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Optimization and its Applications in Learning and Industry (OptALI)

IRSES

Task 2.4

Summer School on Optimization with focus on Robust Optimization,
27-31 August 2012, Göttingen

Start date of the Workpackage:	December 2010
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Participants:	UGOE UNIKL DTU UOA UC
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Contents

1 Introduction

The OptALI team of the optimization working group from UGOE organized a summer school on optimization with focus on robust optimization from 27-31 August 2012. The summer school comprised lectures and presentations by experienced and early-stage researchers. The summer school, while organized as part of the OptALI program, was open to interested participants from all over the world.

2 Organisers

Anita Schöbel, Marie Schmidt, Marc Goerigk, Ruth Hübner, Jonas Ide, Robert Schieweck, Marco Bender, Morten Tiedemann

3 Workshop Program

On Monday, Tuesday and Wednesday morning lectures were given by Matthias Ehrgott from the UOA, Jesper Larsen and Richard Lusby from DTU, and Clemens Thielen from UNIKL. Furthermore, talks were held in the afternoons and on Thursday morning. On Thursday afternoon and on Friday, the summer school merged with a workshop on robust optimization organized in the context of the DFG Priority Program Algorithm Engineering. We heard two lectures on robust optimization: by Anita Schöbel from UGOE and by Sebastian Stiller from the Technical University of Berlin; and some talks on robust optimization. The social event, including an exhibition visit, a rally, and a barbecue, took place on Wednesday afternoon.

3.1 Program

Monday, 27.08.12

8:30-9:00	*Registration for OptALI*
9:00-9:15	Welcome Address
9:15-13:30	**Lecture 1: Multiobjective Optimization for Robust Solutions in Practice** Matthias Ehrgott
	Session 1: Multiobjective Optimization
13:30-14:00	Siamak Moradi: Traffic Assignment and Bi-Objective Multi-Commodity Flow
14:00-14:30	Olga Perederieieva: Solving the Time Surplus Maximization Bi-Objective User Equilibrium Model of Traffic Assignment
14:30-15:00	Jonas Ide: Robustness in Multiobjective Optimization
	Session 2: Scheduling
15:30-16:00	Antony Phillips: Optimization based Models and Methods for the University Course Timetabling Problem
16:00-16:30	Morten Tiedemann: An LP-Based Heuristic for Flexible Job Shop Scheduling
16:30-17:00	Andrew Mason: OpenSolver & SolverStudio - Free tools for optimization using Excel

Tuesday, 28.08.12

9:00-12:30	**Lecture 2: Column Generation in Industrial Applications** Jesper Larsen and Richard Lusby
	Session 3: Transportation
13:30-14:00	Claus Gwiggner: Rules and Algorithms in Tactical Air Traffic Management
14:00-14:30	Andrea Raith: Robust Bicriteria Paths - Robustness Concepts and Solution Methods
14:30-15:00	Per Thorlacius: Rolling Stock Rotation Planning at DSB S-tog
15:30-17:00	OptALI Board Meeting

Wednesday, 29.08.12

9:00-12:30	**Lecture 3: Algorithmic Game Theory and Applications** Clemens Thielen
	Session 4: Nonlinear Optimization
13:30-14:00	Gert Lube: Optimal Control of Convection Dominated Transport Problems
14:00-14:30	Mohammed Thaher: Efficient Algorithms for the Maximum Convex Sum Problem
14:30-15:00	Ruth Hübner: Robust Integer Nonlinear Optimization
15:00-	Social Event

Thursday, 30.08.12

	Session 5: Decision Making under Uncertainty
10:00-10:30	Jutta Geldermann: Uncertainties in Decision Making in Production and Logistics
10:30-11:00	Susanne Wiedenmann: Supply Planning under Uncertainties for the Industrial Use of Renewable Resources
11:30-12:30	**Keynote Talk: Evacuation Planning Using Combined Network Flow and Location Models** Horst Hamacher
14:00-15:00	**Lecture: Robust Optimization** Anita Schöbel
15:00-16:30	**Invited Lecture** Sebastian Stiller
	Session 6: Issues on Robustness
17:00-17:30	Rastislav Sramek: What can we learn from two instances of the same problem?
17:30-18:00	Daniel Schmidt: Single-Commodity Robust Network Design
18:00-18:30	Marie Schmidt: Robust Timetable Information

Friday, 31.08.12

	Session 7: Recovery Robustness
9:00-9:30	Marc Goerigk: Recovery Robustness with Metrics
9:30-10:00	Christina Büsing: k-Distance Recovery Robustness
10:00-10:30	Open problem presentations
11:00-12:30	Group work on open problems
13:30-14:30	Presentation of results

3.2 Abstracts

Matthias Ehrgott: Multiobjective Optimization for Robust Solutions in Practice
Monday, 9:15-12:30
Many ways to deal with uncertainties in input data of optimisation problems have been suggested: stochastic optimisation, fuzzy optimisation and robust optimisation are all established areas in optimisation. They differ in the assumptions they make on what is known about the uncertainty. Robust optimisation, which only assumes that some parameters of an optimisation problem belong to an uncertainty set but does not make statements on distribution of data, has gained a lot of interest in recent years.

Here our interest is motivated by practical application of optimisation problems, for which we desire to find solutions that are robust with respect to uncertainty in data. We argue that it can be possible to interpret robustness as a second objective, that needs to be optimised along with the nominal objective of the optimisation problem. In this way it is possible to quantify the deterioration of the quality of the nominal objective in order to gain robustness.

We use airline crew scheduling as an example to show that traditional concepts of robust optimisation may lead to very conservative solutions that may not be acceptable for implementation in practice, whereas a bi-objective model that minimises cost and maximises robustness allows the consideration of trade-offs when selecting a solution.

Siamak Moradi: Traffic Assignment and Bi-Objective Multi-Commodity Flow
Monday, 13:30-14:00
The traffic assignment problem is a fundamental tool of transportation planning. It is used to determine traffic flow through a road network given traffic demand between a set of origin-destination pairs. Most importantly, traffic assignment models are able to model traffic congestions in road networks and they are applied in modelling the effects of infrastructure developments in road networks worldwide. The focus on a single objective (travel time, or more generally generalised cost) is a simplifying assumption. In fact, different criteria should be considered when determining traffic flow. We investigate the relation between the traffic assignment problem and the multi-commodity minimum cost flow problem. Building upon this relationship, we will explore the correlation of bi-objective traffic assignment problem and bi-objective multi-commodity minimum cost flow (BMCMCF). To do so, we will come up with methods to solve BMCMCF.

Olga Perederieieva: Solving the Time Surplus Maximization Bi-Objective User Equilibrium Model of Traffic Assignment
Monday, 14:00-14:30
The conventional approach to model traffic assignment assumes that all users have the same objective, i.e. to minimise their travel time or generalised cost, which usually represents a linear combination of time and monetary cost. The bi-objective user equilibrium condition is conceptually different from the approaches based on aggregation of objectives. It is inspired by the multi-objective definition of optimality and allows

multiple solutions (potentially infinitely many of them). We propose to apply the time-surplus maximisation model (TSMaxBUE) as a possible way to represent route choice behaviour in tolled road networks. In case of one user class it can be transformed into the time-based equilibrium model which can be solved by optimisation-based algorithms. Therefore, to solve it we adopt some path-based algorithms used for conventional traffic assignment, compare their performance and study how the solution space depends on the parameters of the model. In case of multiple user classes generally it is not possible to derive an equivalent optimisation formulation. Therefore, we propose to use the non-linear complementarity problem formulation to solve the TSMaxBUE model.

Jonas Ide: Robustness in Multiobjective Optimization

Monday, 14:30-15:00

Robust Optimization considers problems with uncertain objective function or feasible set. Due to various applications, many different interpretations of robustness exist.

These various concepts so far only apply to single objective functions. Hence, the question arises how to extend these robustness concepts to multiobjective optimization.

In this talk we present some robustness concepts for multiobjective problems. We will concentrate on strictly robust efficiency and discuss how to compute these robust solutions.

Antony Phillips: Optimization based Models and Methods for the University Course Timetabling Problem

Monday, 15:30-16:00

University timetabling is a large resource allocation problem, in which both times and rooms are determined for each class meeting. The majority of research in the field involves either heuristic methods or constraint logic programming which tend to scale well for large problems. However, these methods typically provide no guarantee of finding a feasible solution or of the timetable quality. Optimisation based methods have the advantage of finding high quality solutions, although due to computational limitations they have only been successfully applied on small problems such as for individual university departments.

My research involves an integration of these methodologies, where a heuristic utilises several optimisation subproblems to efficiently decompose and solve a timetabling problem. By partitioning the problem into a timetabling component and a room allocation component we demonstrate the room allocation component can in fact be solved using optimisation for a given draft timetable. If the room allocation component is infeasible, we obtain structured information which can be used to modify the timetable to improve the room allocation. Preliminary computational results using optimisation on full size datasets will be presented. The problem will be discussed in a practical context and ongoing research directions will be outlined.

Morten Tiedemann: An LP-Based Heuristic for Flexible Job Shop Scheduling

Monday, 16:00-16:30

The flexible job shop scheduling problem (FJSP) is a generalization of the classical job shop scheduling problem allowing each operation to be executed by a set of valid ma-

chines. The problem is to assign each operation to a valid machine and to order the operations on the machines such that a feasible schedule with minimal makespan is obtained. The FJSP is an $\mathcal{NP}$-hard problem and so far no exact algorithms with reasonable running time for instances of practical relevance are found. LP-based heuristics have been successfully applied to find approximation algorithms for single machine, identical parallel machine and flow shop scheduling. In this talk an LP-based heuristic for the FJSP based on a modified version of a time-expanded formulation is presented, leading to an implementable and efficient algorithm with a practicable empirical performance-ratio, even for instances of practical relevance.

Jesper Larsen and Richard Lusby: Column Generation in Industrial Applications

Tuesday, 9:00-12:30

Column generation is well-known decomposition principle used within linear programming. Integrating column generation with branch-and-bound extends the versatility and power of column generation to integer programming.

In formal terms, column generation is a method for solving a linear programming problem that adds columns (corresponding to variables) during the pricing phase of the simplex method of solving the problem. Generating a column in the primal simplex formulation of a linear programming problem can be seen as adding a constraint to the dual formulation.

Many researchers have observed that column generation is a very powerful technique for solving a wide range of industrial problems to optimality or to near optimality. Ford and Fulkerson, for example, suggested column generation in the context of a multi-commodity network flow problem as early as 1958. Two years later Dantzig and Wolfe had adapted it to linear programming problems with a decomposable structure. Gilmore and Gomory then demonstrated its effectiveness in a cutting stock problem, which has remained a classical example for column generation. With the increased power of computers column generation has become a leading tool for solving problems like vehicle routing, crew scheduling, and other integer-constrained problems.

Column generation is based on the fact that in the simplex method, the solver does not need access to all the variables of the problem simultaneously. In fact, a solver can begin work with only the basis and then use reduced cost to decide which other variables to include as needed. This lead to a setup where the master problem and subproblem are solved iteratively, where the subproblem add new improving columns to the master problem until it proves LP optimality.

Many industrial problems, especially in resource scheduling, can be represented as a Generalised Set Partitioning Problem (GSPP). In this model constraints are set partitioning, set covering or set packing constraints and right hand sides will normally be at unit value. In this lecture we will describe the principles of column generation applied to industrial optimization problems that can be represented as using the GSPP. We will introduce the column generation principle and important challenges when using it for solving real-life application projects.

Claus Gwiggner: Rules and Algorithms in Tactical Air Traffic Management
Tuesday, 13:30-14:00
Air transportation is a queuing system; albeit, a very complex one. It consists of several components such as airports, airlines or flow control and several layers such as tactical, pre-tactical and strategic optimization. As such it exhibits the classic queuing behavior. As demand approaches capacity, delays increase sharply. In this talk we show recent results on decision rules for this system. They are heuristic in nature but better understandable than optimal policies. Examples are slot swapping and return to equilibrium from disturbed operations.

Andrea Raith: Robust Bicriteria Paths - Robustness Concepts and Solution Methods
Tuesday,14:00-14:30
Finding robust solutions of an optimization problem is an important issue in practice and well researched for single objective problems. However, in many applications one has to deal with several objective functions. This research is motivated by the application of routing airplanes through convective weather, where the two conflicting objectives considered are the length and risk associated with a route. We extend robustness concepts for the single-criteria to the bicriteria case and develop new robustness concepts. The concepts are analysed for different uncertainty sets and their relations are discussed. We propose solution algorithms for bicriteria shortest path problems with one uncertain objective, and show numerical results together with examples that illustrate our concepts.

Per Thorlacius: Rolling Stock Rotation Planning at DSB S-tog
Tuesday, 14:30-15:00
The purpose of rolling stock rotation planning for a railway operator is to meet the demand for seats by passengers in the individual trains of the public time table, while at the same time minimising operating costs. This implies driving as few train units around as possible. Furthermore, the train units them selves need to go into maintenance at given intervals. A rolling stock rotation plan also needs to meet a number of infrastructure related constraints such as the capacity and topology of the depot (where train units are parked) and also which train movements the given signalling system allows. The talk will introduce all preconditions to the problem and outline possible solutions including the use of heuristics and a proposed partial solution using column generation.

Clemens Thielen: Algorithmic Game Theory and Applications: Why are we paying the second highest bid on ebay?
Wednesday, 9:00-12:30
The lecture gives an introduction to the field of algorithmic game theory, in particular, to the subfield of algorithmic mechanism design. This important research area, for whose foundations the 2007 Nobel prize in econimics was awarded to Lenonid Hurwicz, Eric S. Maskin, and Roger B. Myerson, deals with the problem of designing games that yield desired outcomes and has many applications in auction theory and problems arising in

distributed computing and on the internet. After introducing some basic concepts, we will study some prominent examples of these applications by looking at ebay auctions and machine scheduling problems.

Mohammed Thaher: Efficient Algorithms for the Maximum Convex Sum Problem
Wednesday, 14:00-14:30
The focus of this presentation is on a study of the Maximum Convex Sum Problem (MCSP). In this research we are investigating design and analysis of efficient algorithms for MCSP. MCSP combines theoretical algorithms framework and real-world data. MCSP is an area that employs novel approaches to resolve the problem of finding a region that returns an optimised maximum sums using a minimised computing time. Additionally, we will cover the new classification of the MCSP problem to find the K maximum sums for the two cases; Overlapping and Disjoint. Applications stretch from computer vision to data mining. Mohammed's thesis is supervised by Professor Tadao Takaoka.

Ruth Hübner: Robust Integer Nonlinear Optimization
Wednesday, 14:30-15:00
We consider robust versions of unconstrained integer optimization problems. Thus the uncertainty is only in the objective function. Our goal is to find an integer solution that performs best in the worst case. Since this in general even harder than without the additional integrality constraint, we want to solve the continuous relaxation of this problem instead and round the solution obtained afterwards to get an integer solution. To decide whether this solves the original integer problem to optimality we are going to use the "rounding property" - if the objective function has the rounding property we can solve the problem of minimizing this objective function over the integer lattice by minizing it over the whole space and rounding the optimal solution afterwards. The objective function we have to consider in the robust problem is the supremum of the objective functions for each scenario. So we want to answer the question: Which properties of the problem, i.e. of the scenario-depending objective function and/ or of the uncertainty set guarantee that the supremum over all objective functions has the rounding property.

Jutta Geldermann: Uncertainties in Decision Making in Production and Logistics
Thursday, 10:00-10:30
The complexity of today's industrial production networks constitutes a new challenge for production and logistics management. In order to handle potential risks and uncertainties, input from diverse scientific disciplines and the consideration of various often conflicting criteria is required. However, different types of uncertainty need to be treated in different ways. A classification of uncertainties that may arise in a decision making process and corresponding ways of treatment is very important. However, there are different ways to classify the occurring uncertainties. Among others, French[1] proposed

[1] French, S.: Uncertainty and imprecision: Modelling and Analysis. Journal of the Operational Research Society, 46:70-79, 1995

to group the uncertainties according to the different steps of the modeling process in which they can occur: Constructing the model; (b) exploring the model; (c) interpreting the model results This presentation discusses the various types of uncertainties in decision making in production and logistics. A special focus will be put on renewable raw materials which are becoming increasingly important as an alternative resource base in industrial corporate networks.

Susanne Wiedenmann: Supply Planning under Uncertainties for the Industrial Use of Renewable Resources
Thursday, 10:30-11:00
We investigate the supply planning of a processor of agricultural goods which are required as raw materials in industrial production. The use of linseed and linseed oil is one example that promises to be relevant in the future. Problems arise from uncertain quality, quantity and price. A two stage stochastic program is used as a decision support and its results are evaluated. We use data from linseed and linseed oil for validation.

Horst Hamacher: Evacuation Planning Using Combined Network Flow and Location Models
Thursday, 11:30-12:30
The combination of network flow and location problems (FlowLoc) is very helpful in modeling evacuation planning problems. This is due to the fact that network flows can be used to model the movement of evacuees and locational decisions such as the placement of emergency units or the identification of emergency shelters greatly influence the evacuation process. We present two different FlowLoc models: In the first one the change in the maximal flow value (rather than the standard shortest path distance) is used as measure for the quality of location decisions. In the second one, we identify best locations for sources in a flow network. ă For both of these models we discuss complexity results and solution approaches, and point out current research topics which are related to other OptALI research groups.

4 List of Participants

- Anita Schöbel, Gert Lube, Jutta Geldermann, Ruth Hübner, Morten Tiedemann, Marco Bender, Robert Schieweck, Jonas Ide, Marc Goerigk, Marie Schmidt, Thorsten Krempasky, Susanne Wiedenmann, Sybille Dühring, Matthias Garbs, Sönke Behrends (UGOE)
- Horst Hamacher, Sven Krumke, Clemens Thielen, Bob Grün (UNIKL)
- Mohammed Thaher (UC)
- Matthias Ehrgott, Andrea Raith, Siamak Moradi, Olga Perederieieva, Antony Phillips (UOA)
- Jesper Larsen, Richard Lusby, Per Thorlacius (DTU)

Figure 1: Group photo of the summer school participants

- Lizhen Shao (University of Science and Technology Beijing, China), Claus Gwiggner (FU Berlin, Germany), Andrea Wagner (University of Halle-Wittenberg, Germany), Teresa Schnepper (University of Wuppertal, Germany), Britta Schulze (University of Wuppertal, Germany), Christian Günther (University of Halle-Wittenberg, Germany), Erdal Aydemir(SDU Isparta, Turkey)

- (only in the SPP workshop) Ulrike Große (University of Bayreuth, Germany), Mahdi Moeini (TU Braunschweig, Germany), Sebastian Stiller (TU Berlin, Germany), Daniel Schmidt (University of Cologne, Germany), Timo Kötzing (MPI Informatik Saarbrücken, Germany), Christina Büsing (RWTH Aachen, Germany), Rastislav Sramek (ETH Zurich, Germany), Stephan Beyer (University of Jena, Germany)