XII IWCPRT

12th International Workshop on Cutting, Packing and Related Topics

11-13 September 2017, Gent, Belgium

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Abstracts

Monday, 10:30 – 11:00

Dealing with uncertainty in Cutting and Packing problems: robust planning and optimized replanning in manufacturing and transportation

José Fernando Oliveira

INESC TEC and Faculty of Engineering, University of Porto

Cutting and Packing problems are hard combinatorial optimization problems that arise in the context of several manufacturing and process industries or in their supply chains. The resolution of these problems is not only a scientific challenge, given its intrinsic difficulty, but has also a great economic impact as it contributes to the decrease of one of the major cost factors for many production sectors: the raw-materials. Current research has paid little attention to the role of uncertainty in these problems, hindering a wider adoption of research results by companies. Explicitly taking into account uncertainty, when solving cutting and packing problems with optimization techniques, is the core research idea of this project. Building on the previous experience of the research team with these problems, advanced optimization techniques (based on mathematical programming models, metaheuristics and their hybridization) will be used to develop algorithms closer to real-world needs.

Monday, 11:00 – 11:30

Improving exact methods for solving 3D Cutting and Packing Problems

Everton Fernandes da Silva* · Túlio A. M. Toffolo · Greet Vanden Berghe · Tony Wauters

*KU Leuven, CODeS

3D Cutting and Packing Problems consist of a set of boxes, which must be placed inside one or more larger cuboids, referred to as containers. The primary constraints associated with these problems concern non-overlapping and how the boxes to be placed must fit entirely inside the container. Additional constraints such as rotations may also be included. Different characteristic combinations give rise to different problem variants. This work considers a subset of these variants, known as output maximization problems. The tackled problems consist of a set of items to be placed inside a single container with the objective being to maximize the value of the placed boxes. Given their combinatorial

nature, these problems are known to be challenging and, consequently, most research in the literature addresses them heuristically in hopes of generating good quality solutions within a short amount of time. The ambition of this work is to better clarify the difficulties of solving these problems with exact methods. Different improved techniques such as specialized branch and bound, MIP formulations and lazy constraints were tested and results demonstrate their performance on both instances from the literature and newly-generated benchmark instances compared against existing exact methods. These results further contribute towards gaining insight on solving these problems, technique improvements and development of new formulations.

Monday, 11:30 – 12:00

The three-dimensional rectangular Multiple Bin Size Bin Packing Problem with transportation constraints: A case study in the field of air transportation

Célia Paquay

HEC-University of Liège

This work is a summary of a PhD thesis.

According to the International Air Transport Association and Air Transport Action Group, 51.3 million metric tons of goods were transported by airlines in 2014. To transport luggage, freight and mail, special containers, called Unit Load Devices (ULD), are used. The method of loading packages into ULDs represents a key element for cargo safety and aircraft weight and balance, as well as for the economy of airline companies.

This thesis aims to solve the problem of packing a set of boxes into containers of various shapes without wasting loading space. The goal is to select the best set of ULDs to pack all the boxes achieving a minimum unused volume. As for all the packing problems, geometric constraints have to be satisfied: items cannot overlap and have to lie entirely within the bins. The richness of this application is to manage additional and common constraints: the bin weight limit, rotations, stability and fragility of the boxes, and weight distribution within a ULD. In practice, this problem is manually solved with no strict guarantee that the constraints are met.

First, the problem is formulated as a mixed integer linear program. As this problem is NP-hard, it opens the way to heuristics. A second approach makes use of the formulation to apply three matheuristic methods, combining exact approaches and heuristics. Third, a tailored two-phase constructive heuristic is developed for this specific problem; it aims to find good initial solutions in short computational times. These approaches contain parameters that have been tuned using the irace parametrisation technique. For the experiments, several instances have been created on the basis of a box data set which stems from a real world case.

Monday, 13:30 – 14:00

The Time Window Assignment Vehicle Routing Problem With Product Dependent Deliveries

Fábio Neves-Moreira* · Diogo Pereira da Silva · Luís Guimarães · Pedro Amorim · Bernardo Almada-Lobo

*FEUP and INESC TEC

The Time-Window Assignment Vehicle Routing Problem (TWAVRP) arises in a context where customers need to idle their core activities for receiving goods. Time-windows are usually defined considering the trade-off between customers' constraints and transportation planning reasonableness. We study a challenge inspired by a Portuguese retailer which owns two warehouses and a fleet of vehicles to serve orders posted by stores. However, hard business constraints oblige the stores to demand certain products at very specific periods of the day. Therefore, some time periods have many time-windows overlapping. This fact may result in vehicle necessity peaks if these time-windows are not strategically defined to disperse deliveries along the day. We propose a novel mathematical formulation to redefine product dependent time-windows, complying with operational and business constraints. Representative demand scenarios are considered to define delivery schedules respecting product dependent time-windows which are to remain constant after the optimization process. Demands need to be satisfied, minimizing the cost of vehicle necessities and driven distance. The value of the product dependent TWAVRP is accessed in real-world instances. A sensitivity analysis is performed on the number of time-windows altered, showing that it is possible to obtain quick wins by introducing small changes on the retailer's solution.

Monday, 14:00 – 14:30

Vehicle routing problems with backhauls and three-dimensional loading constraints

Henriette Koch* · Andreas Bortfeldt · Gerhard Wäscher

*Otto-von-Guericke-University Magdeburg

In this presentation, variations of the vehicle routing problem (VRP) with three-dimensional loading constraints (3L-VRP) are considered. In order to provide a realistic modelling, the transported goods are assumed to be three-dimensional (cuboid) items which have to be packed feasibly into the three-dimensional loading space of the delivery trucks. In this context, packing constraints such as stability requirements or loading sequences must be observed.

Moreover, different variants of the VRP with backhauls are dealt with, i.e. goods must not only be delivered to customers, but must also be picked up from them. In particular,

we consider the VRP with clustered backhauls, the VRP with mixed backhauls and the VRP with simultaneous delivery and pickup. Some of these problem variants contain the particular challenge of transporting delivery and pickup items simultaneously. For these cases, different loading approaches will be presented.

A hybrid algorithm was developed for solving the different problem variants. It consists of an Adaptive Large Neighbourhood Search for the routing and different packing heuristics for the loading part of the problem. Extensive numerical experiments were conducted with newly generated instances for the 3L-VRP and well-known instances form the literature for the one-dimensional VRP variants. The corresponding results will be presented.

Keywords: vehicle routing, packing, backhauls

Monday, 14:30 – 15:00

Optimizing multi-item transport cost on direct links considering loading and inventory constraints

Patrick Engelsberg* · Thomas Volling · Fereidoun Rashidi

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Companies operating direct links for multi-item transports face the challenge to comply with delivery schedules released on short-notice while keeping corresponding cost at a minimum. For this purpose shipments can be advanced to fill unused inflexible vehicle capacities. Restrictions arise from limited storage capacity at the destination and vehicle loading constraints due to heterogeneous physical dimensions of goods. The problem results in creating a valid shipping plan which minimizes transport cost while complying with the aforementioned constraints. We interpret the problem as an extended version of the Single Stock-Size Cutting Stock Problem and formulate it as a mixed integer program. To solve the problem, we develop a multi-step heuristic procedure, which utilizes (in)compatibilities of load carriers to enumerate and combine partial solutions. The procedure is tested on a dataset from the German automotive industry. We show the resulting potential for a range of operating conditions. The presentation closes with a list of needs and ideas to enhance the performance and utility of the approach.

Monday, 15:00 – 15:30

Variable Neighborhood Search Algorithms for Pickup and Delivery Problems with Loading Constraints

Telmo Pinto* · Cláudio Alves · José Valério de Carvalho

*University of Minho

In this presentation, we address a capacitated vehicle routing problem with loading constraints and mixed linehauls and backhauls. The addressed problem belongs to the subclass of pickup and delivery problems. Two-dimensional loading constraints are also considered. These constraints arise in many real-world situations, and can improve efficiency since backhaul customers do not need to be delayed in a route when it is possible to load their items earlier and without rearrangements of the items. To tackle this problem, we present an extensive computational study on variants of the variable neighborhood search. The initial solution relies on an insertion heuristic. Both the shaking and local search phases resort to ten neighborhood structures. Some of those structures were specially developed for this problem. The validation of routes is heuristically obtained with a classical bottom-left method enhanced to tackle the explicit consideration of loading constraints.

Monday, 16:00 – 16:30

Patient-Bed Allocation in Large Hospitals

Fabian Schäfer* · Manuel Walther · Alexander Hübner

*Catholic University of Eichstätt-Ingolstadt

Increasing cost pressure for large maximum care hospitals combined with a decrease in average lengths of stay raises the importance of having an efficient bed occupancy management system in place. On an operational level, the actual bed assignment is typically subject to patient preferences, staff workloads, and medical constraints. Planning and committing to specific bed assignments in advance seems impractical given the uncertainty typically seen in hospitals due to high levels of emergency inpatients, frequent changes in lengths of stay, and no-shows among others. To tackle this planning problem, we propose a new approach which allows hospitals to reassess any given occupancy situation, while incorporating anticipated emergency patient arrivals, currently planned elective patients as well as cross-departmental overflow. Furthermore, our approach is designed to be applied to large hospital settings with pooled ward capacities and gives hospital planners the possibility to quickly assess impact on multiple objectives. The algorithm developed is tested with actual data from a large German maximum care hospital. First comparisons with existing approaches in literature show promising results.

Monday, 16:30 – 17:00

Shelf space allocation for multidimensional shelves

Tobias Düsterhöft* · Alexander Hübner

*Catholic University of Eichstätt-Ingolstadt

This presentation addresses the shelf space allocation problem where a retailer needs to assign products to shelves and to determine the space and refill frequency of each product. Shelves have even within one product category different heights and different depths, e.g. if the shelf at the bottom sticks out compared to the others levels. Retailers operate with this different shelf dimensions as they allow a better product presentation and as customers can easier grab products. These shelf types can be observed nowadays in almost every shelf rack in a supermarket. However, current decision models assume only identical shelf sizes. Shelves are not differentiated to account for different shelf heights and depths. Assuming only identical shelves hinders to transfer model solutions to real world planograms. The solutions obtained from an optimization model with one-dimensional shelf space will either result in infeasible planograms or in major adjustments and profit losses. We extend current literature with a decision model and solution approach that builds on shelves with varying sizes. The retailers profit is optimized by the selection of the number of facings and the number of refill frequencies. The first decision variable represents the shelf space allocation, whereas the second decision is required to determine the quantity available for the demand fulfillment and to represent associated logistics costs. The demand is space dependent. We contribute with a model that accounts for the multidimensional shelf sizes, different physical sizes and stackability of each item. We develop an efficient solution approach with preprocessing that allows to obtain exact solutions within short run time. The model and solution approach is tested with simulated data and data obtained from a case study with a German hypermarket.

Monday, 17:00 – 17:30

Solving the retail-store backroom layout problem

Maria Pires* · Elsa Silva · Pedro Amorim

*FEUP and INESCTEC

Competition in the food retail market has increased in recent years. Traditional food retailers have faced fierce pressure requiring them to adapt and develop innovative approaches to face the current challenges. Despite the importance of layout design in several sectors, most of the previous research has been focused on manufacturing and distribution industries. Furthermore, the sales area layout has also been studied due to its direct impact on store sales. Nevertheless, backrooms' layout plays an important role

on in-store operations efficiency and store service levels, such as out-of-shelves. Currently in practice, the design of the backroom layout is mainly established empirically, based on the perception of similar stores by the architect. However, it should be carefully studied based on in-store logistics and operations. In this presentation, we present an effective analytic method for designing backroom layouts considering walking distances, departments adjacency, sales areas layout and other physical restrictions. The application of the model proposed is illustrated with a case study of a European retailer.

Wednesday, 10:00 – 10:30

A decomposition-based algorithm for a leather industry cutting problem

Túlio A. M. Toffolo* · Tony Wauters · Antonio Martinez-Sykora

*KU Leuven, CODeS

This work addresses a real-world leather industry cutting problem commonly referred to under the category of nesting problems within the literature. In this problem, irregular and non-convex shaped pieces must be cut out from leather hides, which are themselves irregular and non-convex. These leather hides may also contain holes and different quality zones due to bites, scars and imperfections. While some pieces may be cut from low-quality leather, others specifically require high-quality material. Therefore, each piece is associated with its own permitted cutting areas, thereby introducing additional constraints to the nesting problem. In this work, the leather industry problem is formulated as a Mixed Integer Program (MIP) using a geometric toolbox developed to robustly calculate no-fit polygons. All characteristics of the problem are addressed, such as quality zones and holes. State-of-the-art commercial solvers are, however, incapable of solving the formulation within acceptable runtimes. To circumvent this issue, the problem is heuristically decomposed into easier-to-solve subproblems. The resulting decomposition-based algorithm, which consists of constructive and local search phases, is proven capable of quickly generating competitive solutions. Different parameters are evaluated and results compared against the state-of-the-art from the literature.

Wednesday, 10:30 – 11:00

A matheuristic for the irregular strip packing problem

Larissa Tebaldi de Oliveira* · Franklina Maria Bragion Toledo · Maria Antónia Carravilla · José Fernando Oliveira

*Institute of Mathematics and Computer Science, University of São Paulo

The irregular strip packing problem consists in cutting a set of small pieces with irregular shapes from a large object with fixed height. The goal is to minimize the length necessary

to cut all the small pieces ensuring that they do not overlap each other and that all of them are inside the object. To tackle this problem, we propose a matheuristic based on the biased random-key genetic algorithm (BRKGA), in which the decoder is a linear programming model that minimizes the used length and the non-overlapping constraints are written based on the edges of the nofit polygons (NFP) of the pairs of pieces. Each solution is encoded as a vector of n random keys, where n is the total number of NFP and each key encodes which edge of the NFP will be used to guarantee the non-overlapping between the pieces.

Wednesday, 11:00 – 11:30

Height estimation for the rectangular two-dimensional strip packing problem

Alvaro Neuenfeldt Júnior* · Elsa Silva · António Miguel Gomes · Carlos Soares · José Fernando Oliveira

*INESC-TEC, University of Porto

In the rectangular two-dimensional strip packing problem, the aim is to pack a set of small items inside a rectangular object with one dimension fixed and the other free, while minimizing the object's dimension that is free. The small items must be positioned without overlapping each other and completely contained inside the object. This description fits the definition of cutting and packing problems and indeed the strip packing problem can be classified as an open dimension cutting and packing problem. In this work a method for the estimation of the strip packing height generated changing the items sequence in a bottom-left-fill heuristic is developed. This value can be used as a reference value by the heuristics. In the problem's version we are dealing with, items should be orthogonally positioned in the empty spaces available in the object and can be rotated. To estimate the strip height we resort to a set of variables that represent the test problem instances characteristics, related to the items and object shape variation, inspired by the structure and parameters of problem generators available in the literature. The bottom-left-fill heuristic was implemented to solve a set of 30000 generated test problem instances. This set of solutions was used both to train the regression models and afterwards to test its performance. Data mining approaches were adopted to develop the regression models, with the aim of understanding the relation between the test problem instances characteristics and the results obtained by the bottom-left-fill heuristic. A different data set was used to test the regression models generalization level. Computational experiments were conducted and will be presented.

Wednesday, 11:30 – 12:00

10 years of Eternity II – from multimillion dollar puzzle to challenging optimization problem

Tony Wauters

KU Leuven, CODeS

The Eternity II (EII) puzzle is a commercial Edge-matching puzzle in which 256 square tiles with four coloured edges must be arranged in a 16 by 16 grid such that all tile edges match the colour of the one it faces. In addition, a complete solution requires that the 'grey' edges, which appear only on a subset of the tiles, should correspond to the perimeter of the grid. The puzzle belongs to the more general class of Edge-Matching Puzzles, which have been shown to be NP-complete. In July 2007, toy distributor Tomy UK Ltd. released this challenging Edge-matching puzzle with a $2 million prize. However, to the best of our knowledge, no complete solution has ever been found. Meanwhile, the final qualifying date for the cash price, 31 December 2010, has passed, leaving the money prize unclaimed. Throughout its ten years of existence many people tried to solve EII and some continue to do so. Many approaches for Edge-matching Puzzles are reported throughout the literature. Among these approaches are constraint programming and backtracking, metaheuristics, and evolutionary methods. Other approaches translate the problem into SAT, MILP or max-clique and subsequently solve it with appropriate state of the art solvers. Some approaches have also been implemented on parallel computing or dedicated hardware. In this talk we will give an overview of this wide variety of approaches and discuss the solved and open problems related to Edge-matching puzzles.

Wednesday, 13:30 – 14:00

Mathematical models for the pre-marshalling problem

Consuelo Parreño* · Ramón Álvarez-Valdes · Rubén Ruiz

*University of Valencia

Given an initial bay configuration of a port yard, the pre-marshalling problem consists of sorting its containers in such a way that in the final configuration the containers are located in the yard in the same order by which they will be required later. The objective of the problem is to minimize the number of moves required to obtain a correct final configuration. Reshuffling can be done before the arrival of a ship, when the work load at the terminal is minimum, so that no shuffling needs to be carried out when ships are being loaded/unloaded, thus increasing the performance of the terminal when it is most needed.

In recent years, the number of contributions to the pre-marshalling problem has increased in a notable way. In this paper, we focus on exact methods for solving the problem

and we propose two mathematical models. Moreover, we also propose a set of valid constraints than enhance and improve the performance of the models. Our final formulation performs better than the proposed by Lee and Hsu (2007), which is, to the best of authors' knowledge, the only mathematical model in scientific literature. We also provide an algorithm to obtain a lower bound for the problem that is better than other lower bounds previously proposed. With the aim of evaluating our contributions, an extended computational analysis has been carried out. Computational experiments involve thousands of instances and results have been studied in comprehensive statistical analyses.

Wednesday, 14:00 – 14:30

A mixed integer linear model for the Berth Allocation Problem in terminals with irregular layouts

Juan Francisco Correcher* · Ramón Álvarez-Valdes · Thomas Van den Bossche · Greet Vanden Berghe

*University of Valencia, Spain

The Berth Allocation Problem (BAP) concerns the assignment of a berthing time and position to each vessel calling at a port terminal, aiming to minimize the overall assignment cost. In doing so, spatial and time constraints must be satisfied to obtain a berth plan compatible with the characteristics of both the terminal and the vessels.

Many ports around the world have irregular layouts, resulting from the construction of piers and other structures that alter the coastline. In terminals whose irregular layouts give rise to adjacency, oppositional, and blocking relations between berths, vessels may be prevented from berthing or departing under given conditions, thereby affecting berth allocation planning.

In this study we analyse the novel BAP arising in terminals with irregular layouts and propose a mixed integer linear model to obtain optimal solutions for real-world instances of the problem. This model is evaluated through extensive computational experiments conducted on diverse sets of instances. Moreover, a comprehensive study is performed to determine how various factors influence the complexity of the problem.

Wednesday, 14:30 – 15:00

Optimizing Costs and Risks in Asset Management

Luis Dias* · Armando Leitão · Luís Guimarães

*University of Engineering of Porto (FEUP- Faculdade de Engenharia do Porto)

With the increasing age of assets related to operational functions, asset management has become increasingly more relevant. There is a need to extract the most value from the assets before they are retired from their functions, so maintenance policies are formulated to prolong the life of these assets. When establishing the maintenance policies, many companies prioritise the minimization of the probability of failure of the assets, compromising their financial efficiency. In this work, we consider an asset management problem in the electricity industry capable of being generalized to several kinds of assets in other industries. This problem takes into consideration the Power Transformer condition, the most critical equipment in the distribution of electricity. Based on a discrete set of states which evolve with the passage of time we model asset degradation. The goal is to determine the optimal degradation state in which preventive maintenance should be performed. The problem is formulated as a multi-objective search aiming at simultaneously optimizing two objectives of interest: risks and costs. For a close approximation to reality, the model describing the evolution of the degrading system is based on the use of the Markov model and the Monte Carlo (MC) simulation. The transition probabilities are estimated from the data using a Hidden Markov Model- HMM algorithm (Baum-Welch algorithm). Maintenance policies are generated using a Genetic Algorithm (GA). The calculation of the risk objective function is based in several criteria that we must consider when analyzing an asset. These criteria coupled with the current asset state will be crucial to calculate the asset risk. The coupled (GA+MC) will be the key to establish the maintenance policies that are able to optimize risks and costs.

Wednesday, 15:30 – 16:00

Optimization Potential of Mobile Deconsolidation Points in Grocery Retail Logistics

Michaela Thulke* · Thomas Volling

*FernUniversität in Hagen, Chair of Production and Logistics Management

Mobile deconsolidation points are an innovative approach towards reorganized structures in distribution logistics. The underlying principle is the following: goods are consolidated to full truck loads in central warehouses to be shipped to strategically placed deconsolidation points. From these points the goods are transshipped to their final destination. As opposed to traditional transshipment concepts, mobile deconsolidation

points have minimal infrastructure requirements and can be dynamically (re-)located to match transportation demands. Mobile deconsolidation points therefore combine the efficiency of hub-and-spoke networks with the flexibility of direct shipments. This makes them a particularly interesting candidate solution to tackle the challenges in grocery retail logistics: high cost pressure, pronounced demand variability and rigid traffic and delivery constraints.

However, the arising interdependencies between locations of deconsolidation points, vehicle routing, and inventory management require new/adapted planning concepts. Before discussing first steps towards an integrated approach, we highlight the potential of mobile deconsolidation points in grocery retail logistics. Building upon the case of a large German grocery retailer, we analyze different operating conditions and specify implications for distribution planning. To conclude, we point out issues for future research.

Wednesday, 16:00 – 16:30

An heuristic approach for product-line trimming decisions

Xavier Andrade* · Luís Guimarães · Gonçalo Figueira

*FEUP

In order for a consumer packaged goods manufacturer to excel at its business, both its marketing and operations policies must be aligned. To attain satisfactory customer service, the expectations which arise from marketing policies must be met by a fitting operations strategy. Currently, many players in the consumer packaged goods industry have exceedingly broad product lines, and could benefit from trimming some products out. This work exposes an analytical approach for the product-line trimming decision problem. By assuming the position of a player in a competitive market, we consider the effects of removing products from our mix. Product removal results, usually in a loss of sales which can be compensated by reduced inventory and manufacturing complexity costs. To derive managerial insights, we generate world-size instances and develop a meta-heuristic algorithm, to determine which products to trim, and which products to keep while maximizing profit. Lastly, we discuss the implications of the instances on the performance of the approach and set aim on future research.

Wednesday, 16:30 – 17:00

The multiple-job repair kit problem with inhomogeneous customers

Christoph Rippe* · Gudrun P. Kiesmüller

*Otto-von-Guericke-Universität Magdeburg

The multiple-job repair kit problem is the problem of determining the optimal contents of a service technician's kit that he is equipped with in order to visit several customers in a tour. As an extension to previous works by Teunter (2006) and Bijvank et al. (2010) we relax their assumption that all customers in such a tour are homogeneous. Instead we assume two different groups of customers reflecting different product types or different types of consumer behavior. This is included in the model by different demand probabilities for the customers of different groups. Contrary to previous studies we consider a minimum rather than an average job fill rate as a performance measure because it describes a service level that can be guaranteed to all customers in the tour. First we derive an exact expression for this minimum job fill rate given two different customer groups. Then we implement a greedy algorithm to determine the contents of the repair kit that makes use of this exact expression. We demonstrate that the minimum job fill rate is not always the last customer's job fill rate. More importantly we show that in case two different customer groups are considered the minimum job fill rate depends not only on the contents of the repair kit but also on the order in which the customers are visited. Finally we compare the repair kits obtained using customer differentiation to those determined without.

Bijvank, M., Koole, G., Vis, I.F.A., 2010. Optimising a general repair kit problem with a service constraint. European Journal of Operational Research, 204, 76-85

Teunter, R.H., 2006. The multiple-job repair kit problem. European Journal of Operational Research, 175, 1103-1116

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