Optimization and its Applications in Learning and Industry

Industry Days Workshop

Technical University of Denmark, June 1st & 2nd, 2015

Monday, June 1st

The last speaker of the session is the chair of the session

APPROACHING MIXED-INTEGER NONLINEAR OPTIMIZATION PROBLEMS

Sönke Behrends

University of Göttingen

09:30
S1
1

Mixed-integer nonlinear optimization problems can be used to model a wide class of applications in industry - e.g., distillation processes, or reactor and heat exchanger networks - as most phenomena in nature are nonlinear, and many resources are integral. We consider some interesting special cases: Regarding the functions involved, we restrict to polynomials. At first, we look at methods that approach the unconstrained mixed-integer case: We present techniques that allow in certain cases to reduce the infinite integer problem to a finite one, and bound the unbounded continuous problems. Furthermore, we discuss possible generalizations to the constrained case and take a look at some computer experiments on random data.

FUSION: AN OBJECT/ORIENTED API FOR CONIC OPTIMIZATION BY MOSEK

Andrea Cassioli

Mosek ApS

10:00
S1
2

Conic optimization is one of the most used optimization tool. Robust and efficient solvers are available, but their interface is not always satisfactory: either is low-level efficient but cumbersome and error-prone; or is high-level and flexible but slow and memory consuming.

In this talk we will introduce Fusion, an object-oriented API available in different languages, whose aim is to provide a simple yet efficient interface to the MOSEK solver. Fusion is specifically designed for conic optimization: it allows for a clean and efficient way for defining conic optimization problem.

RECENT DEVELOPMENTS IN OPENSOLVER AND SOLVERSTUDIO: JULIA/JUMP, .NL FILES AND NON-LINEAR MODELS

Andrew Mason

University of Auckland

10:30
S1
3

OpenSolver (http://opensolver.org) and SolverStudio (http://solverstudio.org) are two free Excel add-ins that provide advanced optimisation and modelling tools for spreadsheet users. Although originally based around the COIN-OR linear/integer programming solver CBC, OpenSolver has now been extended to support a much wider range of linear and non-linear solvers. The latest versions of OpenSolver also support direct translation of spreadsheets into the .nl file format used by AMPL solvers, allowing complex non-linear models to be quickly solved using gradient-based solvers. SolverStudio takes a different approach by allowing Excel users to use modelling languages such as AMPL, GAMS, PuLP, Pyomo etc to model and solve their spreadsheet optimisation problems. SolverStudio has recently been enhanced by the addition of new modelling languages including the COIN-OR modelling language CMPL and the Julia-based JUMP language being developed at MIT. This talk will detail and demonstrate these improvements, and discuss some of the recent commercial applications of these tools.

ROBUST STORAGE LOADING PROBLEMS WITH PAYLOAD CONSTRAINTS

Marc Goerigk, Sigrid Knust, and Xuan Thanh Le

Technical University of Kaiserslautern

We consider storage loading problems in maritime transport, in which items such as containers of uncertain weights need to be loaded onto ships, vessels, or barges, taken into account certain stacking constraints and payload restrictions on the items. Following the robust optimization paradigm, we develop strict and adjustable optimization models that still perform well when the uncertain data is realized. To solve these problems, exact and heuristic solution algorithms are developed. Using experimental results, we show that computation times and algorithm gaps are still reasonable for practical applications. Furthermore, we find that robustness concepts show very different potential depending on the type of data being used.

11:30
S2
1

SPEED OPTIMIZATION IN LINER SHIPPING NETWORK DESIGN

Berit Dangaard Brouer, Christian Vad Karsten, and David Pisinger

Technical University of Denmark

In the Liner Shipping Network Design Problem (LSNDP) services sail at a given speed throughout a round trip. In reality most services operate with a speed differentiated head- and back-haul, or even individual speeds on every sailing between two ports. The speed of a service is decisive for the bunker consumption in the network as well as the transit time of cargo. Speed optimization has been considered for tramp shipping showing significant reductions in fuel consumption. However, variable speeds has not been considered for post optimization of the LSNDP, where speed optimization could result in changes to the cargo flow due to transit time restrictions as well as significant savings in fuel consumption and required vessel deployment due to a weekly frequency requirement. We present a MIP to calculate variable speed on a service considering the current flow of commodities on the service and present computational results for improving a solution of the LSNDP with average speeds to a solution with variable speed. We analyse the results according to transit time, fuel consumption and vessel deployment.

12:00
S2
2

RESIDENTIAL CURBSIDE WASTE COLLECTION

Jakob Birkedal Nielsen, Emil Krapper, Kristian Milo Hauge, and Sune Vang-Pedersen

Transvision - AMCS Group

Residential curbside waste collection covers the collection of household waste in high density residential areas. The waste collection typically follows a fix collection pattern with master routes, where each waste bin is emptied once per week. The main characteristics of residential curbside waste collections are:

- Many thousand customers in one plan
- Many hundred customers on a single route
- Resulting routes must be compact without any overlapping
- Customers can only be served from one side of the street

13:30
S3
1

The following aspects should be taken into consideration when evaluating the quality of a plan:

Compactness and segregation: The resulting routes should be compact and non-overlapping.

Turns: Very often turns should be avoided in the route layout: Left hand turns may be time consuming due to traffic, and right hand turns may jeopardize the safety of pedestrians and cyclists. U-turns are typically only allowed at dead-end streets.

Route logic: The sequence of stops should be logic to the driver and to the citizens: waste bins should be emptied first time the truck drives through the street; there should not be too wide a time span between serving different sides of a given street; several passes through the same street should be avoided; a given area should be served completely before leaving it; the route should make sense to the driver

The challenge of optimising residential curbside waste collection is to include the above topological parameters and combine them with more classical optimization criteria as mileage and time.

MOO: THE MILK OUTPUT OPTIMISER. A MANAGEMENT TOOL FOR NEW ZEALAND DAIRY FARMERS

Oscar Dowson

The University of Auckland

14:00
S3
2

In New Zealand, the dairy industry is the largest export earner, responsible for around a quarter of total goods exports by value. In the 2013/14 season, over 20.5 billion litres of milk were processed from almost five million cows. Therefore, increasing the efficiency and profitability of New Zealand dairy farms will have a large impact on New Zealand's economic performance. A recent development amongst New Zealand farmers is the greater use of supplementation, where farmers purchase additional feed to supplement the herd's diet. In this talk we introduce MOO – the Milk Output Optimiser – an optimisation tool to better manage supplementation. MOO breaks a dairy farming season into weekly intervals, and calculates the optimal level of supplement to feed a cow in each week. It can also be used to determine when the farmer should stop milking the herd during the season. The objective of this is to maximise profit while ensuring the cow meets a target Body Condition Score (a proxy for animal health) at the end of the season. MOO shows promise as a useful tool to help farmers make intelligent management decisions, increasing both profitability and animal health.

PLANNING AND SCHEDULING IN THE FOOD INDUSTRY

Zaza Nadja Lee Hansen

Technical University of Denmark

The food industry is, unlike most industries today, still heavily reliant on manual labour and tacit knowledge from core employees like bakers. Waste percentages in production alone of 20% are normal. In Denmark, as in most of the EU, most food producers are SMEs. The market is very competitive and most products are very price sensitive with a high degree of substitution.

Planning and scheduling in the food industry is essential in limiting waste and improving efficiency; e.g. when to produce what, in what amount and in what order. Companies which produce frozen products mainly produce to stock and here it is important that the sales forecast is as accurate as possible to avoid over- or underproduction.

14:00
S3
3

In this presentation I will show the results from studies we have carried out at a baking company in Denmark. I will illustrate their current challenges and detail our suggested solutions.

The case company mainly produces baked goods like sausage rolls, cakes, scones and bread. They are an SME and need to improve efficiency in order to remain competitive. Currently they forecast based on last year's sales and know they operate with a heavy sales bias (e.g. overestimations). Changeover times between productions are largely estimations but product groups are scheduled to run after each other, if possible. Production plans change often, sometimes also on the day of production itself, mainly due to late or rush orders or delays in previous productions.

I will show how we have used simulation as well as data analysis of the case company's sales and production data from the last 2 years to suggest improved ways the company can plan and schedule their production.

SIMULATING THE ELECTRICITY SPOT MARKET FROM A DANISH PERSPECTIVE

Mette Gamst and Thomas Sejr Jensen

Energinet.dk

15:30
S4
1

The electricity spot market determines the hourly electricity prices a day in advance. It is also denoted the Day Ahead market. The prices are set by matching supply and demand with respect to marginal production costs. Simulating the spot market is typically done by solving the NP-hard unit commitment problem. An energy system must be formulated, including production units (power plants, wind parks, photovoltaics, etc.), energy demand, storages and interconnection lines to neighboring price zones. The goal is to maximize social welfare. When simulating the electricity spot market from a Danish perspective, district heating must be taken into account. Electricity and district heating are tightly coupled in Denmark, as much electricity is produced at "Combined Heat and Production Units" (CHPs). The volume and cost of producing electricity at CHPs depend on heat production. In this talk, I present the spot market simulation tool "Sifre". Sifre is a newly developed tool at Energinet.dk and solves the unit commitment problem. The tool focuses on simulating the behavior of the electricity spot market on a long term scale, say simulating the years 2020 or 2030. In the presentation, I will discuss the challenges of solving a complex problem in an industrial context.

OPERATING VIRTUAL POWER PLANTS - OPTIMIZING PROFIT IN THE GERMAN ELECTRICITY MARKET

Sabine Büttner

Technical University of Kaiserslautern

16:00
S4
2

The decision of the way to sell the overall available volume of current when operating a virtual power plant is a recurrent task for energy companies. In the German electricity market, the trading is organized in several auction-based markets. Each of these follows certain specific rules which differ essentially in the products wich are traded and the way the prices (and contracts) are formed. We describe the specifics of the markets and auctions and analyze the structure of the underlying optimization problem to determine a profit-maximal distribution of the available energy. Moreover, we also analyze some (theoretical) mathematical properties of the traders' profit functions and how to exploit these. For instance, on some markets maximizing the profit turns out to be a special case of a resource-allocation problem with piecewise linear profits. We show, that this case is still NP-hard but can be solved by a dynamic programming algorithm.

OPTIMIZATION OF THE CABLE COLLECTION GRID IN OFFSHORE WIND FARMS

Michael Lindahl

Technical University of Denmark

Wind Energy is expected to play a large role in the transition to renewable energy sources. Offshore wind farms have in the recent years started to grow significantly in size making the task of deciding on how to build the cable collection grid a lot more complex. The goal is to connect all turbines down to a substation by using different types of cables. The objective is then to minimize the cost by minimizing the amount of cables, connections and loss of power. The project is made in collaboration with DONG Energy which is market leader in building offshore wind farms. Using mathematical optimization can generate layouts much faster and also reduce cost significantly.

16:30
S4
3

Tuesday, June 2nd

The last speaker of the session is the chair of the session

PLANNING OF OPERATING ROOMS AT RIGSHOSPITALET

Karoline Foverskov and Line Ravnskjær

Technical University of Denmark

The aim of this project is to assign operations to operating rooms for two specialities at Rigshospitalet in an efficient and robust way, where the overtime work is minimised and unused capacity is released. Both elective and emergency operations are included, such that the elective operations are planned while still taking emergency operations into consideration.

A deterministic model is developed, and the operation plans from this model are used to evaluate the available capacity. As a result, the capacity is not distributed in an efficient way across weekdays and among specialities. It is possible to get a utilisation of almost 100%, if all operations are deterministic. However, a lot of uncertainty is associated with the planning and scheduling problem, so the deterministic model is not suitable for planning the operating rooms prospectively. Therefore a stochastic model is developed, where operation lengths can vary and the arrivals of emergency patients are not known. In addition a MIP-based heuristic is develop. The heuristic gives good results with half of the operating rooms having less than 8 minutes of overtime work. To test the robustness of the solutions, a simulated implementation of the operation plans has been carried out. The simulation shows that the heuristic solutions are fairly robust.

9:00 S5 1

Results found in this thesis show that there is a potential for improving the planning of operating rooms at Rigshospitalet. The conclusions are based on an extensive set compromising 304 days of data, but in order to get more accurate predictions and thereby better operation plans, more precise data is needed.

STUDENT SECTIONING AT DANISH HIGH SCHOOLS

Simon Kristensen

Copenhagen Sports Computing Group

Student Sectioning is the problem of assigning students to sections of courses given their requests. The problem is a yearly recurrent planning problem which precedes the actual timetabling problem at high schools. There exists approximately 200 high schools in Denmark so the goal is to create a generalized mathematical model and hence which provides good solutions for all the high schools. The algorithm developed is based on an Adaptive Large Neighborhood Search and is implemented in the commercial product Lectio and thereby available for the majority of the Danish high schools.

9:30 S5 2

A PARALLEL BRANCH & CUT ALGORITHM FOR THE BI-OBJECTIVE TSP PROBLEM

Thomas Stidsen

Technical University of Denmark

10:00

S5

3

Solving Bi-Objective Mixed Integer Programming models is hard. In this talk we will show how a standard Branch & Cut algorithm, can be altered such that bi-objective MIP models can be solved, i.e. such that the entire Pareto Front is found. The compuntational challenges are however significant, so to reduce the optimization time, parallelization is applied. Furthermore we devise optimization procedures to minimize the parallel computation time. Finally the approach is tested on the Bi-Objective Travelling Salesman Problem.

INTEGRATING LINE PLANNING, TIMETABLING AND VEHICLE SCHEDULING: FIRST APPROACHES

Anita Schöbel

University of Göttingen

Planning of a public transportation system is usually done in a sequential way: After the network design, the lines and their frequencies are planned. Based on these, the timetable is set up, and later on the vehicles' schedules and the drivers' schedules. From an optimization point of view such a sequential planning procedure can be regarded as a Greedy approach: in each planning stage one aims at the best one can do. This usually leads to suboptimal solutions. On the other hand, many of these single steps are already NP hard such that solving the integrated problem to optimality seems out of scope.

11:00
S6
1

In this talk we review line planning, timetabling and vehicle scheduling and argue that public transportation will benefit from an integrated planning. Weaknesses of the sequential approach will be pointed out. Furthermore, different ways of tackling the integration of the three planning stages of line planning, timetabling and vehicle scheduling will be proposed. In our first approach we describe an iterative approach which fixes two of the three plans (line plan, timetable, vehicle schedule) and optimizes the third one in each step. We show that this leads to new problem instances and discuss questions about the convergence of such an approach. In a second approach we present possible IP formulations and some results in star-shaped graphs for the integration of line planning and timetabling.

LINE PLANNING FROM A PASSENGER PERSPECTIVE

Simon Bull

Technical University of Denmark

The line planning problem is that of selecting the routes, stopping patterns and frequencies of lines to operate in a rail network. From the operators perspective these must meet certain service levels and provide sufficient passenger capacity, while having low operating cost. However from each passenger's perspective the line plan should provide a fast route between their origin and destination stations, preferably using lines operating at high frequency to limit their potential waiting time. We present an optimal model for selecting a line plan that meets the operational requirements and routes all passengers in the selected line plan, while exploring the compromise between two objectives: operating cost and total passenger travel time. Working with the rail operator in Denmark and data for the Copenhagen commuter trains and passengers, we show how we find a range of efficient solutions and how they differ from each other and from the current real line plan operated.

11:30
S6
2

GENERATING LINE POOLS WITH LINTIM

Philine Gattermann, **Jonas Harbering**, Anita Schöbel

University of Göttingen

13:00
S7
1

We present this work within the frame idea of integrative public transportation planning which is supported by our software tool LinTim. This discussion is intended to fill the gap between network design and line planning. A set of possible lines, only based on origin-destination data and the public transportation network, is generated as an input for the line planning. The problem of finding suitable lines and their frequencies for a public transportation system is usually approached in two distinct ways. Either possible lines are computed within the optimization or they are given as an input. Since the number of possible lines is of exponential size the computation within the optimization leads to very hard or even intractable programs. When restricting to a given set of possible lines (line pool) some freedom is lost but solving such models performs much more efficient. Still, the size of the pool is crucial for performance issues and hence a small set is favoured. In contrast, since "good" line concepts are desired, with respect to a variety of - possibly contradicting - measures, the number of feasible solutions shall still be big. In this talk we present an algorithm determining "good" lines based on both company and passenger related desires and show its applicability for subsequent line planning models. We will then embed this within the wider framework of public transportation covered by LinTim.

INTEGRATING PASSENGERS' ROUTING DECISIONS IN PUBLIC TRANSPORTATION PLANNING

Marie Schmidt

Erasmus University

13:30
S7
2

To model and solve optimization problems arising in public transportation, data about the passengers is necessary and has to be included in the models in any phase of the planning process. Many approaches assume a two-step procedure: in a first step, the data about the passengers is distributed over the public transportation network using traffic-assignment procedures. In a second step, the actual planning of lines, timetables, etc. takes place, based on the assignment made in the first step.

This approach ignores that, assuming that the network is sufficiently dense, for most passengers there are many possible ways to reach their destinations in the public transportation network, thus the actual connections the passengers will take strongly depend on the decisions made during the planning phase.

Hence, rather than doing these two steps iteratively, the influence of planning decisions on passengers' route choice should be considered in an integrated way when solving public transportation problems.

This talk discusses different approaches to find solutions to public transportation problems with integrated route choice models.

INTEGRATED ROLLING STOCK PLANNING FOR SUBURBAN PASSENGER TRAIN SERVICES

Per Thorlacius

Technical University of Denmark, DSB

14:30
S8
1

A central issue for operators of passenger trains is providing sufficient number of seats while minimising operating costs. This process must be conducted taking a large number of practical, railway oriented requirements into account. Because of this complexity, a stepwise solution was previously used, the result being the loss of optimality. The talk will present a new matheuristic based integrated rolling stock planning model in which the many requirements are handled all at the same time. Real-world results from DSB S-tog, the suburban train operator of the City of Copenhagen are presented.

A MATHEURISTIC APPROACH FOR SOLVING THE RAILROAD HUMP YARD BLOCK-TO-TRACK ASSIGNMENT

Jørgen Haahr and Richard Lusby

Technical University of Denmark

15:00
S8
2

In this talk we present a novel matheuristic for solving the Hump Yard Block-to-Track Assignment Problem. This is an important problem rising in the railway freight industry and involves scheduling the transitions of a set of rail cars from a set of inbound trains to a set of outbound trains over a certain planning horizon. It was also the topic of the 2014 challenge organised by the Railway Applications Section of the Institute for Operations Research and the Management Sciences for which the proposed matheuristic was awarded first prize. Our approach decomposes the problem into three highly dependent subproblems. Optimization-based strategies are adopted for two of these, while the third is solved using a greedy heuristic. We demonstrate the efficiency of the complete framework on the official datasets, where solutions within 4-14% of a known lower bound (to a relaxed problem) are found. We further show that improvements of around 8% can be achieved if outbound trains are allowed to be delayed by up to two hours in the hope of ensuring an earlier connection for some of the rail cars.

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