: demand only from the maritime sector and demand from the whole transportation sector in Norway. The results show that the scenario with higher demand does not lead to a higher number of built facilities due to the economies of scale. The model with higher flexibility leads to higher capacity utilization in the first periods and thus significantly lower production costs. The results further indicate that the initial demand is too low to build a steam methane reforming facility, instead only electrolysis facilities are built in both scenarios and both models.

Keywords: Facility Location, Capacity Expansion, Hydrogen Supply Chain

Machine Learning

Wednesday, Sept. 29, 13:00-14:30

1 **A Learning and Optimization Framework for Collaborative Urban Delivery Problems with Alliances** · *Jingfeng Yang, Hoong Chuin Lau*

2 **Improving the Location of Roadside Assistance Resources through Incident Forecasting** · *Roman Buil Giné, Santiago Garcia Serrano, Jesica de Armas, Daniel Riera*

3 **Chances of Interpretable Transfer Learning for Human Activity Recognition in Warehousing** · *Michael Kirchhof, Lena Schmid, Christopher Reining, Michael ten Hompel, Markus Pauly*

A Learning and Optimization Framework for Collaborative Urban Delivery Problems with Alliances

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Abstract. The emergence of e-Commerce imposes a tremendous strain on urban logistics which in turn raises concerns on environmental sustainability if not performed efficiently. While large logistics service providers (LSPs) can perform fulfillment sustainably as they operate extensive logistic networks, last-mile logistics are typically performed by small LSPs who need to form alliances to reduce delivery costs and improve efficiency and compete with large players. In this paper, we consider a multi-alliance multi-depot pickup and delivery problem with time windows (MAD-PDPTW) and formulate it as a mixed-integer programming (MIP) model. To cope with large-scale problem instances, we propose a two-stage approach of deciding how LSP requests are distributed to alliances, followed by vehicle routing within each alliance. For the former, we propose machine learning models to learn the values of delivery costs from past delivery data, which serve as a surrogate for deciding how requests are assigned. For the latter, we propose a tabu search heuristic. Experimental results on a standard dataset show that our proposed learning-based optimization framework is efficient and effective in outperforming the direct use of tabu search in most instances. Using our approach, we demonstrate that substantial savings in costs and hence improvement in sustainability can be achieved when these LSPs form alliances and requests are optimally assigned to these alliances.

Keywords: Alliance, Collaboration, Machine Learning, Pickup-and-Delivery, Tabu Search

Wednesday, Sept. 29, 13:00-14:30, Session: Machine Learning

Improving the Location of Roadside Assistance Resources through Incident Forecasting

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Abstract. This paper presents a solution for a real-world roadside assistance problem. Roadside assistance companies must allocate their specialised resources to minimize the operating cost associated with servicing when incidents occur. In this process, the location of these resources plays an important role. Therefore, this work proposes a study on the forecasting of incidents and their impact on the location of resources and operating costs. To do this, we have built a machine learning model competition enriched with new features drawn from traditional time series methods and external data such as weather, holidays, and client portfolios. The results show a significant reduction in operating costs thanks to the forecasting of incidents.

Keywords: Road Incident Forecasting, Model Competition, Location of Resources, Machine Learning

Chances of Interpretable Transfer Learning for Human Activity Recognition in Warehousing

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Abstract. Human activity recognition evolves around classifying and analyzing workers' actions quantitatively using convolutional neural networks on the time-series data provided by inertial measurement units and motion capture systems. However, this requires expensive training datasets since each warehouse scenario has slightly different settings and activities of interest. Here, transfer learning promises to shift the knowledge to a deep learning method gained on existing reference data to new target data. We benchmark interpretable and non-interpretable transfer learning for human activity recognition on the LARa order-picking dataset with AndyLab and RealDisp as domain-related and domain-foreign reference datasets. We find that interpretable transfer learning via the recently proposed probabilistic rule stacking learner, which does not require any labeled data on the target dataset, is possible if the labels are sufficiently semantically related. The success depends on the proximity of the reference and target domains and labels. Non-interpretable transfer learning via fine-tuning can be applied even if there is a major domain-shift between the datasets and reduces the amount of labeled data required on the target dataset

Keywords: Domain-Shift, Few-Shot Learning, Interpretability, Logistics, Multi-Label Classification, Time-Series, Zero-Shot Learning

Storage Management

Wednesday, Sept. 29, 13:00-14.30

1 **On the Effect of Product Demand Correlation on the Storage Space Allocation Problem in a Fast-Pick Area of a Warehouse** · *Felipe I. Gre-Carafí, Alberto Ossa-Ortiz de Zevallos, Rosa G. González-Ramírez, Mario C. Velez-Gallego*

2 **Stockyard Storage Space Allocation in Large Iron Ore Terminals** · *Xinyu Tang, Jiangang Jin, Xiaoning Shi*

3 **The Parallel Stack Loading Problem on Large Scale Instances** · *Sven Boge, Irina Wanscheid*

On the Effect of Product Demand Correlation on the Storage Space Allocation Problem in a Fast-Pick Area of a Warehouse

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Abstract. The storage location assignment problem (SLAP), also known as the slotting problem involves the decisions of how much and where should each stock keeping unit (SKU) should be stored in the fast-pick area with the aim to minimize total order-picking and replenishment costs associated to the distance traveled by the picking operators. Motivated by this, we propose to analyze the impact of SKUs demand correlation on the slotting decisions. Based on an experimental design, the effects of SKUs with correlated demand are analyzed. Results show that the most significant factor with respect to the total distance traveled is the number of orders, followed by the capacity of the bins and the number of bins in each location. Results of an instance solved to optimality by a commercial solver and a greedy heuristic in which the latter does not consider the demand correlation illustrate the impact that demand correlation has on the obtained solution.

Keywords: Warehousing, Slotting Problem, Order-Picking, Demand Correlation, Fast-Pick Area

Stockyard Storage Space Allocation in Large Iron Ore Terminals

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Abstract. With the great demand for iron ore, large iron ore terminals have become important nodes in the international shipping transportation networks. Large quantities of iron ore usually arrive at the port by water or rail, and are unloaded from the carriers followed by some handling processes to the stockyard where they are stacked for further distribution. Stockyards act as buffer areas and tend to become bottlenecks in the whole transfer process. Many iron ore terminals manage the stockyard space based on some experience cumulated from the real-world business, which makes it difficult to deal with all the complex constraints that need to be met when stacking. In recent years, some iron ore terminals have launched ore-mixing operation (to mix ores of different qualities together), further complicating the stockyard operation.

Compared to the container yards, relatively little attention has been focused on the stockyard storage space management of dry bulk terminal, in which a "slot" strategy similar to the one used in container yards has been employed to discretize the continuous storage space (Sun et al., 2020; Tang et al., 2016). Thus, it is of great necessity to improve the performance of stockyard storage space allocation of the dry bulk terminals, e.g., iron ore terminals. In this study, we address the Stockyard Storage Space Allocation Problem (SSSAP) in large iron ore terminals, which aims to determine the specific location for each incoming material. We take the complex operational requirements into account, especially the constraints imposed by the relatively new ore-mixing operation. A mixed-integer programming model is developed to minimize the total travel distance of all the incoming materials with continuous variables representing the specific locations of

materials to highlight the continuous cargo flow characteristic. To obtain near-optimal solutions quickly, a heuristic algorithm based on the genetic algorithm is employed.
Computational experiments based on the real terminal background (Shulanghu iron ore terminal of Ningbo-Zhoushan Port in China) are conducted and each set of instances are divided into small (5, 10 materials), medium (15, 20, 25 materials) and large size (30, 40 materials). The results validate the effectiveness, efficiency and stability of the heuristic approach, and especially for large-size instances, near-optimal solutions can be found in a considerably short time (about one second). We extract some useful managerial insights from the calculation results: (1) The place for the mixed materials should be arranged away from the entrance to the stockyard so as to allow the new arrivals to run the shortest possible distance. (2) The stacking of the material requires a balance between the space the material occupies and the product of the mass of individual material and the distance travelled. Moreover, we present the sensitivity analysis on stock pad number which can be employed to determine the appropriate number of pads to be opened for different material scales.

Keywords: Storage Space Allocation, Dry Bulk, Iron Ore Terminal, Ore-Mixing Operation, Mixed-Integer Programming

References:

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https://doi.org/10.1080/0740817x.20

Wednesday, Sept. 29, 13:00-14:30, Session: Storage Management

The Parallel Stack Loading Problem on Large-Scale Instances

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Abstract. In this presentation, we consider the parallel stack loading problem (PSLP) with the objective to minimize the number of reshuffles in the unloading stage. In the PSLP an empty storage of stacks is given, at each stack only the top item can be accessed and incoming items have to be stored according to a fixed arrival sequence. Every item is associated with a unique priority value which reflects the order in which items have to be unloaded from the storage later on. Due to these priorities and the fixed arrival sequence, some items of higher priority (that must be unloaded earlier) may be blocked by items of lower priority. To unload a blocked item all blocking items (also called badly placed items) must be relocated to other stacks such that some relocations (also called reshuffles) cannot be avoided in the unloading stage.
In the literature the surrogate objective function (number of badly placed items, BI) was considered to estimate the number of reshuffles (RS) and optimal solutions were computed for instance sizes of 120 and less with an IP formulation to provide lower bounds. We adapt the existing IP formulation and use a new branch-and-cut approach to solve instance sizes of 300 items and more. In this context we exploit the existence of increasing subsequences in the arrival sequence which correspond to independent sets in the conflict graph. Furthermore we develop fast algorithms based on adaptive large neighborhood search and simulated annealing to tackle the same large instances and try to reduce the gap to the newly proposed lower bounds. We compare our approaches to existing approaches from the literature in a computational study and provide results on previously unsolved instances sizes.

Keywords: Branch-and-Cut, Combinatorial Optimization, Integer Programming, Lower Bounds, Adaptive Large Neighborhood Search, Simulated Annealing

Dispatching

Wednesday, Sept. 29, 13:00-14:30

1 **Automated Tour Planning for Driving Service of Children with Disabilities: A Web-Based Platform and a Case Study** · *Mahdi Moeini, Lukas Mees*

2 **Applying the Flow Interception Problem to a Fugitive Situation** · *Irene van Droffelaar, Jan Kwakkel, Alexander Verbraeck*

3 **On solving the Equipment Dispatching Problem for Underground Mine Under Stochastic Working Times** · *Nour El Houda Hammami, Amel Jaoua, Safa Bhar Layeb*

Applying the Flow Interception Problem to a Fugitive Situation

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Abstract. How to optimally position and move police units to maximize the probability of intercepting a fleeing fugitive? Answering this question is hard for several reasons. First, for any answer to be relevant, it needs to be available within at most a few minutes. Second, it is unclear how to represent the fleeing behavior of the fugitive. Third, there is no canonical mathematical optimization representation of this type of problem. In a first attempt at addressing the overarching question, we formalize the problem as a Flow Interception problem, but with a moving target with unknown location instead of known flows between origins and destinations. Next, rather than trying to model the fleeing behavior through constraints within the optimization model, we instead use a Monte Carlo simulation to sample a set of possible routes as input to the optimization model. This modification drastically reduces the complexity of the optimization problem and thus reduces the time required to exactly solve it. To further explore the runtime of this combined Monte Carlo simulation and optimization setup, we systematically vary the granularity of the representation of the network and the number of possible positions of the fugitive over time. We analyze the results of these experiments with a rule induction algorithm to understand the combinations of conditions under which the runtime or the quality of the solution becomes unacceptable. We find that the size of the network is the most important determinant of the runtime. In light of this, we sketch possible directions for future work to maintain tractability and scalability.

Keywords: Flow Interception Problem, Monte Carlo simulation, Mixed-Integer Programming, Runtime Complexity

Wednesday, Sept. 29, 13:00-14:30, Session: Dispatching

Automated Tour Planning for Driving Service of Children with Disabilities: A Web-Based Platform and a Case Study

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Abstract. In this paper, we focus on a real-world problem called Kindergarten Tour Planning Problem (KTPP), which corresponds to a case study. In the KTPP, the objective consists in running a driving service for a group of children with disabilities to a central kindergarten. We formulate this problem as a Mixed-Integer Linear Program (MILP), which can be solved by any standard MILP solver. However, for practical use, we designed a simple, yet effective heuristic to find good-quality solutions in short computation time. We conducted computational experiments, on randomly generated instances, to verify effectiveness of our heuristic by benchmarking it versus the state-of-the-art solver Gurobi Optimizer. Moreover, we introduce and present a publicly-available web-based platform that we have developed for practical use.

Keywords: Transportation on Demand, Open Vehicle, Routing Problem, School Bus Routing Problem, Health Care Services, Heuristics, Logistics

Wednesday, Sept. 29, 13:00-14:30, Session: Dispatching

On Solving the Equipment Dispatching Problem for Underground Mine under Stochastic Working Times

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Abstract. This work investigates an underground mine equipment dispatching problem under equipment stochastic working times. First, a mathematical model is developed for solving the Equipment Dispatching problem while considering the machines working times as deterministic parameters. Then, Monte Carlo simulation is implemented in order to assess the reliability of the deterministic dispatching under stochastic environment, i.e. stochastic working times that include travel times between stopes, settlement times, and breakdown times. For this challenging problem, an illustrative variability effect analysis is proposed. Promising preliminary results highlight the importance of considering machines working times as stochastic parameters in the case of medium and high variability levels.

Keywords: Underground Mine Equipment Dispatching, Stochastic Working Times, Monte Carlo Simulation

Plenary Talk III:

Digitalization in Maritime Logistics and the Role of Research

Dr. Leonard Heilig

Abstract. Digitalization is pushing the maritime industry beyond its traditional limits and provides many new opportunities to enhance the productivity, efficiency, and sustainability of logistics. In recent years, we have seen a lot of new real-world applications of digital technologies and platforms in the domain of maritime logistics, such as related to the internet of things (IoT), cloud computing, blockchain, smartphones, etc., combined with new business models. This talk will give an overview on opportunities and challenges coming along with the application of digital technologies, especially with respect to seaport and hinterland operations. In this context, examples will be presented and the role of research in the areas of operations research and data science will be discussed.
The second part of the presentation contains several scientific and practical insights from driveMybox, an innovative digital container trucking platform, which demonstrates a successful transition from research into practice. driveMybox is the first digital all-in-one platform that fully supports processes from the booking in a modern cloud-based platform to the execution using a trucker app, with optimization and machine learning approaches at its core and full transparency for customers. Opportunities for future research will be discussed in this context.

Routing

Wednesday, Sept. 29, 16:00-17:30

1 **Solving the Shipment Rerouting Problem with Quantum Optimization Techniques** · *Sheir Yarkoni, Andreas Huck, Hanno Schülldorf, Benjamin Speitkamp, Marc Shakory Tabrizi, Martin Leib, Thomas Bäck, Florian Neukart*

2 **Minimizing the Expected Cost in a Dynamic Stochastic Last Mile Delivery with Crowdsourcing** · *André G. Santos, Xenia Klimentova, Ana Viana, João Pedro Pedroso*

3 **First Mile Logistics Operational Planning Model for Small Fresh-Produce Growers** · *Nicolas E. Palacios-Avilés, Rosa Guadalupe Gonzalez Ramirez, Omar Ahumada Valenzuela, J. Rene Villalobos*

Wednesday, Sept. 29, 16:00-17:30, Session: Routing

Solving the Shipment Rerouting Problem with Quantum Optimization Techniques

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Abstract. In this work we develop methods to optimize an industrially-relevant logistics problem using quantum computing. We consider the scenario of partially filled trucks transporting shipments between a network of hubs. By selecting alternative routes for some shipment paths, we optimize the trade-off between merging partially filled trucks using fewer trucks in total and the increase in distance associated with shipment rerouting. The goal of the optimization is thus to minimize the total distance travelled for all trucks transporting shipments. The problem instances and techniques used to model the optimization are drawn from real-world data describing an existing shipment network in Europe. We show how to construct this optimization problem as a quadratic unconstrained binary optimization (QUBO) problem. We then solve these QUBOs using classical and hybrid quantum-classical algorithms, and explore the viability of these algorithms for this logistics problem.

Keywords: Optimization, Quantum Computing, Quantum Annealing, Logistics

Minimizing the Expected Cost in a Dynamic Stochastic Last-Mile Delivery with Crowdsourcing

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Abstract. The growth of e-commerce and the consequent increase in the number of parcels to deliver to final customers impacted negatively the environment with an increase in traffic and pollutant emissions, mainly in urban areas. To reduce such impact it is vital to develop not only more flexible but also more environmentally friendly delivery models. An alternative considered by some companies is the use of crowdsourcing, where third-part vehicles already heading to a location close to a final customer can contribute to the delivery.

We consider a setting where a company owns a professional fleet of vehicles for delivery of online orders and is willing to decrease the last-mile delivery costs by crowdsourcing the delivery of some of the orders. Occasional couriers (OCs) are non-professional potential deliverers of orders to online customers requiring home delivery. OCs may be in-store customers visiting a physical shop, to whom the shop suggests making a delivery in exchange for a compensation. In this work we consider a setting where OCs arrive sequentially, there is an estimate on the total number of OCs, and all online orders are known in advance. OCs accept to make a delivery with a probability defined by a function of the compensation proposed. In this work we use the `S'-shaped Sigmoid function.

We aim at finding the optimal compensations to be offered to the OCs that minimize the expected cost of delivery of online orders. Besides being a stochastic problem (acceptance of a delivery by

an OC is not deterministic), the problem is dynamic, since the decisions taken for the sequentially arriving OCs are influenced by the acceptance and rejection of offers made to previous OCs.
We start with a simpler case where there is one online order and the aim is to find the optimal compensation to be offered to each arriving OC, knowing that n OCs are expected. Then we move to the case where m online orders are to be delivered. To reduce computation effort we first consider that the cost of delivering by the professional fleet is based solely on the number of online orders. For these two problems, we proved that the vector of optimal compensations may be found by solving a recurrence relation, optimizing the problems sequentially for an increasing number of OCs and orders.
Finally, we consider the general problem, where a vehicle routing problem is to be solved to estimate the cost of delivery of any subset of orders by the professional fleet. The latter problem is highly exponential, as it assumes an enumeration of subsets of all subsets of online orders.
Computational experiments on generated test instances are performed to validate the proposed approach. The expected delivery cost decreases as the number of OCs increases. The optimal compensations for the first arriving OCs are smaller than for the following ones, and compared to a policy of fixed compensations, the reduction in the cost becomes more expressive as the ratio of the number of OCs to online orders increases.

Keywords: Last-Mile Delivery, Occasional Couriers, Crowdsourcing, Stochastic Optimization

First-Mile Logistics Operational Planning Model for Small Fresh-Produce Growers

Nicolas E. Palacios-Avilés[1], Rosa Guadalupe Gonzalez Ramirez[1], Omar Ahumada Valenzuela[2], J. Rene Villalobos[3]

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Abstract. In this work, a two-stage hierarchical optimization model is proposed to support operational harvesting planning and distribution decisions in the agri-food supply chain, considering economic and perishability aspects of agricultural fresh produces for small growers. Small growers face several challenges. Particularly, the logistics for distributing their products is expensive and they face several limitations. Motivated by that, in this work we address an operational planning decision problem considering several small growers that may be coordinated by an articulator and the distribution of their produce can be done in shared vehicles to reduce logistics costs.

Majluf et al. (2021) addressed this problem, based on the operational planning model proposed by Ahumada and Villalobos (2011) that was designed considering a single producer. Accordingly, Majulf et al. (2021) extended that model to consider multiple small growers that coordinate each other and consolidate their products for their transportation to a packing facility. In this work, we extend that model to consider the whole agri-food supply chain, assuming that fresh produces are exported. For this, it is very important to incorporate quality attributes as these are important factors that influence their final price. So, the maturity and shelf-life of the products are incorporated into the model to determine the harvesting decisions (when and how much will be harvested each period of a planning horizon) and distribution decisions related to the transportation of the products to a packing

facility from which the products will be exported. For the distribution of the products, a capacitated vehicle routing problem with time windows is considered.
The proposed hierarchical framework integrates both harvesting and distribution models with a feedback loop. The first iteration, direct shipments are assumed from each grower to the packing facility. Then, routes are defined sharing vehicle capacity among different growers. We assume that all products are compatible to be transported in the same vehicle. Once the routes are defined, the total cost is an input parameter of the first model. The procedure is repeated until both models converge under a certain allowable gap. As a case study, a group of growers located in the Region of Coquimbo in Chile are considered to generate different instances that are evaluated with the proposed framework.
Main findings of the experiments indicate that the most significant factors that contribute to the profits of the small growers are the number of orchards, their yields and the capacity of the vehicles for the distribution of produce to the packing facility. Furthermore, when comparing direct delivery versus consolidated routes, an improvement of 18% on average in profits is obtained.

Keywords: First-Mile Logistics, Agricultural Supply Chain, Small Fresh-Produce Growers, Harvesting, Routing

References:

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Warehousing

Wednesday, Sept. 29, 16:00-17:30

1 **Layout-Agnostic Order Batching Optimization** · *Johan Oxenstierna, Jacek Malec, Volker Krueger*

2 **A Multi-Periodic Modelling Approach for Integrated Warehouse Design and Product Allocation** · *Martin Scheffler, Lisa Wesselink, Udo Buscher*

3 **The Effect of Order Batching on a Cyclical Order Picking System** · *Flora Hofmann, Stephan Visagie*

Wednesday, Sept. 29, 16:00-17:30, Session: Warehousing

Layout-Agnostic Order Batching Optimization

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Abstract. Order batching is an important methodology in warehouse material handling. This paper addresses three identified shortcomings in the current literature on order batching optimization. The first concerns the overly large dependence on conventional warehouse layouts. The second is a lack of proposed optimization methods capable of producing approximate solutions in minimal computational time. The third is a scarcity of benchmark datasets, which are necessary for data-driven performance evaluation. This paper introduces an optimization algorithm, SBI, capable of generating reasonably strong solutions to order batching problems for any warehouse layout at great speed. On an existing benchmark dataset for a conventional layout, Foodmart, results show that the algorithm on average used 6.9% computational time and 105.8% travel cost relative to the state of the art. New benchmark instances and proposed solutions for various layouts and problem settings were shared on a public repository.

Keywords: Order Batching Problem, Order Picking, Discrete Optimization

Wednesday, Sept. 29, 16:00-17:30, Session: Warehousing

A Multi-Periodic Modelling Approach for Integrated Warehouse Design and Product Allocation

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Abstract. Consumers today expect supermarkets to offer a wide variety of items at favourable prices and with consistent availability. These expectations lead to major capacity challenges for distribution centres responsible for replenishing goods since consumer demand fluctuates weekly. Therefore, we investigate an integrated warehouse design and product allocation problem for a distribution centre in the retail food industry. For this purpose, we formulate a multi-periodic mixed-integer program that reflects the flow of goods within the distribution centre and, thus, explicitly captures daily fluctuations in demand. The suitability of the approach is demonstrated using modified data from a distribution centre in Germany. The results show that a static approach violates the weekday-specific capacity restrictions and that only a multi-periodic approach can meet the requirements of practice. In analyzing the real-world case we selected, the trade-off between handling and transport costs reveals that the automated storage and retrieval system is fully utilized. Interestingly, it shows that, even considering 20,000 different items, the problem can be solved in seconds using the presented model formulation.

Keywords: Warehouse Design, Product Allocation, Integrated Approach, Mixed-Integer Programming, Decision Support

Wednesday, Sept. 29, 16:00-17:30, Session: Warehousing

The Effect of Order Batching on a Cyclical Order Picking System

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Abstract. Order batching on a unidirectional cyclical picking system implemented at a prominent South African retailer is investigated. Four interdependent sub-problems are solved sequentially to optimise the entire system. These sub-problems are (a) the picking line assignment problem, (b) the stock keeping unit arrangement problem, (c) the system configuration problem, and (d) the order sequencing problem. The picking is performed in waves. The four sub-problems are viewed as decision tiers that must be solved to optimise each wave. The main objective is to minimise the overall walking distance and thus reduce total picking time for a picking wave. Order batching is introduced to this picking system to explore its effect on total completion time. Orders are formed during the optimisation process and thus are not known from the start. This also raises the question of where to include order batching in the optimisation process. Furthermore, the effect of increasing pick density to indirectly improve order batching is analysed. The combination of all solution approaches for each of the four decision tiers including the additional layer of order batching is evaluated. Three scenarios based on real-life historical data of the retailer are tested. The best solution approach is compared to a benchmark. The suggested batching approach saves up to 27.8% in total picking time.

Keywords: Order Picking System, Optimisation, Assignment Problem, Unidirectional Cyclical Picking Line, Order Batching, Complex Logistics System

Multi-Modal Transport

Wednesday, Sept. 29, 16:00-17:30

1 **Applying Constraint Programming to the Multi-Mode Scheduling Problem in Harvest Logistics** · *Till Bender, David Wittwer, Thorsten Schmidt*

2 **Multi-trip Vehicle Routing Problem with Time Windows for Waste Collection in Amsterdam** · *Çiğdem Karademir, Breno A. Beirigo, Rudy R. Negenborn, Bilge Atasoy*

3 **Intermodal Competition in Freight Transport - Political Impacts and Technical Developments** · *Joachim R. Daduna*

Wednesday, Sept. 29, 16:00-17:30, Session: Multi-Modal Transport

Applying Constraint Programming to the Multi-Mode Scheduling Problem in Harvest Logistics

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Abstract. In this paper, we present a Constraint Programming (CP)-based model for scheduling forage harvesters and transport vehicles during corn harvest. The key aspects are the synchronization of the two resource types and a forage harvester utilization depending on the number of transport vehicles supporting the harvester. The process is modelled as a pre-emptive multi-mode resource-constraint project scheduling problem with fast-tracking, sequence-dependent time lags and synchronization. We use the specialized scheduling features of CP Optimizer for modelling and solving the harvest logistics problem. The results show the suitability of the CP-based approach for modelling the problem in terms of representability of its characteristics. In computational experiments, a solution is found for any of the test instances. Proving optimality, however, is found to be difficult, especially for larger instances. Further variants of the model without pre-emption and fast-tracking and with fewer modes per activity are introduced and tested, showing improvements in computation time and the number of optimal solutions found for the prior variant.

Keywords: Harvest Logistics, Constraint Programming, Resource-Constraint Project Scheduling

Wednesday, Sept. 29, 16:00-17:30, Session: Multi-Modal Transport

Multi-Trip Vehicle Routing Problem with Time Windows for Waste Collection in Amsterdam

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Abstract. Waste collection around Amsterdam's canal network has become burdensome since heavy fossil-fuelled garbage trucks have been damaging the city's fragile quay walls, besides increasing trac and emissions. Amsterdam's municipality considers a hybrid over water and land waste collection system currently under testing that completely removes traditional garbage trucks from the equation. In this system, vessels serve as mobile depots for electric-powered cars that collect on-street garbage and need to regularly unload collected waste to capacitated vessels due to their smaller capacities than traditional heavy garbage trucks. Therefore, the on-street operation produces a series of time-windowed unloading tasks, which, in turn, trigger waste collection requests. This study focuses on modelling the fleet management of vessels for such an over-water collection system, assuming a solution for the on-street waste collection has already been determined to decide the transshipment locations, time windows and expected waste loads of the unloading requests to be served by the vessels. Since we consider that vessels have relatively small capacities to facilitate sailing throughout the waterway network, they may have to carry out the last mile to a central waste facility multiple times. The problem is modelled as a multi-trip vehicle routing problem with time windows, service dependent unloading times, and pickups (MVRPTW-SD). We present a two-index mathematical formulation that reduces the number of binary variables by at least 50% with respect to the

state-of-the-art formulations in the literature. The proposed model can solve classical delivery test instances featuring 25 and 50 nodes, with average gaps of 0.1% and 7.9%, respectively. Since there does not exist any study that considers the problem regarding the operational distances of collection services from delivery services, we provide solutions for the MVRPTW-SD with collections. Our results indicate that the MVRPTW-SD with collections is highly dependent on the geographical distribution of the transshipment locations and the tightness of collection time windows. Finally, we conduct a sensitivity analysis to give insights into the design of hybrid water- and land-based waste collection systems in order to reduce overall transportation costs and propose further improvement directions.

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Keywords: Waste Collection, MVRPTW-SD, Urban Waterways

Wednesday, Sept. 29, 16:00-17:30, Session: Multi-Modal Transport

Intermodal Competition in Freight Transport - Political Impacts and Technical Developments

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Abstract. The competition between the various transport modes is characterized by the question of economic efficiency of transport services on the one hand and (transport) policy objectives on the other hand. A comparison shows that road freight transport dominates the terrestrial transport market, while the other transport modes in this segment generally rely on road transport due to their low network formation capability. Despite political prioritization and massive subsidies, the intended changes in modal split are not achieved, due to significant changes in demand structures and their spatial distribution over the last years. By technological developments, the importance of road freight transport will significantly increase and also of river-sea and short sea shipping, while rail freight transport and also freight transport on inland waterways will significantly loose market share.

Keywords: Competition in Freight Transport, Mono-Modal and Multimodal Transport, Rail Freight Transport