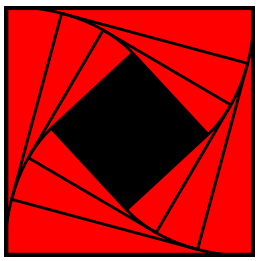

SOAK 2022

The Swedish Operations Research Conference

Hotell Järva Krog, Stockholm, October 24–25

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Program

Monday October 24, 2022

11.00 – 11.15	Opening Remarks
11.15 – 12.00	**Plenary 1** **1. Ulf Brännlund** Optimal power scheduling and some general reflections on using optimization models in practice
12.00 – 13.15	Lunch
13.15 – 14.30	**Session 1** **2. Jakob Nordström** Certified Symmetry and Dominance Breaking for Combinatorial Optimisation **3. Andy Oertel** Certified CNF Translations for Pseudo-Boolean Solving **4. Christian Carling** Visualising weight uncertainty in MCDA: Simple graphical techniques
14.30 – 15.00	Coffee Break
15.00 – 16.15	**Session 2** **5. Jan Rolfes** Finding feasible operation modes for power distribution systems by discrete adjustments in distributional robust optimization **6. Sara Frimodig** Column Generation as a Tool for Automated Radiation Therapy Patient Scheduling **7. Gianpiero Canessa** Chance constrained conic-segmentation support vector machine with uncertain data
16.15 – 16.45	Coffee Break
16.45 – 18.00	**Session 3** **8. Jan Kronquist** Lifted reformulations for mixed-integer nonlinear programming **9. Nils-Hassan Quttineh** An optimization approach for planning a dinner safari **10. André Schnabel** A tour of the GAMS ecosystem in 2022
18.00 – 19.00	Break
19.00 – 21.30	Conference Dinner

Tuesday October 25, 2022

08.00 – 09.15	**Session 4** **11. André Schnabel** Selecting mixed-integer programming formulations for resource-constrained project scheduling problems via machine learning **12. Tomas Lidén** A Bi-level Approach for Scheduling Railway Renewal Projects **13. Ann-Brith Strömberg** Robust optimization of a bi-objective tactical resource allocation problem with uncertain qualification costs
09.15 – 09.45	Coffee Break
09.45 – 11.00	**Session 5** **14. Frej Knutar Lewander** Fundamentals of a Constraint-Based Local Search Solver **15. Emil Karlsson** Maturing technology and gaining knowledge through prototyping **16. Kamran Forghani** Sawing optimization using 3D scanning data for the wood industry
11.00 – 11.15	Coffee Break
11.15 – 12.00	**Plenary 2** **17. Rebecca Jörnsten** On the regularization of neural networks: interpretation and a new approach
12.00 – 13.15	Lunch
13.15 – 14.30	**Session 6** **18. Spartak Zikrin** Super-resolution 3D single-molecule localization in E. coli using deep learning **19. Roghayeh Hajizadeh** Coordination of vehicles in urban snow removal **20. Maria Andreina** Using Constraint Programming to Design Microplate Layouts
14.30 – 15.00	Coffee Break
15.00 – 15.50	**Session 7** **21. Mattias Grönkvist** Crew Teaming in Airline Pairing Optimization **22. Lina Jarl** Military Operations Assessment – Lessons learned
15.50 – 16.00	Concluding Remarks

Abstracts

Plenary 1 (Monday)

1. Ulf Brännlund (Volue)

Optimal power scheduling and some general reflections on using optimization models in practice

In this talk we discuss some models which have been developed for optimal power scheduling at Volue. These are used both for short- and long-term scheduling of very large systems in Europe, where there is a large penetration of hydro power. We touch upon how these models fit in with other systems used for planning and the trends that we see coming in the industry. Some reflections are made about using optimization models in practice, the shortcuts that sometimes are needed and the differences between models used in practice and those studied in academia.

Session 1 (Monday)

2. Jakob Nordström (University of Copenhagen & Lund University)

Certified Symmetry and Dominance Breaking for Combinatorial Optimisation

Symmetry and dominance breaking can be crucial for solving hard combinatorial search and optimisation problems, but the correctness of these techniques sometimes relies on subtle arguments. For this reason, it is desirable to produce efficient, machine-verifiable certificates that solutions have been computed correctly. Building on the cutting planes proof system, we develop a certification method for optimisation problems in which symmetry and dominance breaking are easily expressible. Our experimental evaluation demonstrates that we can efficiently verify fully general symmetry breaking in Boolean satisfiability (SAT) solving, thus providing, for the first time, a unified method to certify a range of advanced SAT techniques that also includes XOR and cardinality reasoning. In addition, we apply our method to maximum clique solving and constraint programming as a proof of concept that the approach applies to a wider range of combinatorial problems.

This is joint work with Bart Bogaerts, Stephan Gocht, and Ciaran McCreesh published at AAAI '22.

3. Andy Oertel (Lund University & University of Copenhagen)

Certified CNF Translations for Pseudo-Boolean Solving

The dramatic improvements in Boolean satisfiability (SAT) solving since the turn of the millennium have made it possible to leverage state-of-the-art conflict-driven clause learning (CDCL) solvers for many combinatorial problems in academia and industry, and the use of proof logging has played a crucial role in increasing the confidence that the results these solvers produce are correct. However, the fact that SAT proof logging is performed in conjunctive normal form (CNF) clausal format means that it has not been possible to extend guarantees of correctness to the use of SAT solvers for more expressive combinatorial paradigms, where the first step is an unverified translation of the input to CNF.

In this work, we show how cutting-planes-based reasoning can provide proof logging for solvers that translate pseudo-Boolean (a.k.a. 0-1 integer linear) decision problems to CNF and then run CDCL. To support a wide range of encodings, we provide a uniform and easily extensible framework for proof logging of CNF translations. We are hopeful that this is just a first step towards providing a unified proof logging approach that will also extend to maximum satisfiability (MaxSAT) solving and pseudo-Boolean optimization in general.

This is joint work with Stephan Gocht, Ruben Martins and Jakob Nordström.

4. Christian Carling (FOI)

Visualising weight uncertainty in MCDA: Simple graphical techniques

Many techniques have been proposed to handle uncertainty in MCDA. Explicitly modelling uncertainties within a modified MCDA model has produced powerful tools, but at the cost of increased complexity, making them hard to use in many practical situations.

At FOI Defence Analysis, we tend to use MCDA as a simple supporting technique, within a more complex analytical process. The typical problem is evaluation of a fixed set of alternatives, using basic MCDA tools. The setting is often interactive, working with subject matter experts or decisions makers in small groups.

In our experience, decision makers can reason well about uncertainties in performance values, since these can be related to known systems or processes. The choice of criteria weights, on the other hand, is necessarily more ad-hoc and thus, uncertain. We have developed a simple technique to find the full set of solutions, i.e. feasible orderings of alternatives, over the entire weight space. For small models, or sub-sets, the solutions can be visualised in many ways. For models with larger number of criteria, we also investigate the use of tournament graphs to represent shifting precedences between alternatives.

Session 2 (Monday)

5. Jan Kronqvist and Jan Rolfes* (KTH)

Finding feasible operation modes for power distribution systems by discrete adjustments in distributional robust optimization

In recent years the amount of distributed generators (DG), such as local wind farms or solar cells, in power distribution systems (PDS) has increased rapidly. However, the power generation of these DGs is affected by uncertainties, e.g. stemming from weather conditions. These uncertainties may threaten the grid safety and thus smart inverters were developed to stabilize the voltage. In this talk we propose a mathematical framework to optimize the operation mode of the smart inverters. The framework boils down to a distributional robust optimization problem, where it is possible to adjust some of the variables to the realized uncertainty in the capacity of the DGs. Particularly, one obtains a three-level optimization problem with discrete decisions on the lowest level. In order to address this problem, we aim to develop a branch-and-bound algorithm, that provides feasible solutions for this very challenging problem.

6. Sara Frimodig (KTH)

Column Generation as a Tool for Automated Radiation Therapy Patient Scheduling

Cancer is one of the leading causes of premature mortality worldwide. One of the most common technologies used to treat cancer is radiation therapy (RT), where radiation from linear accelerators is used to kill malignant tumor cells. To better use resources in RT, optimization methods can be used to automatically create patient schedules on the machines, a task that today is done manually in almost all clinics. We present a Column generation model to solve the RT patient scheduling problem and evaluate it using data from Iridium Netwerk, a large cancer center in Belgium. The model includes all constraints necessary for the schedules to work in practice, including for example different machine compatibilities, patient priorities and protocols, and interruptions in treatments due to maintenance on machines. The optimized schedules are compared to historical schedules from Iridium Netwerk, and although the analysis is not completed yet, the preliminary results look promising. The proposed methodology provides a tool for automated scheduling of RT treatments, which could improve resource utilization in cancer clinics around the world.

7. Gianpiero Canessa*, Shen Peng and Zhihua Allen-Zhao (KTH)

Chance constrained conic-segmentation support vector machine with uncertain data

Support vector machines (SVM) is one of the well known supervised machine learning model. The standard SVM models are dealing with the situation where the exact values of the data points are known. This paper studies the SVM model when the data set contains uncertain or mislabelled data points. To ensure the small probability of misclassification for the uncertain data, a chance constrained conic-segmentation SVM model is proposed for multiclass classification. Based on the data set, a mixed integer programming formulation for the chance constrained conic-segmentation SVM is derived. Kernelization of chance constrained conic-segmentation SVM model is also exploited for nonlinear classification. The geometric interpretation is presented to show how the chance constrained conic-segmentation SVM works on uncertain data. Finally, experimental results are presented to demonstrate the effectiveness of the chance constrained conic-segmentation SVM for both artificial and real-world data.

Session 3 **(Monday)**

8. Jan Kronqvist (KTH)

Lifted reformulations for mixed-integer nonlinear programming

Mixed-integer nonlinear programming (MINLP) is one of the most versatile optimization paradigms with a large variety of applications ranging from drug discovery to system design and optimal planning. In this talk, we cover some lifted reformulations that can be employed to enforce and utilize separability of nonlinear expressions. Exploiting the separability enables us to construct significantly stronger polyhedral relaxations, and for some practical problems this transforms some computationally intractable problems to become solvable within a few seconds. In the talk we cover some basic theory behind lifted reformulations, and present some new combined reformulations based on eigenvalue decomposition and LDL decomposition.

9. Nils-Hassan Quttineh (Linköping University)

An optimization approach for planning a dinner safari

A dinner safari (or progressive dinner, safari supper), or "cykelfest" in Swedish, is a social activity where friends or neighbours participate in a dinner party with successive courses prepared and eaten at the residences of different hosts. This involves the consumption of one course at each location, to always meet new people, and to travel by bike between the residences. Already with a moderate number of participants this becomes a combinatorial nightmare, especially when trying to keep total traveling distances down.

We present a mathematical optimization model for this problem, where the objective is to minimize the longest total distance for any participant while never meeting the same people more than once throughout the evening. Results are presented for the annual dinner safari "Cykelfesten" organized by the students at Linköping University, which is typically attended by several hundreds of participants.

10. André Schnabel (GAMS)

A tour of the GAMS ecosystem in 2022

The GAMS ecosystem surrounding its modeling language has significantly evolved in recent years. There have been major additions like MIRO, Transfer, Engine, and a vastly more modern integrated development environment with Studio. MIRO allows to rapidly obtain an interactive web application frontend for a GAMS model with extensive visualization options for the end-user. Transfer makes (interactively) working with data seamless and more natural in languages such as Python and Matlab. Engine allows running GAMS jobs in a cloud environment and thus making even quite hard problems tractable. Studio is a powerful IDE for GAMS with tight integrations to MIRO and Engine. This talk will give a tour through these new tools and show examples of their application.

Furthermore, the talk will present the recently published Connect framework. Connect is inspired by the ETL (extract, transform, load) procedure for integrating data from various sources. With Connect, the user can read data from various formats into the Connect database, where he can transform the data before exporting it into a file format of choice. This approach is general and will simplify switching between different formats and make many of the conversion utilities from the GAMS distribution obsolete. As an interesting toy example, it will be shown how GAMS together with Connect can be used to determine the shortest hiking tour that collects all hiking awards in the Harz mountains in central Germany.

Session 4 **(Tuesday)**

11. André Schnabel (GAMS)

Selecting mixed-integer programming formulations for resource-constrained project scheduling problems via machine learning

The resource-constrained project scheduling problem (RCPSP) describes the task of finding the shortest feasible schedule for a given project, considering restrictions on activity ordering and resource capacities. Several exact and heuristic solution algorithms as well as various mixed-integer programming (MIP) model formulations exist for this problem. The relative performance of these different solution approaches depends on the structural characteristics of the project instances. Furthermore, there is no single best solution approach that consistently dominates the other approaches on all instances.

Throughout this talk, the construction of a MIP model formulation selection tool for the RCPSP is documented. Generating the training data involves the identification of useful instance characteristics and running a portfolio of competitive model formulations on representative test sets. This data is then used as an input for different ML methods in order to build a classifier that predicts the best solution approach for a given instance. As two comparatively novel ML methods, we evaluated AutoML and deep learning and present the corresponding numerical results. The results show a high classification accuracy and a considerable performance impact in comparison to only using the single MIP formulation with the best performance on average.

12. Tomas Lidén (Linköping University and VTI)

A Bi-level Approach for Scheduling Railway Renewal Projects

National planning of railway renewal and upgrade projects need to consider both the project completion aspects as well as the impact that these works will have on the traffic throughput. Renewal and upgrade planning does however take place before the details of the railway traffic (i.e. the timetable) is known, which means that a more general traffic model is needed. We present a bi-level approach for solving this planning problem. The upper level schedules a set of projects, each consisting of a sequence of tasks with resource requirements and different types of capacity blockings on the traffic network. The lower level finds a traffic assignment for a given traffic demand under the current capacity restrictions. The modified traffic flows are then given as input to the upper level so as to allow for adjustment of the project scheduling in an iterative approach. The project scheduling part is modelled as a mixed integer program while a novel approach for timed traffic flow with routing decisions, dwelling possibilities and capacity restrictions is used in the lower level. We will describe the mathematical modelling and some of the challenges encountered when applying these models to practical problem instances.

13. Sunney Fotedar, Ann-Brith Strömberg*, Edvin Åblad and Torgny Almgren (Chalmers)

Robust optimization of a bi-objective tactical resource allocation problem with uncertain qualification costs

In the presence of uncertainties in the parameters of a mathematical model, optimal solutions using nominal or expected parameter values can be misleading. In practice, robust solutions to an optimization problem are desired. Although robustness is a key research topic within single-objective optimization, little attention is received within multi-objective optimization, i.e. robust multi-objective optimization. This work builds on recent work within robust multi-objective optimization and presents a new robust efficiency concept for bi-objective optimization problems with one uncertain objective. Our proposed concept and algorithmic contribution are tested on a real-world multi-item capacitated resource planning problem, appearing at a large aerospace company manufacturing high precision engine parts. Our algorithm finds all the robust efficient solutions required by the decision-makers in significantly less time than the approach of Kuhn et al. (Eur J Oper Res 252(2):418–431, 2016) on 28 of the 30 industrial instances.

Session 5 **(Tuesday)**

14. Frej Knutar Lewander (Uppsala University)

Fundamentals of a Constraint-Based Local Search Solver

Constraint-Based Local Search (CBLS) is a method for solving combinatorial problems by combining local search with propagation algorithms of constraint programming. MiniZinc is a solver-independent modelling language supported by CP, MIP, SAT, SMT, and CBLS backends. With the knowledge gained from implementing the fzn-oscar-cbls MiniZinc backend and evaluating the performance of fzn-oscar-cbls on MiniZinc models, we have started developing Atlantis, a black-box CBLS solver with a MiniZinc backend. In this presentation, we describe the fundamentals of a CBLS solver, focusing on the propagation algorithms of Atlantis.

15. Emil Karlsson* and Bo Granbom (Saab)

Maturing technology and gaining knowledge through prototyping

The process of moving from applied research to early product development takes a considerable amount of time and effort for a company. In this talk, I share some experiences on how we, in a project at Saab, work with combining knowledge acquisition and feature prototyping in the area of tactical autonomy. A key objective of the project is the goal of moving from a one-slide power-point sketch to a technical demonstration in 3-4 months. This focused effort enables us to explore a potential feature or technique in reasonable amount of time and gives valuable feedback on the maturity of the technique, the potential of a feature and our own processes and environments. By working cross-site, primarily online and expecting a part-time involvement of the project members, we are able to involve our industrial PhD students, research scientists, and senior engineers with different skill sets and background.

16. Kamran Forghani *, Di Yuan, Justin Pearson, Mats Carlsson and Pierre Flener (Uppsala University)

Sawing optimization using 3D scanning data for the wood industry

Sawing optimisation is an important issue in the wood industry. The aim is to cut logs into timbers with given profiles so that criteria such as waste or quality are optimized. The introduction of 3D scanning technology in the wood industry has made it possible to extract detailed information regarding log geometry and its internal characteristics. This information can be used to assess the log yield more realistically.

In this project, we work on a sawing optimisation problem where each candidate timber is assigned a quality label depending on its dimension and position within the log. We formulate the problem as a type of Maximum Set Packing Problem (MSPP). In practice, sawing takes place immediately after the scanning process. As a result, to avoid any delay in the sawing process, it is very important to solve the optimisation problems efficiently in a short amount of time. To speed up the model generation and data processing, we take advantage of parallel computing where the cost parameters of the MSPP are calculated on multiple threads. Finally, we use the CPLEX solver to solve the resulting optimization problem. The Swedish Pine Stem Bank database, involving hundreds of computer tomography scans, is used as a benchmark in the project.

Plenary 2 **(Tuesday)**

17. Rebecka Jörnsten (Chalmers)

On the interpretability of regularization for neural networks through model gradient similarity

Most complex machine learning and modelling techniques are prone to over-fitting and may subsequently generalize poorly to future data. Artificial neural networks are no different in this regard and, despite having a level of implicit regularization when trained with gradient descent, often require the aid of explicit regularizers. We introduce a new framework, Model Gradient Similarity (MGS), that (1) serves as a metric of regularization, which can be used to monitor neural network training, (2) adds insight into how explicit regularizers, while derived from widely different principles, operate via the same mechanism underneath by increasing MGS, and (3) provides the basis for a new regularization scheme which exhibits excellent performance, especially in challenging settings such as high levels of label noise or limited sample sizes.

Authors: Vincent Szolnoky, Viktor Andersson, Balazs Kulcsar and Rebecka Jörnsten

Session 6 (Tuesday)

18. Spartak Zikrin *, Patrick Hennig, Konrad Gras, Praneeth Karempudi and Johan Elf (Uppsala University)

Super-resolution 3D single-molecule localization in E. coli using deep learning

Super-resolution fluorescence microscopy techniques allow for the localization of single fluorescent emitters below the diffraction limit. The DECODE method (Spieser et al,2021) is a super-resolution deep learning-based method which enables fast and dense single-molecule localization with high accuracy. It outperformed the other methods in a public software benchmark competition in 2021. We apply DECODE for 3D localization of fluorescently labelled probes attached to chromosomes in E.coli cells. We use simulated fluorescence microscopy images for model training where the true emitter positions are known. The efficiency of DECODE on experimental images is demonstrated by comparing it with a maximum likelihood estimator-based method (Lindén et al, 2017).

19. Roghayeh Hajizadeh * and Kaj Holmberg (Linköping University)

Coordination of vehicles in urban snow removal

Snow removal is an unavoidable problem in Nordic countries like Sweden. A number of streets in a city need to be cleared of snow by a limited number of vehicles. The problem can be formulated as a very large mixed integer programming model, which is practically unsolvable. In order to find a feasible solution, first we break done the work into smaller parts, one for each vehicle. To find which streets a vehicle shall take care of, we solve a weighted k-Chinese postman problem. Based on the allocation obtained, we consider snow removal problems for single vehicles, where details such as turning penalties and precedences are included. These problems can be reformulated to asymmetric traveling salesman problems in extended graphs, and we have a heuristic for finding feasible solution of those. In this paper, we discuss combined solution approaches and coordination of the vehicles to find a feasible solution for the whole original problem including all details. We use an iterative procedure to combine the tours, based on the tools mentioned above, and a procedure for constructive coordination of the tours. We also have new improvement procedures for the combined solution. We have implemented the methods and applied them to real life city networks. The numerical results show that the methods obtain feasible tours for large problems within a reasonable time.

20. Maria Andreina Francisco Rodriguez*, Jordi Carreras Puigvert and Ola Spjuth (Uppsala University)

Using Constraint Programming to Design Microplate Layouts

A microplate is a flat surface that typically consist of a 2:3 matrix of wells, such as 96 or 384 wells. Since they were first introduced in the 1960s, they have been an essential tool in disciplines such as drug discovery and clinical diagnostic testing. An assay is a procedure for assessing or measuring the presence, amount, or function of a particular target (like a cell or a drug). Most assays give one result per well, but it is also possible to perform time-resolved assays with one measurement per time-point per well. In high-throughput settings, thousands of measurements are generated by automatic plate handling robots.

Assays commonly exhibit systematic variations across the geometry of the plate due to factors such as well location, temperature, and humidity being unequally distributed, and said variations can affect the results to the point of rendering the assay unusable. Proper experimental design, including blocking and randomization of experimental samples and conditions, can help reduce unwanted bias and control for potential plate or batch effects. Traditionally, microplate layouts have been designed manually, following patterns that intuitively distribute samples over several plates. More recently, some tools have been developed, but most of which still require a human in the loop, and none of which is easily customizable.

In this work, we discuss the desired properties of effective microplate layouts for dose-response and screening experiments, and implement them as a constraint model in MiniZinc. Our goal is to design an automated laboratory system capable of iteratively designing experiments, execute them, evaluate them, and based on the results, repeat the process again. Towards this goal, we designed a flexible model that 1) helps researchers plan well-designed experiments reducing the rate of (partial) microplate rejection, and 2) will be a key component of our automated robotic laboratory system. We also believe this is the first attempt to use constraint programming to design microplate layouts.

Session 7 **(Tuesday)**

21. Waldemar Kocjan and Mattias Grönkvist * (Jeppesen)

Crew Teaming in Airline Pairing Optimization

Airline crew planning is a process performed in several consecutive stages. It starts with manpower planning, estimating the crew necessary to perform planned airline operations. In the next crew pairing phase, a set of anonymous trips are created, series of flights starting and ending at a specific crew base, which take into consideration crew needed to perform each flight. Finally, in the rostering stage, created trips are assigned to the real crew.

Creating trips in the pairing phase is subject to different requirements. Crew teaming is a requirement to keep a flight crew together between certain flights, during a working day or even throughout a whole trip. Fulfilling such requirement is of great importance from the point of view of operational stability of a crew schedule, however it is very difficult due to differences in rules and costs between different crew positions. The trade-off between cost of the solution and degree of teaming is a significant challenge.

In this presentation we will address how teaming is encourage inside the Jeppesen Crew Pairing product.

22. Linda Jarl (FOI)

Military Operations Assessment – Lessons learned

Operations Assessment (OA) is the process in which military leaders receive valuation and recommendations in order to make decisions concerning the military operation. The process is an important feedback cycle that starts with problem analysis and ends with the Chief of Joint Operations (CJO) direction. However, the research field of OA is sparse and there is no general best practice for Swedish circumstances. Most part of assessment theories and handbooks derives from the North Atlantic Treaty Organization (NATO), but do not necessarily fit the Swedish conditions. Nevertheless, there are analytical experiences of assessment within the military organization of the Swedish armed Forces that might be useful to discuss or investigate further in the academic environment. Therefore, this presentation aims to share lessons learned, give examples and problematize the military operational assessment. The presentation is based on experiences from operational planning processes within the Swedish armed forces and military exercises. Military exercises is reoccurring activities with the purpose to increase military capacity, test and develop military planning as well as OA. Exercises make it possible to both test and to valuate analytical methods under time pressure and then use the results for improvement in ordinary assessment processes. In conclusion, it is from this analytical cycle of testing and implementing assessment methods that best practice is gained on group level.