SOAK 2019

The Swedish Operations Research Conference

Blommenhof, Nyköping, 23-24 October 2019

Dear conference guest,

Welcome to Blommenhof and SOAK 2019!

SOAK is the bi-annual Swedish Operations Research Conference and its name is originally an acronym of the Swedish name of the conference *Svenska operationsanalyskonferensen*. This year's conference has attracted 53 participants and 36 contributed talks that together cover a wide range of OR topics. We are also happy to have two invited speakers, Thomas Schön, Uppsala University and Arne Andersson, Coupa Software.

Previous editions of the conference included Linköping University (October 19-20, 2017), Mälardalen University (October 23, 2015), Chalmers University (October 24-26, 2013, co-hosted with the Nordic Optimization Symposium) and FOI in Kista (September 28, 2011). Traditionally, the conference has been hosted by one of our members, but this year we have chosen to try something new by going to Blommenhof. We hope that you will enjoy your stay here!

Wishing you an inspiring event,
Elina Rönnberg, President of the Swedish Operations Research Association

Getting to the conference venue – Hotel Blommenhof

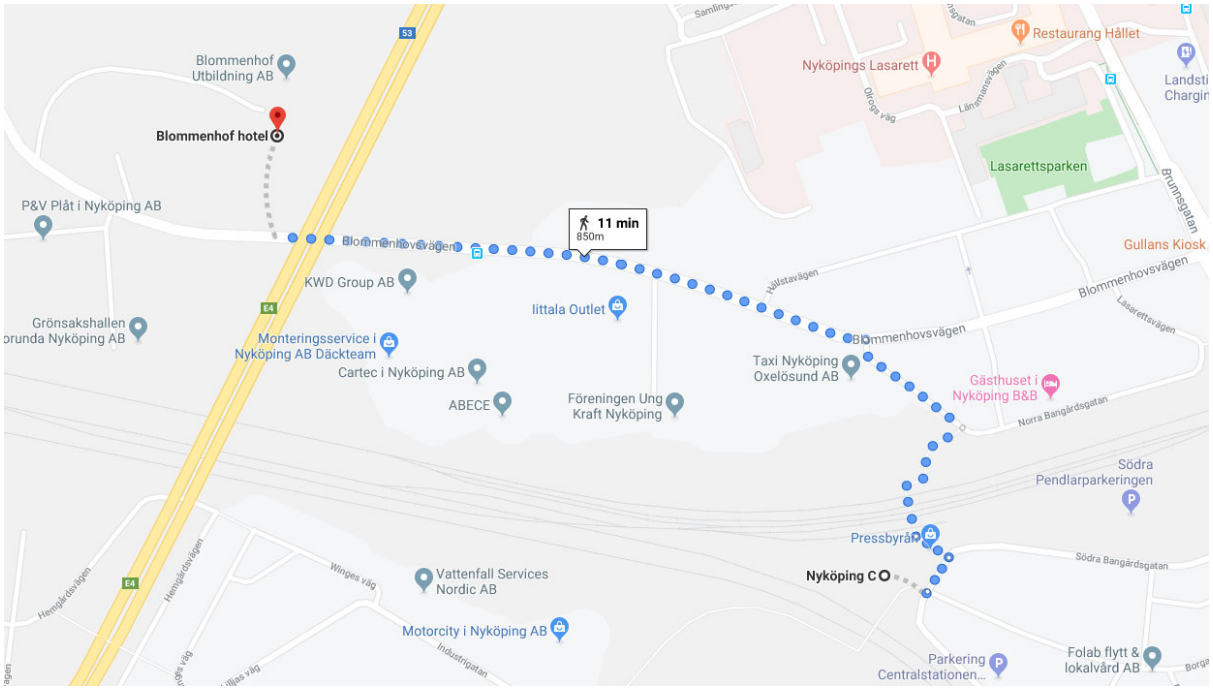
Hotel Blommenhof address is Blommenhovsvägen 41, Nyköping.

By car:

Take the second exit from the E4 motorway (Exit 133) at Nyköping when travelling both from south and north. Exit is the same for: the hospital, center, airport, towards the center. That also applies when you come from both Katrineholm and Eskilstuna. You pass the hospital on your right. When you see a sign Blommenhof you turn right onto Blommenhovsvägen (if you go under the railway you have gone too far). Now, just follow the Blommenhov road until you see the next sign.

By train:

The hotel is 850 meters from the railway station.



Note to speakers

- Sessions are moderated by session chairs. Chairs open and close sessions and are responsible for timekeeping.
- There are projectors in the rooms, and we would prefer if you use your own computer for the presentation, the available connections for the projectors are VGA and HDMI. If you do not plan on using your own computer, please bring your presentation on a USB stick.
- You are kindly requested to come to the presentation room five minutes before the session starts and introduce yourself to the session chair.

Gurobi Optimization is dedicated to helping our users succeed with optimization. We provide the leading math programming solvers, offering best-in-class performance as well as a broad array of tools for developing and deploying optimization applications on top of these solvers. We support all of the most popular programming languages, as well as client-server architectures, cloud computing, and distributed optimization. We also provide outstanding, easy-to-reach support and transparent, no-surprises pricing.

The Boeing subsidiary Jeppesen is one of the largest software development companies in Göteborg. We develop optimization solutions for the world's leading airlines. We focus on innovation and continuous improvement to bring more value to our clients, and explore emerging technologies such as quantum computing, AI and big data analytics.

At Boeing's office in central Göteborg you will work in a one-of-a-kind software development organization with fascinating solutions that make a real difference to people around the world. You will be working in an agile learning organization, surrounded by a team of talented and creative colleagues who are dedicated to our customers. You will learn and broaden your perspective by working with 400 IT professionals from more than 30 different nations, as part of a global organization where you collaborate with customers and colleagues across the world. Most importantly, you will be expected to make a difference.

At Boeing we are all innovators on a mission to connect, protect, explore and inspire. From the seabed to outer space, you'll learn and grow, contributing to work that shapes the world. Find your future with us!

www.soaf.se

The Swedish Operations Research Society

The Swedish operations research association (Swedish: Svenska Operationsanalysföreningen, SOAF) is a professional non-profit association for the promotion and dissemination of the scientific field of Operations Research in Sweden. SOAF was founded in 1959 with the dual purpose of promoting the development within the different branches of operations research, and work for its application within different problem domains. The association is a member of the European umbrella organization, the Association of European Operational Research Societies (EURO), and of the International Federation of Operational Research Societies (IFORS). SOAF has around 100 members: most belong to some of our approximately 20 member organizations that consist of industrial companies, state authorities and academic groups.

SOAF's members and others who are interested in operations research meet at our biannual conference, annual meeting or some of the gatherings organized by subgroups. The members' magazine ORbit, published in cooperation with the Danish Operations Research Society, is sent out to all members twice a year.

The society is managed by a board consisting of up to eight members. The board should always have a president, a vice president, a secretary, a treasurer, and an editor. The board is elected by the members at the annual meeting for a period of one year.

SOAF
SVENSKA OPERATIONSANALYSFÖRENINGEN

SOAK 2019 Programme

Schedule

		Track A	Track B
23/10	10:00-11:00	Coffee and registration	
	11:00-11:15	Welcome (room: Blåsippan)	
	11:15-12:00	**Plenary session I.** Thomas Schön, Uppsala University, "Constructing Stochastic Quasi-Newton Algorithms Using Gaussian Processes" (room: Blåsippan)	
	12:00-12:10	Photo session	
	12:10-13:30	Lunch	
	13:30-15:25	**Session 1A (room: Blåsippan)** 1. Björn Morén, "Mathematical Optimization of Dose Planning of High Dose-Rate Brachytherapy – Challenges and Pitfalls of Modelling" 2. Michelle Böck, "Toward Robust Optimization of Adaptive Radiation Therapy" 3. Sara Frimodig, "Models for Radiation Therapy Patient Scheduling" 4. Stella Riad, "Inverse Planning in Radiosurgery" 5. David Tilly, "Probabilistic Optimization of the Percentile Dosage in Radiotherapy"	**Session 1B (room: Gullvivan)** 1. Jo Devriendt, "Learn to Relax: Leveraging Integer Linear Programming for Conflict-Driven Search" 2. Biressaw C. Wolde, "A Steepest Feasible Direction Extension of the Simplex Method" 3. Uledi Ngulo, "A Dissection of the Duality Gap of Set Covering Problems" 4. Elina Rönnberg, "An Integer Optimality Condition for Column Generation on Binary Linear Programs" 5. David Ek, "Approximate Solution of System of Equations Arising in Interior-Point Methods for Bound-Constrained Optimization"
	15:25-16:00	Coffee	
	16:00-17:30	**Session 2A (room: Blåsippan)** 1. Tobias Andersson Granberg, "Quantitative Evaluation of New First Response Initiatives in Emergency Services" 2. Niki Matinrad, "Modelling Uncertain Task Compliance in the Dispatch of Volunteers to Out-Of-Hospital Cardiac Arrest Patients" 3. Anna-Maria Grönbäck, "Effekten av tourniquetplaceringar vid en större skadehändelse" 4. Stephan Gocht, "On Division Versus Saturation in Pseudo-Boolean Solving"	**Session 2B (room: Gullvivan)** 1. Mats Carlsson, "Mobile Phone Base Station Link Configuration" 2. Gianpiero Canessa, "The Risk-Averse Ultimate Pit Problem" 3. Shen Peng, "Rectangular Chance Constrained Geometric Optimization" 4. Roghayeh Hajizadeh, "A Branch-And-Bound Heuristic for Snow Removal Problem"
	18:30	Conference dinner	

		Track A	Track B
24/10	9:00-9:45	**Plenary session II.** Arne Andersson, Coupa Software "Applying Mathematical Optimization to Sourcing" (room: Blåsippan)	
	9:45-10:20	Coffee	
	10:20-12:15	**Session 3A (room: Blåsippan)** 1. Gabrijela Obradovic, "Simultaneous scheduling of preventive system maintenance and the maintenance workshop" 2. Quanjiang Yu, "Optimal Maintenance of Wind Power Plants" 3. Caroline Granfeldt, "Long-Term Investment Models for Large-Scale Integration of Wind Power in Europe" 4. Ghafour Ahani, "Optimal Caching on the Edge" 5. Jan Adriaan Elffers, "On-The-Fly Cardinality Detection"	**Session 3B (room: Gullvivan)** 1. Mattias Grönkvist, "Quantum Computing for Airline Planning" 2. Björn Thalén, "Teaming in Airline Pairing Optimization" 3. Hannes Uppman, "Details of an Industrially Relevant Avionics Scheduling Problem" 4. Emil Karlsson, "A Matheuristic Based on Adaptive Large Neighbourhood Search for Solving an Avionic Scheduling Problem" 5. Alan Kinene, "The Tendering of Subsidised routes in Air Transportation: A Game Theoretic Approach"
	12:15-13:30	Lunch	
	13:30-15:00	**Session 4A (room: Blåsippan)** 1. Kostja Siefen, "What's New in Gurobi 9" 2. Tomas Lidén, "Scheduling Railway Maintenance Together with Trains: Models and Results" 3. Sara Gestrelius, "Timetable Quality from the Perspective of the Swedish Infrastructure Manager" 4. Irfan Caner Kaya, "An optimization model for railway network design concerning switches"	**Session 4B (room: Gullvivan)** 1. Edvin Åblad, "Tight Formulations for the Unrelated Parallel Machine Problem with Set Packing Constraints" 2. Nils-Hassan Quttineh, "Modeling of a Rich Bin Packing Problem from Industry" 3. Sunney Fotedar, "Mathematical Optimization of the Tactical Allocation of Machining Resources for an Efficient Capacity Utilization in Aerospace Component Manufacturing" 4. Sabino Roselli, "On SMT Solvers and Job Shop Scheduling Problems"
	15:00-15:30	Coffee	

Plenary Sessions

Constructing stochastic quasi-Newton algorithms using Gaussian processes

23 October, 11:15-12:00

Thomas Schön, Uppsala University

In this talk I will focus on one of our recent developments where we show how the Gaussian process (GP) can be used to solve stochastic optimization problems. We start from the fact that many of the existing quasi-Newton algorithms can be formulated as learning algorithms, capable of learning local models of the cost functions.

Inspired by this we can start assembling new stochastic quasi-Newton-type algorithms, applicable in situations where we only have access to noisy observations of the cost function and its derivatives. We will show how we can make use of the GP model to learn the Hessian allowing for efficient solution of these stochastic optimization problems. Additional motivation for studying the stochastic optimization problem stems from the fact that it arise in almost all large-scale supervised machine learning problems, not least in deep learning. I will very briefly mention some ongoing work where we have removed the GP representation and scale our ideas to much higher dimensions (both in terms of the size of the dataset and the number of unknown parameters).

Applying Mathematical Optimization to Sourcing

24 October, 09:00-09:45

Arne Andersson, Coupa Software

In the field of e-sourcing, buyers communicate and negotiate with suppliers competing for contracts in online sourcing events.

The use of a sourcing tool facilitates data management and processing, and allows the buyer to handle events ranging from few easily described items to highly complex settings with millions of bids. Applying mathematical optimization to the analysis of the bids opens a number of opportunities when concepts like volume discounts and bundle bids can be managed. In addition, stakeholder constraints such as keeping a certain percentage of incumbent suppliers, minimizing risk, etc, can be considered and assessed. It is done by modelling a number of scenarios with varying constraints to find the best solution. In this way, even large, multi-step supply chains, where the structure is dynamically determined by buyer constraints and supplier quotes, can be analyzed to support an award decision.

Buyers, despite excelling in their field, typically have no or little insight into Operations Research or mathematical optimization. They need assistance in modelling and troubleshooting their optimization problems and the results have to be presented in a way that can be understood and acted on.

This presentation will discuss a number of interesting challenges and approaches to advanced e-Sourcing.

List of talks

Session 1A

23 October, 13:30-15:25, Room Blåsippan

Mathematical Optimization of Dose Planning of High Dose-Rate Brachytherapy – Challenges and Pitfalls of Modelling

Björn Morén, Torbjörn Larsson*, Åsa Carlsson Tedgren ** *** *****
** Department of Mathematics, Linköping University*
*** Radiation Physics, Department of Medical and Health Sciences, Linköping University*
**** Medical Radiation Physics and Nuclear Medicine, Karolinska University Hospital*
***** Department of Oncology Pathology, Karolinska Institute*

The topic of this presentation is how mathematical optimization is and can be used for dose planning of high dose-rate brachytherapy. Brachytherapy is a modality of radiation therapy which is used for cancer treatment. As the treatment aim is both to give the tumour a high enough dose and to spare healthy tissue and organs, the dose planning problem is essentially a multi-objective optimization problem. Concepts that are relevant from a clinical and modelling perspective will be discussed, including evaluation criteria in clinical treatment guidelines and criteria that are based on radiobiological models. Because of the multiple treatment goals and the existence of several clinical treatment protocols, the modelling is not straightforward and there is not a single established model. Aspects and risks of explicit modelling of the clinical criteria are exemplified, and a model to remediate certain pitfalls is presented. This model includes the conditional value-of-risk measure, also known as mean-tail-dose.

Toward Robust Optimization of Adaptive Radiation Therapy

Michelle Böck, KTH Royal Institute of Technology, RaySearch Laboratories AB

Adaptive radiation therapy is an evolving cancer treatment approach which relies on adapting the treatment plan in response to patient-specific interfractional geometric variations occurring during the fractionated treatment. If those variations are not addressed through adaptive replanning, the resulting treatment quality may be compromised.

The purpose of this thesis is to introduce a conceptual framework that combines a variety of robust optimization approaches with the concept of adaptive radiation therapy. Robust optimization approaches are useful in radiation therapy, since interfractional geometric variations are accounted for while optimizing the treatment plan. Thus, combining these two concepts in a framework for robust adaptive radiation therapy gives the opportunity to optimize adapted robust plans which account for the actual interfractional variations in the individual case. In this thesis, a variety of frameworks with increasing complexity is introduced and their ability to handle interfractional variations is evaluated.

In the first paper, a framework based on the concept of combining stochastic minimax optimization with adaptive replanning is introduced. Within this framework, three adaptive strategies are evaluated based on their ability to mitigate the impact of interfractional variations on the accumulated dose. In these strategies, treatment plans are adapted in response to the measured

variations by (i) modifying the probability distribution that governs the variations accounted for in the optimization, (ii) varying the level of conservativeness of the robust optimization approach, and (iii) modifying safety-margins around the tumor.

In the second paper, robust optimization approaches of varying levels of conservativeness are combined with optimization variables of varying degrees of freedom which account for fractionation and the interfractional geometric variations. The mathematical analysis shows that the solution of a time-independent problem is as good as the solution by the corresponding time-dependent problem, under the condition of convexity and independently and identically distributed interfractional geometric variations.

In the third paper, the framework from the second paper is extended to (i) handle unaccounted interfractional geometric variations with Bayesian inference, (ii) address adaptation cost through varying the adaptation frequency, and (iii) address computational tractability of robust optimization approaches with an approximation algorithm.

To emphasize the mathematical properties of the introduced frameworks, their performance is evaluated on an idealized one-dimensional phantom geometry subjected to a series of rigid translations. In this idealized phantom geometry, the relation between a modified optimization parameter and a feature in the resulting dose profile can be identified in a straightforward manner. This contributes to a better understanding of the underlying mechanisms between robustness, the adaptive strategies and the optimized dose profiles. The findings of this thesis are intended to provide a mathematical foundation for further development of the framework for, and research on, robust optimization of adaptive radiation therapy toward a clinical setting.

Models for Radiation Therapy Patient Scheduling

Sara Frimodig **, Christian Schulte**
* KTH Royal Institute of Technology*
** RaySearch Laboratories*

In Europe, around half of all patients diagnosed with cancer are treated with radiation therapy. To reduce waiting times, optimizing the use of linear accelerators for treatment is crucial. This talk will introduce an Integer Programming (IP) and two Constraint Programming (CP) models for the non-block radiotherapy patient scheduling problem. Patients are scheduled considering priority, pattern, duration, and start day of their treatment. The models include expected future patient arrivals. Treatment time of the day is included in the models as time windows which enable more realistic objectives and constraints. The models are thoroughly evaluated for multiple different scenarios, altering: planning day, machine availability, arrival rates, patient backlog, and the number of time windows in a day. The results demonstrate that the CP models find feasible solutions earlier, while the IP model reaches optimality considerably faster.

Inverse Planning in Radiosurgery

Stella Riad, J. Sjölund, H. Nordström*
* Elekta AB*

Purpose: The Leksell Gamma Knife® is a device primarily designed to treat brain tumors and it has excellent dose characteristics admitting high quality plans to be delivered. To fully utilize its potential, a new inverse planning approach has been developed that both resolves shortcomings of earlier approaches and unlocks new capabilities.

Methods: We present an inverse planning approach, where the positions of the focus of the radiation beams are determined and fixed prior to the optimization step, where the irradiation times are determined for all the beams, done using a linear programming approach. In the context of a linear programming approach, we describe two methods for problem size reduction: dualization and representative subsampling. We can constrain dose to organs at risk and we study the effect of an efficient beam-on time penalization on the trade-off between treatment plan quality and beam-on time.

Results: Dualization and representative subsampling both leads to optimization time-savings by a factor 5-20. Overall, we find in a comparison with 75 clinical plans that we can always find plans with similar or better plan quality and beam-on time. On a standard treatment planning workstation, the optimization times for typical cases are less than a minute, which is considerably less than common forward planning time.

Conclusion: We present a combination of techniques that enables an inverse planning method for Gamma Knife radiosurgery in a clinically feasible time frame.

Probabilistic Optimization of the Percentile Dosage in Radiotherapy

David Tilly ** ***, Åsa Holm*** ****, Anders Ahnesjö* ***
* Medical Radiation Physics, Dept. of Immunology, Genetics and Pathology, Uppsala University*
*** Medical Physics, Uppsala University Hospital,*
**** Elekta AB,*
***** 4Diffinder*

Introduction

Uncertainties in radiotherapy are commonly handled by expanding the treated clinical target volume CTV with a margin to ensure sufficient dose coverage. We define the percentile dosage as the dose coverage that is fulfilled to a given probability. The widely used margin recipe [1] can be expressed in terms percentile dosage, i.e. the entire CTV will receive at least 95% of the prescribed dose for 90% of the treatment fractions. To facilitate the adoption of probabilistic planning [2] and fair comparison with margin based planning, we formulated a novel probabilistic planning method based on the same statistical motivations as planning with margins. The new probabilistic method was applied to data from five cervix cancer patients.

Materials & Methods

In probabilistic optimization scenarios are sampled where each scenario is a realization of a treatment where all considered uncertainties are sampled from their respective probability distributions. Here, we consider systematic errors in the form of setup-errors and deformations sampled from a motion model [3]. The convex optimization formulation Conditional Value at Risk [4] (CVaR) was employed to fulfil the target percentile dosage as a constraint. By utilizing CVaR we constrained the expectation value of the 10% worst scenarios with respect to target dose coverage. The constraint was iteratively tightened during repeated optimizations until converging to the prescribed CTV percentile dosage. Margin based plans were created as reference where the isotropic margin was increased until the prescribed CTV percentile dosage was met. The percentile dosages to the surrounding risk organs was used to compare the plan quality.

Results

The average CTV percentile dosage after 10 optimization rounds exactly meeting the percentile dosage constraint. It drops after evaluation using 1000 scenarios because of the limitation of using 100 scenarios during the optimization. The probabilistic plans were superior to margin based plans

since the percentile dosages shows that the CTV dose homogeneity was improved and the rectum near max dose was lower.

References

[1] van Herk et al, Int. J. Radiation Oncology Biol Phys, 47(4) p1121 (2000)
[2] Unkelbach et al, Physics in Medicine and Biology, 63 (2018)
[3] Tilly et al, Physics in Medicine and Biology, 62 (2017) p4140
[4] Rockafellar et al, Journal of Risk, 2 (42) (2000) p21.

Session 1B

23 October, 13:30-15:25, Room Gullvivan

Learn to Relax: Leveraging Integer Linear Programming for Conflict-Driven Search
Jo Devriendt, Lund University; Jan Elffers, Lund University; Ambros Gleixner, Zuse Institut Berlin; Jakob Nordström, Copenhagen University

Pseudo-Boolean (PB) solvers optimize 0-1 integer linear programs by harnessing techniques from conflict-driven clause learning (CDCL) SAT solvers. Although PB solvers should be exponentially more efficient than CDCL in theory, however, in practice they can get hopelessly stuck even when the relaxed linear program (LP) is infeasible over the reals. Inspired by mixed integer programming (MIP), we address this problem by integrating an LP solver in the search loop and by generating LP-based cuts to tighten the LP relaxation as well as improve PB search propagation. Our experiments indicate that this significantly improves performance on a wide range of benchmarks, approaching a "best of two worlds" scenario for SAT-style conflict-driven search and MIP-style branch-and-cut.

A Steepest Feasible Direction Extension of the Simplex Method
Biressaw C. Wolde, Torbjörn Larsson, Department of Mathematics, Linköping University

We present a feasible direction approach for general linear programming. It can be embedded in the framework of the simplex method, although it works with non-edge feasible directions. The principle used for choosing the feasible direction is the same as that of the steepest edge entering variable criterion in the simplex method, but in our method the directions of movement are not restricted to edges of the feasible polyhedron. The feasible direction is the steepest in the space of all variables, or an approximation thereof. Given a basic feasible solution, the problem of finding a (near-)steepest feasible direction can be stated as a strictly convex quadratic program in the space of the non-basic variables and with only non-negative restrictions. In order to remain in the framework of the simplex method, this direction is converted into an auxiliary non-basic column, known as an external column. Our feasible direction approach allows many computational strategies. First, one may choose how frequently external columns are created. Secondly, one may choose how accurately the direction-finding quadratic problem is solved. Thirdly, near-steepest directions can be obtained from low-dimensional restrictions of the direction-finding quadratic program or by the use of approximate algorithms for this program. Further, we show that the direction-finding quadratic program can be solved by a column generation method, with the same pricing as in the simplex method but with a modified dual solution. We present encouraging computational results from preliminary experiments.

A Dissection of the Duality Gap of Set Covering Problems
Uledi Ngulo, Torbjörn Larsson, Nils-Hassan Quttineh, Department of Mathematics, Linköping University

Set covering problems are well-studied and have many applications. Sometimes the duality gap is significant and the problem is computationally challenging. We dissect the duality gap with the purpose of better understanding its relationship to problem characteristics, such as problem shape and density. The means for doing this is a set of global optimality conditions for discrete optimization problems.

These decompose the duality gap into two terms: near-optimality in a Lagrangian relaxation and near-complementarity in the relaxed constraints. We analyse these terms for numerous instances of large size, including some real-life instances. We conclude that when the duality gap is large, typically the near-complementarity term is large and the near-optimality term is small. The large violation of complementarity is due to extensive over-coverage.

Our observations should have implications for the design of solution methods, and especially for the design of core problems.

An Integer Optimality Condition for Column Generation on Binary Linear Programs
Elina Rönnberg, Torbjörn Larsson, Department of Mathematics, Linköping University

The application of the column generation technique has been very successful for many problem structures in large-scale integer programming, such as routing and scheduling. In the case of solving a linear program by column generation, it is well known that a restricted master problem contains an optimal solution if there remains no column with profitable reduced cost to be added to it. This talk addresses the corresponding question posed for binary linear programs and provides a generic sufficient optimality condition for determining when a restricted master problem contains the columns required to find an integer optimal solution.

The presented condition is also on the reduced costs for columns not yet added, and it is derived from an integer feasible solution to the restricted master problem and dual information from its linear programming relaxation. The integer solution is preferably optimal or near optimal. The dual solution does not need to be optimal; it is however natural to use a high-quality one. We review some situations from the literature when this type of condition is useful and elaborate on how it can be further exploited.

Approximate Solution of System of Equations Arising in Interior-Point Methods for Bound-Constrained Optimization
David Ek, KTH Royal Institute of Technology

We consider interior-point methods for bound-constrained nonlinear optimization where the system of nonlinear equations that arise are solved with Newton's method. There is a trade-off between solving Newton systems directly, which give high quality solutions, and solving many approximate Newton systems which are computationally less expensive but give lower quality solutions. We discuss approximating partial and full solutions of the Newton systems using Schur complements. In addition, we discuss the inherent ill-conditioning specific for optimization. The theoretical setting is introduced and asymptotic error bounds are given along with numerical results for bound-constrained convex quadratic optimization problems.

Session 2A

23 October, 16:00-17:30, Room Blåsippan

Quantitative Evaluation of New First Response Initiatives in Emergency Services
Tobias Andersson Granberg, Department of Science and Technology, Linköping University

By training and equipping human resources from other public service sectors, to act as emergency responders, it is possible to reduce the first response times at a low cost. Before launching such an initiative, it is however important to evaluate the potential benefits. In this work, a method for doing this kind of evaluation is developed and applied to a potential initiative, utilizing fire service day personnel as new first responders. To obtain quantitative data, a smartphone application is developed and an experiment performed, where alerts are sent to potential first responders. This is combined with expert reviews of the possible value of their contribution. By calculating the probabilities for having different numbers of new first responders arriving before the professional emergency services, it is possible to estimate the response time reductions, as well as the monetary benefits of the initiative. The results show that there is a monetary benefit, even with a low number of new first responders, but that it is highly dependent on how quickly they can start travelling towards the emergency site.

Modelling Uncertain Task Compliance in the Dispatch of Volunteers to Out-Of-Hospital Cardiac Arrest Patients
Niki Matinrad, Tobias Andersson Granberg, Vangelis Angelakis, Department of Science and Technology, Linköping University

Volunteers are an emergency response resource that has been facing rising interest in the past few years. Many projects are utilizing semi-organized volunteers for daily emergencies. Among them, there is SMS life savers (https://www.smslivraddare.se/) who are registered volunteers contributing in out-of-hospital cardiac arrest (OHCA) cases. Although the positions of these volunteers are known, it is not trivial to decide which and how many volunteers to dispatch, or who should go directly to the patient and who should collect an AED en route to the patient. Moreover, response uncertainties, e.g. the task compliance of volunteers, complicate the dispatch problem. In this work, uncertainties associated with the volunteers' actions once assigned a task are explicitly modeled. This is done by considering the probabilities of mission abort, non-complying actions, and full compliance to instructions for each task assignment. We present a method for dispatch of volunteers in order to maximize OHCA patient's survivability. Results, based on historical data of the SMS life savers project, indicate a potential improvement in patient's survivability compared to the algorithm used in the SMS life savers project today.

Effekten av tourniquetplaceringar vid en större skadehändelse
Anna-Maria Grönbäck, Tobias Andersson Granberg*, Krisjanis Steins*, Carl-Oscar Jonson***
** Institution för teknik och naturvetenskap, Linköpings universitet*
*** Katastrofmedicinskt centrum, Region Östergötland*

I USA finns sedan tidigare blödningskit innehållandes bland annat tourniqueter, utrustning för avsnörande förband, placerade på allmänt tillgängliga platser. Detta till följd av en kampanj med syfte att uppmuntra civila att agera och stoppa blödningar vid större skadehändelser.

Denna studie undersöker hur användningen av tourniqueter kan påverka förblödningar vid en potentiell skadehändelse, i en svensk kontext.

Scenariot som studeras behandlar en explosion som sker vid ett stort arenaevenemang med många besökare, där tourniqueter har placerats på olika platser i lokalen. Syftet är att utvärdera vilken eller vilka platser som skulle kunna vara lämpligast för denna utrustning.

För studien används simulering som metod, vilken utförs i programvaran Arena. För att hitta lämpliga indata till modellen görs en kvalitativ kategorisering för de parametrar som ska ingå i scenariot.

I studien framkommer bland annat att det är svårt att bedöma hur många som skadas vid en händelse, varvid en riskanalys för potentiella händelser med bland annat antalet skadade bör finnas med som ett led i att bestämma lämpligt antal tourniqueter för en viss plats.
Resultatet från simuleringen av olika placeringar visar att det inte är så stor skillnad på var tourniqueterna placeras i lokalen utan att det viktigaste är att det finns personer som har kunskap om att använda dem och som använder dem. Det finns i resultatet en tendens mot att en utspridd placering av tourniqueterna i lokalen är att föredra och att eventuella hinder som exempelvis evakuerande personer kan påverka möjligheten att snabbt hitta en tourniquet. Därför bör scenarioanalyser ingå i riskanalysen, där utrymningsvägar och andra flaskhalsar identifieras och tas i beaktning vid planeringen av var tourniqueter ska placeras.

On Division Versus Saturation in Pseudo-Boolean Solving
Stephan Gocht, Lund University

The conflict-driven clause learning (CDCL) paradigm has revolutionized SAT solving over the last two decades. Extending this approach to pseudo-Boolean (PB) solvers doing 0-1 linear programming holds the promise of further exponential improvements in theory, but intriguingly such gains have not materialized in practice. Also intriguingly, most PB extensions of CDCL use not the division rule in cutting planes as defined in [Cook et al., '87] but instead the so-called saturation rule. To the best of our knowledge, there has been no study comparing the strengths of division and saturation in the context of conflict-driven PB learning, when all linear combinations of inequalities are required to cancel variables. We show that PB solvers with division instead of saturation can be exponentially stronger. In the other direction, we prove that simulating a single saturation step can require an exponential number of divisions. We also perform some experiments to see whether these phenomena can be observed in actual solvers. Our conclusion is that a careful combination of division and saturation seems to be crucial to harness more of the power of cutting planes.

Session 2B

23 October, 16:00-17:30, Room Gullvivan

Mobile Phone Base Station Link Configuration
Mats Carlsson, RISE Research Institutes of Sweden

Configuring a mobile phone base station involves solving a number of engineering tasks concerning: the antennas that send and receive radio signals, the supporting structure where the antennas are mounted, the computing and radio units that connect the network to the antennas, and the links between those hardware units. In this talk, we study the link configuration problem, i.e. how to select a set of links so that the required connectivity is achieved, subject to various hardware constraints, so as to maximize various desiderata such as low hardware cost and ease of maintenance. The problem can be seen as the combination of a routing and a multicommodity flow problem, and has been modeled in the constraint modeling language MiniZinc. In the talk, we describe the problem, briefly overview of the model, and present experimental results. This work is a collaboration between Ericsson and RISE.

The Risk-Averse Ultimate Pit Problem
Gianpiero Canessa, Eduardo Moreno, Bernardo K. Pagnoncelli*
** KTH Royal Institute of Technology*

In this work, we consider a risk-averse ultimate pit problem where the grade of the mineral is uncertain. We propose a two-stage formulation of the problem and discuss which properties are desirable for a risk measure in this context. We show that the only risk measure that satisfies these properties is the entropic. We propose an efficient approximation scheme to solve the risk-averse version of the problem and show its viability in large-scale mines.

Rectangular Chance Constrained Geometric Optimization
Jia Liu **, Shen Peng* **, Zhiping Chen*, Abdel Lisser***
** School of Mathematics and Statistics, Xi'an Jiaotong University, Xi'an, Shaanxi*
*** Laboratoire de Recherche en Informatique (LRI), Universite Paris Sud*

This paper discusses joint rectangular chance or probabilistic constrained geometric programs. We present a new reformulation of the joint rectangular chance constrained geometric programs where the random parameters are elliptically distributed and pairwise independent. As this reformulation is not convex, we propose new convex approximations based on the variable transformation together with piecewise linear approximation methods. For the latter, we provide a theoretical bound for the number of segments in the worst case. Our numerical results show that our approximations are asymptotically tight.

A Branch-And-Bound Heuristic for Snow Removal Problem
Roghayeh Hajizadeh, Kaj Holmberg, Department of Mathematics, Linköping University

Snow removal is an important problem in northern countries. A number of streets in a city need to be cleared of snow by a limited number of vehicles within a certain time. We have formulated the problem as a very large mixed integer programming problem, which is practically unsolvable. We have some relaxations of the model that yield rather good lower bounds in rather short time. We

assume that the work has been broken down into small tasks in order to find which streets a vehicle shall take care of. Hence, we consider the problem facing a single vehicle with all details. This problem can be reformulated to an asymmetric traveling salesman problem in an extended graph, and we have a heuristic for finding a feasible solution. Now, we describe a branch-and-bound heuristic for improving the solution by using all the parts mentioned above.

Session 3A

24 October, 10:20-12:15, Room Blåsippan

Simultaneous scheduling of preventive system maintenance and the maintenance workshop
Gabrijela Obradovic, Department of Mathematical Sciences, Chalmers University of Technology

While a system operates, its components deteriorate and in order for the system to remain operational, maintenance of its components is required.

Preventive maintenance (PM) is performed so that component failure is avoided. This research aims at scheduling PM activities for a multi-component system within a finite horizon. The system to be maintained possesses positive economic dependencies, meaning that each time any component maintenance activity is performed, a common set-up cost is generated. Each component PM activity generates a cost, including replacement, service, and spare parts costs.

Corrective maintenance (CM) is performed after a failure has occurred in order to restore the system back to an operational state. Unexpected events (such as component breakdowns) require that CM is performed, which leads to our PM scheduling problem being dynamic. The dynamics of the PM scheduling problem is also due to the plan of operation and maintenance windows for the system studied, as well as the scheduling of component repair in the maintenance/repair workshop(s).

We start from a 0-1 mixed integer linear programming model of the PM scheduling problem with interval costs (PMSPIC; Gustavsson et al., Computers & Industrial Engineering 76:390{400, 2014), which is to schedule PM of the components of a system over a finite and discretized time horizon, given common set-up costs and component costs, of which the latter vary with the maintenance interval. We extend the PMSPIC model to incorporate the flow of components through the maintenance/repair workshop, including stocks of spare components, both the components that require repair and the repaired ones.

Optimal Maintenance of Wind Power Plants
Quanjiang Yu, Chalmers University of Technology

Climate change now affects every country on every continent. It disrupts national and personal economies, affects lives, communities, and countries, today and even more tomorrow. Global warming has been attributed to increased greenhouse gas emission concentrations in the atmosphere through the burning of fossil fuels. Renewable energy, as an alternative, is capable of displacing energy from fossil fuels. Wind power is abundant, renewable, and produces almost no greenhouse gas during operation. A large part of the cost of operations is due to the cost of maintaining the wind power equipment, especially for offshore wind farms. These areas are growing business opportunities in the wind energy industry. To reduce the maintenance cost, we can improve the design of the components, making them more reliable. We can design better condition monitoring systems, such that we can estimate more accurately when a component needs replacing. We can also maintain the equipment through a better planning methodology, which is what we focus on. We introduce a binary linear optimization model – the strategic preventive maintenance problem (SPMP) – whose solution may suggest wind farm owners which components should be maintained in the near future. Since the SPMP is both fast and accurate, we can then combine the model with the data we receive from the condition monitoring systems. We use a log-linear model to describe how the parameters of the Weibull distribution depend on the covariates (e.g. for the gearbox, we can consider the gearbox bearing temperature and oil temperature).

Long-Term Investment Models for Large-Scale Integration of Wind Power in Europe
Caroline Granfeldt, Mathematical Sciences, Chalmers University of Technology

In order to sufficiently decrease greenhouse gas emissions, the future electricity system most likely needs to contain a large share of variable renewable energy sources, such as wind and solar power. To be able to capture the large and fast variations from these production resources, a realistic modeling of such a system must include a fine discretization of time. There is, however, a conflict between a high temporal resolution and reasonable solution times for such a model. For large problem instances, traditional energy models typically favors the latter. We have developed an optimization model that captures some typical characteristics of the problem to minimize the future costs of energy production, such as technology investments and dispatch. In my talk, I will discuss a decomposition method applied to this model. More specifically, I will discuss how Lagrangian relaxation in combination with a subgradient algorithm and a problem specific feasibility heuristic enables a parallelization of the solution process for this type of model, along with preliminary computational results.

Optimal Caching on the Edge
Ghafour Ahani, Di Yuan, Department of Information Technology, Uppsala University

The explosive growth in mobile data traffic and massive device connectivity are becoming two main challenges for existing cellular networks. The mobile data traffic put a heavy burden on communications networks. Caching is a promising technology to alleviate the burden of networks by storing the requested files or contents in advance on edge devices. In mobile networks, an edge device refers to a device close to users such as base stations and/or user themselves. With caching, users can obtain their requested files from the edge devices so as to improve the network performance in terms of energy efficiency and burden of the network. Caching performance depends heavily on to what extent the cache capacity is optimized over time. In this talk, we discuss modeling and solution approaches for an array of caching optimization problems and outline interesting extensions for forthcoming research.

On-The-Fly Cardinality Detection
Jan Adriaan Elffers, KTH Royal Institute of Technology

Pseudo-Boolean solvers hold out the theoretical potential of exponential improvements over conflict-driven clause learning (CDCL) SAT solvers, but in practice perform very poorly if the input is given in the standard conjunctive normal form (CNF) format. We present a technique for detecting and rewriting cardinality constraints from CNF by collecting potential building blocks of such constraints during propagation and combining them during conflict analysis. Our implementation has a non-negligible but manageable overhead when detection is not successful. Experiments show significant gains for some SAT competition and crafted benchmarks for which pseudo-Boolean reasoning is stronger than CDCL, and also for some native pseudo-Boolean formulas where the technique helps to improve learned constraints.

Session 3B

24 October, 10:20-12:15, Room Gullvivan

Quantum Computing for Airline Planning
Mattias Grönkvist, Jeppesen. A Boeing Company

Quantum computing is a potentially disruptive technology for high performance computing such as large-scale airline planning. Jeppesen recently entered as an industrial partner in the Wallenberg Center for Quantum Technology (WACQT). The WAQCT project involves multiple Swedish universities and industry partners and aims to build a 100 qubit general purpose quantum computer within 10 years, along with practical industrial and academic use cases. We will present Jeppesen's involvement in the project, why we think quantum computing could be important for optimization and what we are currently doing.

Teaming in Airline Pairing Optimization
Björn Thalén, Jeppesen. A Boeing Company

Airline Crew scheduling is a very complex operations research problem which creates some of the hardest optimization problems with good commercial solutions. Pairing is the first step in crew scheduling were anonymous schedules are created that can then be used as building block for the rostering phase.

Operational stability of a crew schedule is improved by keeping crew together as much as possible. To obtain the lowest possible cost there are benefits to splitting crew. The desire to split crew is driven by base imbalances as well as different crew need for different flights. Splitting may also be driven by different rules for different crew categories. In this presentation I will address how teaming is encouraged inside the Jeppesen Crew Pairing product, as well as describe the benefit to some of our clients.

Details of an Industrially Relevant Avionics Scheduling Problem
Hannes Uppman, Emil Karlsson**, Elina Rönnberg***
** Saab AB*
*** Linköping University*

Electronic systems used in aircraft are called avionics. For this class of systems it is critical both that results of functions are correct and that they are obtained in time. One way of ensuring these properties is to schedule all activities in the system pre-runtime. In this way correct timing behavior of the system can be guaranteed even under worst-case conditions.

Modern avionics are large and complex systems, and future systems will likely be even larger. Efficient scheduling is therefore important. To explore ways of meeting this need, a research project is run in collaboration between Saab and Linköping University (LiU).

In this talk we present an industrially relevant scheduling problem studied in the Saab-LiU collaboration. We give a detailed description of the system requirements and the mathematical modelling. On top of the normal sequencing and precedence constraints, our multiprocessor scheduling problem includes constraints for: how messages on a time-slotted communication network can be scheduled; how messages must relate to other scheduled activities; limitations on

time lags associated with precedence constraints; and a mechanism for co-allocation of messages. In addition to describing this problem, we briefly present our constraint generation method that is capable of solving large scale instances.

A Matheuristic Based on Adaptive Large Neighbourhood Search for Solving an Avionic Scheduling Problem

Emil Karlsson, Elina Rönnberg*, Hannes Uppman***
** Linköping University*
*** Saab AB*

The focus of this talk is a matheuristic for solving a multiprocessor scheduling problem of interest in the development of future avionic systems. A feasible schedule needs to respect multiple time windows, precedence relations, and additional technical constraints.

The proposed matheuristic combines a constraint generation procedure with an adaptive large neighbourhood search. The adaptive large neighbourhood search is of a kind that solves a mixed integer program in each iteration. This mixed integer program is defined by selecting one destroy operator and one repair operator. The destroy operators utilise problem structure to select a core set of tasks to move. The repair operators either focus on feasibility or objective value in a given iteration and solves the resulting mixed integer program to improve the current solution.

The performance of the matheuristic is evaluated for two categories of instances, developed in collaboration with our industrial partner Saab. The results show that the proposed matheuristic can solve larger instances than was previously possible.

The Tendering of Subsidised routes in Air Transportation: A Game Theoretic Approach

Alan Kinene, Nicole Adler**, Tobias Andersson Granberg*, Valentin Polishchuk* and Clas Rydergren**
** Department of Science and Technology, Linköping University*
*** School of Business Administration, The Hebrew University of Jerusalem, Israel*

Governments through their transportation authorities offer subsidies along routes that are considered commercially non-viable but economically and socially essential. These subsidised routes have received continuous criticism because of unjustified cost of subsidization mainly due to inefficiencies, which mostly arise during the tendering process. The combination of low passenger volumes and the strict requirements associated with subsidised routes has often resulted into low competition during the tendering process and discontinuous services because of underestimation of operation costs for the contracted subsidised routes by the air carriers.

In this study, we use a game theoretic approach to study how the behavior of air carriers during the tendering of subsidized routes affects the total amount of subsidies. This work therefore aims to explore the potential of having less strict requirements in the tendering process and suggests valid route combinations, which complement each other and lead to efficient operations by the air carriers. The study further explores the possibility of having multiple-airport regions instead of the current single-airport region during the tendering process of subsidised routes. Sweden is used as a case study.

The results shall assist the transportation authorities with minimising the amount of subsidies spent on subsidised routes by efficiently designing a tendering process that considers how the different tendering requirements affects the air carriers.

Session 4A

24 October, 13:30-15:00, Room Blåsippan

What's New in Gurobi 9
Kostja Siefen, Gurobi Optimization

More than 2,400 companies in over 40 industries turn data into smarter decisions with Gurobi. Gurobi is a state-of-the-art mathematical programming solver designed from the ground up to exploit modern architectures and multi-core processors, using the most advanced implementations of the latest optimization algorithms.

This year, Gurobi will celebrate its 10th birthday and our next major release will add a number of innovative new features that are not available in any commercial, industry-tested solver of this kind. In this talk, we will bring you up-to-date with all the latest developments around the Gurobi Optimizer with an exclusive preview of the upcoming release.

Scheduling Railway Maintenance Together with Trains: Models and Results
Tomas Lidén, Department of Science and Technology, Linköping University and VTI

In this presentation I will describe the optimization models that were developed during the course of my PhD research project. Focus will be on how the track capacity limitations have been handled and some reformulations which strengthened the model and improved the solving performance. If time permits, some results from previous and ongoing case studies will also be presented along with some outlooks for the future.

Timetable Quality from the Perspective of the Swedish Infrastructure Manager
Sara Gestrelius **, Anders Peterson**, Martin Aronsson**
* RISE Research Institutes of Sweden*
** Department of Science and Technology, Linköping University*

There are many stakeholders in railway timetable planning, e.g. infrastructure managers, railway undertakings and train passengers. There are also many different measurements for timetable quality. This talk presents timetable quality from the perspective of the Swedish infrastructure manager. Seven categories of timetable quality are discussed: feasibility, disturbance resistance, competition management, capacity safeguarding, application fulfilment, attractiveness and compatibility with surrounding planning areas. As a step towards multi-objective optimization for train timetables, an interview study with staff from the Swedish infrastructure manager was carried out. The priority ranking method from the analytical hierarchical process by Saaty was used to rank the different quality categories based on (1) importance and (2) difficulty. The results show that feasibility is both most important and easiest to handle. Capacity guarding is considered least important, despite its prevalence in legal documents and envisioned process developments, and is also considered hardest to handle. Operational research can contribute to closing the gap between the wanted state as depicted by legal documents and development projects, and the current state of practice in Sweden. There results from the interview study indicate a need both for formal guidelines and measurements for quality aspects, and for better timetable planning support tools.

An optimization model for railway network design concerning switches

Irfan Caner Kaya, Tomas Lidén, Department of Science and Technology, Linköping University

With the growing demand of railway transportation, the cost of railway infrastructure maintenance has increased. Railway planners seek to develop new strategies to handle with those costs. According to studies conducted by Netherlands and Japan, in order to reduce railway infrastructure maintenance costs, there is a chance to simplify railway network and remove redundant components of it by concentrating on switches and crossings, which give flexibility to the railway traffic and are useful for failure incidences. The primary planning question is how to acquire optimal balance between traffic requirements, reliability and maintenance costs. In this study, an optimization model is proposed, which chooses the minimum selection of switches, tracks and paths that satisfy all traffic requirements concerning connecting location points, simultaneous train routes and overtaking cases in a given station layout. The model is implemented for a real world case study (Katrineholm Station). We will present the optimization model with different traffic instances, objective functions, cost coefficients and results from the case study.

Session 4B

24 October, 13:30-15:00, Room Gullvivan

Tight Formulations for the Unrelated Parallel Machine Problem with Set Packing Constraints
*Edvin Åblad * **, Ann-Brith Strömberg *, Domenico Spensieri ***
** Department of Mathematical Science, Chalmers University of Technology and Gothenburg University*
***Department of Geometry and Motion Planning, Fraunhofer Chalmers Research Centre*

We aim to solve a robot load-balancing problem in the automotive assembly process by improving on a suggested MILP model that is adapted from the unrelated parallel machine problem (UPMP). This model proved hard to solve for a general-purpose MILP solver, since the formulation had poor LP relaxation bounds; this as a result of a min-max objective and packing constraints. In an attempt to solve larger instances we aim to improve these bounds by finding a tighter formulation; where cliques of the set packing graph plays a central role. We formulate a set packing polytope that induce facets of the original polyhedron and suggest lifting the model, these two modifications greatly aided the MILP solver and reduced the computational time. In addition, we compare the general MILP solver with our implemented branch-and-cut algorithm, tailored for this problem it utilizes strong minimal covers, additive lower bounds, local-search, and a Lagrangian heuristics; two approaches were roughly equally fast.

Modeling of a Rich Bin Packing Problem from Industry
Nils-Hassan Quttineh, Department of Mathematics, Linköping University

We present and share the experience of modeling a real-life optimization problem. This exercise in modeling is a text book example of how a naive, straightforward mixed-integer modeling approach leads to a highly intractable model, while a deeper problem analysis leads to a non-standard, much stronger model. Our development process went from a weak model with intractable run times, via meta-heuristics and column generation, to end up with a strong model which solves the problem within seconds. The problem in question deals with the challenges of planning the order-driven continuous casting production at the Swedish steel producer SSAB. We study the cast planning problem, where the objective is to minimize production waste which unavoidably occurs as orders of different steel grades are cast in sequence.

Mathematical Optimization of the Tactical Allocation of Machining Resources for an Efficient Capacity Utilization in Aerospace Component Manufacturing
Sunney Fotedar, Torgny Almegren**, Stefan Cedergren**, Ann-Brith Strömberg*, Michael Patriksson**
** Mathematical Sciences, Chalmers University of Technology*
*** GKN Aerospace, Trollhättan*

In the aerospace industry, with low volumes and many products, there is a critical need to efficiently use available manufacturing resources. Currently, at GKN Aerospace, resource allocation decisions are to some extent made with a short-term focus on the product cost, which results in an over-utilization of certain machines, which are more capable with respect to machining speed and/or have other additional features while less capable machines are under-utilized. This imbalance in capacity utilization increases the lead times for products. Our aim is to use mathematical optimization to allocate products to machining resources such that the overall

capacity utilization increases without increasing the tied-up capital. The proposed model also facilitates cross-functional knowledge integration and helps in codifying the tacit knowledge of manufacturing and logistics specialists, i.e., transmit knowledge for future users.

The scope of the proposed tactical resource allocation model is restricted to allocating products to machines which perform cutting operations. This includes milling, drilling, grinding, and turning machines. The model should ideally be used when a new product is introduced, or when there are significant changes in the machining capacity (e.g., decommissioning of machines or introduction of new machines). The proposed model should be used by the capacity planner and product introduction managers at the company.

On SMT Solvers and Job Shop Scheduling Problems
Sabino Roselli, Chalmers University of Technology

The Job Shop Problem (JSP) is a combinatorial NP-Hard problem within the community of Operation Research and some of its instances have challenged researchers from both industry and academia over the last sixty years and are nowadays still unsolved. Its basic formulation, as well as its several variations can represent many real world industry scenarios, especially in a modern context, where automation is taking over on the shop floor and a more rigorous planning is required to manage resources.

Satisfiability Modulo Theories (SMT) solvers, an offspring of the Boolean Satisfiability (SAT) revolution, are now an established and widely recognized technology for optimization and their performance is increasing year after year, making them a recommendable choice to tackle combinatorial problems.

Over the years, different mathematical models have been formulated to represent the JSP. We translate several of the proposed formulations into the SMT standard language for both Standard and Flexible JSP, provide an insight about algorithms and decision procedures running under the hood of state-of-the-art SMT solvers and we present a brand new formulation based on bit vectors theory for the Standard JSP.