Optimization
Guimarães 2014

Optimization 2014 Conference

SCHOOL OF ENGINEERING
UNIVERSITY OF MINHO
GUIMARÃES, PORTUGAL
JULY 28 - 30, 2014

BOOK OF ABSTRACTS

University of Minho
School of Engineering

Book of Abstracts

July 28-30, 2014

Department of Production and Systems

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Campus of Azurém

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Contents

Opening Notes

Welcome to Optimization 2014!

On behalf of the Organizing and Program Committees, we are very pleased to welcome you to Optimization 2014, the eighth edition of the Optimization series of conferences, hosted by the Department of Production and Systems, School of Engineering, University of Minho, in the city of Guimarães.

We are very pleased to announce that we have more than 100 presentations and participants, from 12 different countries. We thus hope that the meeting will allow a fruitful exchange of ideas and promote scientific collaborations.

The success of a conference depends on many factors, one of which is the prestige of the plenary speakers. We would like to express our gratitude to the Optimization 2014 plenary speakers for accepting our invitation. We are also grateful to those who kindly accepted our invitation to organize a session. Finally, we are most thankful to all the participants who will contribute to enhance the quality of the conference.

We are fully aware that the location of the meeting and the social program also play a key role. We tried to select some of the gastronomic, cultural, and natural aspects of our region. We hope you will enjoy the food, the wine, the music, and the landscape that this part of Portugal has to offer.

On a personal note, we would like to express our pleasure in organizing this meeting.

Finally, we thank our colleagues from the organizing committee who generously contributed with their work and time to the success of the conference. We also thank our sponsors for the support provided, which was crucial to this organization.

We hope that you enjoy Optimization 2014!

J. M. Valério de Carvalho | Co-chair, Organizing Committee
A. Ismael F. Vaz | Co-chair, Organizing Committee

Aims and Scope

Optimization 2014 aims to bring together researchers and practitioners from different scientific areas and with distinct backgrounds, but with common interests in optimization.

This meeting has international recognition as an important forum of discussion and exchange of ideas. It is the eighth edition of a series of international conferences in optimization organized in Portugal under the auspices of APDIO (the Portuguese Operational Research Society).

The previous seven meetings were the following:

Optimization 91, Coimbra

Optimization 95, Braga

Optimization 98, Coimbra (http://www.co.it.pt/~opti98)

Optimization 2001, Aveiro (http://www2.mat.ua.pt/opt2001)

Optimization 2004, Lisboa (http://www.opti2004.fc.ul.pt)

Optimization 2007, Porto (http://www.fep.up.pt/opti2007)

Optimization 2011, Almada (http://eventos.fct.unl.pt/optimization2011/home)

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General Information

Language

The conference official language is English. No simultaneous translation will be provided.

Conference Venue

The conference is taking place in the Department of Production and Systems, School of Engineering, University of Minho, Campus of Azurém, Guimarães. A campus map may be found in page 7, indicating the location of the buildings where sessions, coffee-breaks and lunch take place. All buildings are within a walking distance.

Registration Desk

The registration desk will be located at the entrance of the Auditorium (Room 1). The registration desk will be open on Sunday 27th, from 16:30 to 19:00, and during the conference days.

Internet Access

Free wireless access is available through the University Campus (network name: eduroam; login: optimization2014@guest; password: optimization2014). Warning: This is an unsecured wireless network. Internet access is also available in two computers located in the hall in front of the Auditorium (Room 1).

Guidelines for Organized and Contributed Session Chairs

In the Session Chairs Index on page 65 you can find the codes of all the sessions chaired by a given participant. The session location is given in the Abstracts section of the Conference book. As a session chair please make sure to:

- Contact the speakers before the session, to verify who is presenting and to preempt any technical problems.
- Ensure that the session begins and ends on time. All talks last 30 minutes, including the time for questions.
- Introduce the speaker and the title of each talk.

- Ensure that talks respect the program order, to allow participants to jump between sessions. If a speaker cancels or does not attend, the session schedule should be respected, rather than shifting every talk backwards.
- When appropriate inform the speaker of the remaining time till the end of the presentation.

VERY IMPORTANT: We ask session chairs to notify the session assistant about any last minute changes or cancellations. These changes will be posted outside the meeting rooms.

Guidelines for Speakers

In the Authors Index, next to the author name, you can find the code of the session in which a given author participates. The session location is given in the Abstracts section of the Conference book. All session rooms will be equipped with laptops or desktop computers and overhead projectors. You may use your own laptop to ensure that your presentation use the right version of the software and fonts installed, so that it looks like what you have planned and designed. Please follow these guidelines to ensure a successful presentation.

- If you bring your own laptop to your session, bring along the power supply cable. You may need an adapter to connect your computer to the local voltage (220V) and wall plug type.
- If your laptop is a Mac, bring the required adapter for the external video output.
- Arrive at your session at least 10 minutes before it begins. All presenters in a session should set up and test the connection to the projector before the session begins.
- We encourage speakers to put their presentations on a Universal Serial Bus data stick (USB pen) as a backup.
- Time your presentation to fit the allotted time (30 minutes), including time for questions and audience participation.
- Feel free to bring along copies of your paper to distribute or to provide a handout with related information. No proceedings with complete papers are produced for this meeting. To obtain complete copies of any papers abstracted in the program, please contact the authors directly at the address supplied with each abstract.
- One or more session assistants (student volunteers) will be available at each room. You can address the session assistant for any request or help regarding problems related to audiovisual equipment.

Lunches

Lunches will be served in the restaurant facilities. You are kindly required to wear your badge. Vegetarian food is available.

Coffee-breaks

Coffee, tea, juices, and bottled water will be available during the conference coffee-breaks.

Facilities inside the Campus

You can find several facilities in the campus:

- several ATM machines available
- Caixa Geral de Depósitos bank agency, open from Monday to Friday (8:30 to 12:00 / 13:00 to 17:00)
- Restaurant (Grill), open from Monday to Friday (12:00 to 14:00)
- Self-service restaurant (Rampa B), open from Monday to Friday (12:00 to 14:00)
- Café, open from Monday to Friday (9:00 to 19:00)

Transportation

Transportation to the conference site is available in the morning. The BUS departures from Hotel Guimarães and goes by Hotel Ibis and Hotel Toural, arriving at the university campus. More information is available at the hotel reception.
Guimarães is a small city, where almost all visiting sites are in a walking distance. However, there is an urban transportation bus that circles the city. The BUS departures and arrives at the Coach (BUS) Station. A map with the bus stops can be found at TUG website: *http://tug.com.pt/horarios/h-l-01.pdf*. You may buy a ticket for 1,70€ from the BUS driver (the ticket is valid for one trip).

Social Program

- Monday 28th July, from 18:30 to 19:30: **Welcome Reception**

  The welcome reception will take place at university, next to Auditorium (outdoors).

- Tuesday 29th July, from 19:45 to 22:30: **Conference Dinner**

  Conference dinner will be served in Instituto de Design de Guimarães (IDEGUI), Lugar de Couros, Rua da Ramada (Guimarães city centre).

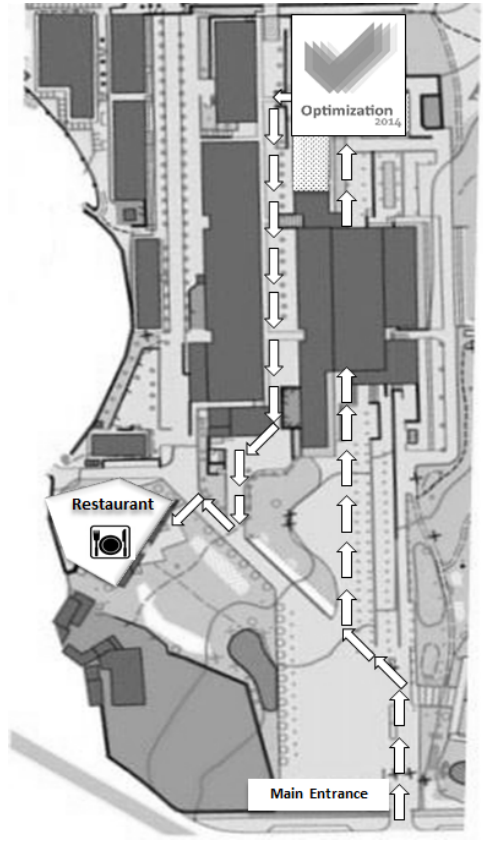
- Wednesday 30th July, from 15:30 to 18:00: **Tour**

  The tour will visit the Sameiro Sanctuary, Bom Jesus do Monte Sanctuary, and the historical centre of Braga (Guimarães - Sameiro - Bom Jesus - Braga - Guimarães).

Maps

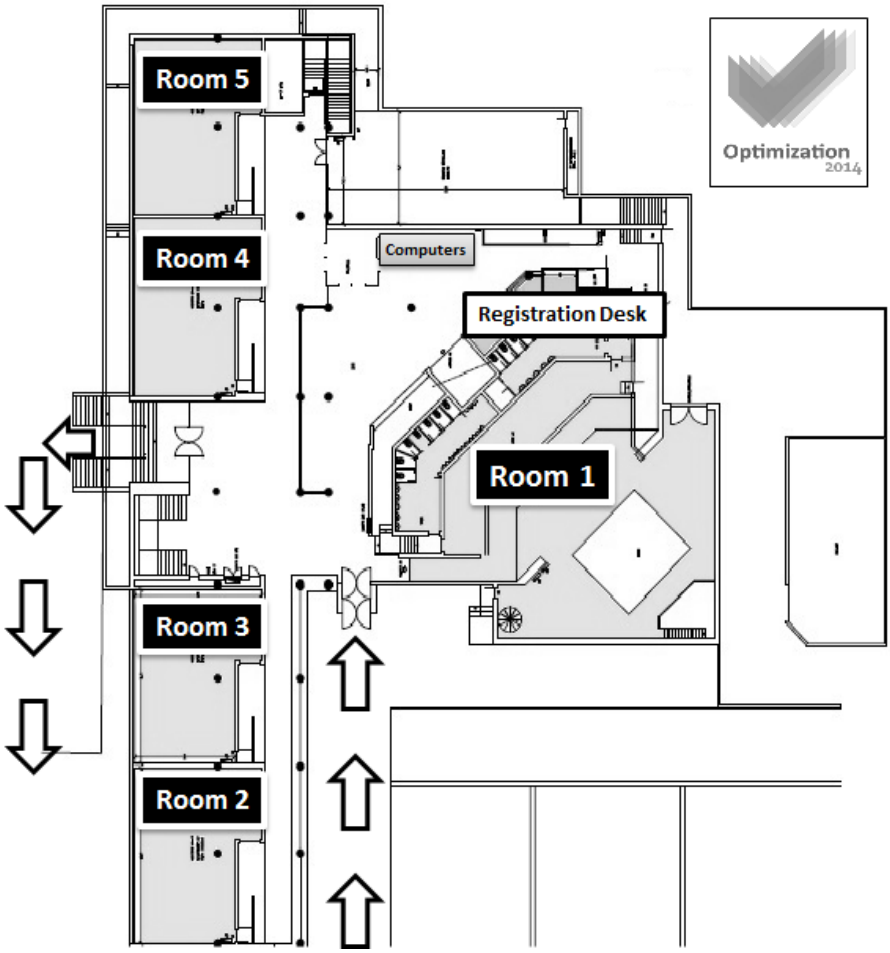
Campus map

Campus de Azurém - Alameda da Universidade
(GPS: [latitude: 41^o 27' 6.85" N - longitude: 8^o 17' 33.19" W])



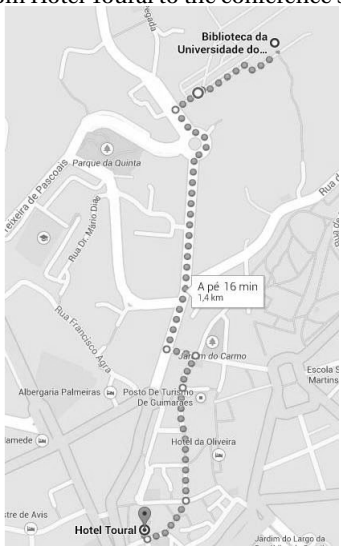
Conference Rooms

The sessions take place in five rooms: Room 1 (Auditorium), Room 2, Room 3, Room 4, and Room 5.



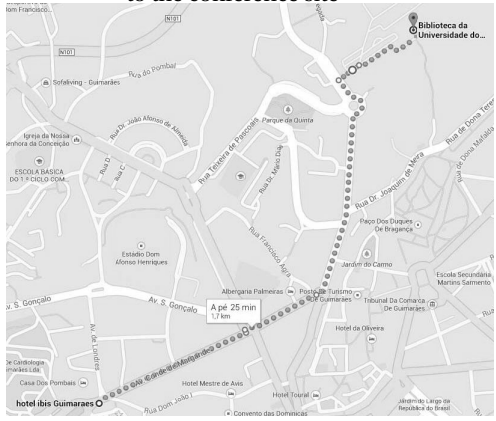
Directions to the Conference Site

From Hotel Toural to the conference site

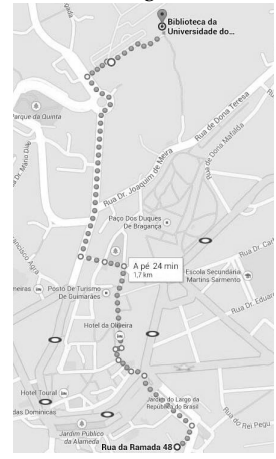


From Hotel Guimarães/Hotel Fundador/Train Station to the conference site

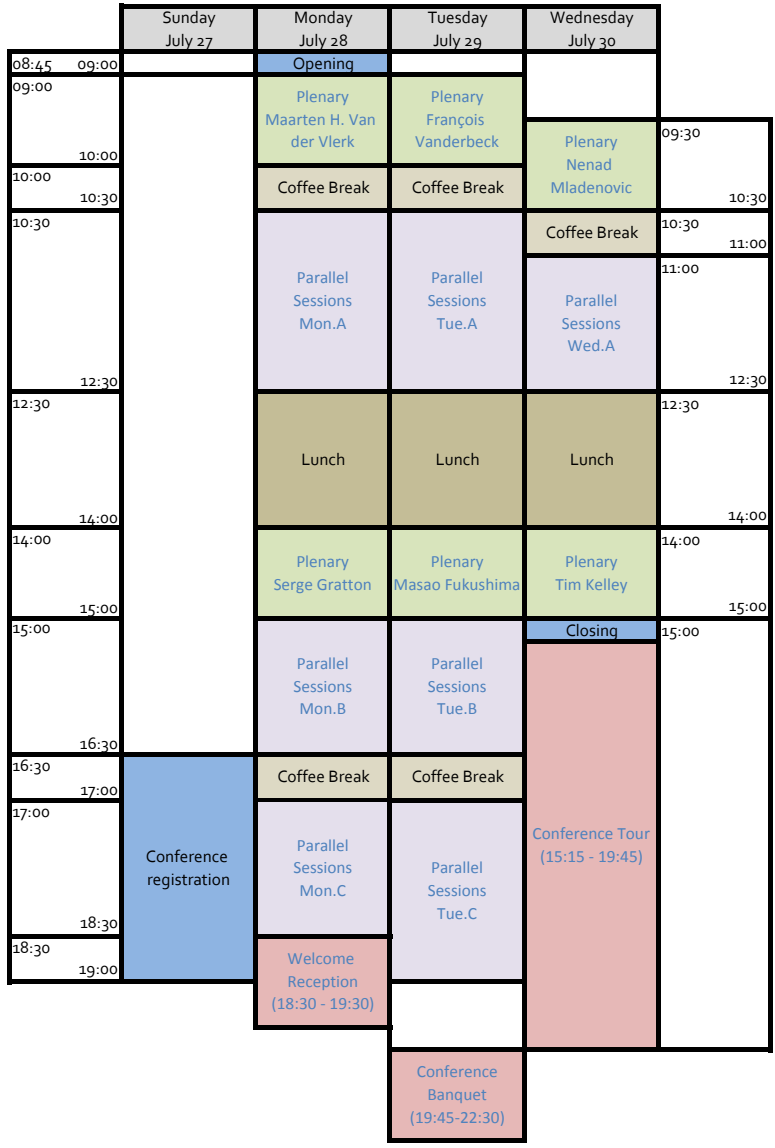
From Hotel Ibis/Coach Station to the conference site



From the conference site to the conference dinner site (Instituto de Design de Guimarães, Lugar de Couros)



Program Overview



Monday, July 28, 10:30-12:30

Monday, July 28, 15:00-16:30

Monday, July 28, 17:00-18:30

Tuesday, July 29, 10:30-12:30

Tuesday, July 29, 15:00-16:30

Tuesday, July 29, 17:00-19:00

Wednesday, July 30, 11:00-12:30

Plenary Sessions

MASAO FUKUSHIMA
Faculty of Science and Engineering, Nanzan University, Seto, Aichi, Japan,
fuku@nanzan-u.ac.jp

SOME RESULTS IN MULTI-LEADER-FOLLOWER GAMES

Tuesday, July 29, 14:00-15:00, Room 1/Auditorium
Chair: Joaquim João Júdice

Multi-leader-follower games play an important role in modeling complex 'conflict situations' that arise, for example, in economics and engineering. In this talk, we discuss some issues in studying such games, and then particularly mention our recent result on a class of multi-leader-follower games under uncertainty with some special and simplified structure. By means of the robust optimization technique, the game is first formulated as a robust Nash equilibrium problem, and then a generalized variational inequality problem. A numerical method is presented to compute a solution of the game.

Professor Masao Fukushima obtained all academic degrees in Engineering from Kyoto University. Currently he is a full professor at the Faculty of Science and Engineering, Nanzan University, and professor emeritus at Kyoto University. His research interests include nonlinear optimization, variational inequality and complementarily problems, parallel optimization, nonsmooth optimization, global optimization, game theory, and applications in transportation, finance, data mining, etc. He has published over 200 papers in peer reviewed journals and has been selected as an ISI Highly Cited Researcher in Mathematics. Professor Fukushima is one of the founders of the Pacific Optimization Research Activity Group, and had served as the Chairman of the Working Committee. He is also the founder and the Co-Editor of Pacific Journal of Optimization. Besides, he is currently on the editorial boards of 16 international journals in optimization and operations research, including Computational Optimization and Applications, Optimization Methods and Software, Journal of Optimization Theory and Applications, etc.

SERGE GRATTON

CERFACS and INPT-IRIT, Toulouse, France, gratton@cerfacs.fr,serge.gratton@enseeiht.fr

OPTIMIZATION METHODS FOR LARGE SCALE INVERSE PROBLEMS

Monday, July 28, 14:00-15:00, Room 1/Auditorium
Chair: Luís Nunes Vicente

Solving non-convex optimisation problems on parallel computers in a challenge that arise frequently in Geosciences, especially in the area of numerical prediction of physical phenomena. In this talk we discuss the state of the art algorithms that are used in operational centers, for solving this problems. Most of them rely on an adaptation of known optimization techniques, with an appropriate use of the problem geometry. We will also discuss also the new directions that are considered for future systems, where, due to the increase of the problem complexity, solution are expected to rely on stochastic approaches, and multi-domain, multi-fidelity or multi-grid ideas. Some results will be presented in the area of Data Assimilation for Oceanography.

Serge Gratton got a PhD in applied mathematics in Toulouse. He is currently full professor of applied mathematics in the University of Toulouse and director the CERFACS-IRIT joint laboratory. His research nowadays mainly focuses on theoretical and practical aspects of optimisation methods for large scale gradient based optimization or derivative free optimization. He is also the scientific coordinator of the CERFACS "Parallel Algorithms" team working on numerical methods for solving systems of equations and optimization problems. He is on the editorial borad of Optimization Methods and Software and has co-authored 60 peer-reviewed papers in international journals covering theoretical and practical aspects of numerical algorithms.

TIM KELLEY

North Carolina State University, USA, tim_kelley@ncsu.edu

IMPLICIT FILTERING AND HIDDEN CONSTRAINTS

Wednesday, July 30, 14:00-15:00, Room 1/Auditorium
Chair: A. Ismael F. Vaz

Implicit Filtering is a derivative-free optimization method which evaluates the objective function on a set of search directions. If the search fails to find a better point, the next step is to reduce the length of the direction vectors, updated the directions, and try again. Otherwise one approximates a gradient based on the values and tries a quasi-Newton step. For unconstrained problems where the objective function is everywhere defined, the positive and negative coordinate directions work well.

For many problems, however, the objective function may fail to return a value. Among the reasons for this are failure of internal simulations or failure of a postiori tests for validity within the function. In this case one must do more than compute a finite-difference approximation to the gradient and must also augment the direction set to avoid stagnation at non-critical points.

In this talk we will discuss how one resolves these problems, discuss some recent results on functions which have embedded Monte Carlo simulations, and show, in the context of an application, how our implementation of implicit filtering can be used to solve problems with hidden constraints.

C. T. Kelley is a Drexel Professor of Mathematics at North Carolina State University. His research interests are in numerical methods for nonlinear equations and optimization and applications of those methods. He is currently working on applications to neutron transport, subsurface hydrology, computational chemistry, and electronic structure computations. He is the author of four books and over 160 papers. He is a fellow of the Society for Industrial and Applied Mathematics (SIAM), editor-in-chief of SIAM Review, and chair of the SIAM Board of Trustees.

NENAD MLADENOVIC

Brunel University, UK, nenad.mladenovic@brunel.ac.uk

CLUSTERING COMMUNITY NETWORKS BY VARIABLE NEIGHBOURHOOD SEARCH

Wednesday, July 30, 9:30-10:30, Room 1/Auditorium
Chair: Luís Gouveia

In this talk I will first briefly present basic steps and facts regarding Variable Neighborhood Search (VNS) metaheuristic. Then I will present its three recent successful implementation in solving clustering problems on community networks. Network clustering is currently hot topic since it can be applied to social networks, telecommunication networks, biological, internet and all other networks. Many clustering criteria are proposed in the literature taking into account different needs for grouping. I will present three such clustering criteria solved by VNS: (1) VNS for divisive hierachical ratio/cut clustering; (2) VNS for multi diversity grouping; (3) Clique partitioning. Computational results and a comparative analysis will be given too.

Professor Nenad Mladenovic is currently professor (International chair) at LAMIH - CNRS, University of Valenciennes, France. He received all his degrees from the University of Belgrade, Yugoslavia (BA in mathematics, MSc and PhD in Operational Research). He started his university career in Belgrade, but has since spent about 10 years in Montreal, Canada at the Operational Research (OR) center GERAD and at McGill University. He was teaching at University of Birmingham and Brunel university, UK during 9 years. He has participated in

more than 20 industrial projects and was leader of several industrial and research projects in Yugoslavia, Canada, Belgium, U.K. and France. He has had visiting professor positions in Canada, Spain, Hong Kong, Germany, France and Belgium. In 2012 he became a member of the Academia Europe (The European Academy of Science). He is also a president of YuSIAM (Yugoslav Society of Industrial and Applied Mathematics), member of Serbian Scientific society etc. He has written 21 books and chapters, and has published more than 150 papers in edited proceedings and journals (such as SIAM J Computing, Management Science, Mathematical Programming, Operations Research, INFORMS J on Computing, OR Letters, EJOR, JOGO, JORS). He serves on the editorial board of a number of journals. His H and G research indices are 37 and 90 respectively, according to Google scholar. He has organized many international conferences and was guest editor of more than 10 special issues.

FRANÇOIS VANDERBECK

University of Bordeaux, France, fv@math.u-bordeaux.fr

LAGRANGIAN DUALITY AND COLUMN GENERATION: A REVIEW OF SOLUTION METHODS, THEIR COMMON BASE AND SPECIFIC FEATURES, AND EXTENSIONS OF THE PARADIGM

Tuesday, July 29, 9:00-10:00, Room 1/Auditorium
Chair: J. M. Valério de Carvalho

Large scale Mixed Integer Programming (MIP) optimization models are intricate to solve. When the model decomposes into blocs, for instance when optimizing the use of multiple ressources, relaxing the linking constraints in a Lagrangian way can make the model tractable. Exploiting such decomposition to develop tight approximations has lead to tremendous progress in solving important applications. In this presentation, we review the alternative methods to solve the so-called Lagrangian dual model or its linear programming counterpart, the Dantzig-Wolfe master (associated with the column generation algorithm). We highlight their drawbacks, their common base, and their specific features, while discussing extentions of such methods.

François Vanderbeck is a Professor in Operations Research at the University of Bordeaux. He is a member of the Mathematics Institute of Bordeaux and animates an INRIA research team named "RealOpt". Before that, he was a Lecturer at the University of Cambridge and was associated with both the Engineering Department and the Judge Institute of Management Studies.

François holds an Engineering Degree in Applied Mathematics (from UCL), a Master Degree in Operations Research (from MIT, ORC). He did his Ph.D. in Operations Research at the Centre for Operations Research and Econometric (CORE, UCL) under the direction of Professor Laurence A. Wolsey.

His research is in Combinatorial Optimisation, Integer Programming, Reformulation and Decomposition Methods (Branch-and-Price algorithms) and their Applications (Plan-

ning and Scheduling problems, Logistic and Routing, Cutting and Packing problems, Production and Inventory control).

MAARTEN H. VAN DER VLERK
University of Groningen, The Netherlands, m.h.van.der.vlerk@rug.nl

SIMPLE RECOURSE AND RELATIVES

Monday, July 28, 9:00-10:00, Room 1/Auditorium
Chair: Francisco Saldanha-da-Gama

The simple recourse model is indeed the simplest example of the general recourse concept of Stochastic Programming, modeling linear penalty costs for shortages and surpluses with respect to individual constraints. Simple recourse serves well to introduce the general concept, and moreover problems of realistic size, e.g. involving hundreds of constraints with random right-hand side parameters, can be solved in reasonable time.

We extend the simple recourse model to allow for a more refined penalty cost structure as well as integer recourse variables. We show how a solution approach developed for the latter problem class can be extended to more general integer recourse models. Finally, we discuss the concept of integrated chance constraints (ICC), an early predecessor of conditional value-at-risk. We present an algorithm for ICC models, which as a spin-off yields an algorithm for simple recourse models with random technology matrix.

Maarten H. van der Vlerk (University of Groningen) holds the chair Stochastic Optimization within the research institute OPERA (Operations Management and Operations Research). The chair specializes in design, analysis and implementation of mathematical models of optimization to support decision-making under uncertainty.

Following his PhD in 1995 and a post-doc year at CORE (Louvain-la-Neuve) prestigious fellowships from NWO and KNAW allowed him to continue his research in Groningen, focusing on recourse models with mixed-integer variables. In 2004-2007 he served as chair of the MPS Committee on Stochastic Programming. His publications appeared in a.o. Mathematical Programming, Operations Research, European Journal of Operational Research, and Annals of OR. From 2006 onwards, he is director of the bachelor and master programs Econometrics, Operations Research & Actuarial Studies.

Sessions

Mon.A.1, *Monday, July 28, 10:30-12:30, Room 1*

Derivative-Free Optimization (I)

Session organized by: *Serge Gratton*
Session chair: *Serge Gratton*

1. **Direct search based on probabilistic descent**

Clément W. Royer
(clement.royer@enseeiht.fr)
ENSEEIHT-IRIT, France, *Serge Gratton, Luis Nunes Vicente, Zaikun Zhang*

Direct-search methods are a class of popular derivative-free algorithms characterized by evaluating the objective function using a step size and a number of (polling) directions. When applied to the minimization of smooth functions, the polling directions are typically taken from positive spanning sets which in turn must have at least $n+1$ vectors in an n-dimensional variable space. In addition, to ensure the global convergence of these algorithms, the positive spanning sets used throughout the iterations are required to be uniformly non-degenerate in the sense of having a positive (cosine) measure bounded away from zero.

However, recent numerical results indicated that randomly generating the polling directions without imposing the positive spanning property can improve the performance of these methods, especially when the number of directions is chosen considerably less than $n+1$.

In this talk, we analyze direct-search algorithms when the polling directions are probabilistic descent, meaning that with a certain probability at least one of them is of descent type. Such a framework enjoys almost-sure global convergence. More interestingly, we will show a global decaying rate of $1/\sqrt{k}$ for the gradient size, with overwhelmingly high probability, matching the corresponding rate for the deterministic versions of the gradient method or of direct search. Our analysis helps to understand numerical behavior and the choice of the number of polling directions.

Keywords: Derivative-free optimization, direct-search methods, polling, positive spanning sets, probabilistic descent, random directions

2. **Global exploration strategy for derivative free optimization**

Nacer Soualmi
(nacer.soualmi@cerfacs.fr) CERFACS, *Youssef Diouane, Serge Gratton, Luis Nunes Vicente*

For enhancing global performance of optimization algorithms in a Derivative Free Optimization (DFO) context, hybrid approaches have been developed, combining two levels of abstraction : a global level responsible for defining regions of interest, and a local level performing refined optimization, using classical DFO techniques. The performance of such methods relies at first on the global level. The most successful algorithms are branch and bound inspired techniques (e.g., Multilevel Coordinate Search), others are based on multistart strategies or generate asymptotically dense sets of points in the search space.

In this work, we are proposing a new global level approach, naturally parallelizable, inspired by stochastic methods. The proposed solver is

compared to the most efficient current global solvers.

Keywords: Global optimization, derivative-free optimization, stochastic methods

3. **Globally convergent evolution strategies for constrained optimization**
Youssef Diouane (youssef.diouane@cerfacs.fr) CERFACS, France, *Serge Gratton, Luis Nunes Vicente*

In this talk we propose a new framework to extend evolution strategies (ES) to handle general constrained optimization. Two approaches are considered to handle the constraints. In a first approach, the objective function is evaluated directly at the generated sampled points, the feasibility being handled by an extreme barrier function mechanism. A second approach uses a projection of the generated sampled points onto the feasible domain before evaluating the objective function.

The resulting algorithms enjoy favourable global convergence properties (convergence to stationarity from arbitrary starting points), regardless of the linearity of the constraints.

The algorithmic implementation addresses general linearly constrained optimization. Our solver is compared to others, and the numerical results confirm its competitiveness in terms of efficiency and robustness.

Keywords: Evolution strategies, constrained optimization, global convergence, extreme barrier function, projection, linear constraints, bound constraints

4. **A subspace decomposition framework for nonlinear optimization: global convergence and global rates**
Zaikun Zhang (zhang@mat.uc.pt) Department of Mathematics, University of Coimbra, Portugal, *Serge Gratton, Luis Nunes Vicente*

We discuss a general subspace decomposition framework for optimization (for the moment without constraints). Two versions of the framework are presented, namely a Levenberg-Marquardt version and a trust-region one. We establish global (asymptotic) convergence and derive global rates for both of them. We also discuss how to exploit the framework to design parallel and multilevel derivative-free algorithms for large-scale problems.

Keywords: Subspace decomposition, global convergence, global rates, derivative-free optimization, large scale problems

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Mon.A.2, *Monday, July 28, 10:30-12:30, Room 2*

Mixed Integer Nonlinear Programming

Session organized by: *Laura Palagi*
Session chair: *Laura Palagi*

1. **A heuristic algorithm for general multiple nonlinear knapsack problems**
Luca Mencarelli (mencarelli@lix.polytechnique.fr) LIX Ecole Polytechnique, *Claudia D'Ambrosio, Silvano Martello, Angelo Di Zio*

We consider the multiple nonlinear knapsack problem (MNLKP) involving separable functions. Depending on the assumption on the integrality of the variables, this problem can be modeled as a nonlinear programming (NLP) or as a (mixed) integer nonlinear programming problem (MINLP). In both cases, this class of problems is very difficult to solve, both from a theoretical and a practical viewpoint.

MNLKP represents a challenging optimization problem: on the one hand it constitutes a general framework for completely separable nonconvex MINLP, on the other this problem typically arises in multiple nonlinear resource-allocation applications.

We propose a fast heuristic algorithm and a local search post-optimization procedure. A preliminary series of computational comparisons with a heuristic method for general nonconvex mixed integer nonlinear programming and with global optimization methods shows that the proposed algorithms provide high-quality solutions

within very short computing times. This works extends the heuristic algorithm proposed by Claudia D'Ambrosio and Silvano Martello (Computers and Operations Research, 32(2):505-513, 2011) for the general nonlinear separable single knapsack problem.

Keywords: Heuristic algorithm, multiple nonlinear knapsack problem

2. **A Feasible Active Set Method with Reoptimization for Convex Quadratic Mixed Integer Programming**

Marianna De Santis (msantis@math.tu-dortmund.de) Technische Universität Dortmund, *Christoph Buchheim, Stefano Lucidi , Francesco Rinaldi, Long Trieu*

We present a fast branch-and-bound algorithm for solving convex quadratic mixed integer programs with linear constraints. In each node, we solve the dual problem of the continuous relaxation using an appropriate active set feasible method to get a lower bound. This active set algorithm is well suited for reoptimization and is tailored for convex quadratic programming problems with non-negativity constraints. Theoretical properties of the active set estimation will be highlighted. Our algorithm generalizes a branch-and-bound approach for unconstrained convex quadratic integer programming proposed by Buchheim, Caprara and Lodi in 2012 to the presence of linear constraints. The main feature of the latter approach consists in a sophisticated preprocessing phase, leading to a fast enumeration of the branch-and-bound nodes. Experimental results for randomly generated instances are presented. The new approach significantly outperforms the MIQP solver of CPLEX 12.6 for instances with a small number of constraints.

Keywords: Integer nonlinear programming

3. **Energy efficiency in cellular network: a non linear programming approach**

Kai Yang (kai.yang@lri.fr) LRI, Univerity of Paris Sud XI, *Dominique Quadri, Steven Martin*

The explosive wireless traffic growth triggers rapidly rising power consumption and carbon dioxide emission, which highlight the urgent need for energy-efficient design in wireless networks. For example, spectral efficiency (SE) is a strictly monotone increasing function with respect to the transmit power; Actually, improving SE directly leads to an increase in energy consumption in many situations, and it is shown that EE is strictly quasiconcave in SE. We proposed a two steps piecewise linear functions to convert the nonlinear fractional programming problem into linear programming problem. Experimentations will be conducted so as to assess the proposed optimization approach.

Keywords: Non linear fractional program, linearization, continuous variables

4. **Using the SpeeDP algorithm to solve max cut instances to certified optimality**

Laura Palagi (laura.palagi@uniroma1.it) Sapienza Università di Roma, *Veronica Piccialli, Giovanni Rinaldi, Maryam Salami*

We describe an algorithm that provides solutions to Max-Cut, along with a guaranteed optimality error certificate, that is based on "SpeeDP", a fast method for the solution of low-rank semidefinite programming relaxations of unconstrained -1,1 quadratic problems. Valid inequalities of the Cut Polytope are also exploited in a Lagrangian fashion to strengthen the SDP bound. The bounding procedure is finally embedded into an enumeration scheme. We report on experimental results obtained with this algorithm on very large

graphs (relative to what today's exact methods are able to handle) designed with the purpose of verifying the effectiveness of SpeeDP with respect to commonly used interior-point based SDP solvers.

Keywords: Max-cut, low-rank semidefinite programming, Lagrangian relaxation, branch&bound

Mon.A.3, *Monday, July 28, 10:30-12:30, Room 3*

Scheduling (I)

Session chair: *António Pais Antunes*

1. **Automatic timetabling in higher education institutions - Bullet TimeTabler education**

Pedro Fernandes (pedro.fernandes@bulletsolutions.com) Bullet Solutions, *Armando Barbosa*

In a time where the need to reduce costs has become part of day to day reality of all Educational Institutions, it is inefficient to continue manually performing those tasks that can be automated and optimized - the creation of timetables. In our previous work, a new automatic and optimized generator of timetables for Higher Education Institutions was presented - the product Bullet TimeTabler Education (BTTE), which is successfully used in more than half of the Portuguese Higher Education Schools, including the 10 major ones. BTTE has been improved over the years, and some important updates to the aforementioned previous work are relevant enough to be presented, as well as the next research directions that were chosen by Bullet Solutions to continuously refine the BTTE software.

Keywords: Automatic timetabling, heuristics, combinatorial optimization

2. **A branch-and-cut approach for solving forest harvest scheduling problems with constraints on clearcut area and interior space**

Isabel Martins (isabelinha@isa.utl.pt) Centro de Investigação Operacional, Instituto Superior de Agronomia, Universidade de Lisboa, *Miguel Constantino*

Forest fragmentation occurs when large and continuous forests are divided into smaller patches, with a proportionately less amount of interior space. Addressing forest fragmentation into forest planning models with no constraints on clearcut area may not prevent the excessive harvesting of a particular area, and the opposite tend to disperse harvests across the forest and thus, a more fragmented landscape. The aim of this study is to investigate the possibility of solving forest harvest scheduling problems with both constraints on clearcut area and interior space. We describe an integer programming model with an exponential number of constraints based on the so-called path formulation. We propose to solve the model by branch-and-cut. Computational results with real and hypothetical forests are reported.

Keywords: Forest management scheduling, spatial modeling, core area, integer programming, branch-and-cut

3. **The integrated lot sizing and scheduling problem - a hierarchy of models**

Michelli Maldonado (michelli@ibilce.unesp.br) UNESP - Univ. Estadual Paulista , *Socorro Rangel*

The solution of a lot sizing problem determines the timing and level of production to meet deterministic product demand over a finite planning horizon. The scheduling problem establishes the order in which the lots are produced, and might take into account sequence-dependent

setup. The Integration of these two problems enables the creation of better production plans than those obtained when solving the two problems hierarchically. We will present three mathematical models for the integrated lot sizing and scheduling problem based on different strategies to treat the scheduling decisions. A hierarchy of the models is presented based on an initial computational study.

Keywords: Mathematical models, mixed integer programming, lotscheduling

4. **Optimum management of boarding gates: application to Guarulhos airport (São Paulo)**

António Pais Antunes
(antunes@dec.uc.pt) CITTA, Department of Civil Engineering, University of Coimbra, *João Pedro Pita*

Aircraft arrive to and depart from an airport either at a boarding gate or at some apron position. In the former case passengers reach the terminal or the aircraft through an aerobridge, whereas in the latter they have to be taken there by bus, which is less convenient to passengers and airlines, and more expensive to the airport. In this paper, we describe an optimization model whose objective is to maximize the number of aircraft (weighted by seat capacity) that arrive to or depart from a boarding gate, given the respective arrival and departure times and the set of gates available. The usefulness of the model is demonstrated through an application to the busiest airport in South America - Guarulhos (São Paulo).

Keywords: Air transport, airports, gate assignment, mixed-integer optimization

Mon.A.4, *Monday, July 28, 10:30-12:30, Room 4*

Optimal Control Applications

Session chair: *Delfim F. M. Torres*

1. **Dengue outbreak in Madeira - what could happen if two virus serotypes coexist?**

M. Teresa T. Monteiro
(tm@dps.uminho.pt) Department of Production and Systems, University of Minho, Portugal, *Filipa Portugal Rocha, Helena Sofia Rodrigues, Delfim F. M. Torres*

Dengue is a vector-borne disease transcending international borders. It can be found in tropical and subtropical regions, predominantly in urban and semi-urban areas. In Madeira, a Portuguese island, an unprecedented outbreak was detected on October 2012 caused by DEN-1 virus serotype. A model of ordinary differential equations for dengue transmission, composed by mutually-exclusive compartments representing the human and vector dynamics, is presented in this study. The model considers two virus serotypes and the insecticide as a control variable. The coexistence of two serotypes may lead to more severe cases of illness. The aim of this work is to minimize the number of human infected and/or the insecticide amount. Numerical tests are performed to simulate a hypothetical outbreak caused by two virus serotypes using the data from Madeira.

Keywords: Dengue, two virus serotypes, optimization

2. **Optimal control of incompressible flow driven systems**

Teresa Grilo (tgrilo@fc.up.pt)
FCUP/FeUP, *Fernando Lobo Pereira, Sílvio Gama*

The objective of this work is to develop a mathematical framework for the modeling, control and optimization of dynamic control systems whose state variable is driven by interacting ODE's and

PDE's. This framework should provide a sound basis for the design and control of new advanced engineering systems arising in many important classes of applications, some of which may involve gliders and mechanical fishes.

Until now, the research effort has been focused in gaining insight by applying necessary conditions of optimality for shear flow driven dynamic control systems which can be easily reduced to problems with ODE dynamics.

Currently, we are extending this methodology to the two-dimensional incompressible Navier-Stokes flow by using vortex methods. In particular, we are studying the position of a particle when it is subject to the motion of a flow created by two vortices.

Keywords: Optimal control, dynamic systems, ordinary differential equations, point vortices

3. **Optimal control interventions in Tuberculosis-HIV/AIDS co-infection**

Delfim F. M. Torres (delfim@ua.pt) University of Aveiro, *Cristiana J. Silva*

Tuberculosis (TB) is a major cause of death among people living with human immunodeficiency virus (HIV), and HIV presents a big challenge to TB control. Each disease speeds up the progress of the other, and TB considerably shortens the survival of people with HIV/AIDS. An estimate one-third of the 40 million people living with HIV/AIDS worldwide are co-infected with TB.

We propose and analyze a model for TB-HIV/AIDS co-infection which considers single disease (TB or HIV/AIDS) and co-infection TB-HIV/AIDS treatment. The basic reproduction number of the system model is computed and stability is analyzed. Optimal control treatment procedures are derived for the reduction of co-infected TB-HIV/AIDS individuals.

Keywords: Optimal control, epidemiology, tuberculosis, HIV

Mon.A.5, *Monday, July 28, 10:30-12:30, Room 5*

Data Envelopment Analysis and Benchmarking

Session chair: *Teresa Peña*

1. **Real time data envelopment analysis: telemetry for formula 1 on mobile platforms**

Aparecido Jorge Jubran (jubran@uninove.br) Universidade Nove de Julho, *Laura Jubran, Sarah Jubran, Marcilio Lima, Irian Francisco*

The current pilot and team classification system in the Formula 1 championship does not allow for an impartial and unbiased comparison of the results, due to the lack of consistency in the scoring criteria, which directly influence the rankings generated by season; by pilot; by nationality; by constructor; by engine and tire suppliers, amongst others. This paper aims to offer a real time WEB demonstration of the efficiency border of pilot and team results using subject-area searches and Operations Research (OR) analytical techniques, including the theoretical and methodological developments of Linear Programming and Data Envelopment Analysis, also contributing to elucidate complaints made by F-1pilots and agents about the constant changes to the scoring criteria established by FIA-Fédération Internationale de l'Automobile.

Keywords: Telemetry, data envelopment analysis, real time

2. **Analyzing models with variable weights from a social choice perspective**

Teresa Peña (maitepe@eco.uva.es) Departamento de Economía Aplicada, Universidad de Valladolid, *Bonifacio Llamazares*

There are decisional contexts where fixed scores are assigned to the different ranks obtained by the candidates and those ones with the highest total score are the winners. Among these con-

texts we can mention sport competitions like the Formula One World Championship or the Motorcycle World Championship. In this framework, one of the most important issues is the determination of the scoring vector to use because the winner(s) may change depending on that vector. To avoid this shortcoming, several methods have appeared in the literature, where, by using mathematical programming techniques, each candidate is evaluated with the most favourable scoring vector for him/her. In this work we analyze these methods from a social choice perspective in order to be able to make an assessment based on their respective strengths and weaknesses.

Keywords: Decision support systems, scoring vectors, variable weights

Mon.B.1, *Monday, July 28, 15:00-16:30, Room 1*

Derivative-Free Optimization (II)

Session organized by: *Francesco Rinaldi*

Session chair: *Francesco Rinaldi*

1. Different second order approximations in a model-based SQP trust-region DFO method

Anke Tröltzsch (anke.troeltzsch@dlr.de)
German Aerospace Center

A trust-region SQP method for general nonlinear constrained optimization without derivatives is proposed. The trust-region step is computed by a Byrd-Omojokun-like approach. An active-set strategy is used to handle bound constraints and inequality constraints. The objective and constraint functions are approximated by local linear or quadratic interpolation. In this work, we want to examine different approximation techniques. Numerical results will be reported using a set of constrained problems from the CUTEst testing environment.

Keywords: Derivative-free optimization, SQP, constrained optimization

2. A derivative-free method for multiobjective problems combining global and local strategies

Stefano Lucidi (lucidi@dis.uniroma1.it)
DIAG Sapienza University of Rome,
Giovanni Fasano, Giampaolo Liuzzi, Francesco Rinaldi

This work focuses on the solution of black-box constrained multiobjective optimization problems, with both nonlinear inequality constraints and bound constraints. We propose a method combining a global and local strategy. In the global phase, we use a DIRECT-type approach, while in the local phase we adopt a line search based derivative free method. We further report some numerical results proving the effectiveness of the proposed approach.

Keywords: Derivative-free optimization, multiobjective problems, DIRECT algorithm

3. The BFO derivative-free algorithm and its application to parameter tuning in algorithm design

Margherita Porcelli
(margherita.porcelli@unibo.it)
University of Bologna, *Philippe L. Toint*

The estimation of algorithmic parameters is extremely important to ensure the best algorithmic performance for the broadest class of problems and to provide reliable default settings to non-expert users. We introduce an original formulation for the automatic parameter identification problem and use an improved version of the derivative-free BFO algorithm to find optimal parameters even in the absence of regularity of the (black-box) objective function. Numerical experiments on the BFO self-tuning are presented together with a numerical comparison among BFO and other DFO algorithms.

Keywords: Derivative-free optimization, parameter estimation

Mon.B.2, *Monday, July 28, 15:00-16:30, Room 2*

Copositive and Polynomial Optimization

Session organized by: *Immanuel Bomze*
Session chair: *Immanuel Bomze*

1. Optimization of constrained fractional quadratic problems

Paula Amaral (paca@fct.unl.pt) Dep. Mathematics FCT UNL

The correction of inconsistent linear systems and the eigenvalue complementarity problem are two classes of problems that can be formulated as Constrained Fractional Quadratic Problems (CFQP). CFQP consists in the minimization of the ratio of two quadratic functions over a polytope. For global optimization purposes, the nonconvexity of the objective function causes known difficulties. The role of lower bounds is crucial, for instance in branch and bound approaches. In this paper we will present Completely Positive and Copositive formulations which SDP relaxations provide efficient lower bounds. Some preliminary results in a sequential optimization method are also presented.

Keywords: Fractional quadratic problems, copositive formulations, inconsistent systems

2. Copositive programming: properties of copositive and completely positive matrices

Georg Still (g.still@math.utwente.nl)
University of Twente

A symmetric $m \times m$ matrix is called copositive if

$$z^T Az \geq 0 \quad \text{holds for all } z \in I\!R^m, z \geq 0.$$

A symmetric $m \times m$ matrix B is said to be completely positive if B can be represented in the form

$$B = \sum_{j=1}^{N} c_j c_j^T \quad \text{with } c_j \in I\!R^m, c_j \geq 0 \quad N \in I\!N.$$

The smallest number N in such a representation of B is called the cp-rank of B. A linear copositive program is a problem, where a linear objective is optimized under the constraint that an affine combination of symmetric matrices is copositive or completely positive.

In this talk we give a short introduction into copositive programming. Then, some of the properties of copositive and completely positive matrices are discussed.

Interested in particular in the cp-rank of copositive matrices we present recent results on the topological properties of the cp-rank function.

Keywords: Convex programming, copositive programs, completely positive matrices

3. Copositive relaxation beats Lagrangian dual bounds in quadratically and linearly constrained QPs

Immanuel Bomze
(immanuel.bomze@univie.ac.at)
University of Vienna

For all-quadratic problems (without any linear constraints), it is well known that the SDP relaxation coincides basically with the Lagrangian dual. Here we study a more general case with linear and quadratic constraints by including explicit sign constraints on the problem variables. Both the full Lagrangian dual and the Semi-Lagrangian relaxation are treated: the stronger Semi-Lagrangian dual bounds coincide with those provided by copositive relaxation. This way, we arrive at a full hierarchy of tractable conic bounds stronger than the usual Lagrangian dual (and thus than the SDP) bounds. We also specify sufficient conditions for tightness of the Semi-Lagrangian (i.e. copositive) relaxation and show that copositivity of

the slack matrix guarantees global optimality for KKT points of this problem.

Keywords: Copositive matrices, non-convex optimization, polynomial optimization, quadratically constrained problem, approximation hierarchies, global optimality condition

Mon.B.3, *Monday, July 28, 15:00-16:30, Room 3*

Scheduling (II)

Session chair: *Francisco Saldanha-da-Gama*

1. **Mixed-model assembly line balancing in the footwear industry**

Parisa Sadeghi (p.sadeghii@yahoo.com) INESC TEC, *Rui Rebelo, José Soeiro Ferreira*

Footwear is one of the most dynamic and successful industrial sectors in Portugal. Almost all the production is exported around the world. New efficient and automated assembly lines are being designed and installed, replacing mass assembly lines, to address the need to produce various models (always changing) at the same time Modeling these lines is quite challenging. Critical issues are the wide variety and small quantities of models, graph sequencing of tasks, limited deadlines, multi-functional operators, different types of machines and specific buffers. This work focuses on balancing a mixed-model stitching line in a real company. Optimization models will be presented, taking into account objectives such as the number of workstations and the workload smoothness of operators. Solution methods based on exact and heuristics methods will be described, together with an analysis of the computational results.

Keywords: Footwear industry, assembly line balancing, heuristic methods

2. **Scheduling aircrafts' engines repair process: a mathematical model**

Isabel Cristina Lopes (cristinalopes@eu.ipp.pt) UNIAG, ESEIG - Polytechnic Institute of Porto, Minho University, *Eliana Costa e Silva, Jorge Orestes Cerdeira*

In this talk, we discuss a scheduling problem that originated at TAP - Maintenance & Engineering - the maintenance, repair and overhaul organization of Portugal's leading airline. In the repair process of aircrafts' engines, the operations to be scheduled may be executed on a certain workstation by any processor of a given set, and the objective is to minimize the total weighted tardiness. A mixed integer linear programming formulation, based on the flexible job shop scheduling, is presented here, along with computational experiment on a real instance, provided by TAP-ME, from a regular working week. The model was also tested using benchmarking instances available in literature.

Keywords: Real world scheduling, flexible job shop, mixed integer linear programming

3. **The impact of fixed and variable costs in a multi-skill project scheduling**

Francisco Saldanha-da-Gama (fsgama@fc.ul.pt) DEIO-CIO, Faculdade de Ciências, Universidade de Lisboa, *Isabel Correia*

In this work we investigate a project scheduling problem in which several skills are required for executing the activities. A pull of resources mastering these skills is assumed to exist. Each resource can contribute with at most one skill for the execution of an activity. In turn, each activity may require more than one resource for each skill. Costs are associated with resource usage and are to be minimized. The 'natural' mathematical programming model contains a non-linear objective function which, nonetheless, can be linearized at the expense of one additional set of continuous variables. The linearized model is enhanced using several sets of

additional inequalities. The results of an extensive set of computational tests performed with the final model are reported.

Keywords: Project scheduling, multi-skilled resources, cost minimization

Mon.B.4, *Monday, July 28, 15:00-16:30, Room 4*

OR Modelling and Applications

Session chair: *Diogo Alagador*

1. Optimizing extraction duration of front loader washing machines to improve water extraction performance under a constraint of energy consumption

Talip Caglar (talip.caglar@arcelik.com) Arçelik , *Aysegul Sarac*

In washing machines, there is some water left on laundry after spinning. If the wet laundry is held inside of houses, the humidity of the air increases. It affects human health as well as causes decay on furniture and interior walls. That's why improving spinning performance of washing machines is critical for users. Decreasing moisture on clothes at the end of spinning aimed to be provided with optimum energy consumption of spinning process. At high spinning speeds, due to the effect of pressure and air flow in the tub, droplets, which has been extracted from drum, returns back to the laundry. This is an undesirable situation so it must be prevented. This problem can be solved by optimizing the design of some components such as drum, tub and spinning algorithm etc. Prior to this optimization, water flow behavior must be analyzed in the tub during spinning. The scope of this study is to analysis different parameters which affect the spinning efficiency. Therefore, it is aimed to provide optimum water extraction and spinning efficiency in washing machines with optimum energy consumption by using 6-Sigma methodology.

Keywords: Optimization, spinning efficiency, enegy consumption, 6-Sigma

2. Linear programming: a computational model for elaborating dietary plans focusing on meals served in elementary schools

Laura Martinson Jubran (laura.jubran@uninove.br) Universidade Nove de Julho, *Aparecido Jorge Jubran, Jaqueline Botelho da Ponte, Sarah Martinson Provasi Jubran, Tania Pinho dos Santos, Thiago Correa Carneiro*

Recent studies have shown that a balanced diet contains active components that prevent problems such as delayed growth and learning disabilities. Dietary plans include more nutritious foods in terms of active compounds, and aim to aid nutritionists in developing the best possible menus. This paper presents a computational model for development of low-cost dietary plans that take into consideration the established Dietary Reference Intakes (DRI), as modified according to the nutritionist's line of work, and its main goal is to help plan meals for children from age four to six. In addition, this paper aims to analyze the decrease in meal costs, obtained by using seasonal foods. The model is supported by a body of knowledge in various fields, such as operations research, information systems, biology and nutrition.

Keywords: Linear programming, dietary plans, elementary schools

3. Optimizing costs to ensure persistence of species under climate change

Diogo Alagador (alagador@uevora.pt) Centro de Investigação em Biodiversidade e Recursos Genéticos, CIBIO, Universidade de Évora, *Jorge Orestes Cerdeira*

Climate change will affect species distributions and therefore has impact on the effectiveness

of conservation areas. Therefore the location of conservation areas requires optimal guidance to make them efficient and effective in protecting species. We formalize such a challenge proposing a network flow model to identify, at minimum cost, efficient corridors (sequences of climatically suitable grid cells that each species is able to colonize along time) ensuring the persistence of each species within the system to exceed a minimum threshold. Persistence of a species along a corridor combines the suitability of each corridor's cell and the ability of species to disperse between consecutive cells corresponding to different time periods. Heuristics to handle this optimization problem and preliminary results on a realistic biodiversity conservation case study will be given and discuss.

Keywords: Biodiversity conservation, connectivity, graphs, heuristics, network flow

Mon.B.5, *Monday, July 28, 15:00-16:30, Room 5*

Nonlinear Optimization (I)

Session chair: *Maria Gardênia Sousa Batista*

1. **A twist on sequential linear programming methods**

Julio González-Díaz
(julio.gonzalez@usc.es) University of Santiago de Compostela, *María P. Fernández de Córdoba, Ángel M. González Rueda*

Sequential linear programming (SLP) is a widely used approach to solve complex nonlinear optimization problems. Informally, it consists of an iterative procedure which, at each step, works with a linearization of the problem around the current solution. This solution is then updated by taking a certain step in the direction of the optimum of the LP problem at hand. We study a natural modification of SLP in which, at each step of the iterative process, instead of moving towards the optimum of the current LP problem, we use this optimum as the new solution of the nonlinear problem. We study to what extent this modification preserves the theoretical properties of the classic SLP. Further, this modified SLP algorithm is easier to implement and it readily leads to a heuristic algorithm for mixed-integer nonlinear optimization problems. Interestingly, this heuristic has already been applied in a real-life problem on gas network optimization.

Keywords: Sequential linear programming, successive, nonlinear optimization, KKT conditions

2. **Use of smoothing algorithm hyperbolic in taxonomy of macroalgae**

Maria Gardênia Sousa Batista
(batistamariagardenia@gmail.com) UESPI, *Adilson Xavier, Francisca Lúcia Lima, Andre Macedo Santana*

This paper presents a new methodology for grouping data in Taxonomy. Macroalgae of the genus Caulerpa were chosen as a model for your application by great morphological plasticity and difficulty in their identification by traditional systematic methods. The results obtained using the hyperbolic smoothing algorithm demonstrate its feasibility for use in biological taxonomy. This new methodology may be used alone or in combination with other methodologies already established, not only in phycology, but also in other areas of biology.

Keywords: Hyperbolic smoothing, biological taxonomy, macroalgae

Mon.C.1, *Monday, July 28, 17:00-18:30, Room 1*

Derivative-Free Optimization (III)

Session organized by: *Francesco Rinaldi*
Session chair: *Francesco Rinaldi*

1. **A derivative-free trust-funnel algorithm for optimization problems with general inequality constraints**
Phillipe R. Sampaio (phillipe.sampaio@unamur.be) University of Namur, *Phillipe R. Sampaio, Philippe Toint*

A new derivative-free method is proposed for solving nonlinear optimization problems with general inequality constraints. This methods is of the trust-funnel variety and is also based on the use of polynomial interpolation models. In addition, it uses a self-correcting geometry procedure in order to ensure that the interpolation problem is well defined in the sense that the geometry of the set of interpolation points does not differ too much from the ideal one. Some initial numerical results are presented.

Keywords: Derivative-free optimization, nonlinear optimization, trust-region methods, trust funnel, inequality constraints

2. **A derivative-free approach for a simulation-based optimization problem in healthcare**
Massimo Roma (roma@dis.uniroma1.it) SAPIENZA - Universita' di Roma, *Stefano Lucidi, Massimo Maurici, Luca Paulon, Francesco Rinaldi*

In this work a simulation-based optimization model is considered in the framework of the management of the hospital services. Given specific parameters which describe the hospital setting, the simulation model aims at reproducing the hospital processes and evaluating their efficiency. In order to obtain the optimal setting, we combine derivative-free optimization methods with a simulation tool. The resulting framework has been tested on a real healthcare problem.

Keywords: Simulation-based optimization, derivative-free method, healthcare problems

3. **GLODS: clever multistart in directional direct search**
Ana Luísa Custódio (alcustodio@fct.unl.pt) Universidade Nova de Lisboa, *José Aguilar Madeira*

Locating and identifying points as global minimizers is, in general, a hard and time-consuming task. Difficulties increase in the impossibility of using derivatives. We present a new algorithm suited for global derivative-free constrained optimization. Using direct search of directional type, the method alternates between a search step, where potentially good regions are located, and a poll step where the previously located regions are explored. This exploitation is made through the launching of several pattern search methods (PSMs), one in each of the regions of interest. Differently from a multistart strategy, the several PSMs will merge when sufficiently close. The goal is to end with as many active PSMs as the number of local minimizers, which would easily allow locating the global extreme value. Numerical experience will be reported showing that the proposed method is competitive with currently commonly used solvers.

Keywords: Derivative-free optimization, global optimization, pattern search methods, multistart strategies

Mon.C.2, *Monday, July 28, 17:00-18:30, Room 2*

Matrices and Complementarity

Session chair: *Carmo Brás*

1. **Fantastic sport leagues and matrices of weighing**

José G. Hernández R. (jhernandez@unimet.edu.ve) Universidad Metropolitana, Caracas, Venezuela, *Javier J. Hernández G., María J. García G., Gilberto J. Hernández G.*

The Fantastic Sport Leagues (FSL) has become a new way to enjoy sports. One of the first tasks for a participant in an FSL is create his squad. The creation of a team, given the rules of each SFL, it is usually a problem multicriteria, so one of the simplest models, the Matrixes Of Weighing (MOW), should be useful for this task. The objective of this work will: Show how it can use the MOW to create the squad of a participant of a FSL. To achieve this objective will be used the Integrated-Adaptable Methodology for the development of Decision Support System (IAMDSS), already applied to other similar work. As limitations and scopes, there will be no field study, but that the illustration of the creation of the squad in a FSL with MOW will be under a hypothetical case for greater generality.

Keywords: Fantastic sport leagues (FSL), soccer, matrixes of weighing (MOW), multicriteria models, squad, selection

2. **The second-order eigenvalue complementarity problem**

Luis Merca Fernandes (lmerca@co.it.pt) Instituto Politécnico de Tomar e Instituto de Telecomunicações, *Masao Fukushima, Joaquim Júdice, Hanif Sherali*

The Eigenvalue Complementarity Problem (EiCP) differs from the traditional eigenvalue problem on the fact that the primal and dual variables belong to a self-dual cone K and satisfy a complementarity condition. In this talk we investigate the solution of the Second-Order Cone EiCP (SOCEiCP) where K is the Lorentz Cone. A new enumerative algorithm is introduced for finding a solution of the SOCEiCP. The method attains to find a global minimum of an appropriate merit function on K using a special branching scheme and a local nonlinear optimizer that computes stationary points of this merit function on subsets of K associated to the nodes generated by the algorithm. A semi-smooth Newton's method is combined with this enumerative algorithm to enhance it numerical performance. Numerical experience is included and illustrates the efficiency of the proposed techniques in practice.

Keywords: Second-order eigenvalue complementarity problem, nonlinear programming, global optimization

3. **On the quadratic eigenvalue complementarity problem**

Carmo Brás (mb@fct.unl.pt) CMA / FCT-UNL, Portugal, *Alfredo Iusem, Joaquim Júdice*

A new sufficient condition for the existence of solutions to the Quadratic Eigenvalue Complementarity Problem (QEiCP) is established. This condition exploits the reduction of the QEiCP to a normal EiCP. An upper bound for the number of solutions of the QEiCP is presented. New strategies for the QEiCP are analyzed which solve the resulting EiCP by an equivalent Variational Inequality Problem or by a special nonlinear program with linear constraints. Numerical experiments illustrate the interest of these formulations in practice.

Keywords: Eigenvalue problems, complementarity problems, nonlinear programming

Mon.C.3, *Monday, July 28, 17:00-18:30, Room 3*

Routing (I)

Session chair: *Agostinho Agra*

1. Integrated approaches for the vehicle routing and packing problems

Telmo Pinto (telmo@dps.uminho.pt) University of Minho, *Cláudio Alves, José Valério de Carvalho*

The capacitated vehicle routing problem (CVRP) has motivated many variants and several approaches for decades. In the recent past, some authors proposed the integration of the CVRP with the bin-packing problem. The combination of these two problems arises in many real-world situations. The resulting problem is denominated by capacitated vehicle routing problem with loading constraints (L-CVRP). The LVRP is NP-hard and thus difficult to solve to optimality when it considers instances with large number of customers. Not surprisingly, the vast majority of the approaches to the L-CVRP are based on heuristics. However, some recent works have addressed both the exact solution of the LVRP and the exact solution of two-dimensional packing problems explicitly considering loading constraints. In this talk, we intend to describe new approaches towards the exact resolution of the LCVRP.

Keywords: Vehicle routing, packing, integer programming

2. Network flow formulation and variable neighborhood search for the location and routing problem with multiple routes

Rita Macedo (rita.sgd.macedo@gmail.com) Université de Valenciennes, France, *Bassem Jarboui, Bruna Ramos, Cláudio Alves, José Valério de Carvalho, Saïd Hanafi, Nenad Mladenovic*

We address a variant of the Location Routing Problem (LRP) where vehicles can perform several routes and both depots and vehicles have capacities. We explore a network flow formulation, whose variables represent feasible vehicle routes, and present valid inequalities to improve the quality of its continuous lower bound. This formulation is compared with another formulation proposed in the literature. We also propose a Variable Neighborhood Search (VNS) algorithm for this problem. We propose six neighborhood structures and consider, during the exploration of the solution space, solutions which violate the capacity constraints of vehicles or depots. To evaluate the quality of our methods, we conduct a set of computational experiments on benchmark instances from the literature.

Keywords: Location routing, network flow models, variable neighborhood search

3. A maritime inventory routing problem with uncertain travel times

Agostinho Agra (aagra@ua.pt) Universidade de Aveiro, *Marielle Christiansen, Alexandrino Delgado, Lars Magnus Hvattum*

We consider a maritime inventory routing problem where a company is responsible for both the distribution of oil products between islands and the inventory management of those products. Due to weather conditions and unpredictable waiting times at ports, traveling times are assumed uncertain. A two-stage stochastic programming model with recourse is presented where the first-stage consists of routing, loading and unloading decisions, and the second stage consists of scheduling decisions. The model is solved using a decomposition approach similar to an L-shaped algorithm where optimality cuts are added dynamically, and this solution process is embedded within the sample average approximation method. A computational study based on ten real-world instances is presented.

Keywords: Maritime transportation, inventory routing, stochastic programming

Mon.C.4, *Monday, July 28, 17:00-18:30, Room 4*

Engineering Applications in the Electric Power Sector

Session chair: *Luis A Roque*

1. **Efficient solutions for electrical load management in smart homes**

Semya Elaoud (samia.elaoud@inria.fr)
INRIA Lille Nord Europe, *Semya Elaoud, El-Ghazali Talbi*

Smart Homes of the future will include automation systems and could provide lower energy consumption costs with comfortable living environment to consumers. Residential users are expected to play a key role in improving the efficiency of the energy system through the adoption of intelligent mechanisms for managing the energy demand. We present a new mathematical formulation for the electrical load management in smart homes. The home automation system manage the equipments in housing by determining the starting time of some appliances, control the temperature set point of heater and cooling systems and optimize the recharging processes of domestic batteries including electric cars. Two objectives are simultaneously optimized: the total energy cost and the customer satisfaction.

Keywords: Bi-objective optimization, smart grids, smart homes, linear programming

2. **Short-term electricity planning with increase wind capacity using an optimization model**

Sérgio Pereira (sergiop@dps.uminho.pt)
University of Minho, *Paula Ferreira, A. Ismael F. Vaz*

The variable electricity output of the renewable energy sources power plants, such as wind and hydro power, is an important challenge for the electricity system managers. This paper addresses the problem of an electricity system supported mainly on hydro, thermal, and wind power plants. A binary mixed integer non-linear optimization model with hourly time step is described. The main objective of this paper was to analyze the impact that different levels of installed wind power can have in the operation of this electricity system, using optimization models. The results, obtained by running several simulations, confirmed wind power as strategic technology to reduce both the marginal cost and CO2 emissions.

Keywords: Electricity planning, renewable energy sources, non-linear mixed integer programming

3. **The unit commitment problem with periodicity constraints**

Luis A Roque (lar@isep.ipp.pt)
LIAAD-INESC-TEC, Department of Mathematics, Instituto Superior de Engenharia do Porto, *Luis A Roque, Dalila B.M.M. Fontes, Fernando A.C.C. Fontes*

This work addresses the Unit Commitment (UC) problem. In the UC problem, the goal is to schedule a subset of a given group of electrical power generating units and also to determine their production output in order to meet energy demands at minimum cost. In addition, the solution must satisfy a set of technological and operational constraints. Most problems in the literature consider a short horizon scheduling, typically 24 hours, but the solution obtained cannot be repeated even when load demand pattern remains the same. We analyse the "short horizon effect" when 24 hour scheduling is used repeatedly on a longer period and we introduce periodicity constraints that improve the overall solution on longer periods without compromising the computational load.

Keywords: Unit commitment, heuristics, metaheuristics, electrical power generation

Mon.C.5, *Monday, July 28, 17:00-18:30, Room 5*

Nonlinear Optimization (II)

Session chair: *Oleg Burdakov*

1. **Global convergence and worst-case complexity of smoothing adaptive cubic with regularization for non-smooth non-convex optimization**

Rohollah Garmanjani (nima@mat.uc.pt) Department of Mathematics, University of Coimbra, *Suvendu Pattanaik*

A smoothing adaptive cubic with regularization algorithm for minimizing unconstrained optimization problems with non-smooth non-convex objective functions is introduced. The global convergence analysis of the algorithm to first-order critical points is presented. The worst-case complexity of the algorithm in general case and for some structured problems will be discussed.

Keywords: Non-smooth non-convex optimization, smoothing adaptive cubic with regularization, global convergence, worst-case complexity

2. **On efficiently combining limited-memory and trust-region techniques**

Oleg Burdakov (oleg.burdakov@liu.se) Linkoping University, *Lujin Gong, Ya-xiang Yuan, Spartak Zikrin*

Limited memory quasi-Newton methods and trust-region methods represent two efficient approaches used for solving unconstrained optimization problems. A straightforward combination of them deteriorates the efficiency of the former approach, especially in the case of large-scale problems. For this reason, the limited memory methods are usually combined with a line search. We show how to efficiently combine limited memory and trust-region techniques. One of our approaches is based on the eigenvalue decomposition of the limited memory quasi-Newton approximation of the Hessian matrix. The decomposition allows for finding a nearly-exact solution to the trust-region subproblem defined by the Euclidean norm with an insignificant computational overhead compared with the cost of computing the quasi-Newton direction in line-search limited memory methods. The other approach is based on two new eigenvalue-based norms. The advantage of the new norms is that the trust-region subproblem is separable and each of the smaller subproblems is easy to solve. We show that our eigenvalue-based limited-memory trust-region methods are globally convergent. Moreover, we propose improved versions of the existing limited-memory trust-region algorithms. We present results of numerical experiments demonstrating the efficiency of our approach which is competitive with line-search versions of the L-BFGS method.

Keywords: Unconstrained optimization, large-scale problems, limited-memory methods, trust-region methods

Tue.A.1, *Tuesday, July 29, 10:30-12:30, Room 1*

Large Scale Optimization

Session organized by: *Francesco Rinaldi*

Session chair: *Francesco Rinaldi*

1. **A modified Frank-Wolfe method for large scale quadratic programming**

Giovanni Fasano (fasano@unive.it) University Ca'Foscari of Venice, Department of Management, *Luigi Grippo, Francesco Rinaldi*

This work proposes a modified Frank-Wolfe (FW) method, for the solution of possibly large scale quadratic programming problems. Similarly to the standard FW method, at each iteration a linear subproblem is solved. Then, instead of applying a linesearch procedure along a search direction, we perform the exact minimization of the objective function, over a two di-

mensional manifold. The latter manifold corresponds to the subspace spanned by both a modified FW direction and the previous search direction computed. This may be regarded as a possible extension of the Conjugate Gradient method to the constrained case. Global convergence results, similar to the FW method, may be established. We test our proposal over standard constrained problems from the literature.

Keywords: Conditional gradient, quadratic programming, conjugate gradient method

2. **On Frank-Wolfe Methods: recent variants, perspectives and applications to Machine Learning**

Emanuele Frandi
(efrandi@esat.kuleuven.be)
ESAT-STADIUS, KU Leuven, *Ricardo Ñanculef, Claudio Sartori, Johan Suykens*

The Frank-Wolfe method is a simple iterative scheme for solving concave optimization problems on the unit simplex and other convex polyhedra. Recently, there has been a renewed interest in the optimization and machine learning communities for variants of this procedure, as they allow to efficiently compute sparse approximate solutions to large-scale nonlinear problems arising in those fields.

In this talk, we provide a self-contained presentation of Frank-Wolfe methods and their analysis of convergence. We explain the connections between these algorithms and classic computational geometry problems. We also discuss some variants of the original method devised to improve performance on modern machine learning applications, summarizing recent experimental results in this field. Finally, we examine some open questions and future research possibilities.

Keywords: Frank-Wolfe algorithm, support vector machines, machine learning

3. **A fast active set block coordinate descent algorithm for l1-regularized least squares**

Francesco Rinaldi
(rinaldi@math.unipd.it) Dipartimento di Matematica, Università di Padova,
Marianna De Santis, Stefano Lucidi

The problem of finding sparse solutions to underdetermined systems of linear equations arises in several real-world problems (e.g. signal and image processing, compressive sensing, statistical inference). A standard tool for dealing with sparse recovery is the l1 -regularized least-squares approach that has been recently attracting the attention of many researchers. In this paper, we describe an efficient active set block coordinate descent algorithm that at each iteration use a bunch of variables (i.e. those variables which are non-active and violate the most some specific optimality conditions) to improve the objective function. We further analyze the convergence properties of the proposed method. Finally, we report some numerical results on some test problems showing the effectiveness of the approach.

Keywords: L1 -regularized least squares, active set, sparse optimization

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Tue.A.2, *Tuesday, July 29, 10:30-12:30, Room 2*

Healthcare and related applications

Session organized by: *David Manlove*
Session chair: *David Manlove*

1. **An integer programming approach to the hospital/residents problem with ties**

Augustine Kwanashie
(a.kwanashie.1@research.gla.ac.uk)
University of Glasgow, *David Manlove*

The classical Hospitals/Residents problem (HR) models the assignment of junior doctors to hospitals based on their preferences over one another. In an instance of this problem, a stable matching M is sought which ensures that no

blocking pair can exist in which a resident r and hospital h can improve relative to M by becoming assigned to each other. Such a situation is undesirable as it could naturally lead to r and h forming a private arrangement outside of the matching.

The original HR model assumes that preference lists are strictly ordered. However in practice, this may be an unreasonable assumption: an agent may find two or more agents equally acceptable, giving rise to ties in its preference list. We thus obtain the Hospitals/Residents problem with Ties (HRT). In such an instance, stable matchings may have different sizes and the problem of finding a maximum cardinality stable matching is NP-hard.

In this talk, we provide an Integer Programming (IP) model for HRT. We show that an exploitation of the structure of the problem can be used to greatly reduce the size of the model it produces. We also discuss several ways of improving optimisation performance of the IP solver. Finally we provide results obtained from an empirical evaluation of the IP model based on real-world and randomly generated data.

Keywords: Integer programming, stable marriage problem, hospitals/residents problem, blocking pairs

2. **The hospitals/residents problem with couples: complexity and integer programming models**

Iain McBride
(i.mcbride.1@research.gla.ac.uk) School of Computing Science, University of Glasgow, *David Manlove*

The National Resident Matching Program is a centralised matching scheme that matches graduating medical students to hospitals in the US. The Scottish Foundation Allocation Scheme (SFAS) served a similar purpose in Scotland. These schemes permit couples to submit linked applications and the underlying matching problem may be modelled by the Hospitals / Residents problem with Couples (hrc). We prove that, even under severe restrictions, deciding whether a stable matching exists in an instance of hrc is NP-complete, and approximating a matching which is 'almost stable' is NP-hard. We describe an Integer Programming model of hrc which produces optimal solutions in instances of hrc and demonstrate the empirical performance of an implementation over random datasets and real data from the SFAS context.

Keywords: Stable matching allocation couples

3. **Robust kidney exchange**

Miguel Constantino
(mfconstantino@fc.ul.pt) Universidade de Lisboa - Faculdade de Ciências, *Margarida Carvalho, Kristiaan Glorie, Abdur Rais, Ana Viana*

Kidney exchange programs aim to enable transplants between incompatible donor-patient pairs. A set of pairs is chosen in such a way that each selected patient can receive a kidney from a compatible donor from another pair in the set. The pairs are then notified and crossmatch tests are performed to ensure the success of the transplants. Sometimes a partaker withdraws or a test fails, preventing the intended transplants from being performed. In those cases, a new set of pairs may be selected. The new set should be as close as possible to the initial set in order to minimize the material and emotional costs of the alteration. In this talk, we present a robust optimization approach that intends to maximize the number of pairs selected in both the first and second set in a worst case scenario.

Keywords: Kidney exchange, robust optimization

4. **Kidney exchange problem: a simulation-optimization approach**

Paolo Tubertini
(paolo.tubertini@unibo.it) DEI - Università di Bologna, *Nicolau Santos, Ana Viana, João Pedro Pedroso*

In recent years several countries have set up kidney exchange programs (KEPs) that allow exchange of kidneys between incompatible living

donor-patient pairs. These exchange programs can also consider compatible pairs, as well as altruistic donors. We present a simulation-optimization tool that gives the possibility, to clinicians and policy makers, of testing different program configurations regarding matching frequency of pairs (monthly, bimonthly or quarterly matching), matching characteristics (different cycle and chain lengths) and pool characteristics (involved actors, death related dropouts and after matching crossmatch). We discuss simulation results, focusing on the impact that different policies can have in terms of the number of incompatible patients that receive a transplant.

Keywords: Kidney exchange problem, discrete event simulation, combinatorial optimization

Tue.A.3, *Tuesday, July 29, 10:30-12:30, Room 3*

Network Design and Graphs

Session chair: *Ana Amaro*

1. Compact formulations for the maximum edge-weight clique problem

Pedro Martins (pmartins@iscac.pt) Polytechnic Institute of Coimbra and Operations Research Center, *Luis Gouveia*

We address compact formulations for solving the maximum edge-weight clique (MEWC) problem in sparse graphs. The MEWC problem has long been discussed in the literature, but mostly considering complete graphs, with or without a cardinality constraint on the clique. However, several real-world applications are defined on sparse graphs, where the missing edges are due to some threshold process or because they are not supposed to be in the graph, at all. We propose new node-discretized formulations for the problem, which are more compact than other models known from the literature. Computational experiments on benchmark and real-world instances indicate that the node discretized formulations are more efficient for solving large sized sparse graphs.

Keywords: Cliques in graphs, discretized formulations, biological networks

2. Design optimization of the wind farm cable networks

Maria Adelaide Cerveira (cerveira@utad.pt) UTAD & CIO, *Amaro de Sousa, Eduardo Pires, José Baptista*

The current trend for clean energy is leading to a significant increase in the generation of electrical power from wind energy. Therefore, it becomes important to develop optimization techniques to improve the wind farm production efficiency. In this work, we address the design of the cable network connecting the wind turbines of a wind farm to the central substation. In this problem, we aim to minimize not only the network setup costs (cable costs and digging costs) but also the cable power losses, over the farm life time, considering several cables types with different cross sections. We describe how the problem can be formulated as a Capacitated Minimal Spanning Tree Problem. The proposed models are applied to real case studies and the computation results are analyzed.

Keywords: Distribution networks, cable power loss, wind farm, discrete optimization

3. Valid inequalities for constrained minimum spanning trees

Cristina Requejo (crequejo@ua.pt) University of Aveiro, *Agostinho Agra, Eulália Santos*

We consider the minimum constrained spanning tree problem where the aim is to find the minimum spanning tree subject to a constraint on the total weight of the selected edges. We present valid inequalities that incorporate information from the set of spanning trees and the knapsack set simultaneously. These inequalities generalize the well-known cover inequalities for feasible sets corresponding to independent sets that result from the intersection of a knapsack set and the bases of a matroide. We discuss different lifting strategies. Computational experi-

ments are also reported.

Keywords: Valid inequalities, minimum spanning tree, cover inequalities

4. **Colaborative supply chain sustainability: optimal network configuration and planning**

Ana Amaro (aamaro@iscac.pt)
IPC-ISCAC/ CEGIST, *Ana Barbosa-Póvoa*

Nowadays, social, environmental and economic indicators are major concerns to companies. A great challenge is placed around their supply chain, SC, network configuration and operability. A new model is proposed to trade those decision challenges at both, SC network configuration and planning. The approach focus on collaborative planning flows, to enhance sustainability indicators with the minimal SC configuration costs'. A single level Mixed Integer Linear Model (MILP) formulation is obtained, where different topological, operational and processing conditions are integrated. Different networks configuration and planning strategies are studied, using a scenarios approach. The model applicability is shown through the solution of an industrial case-study.

Keywords: Supply chain, optimization, sustainability, network configuration, panning

Tue.A.4, *Tuesday, July 29, 10:30-12:30, Room 4*

Engineering Applications

Session chair: *Aldina Correia*

1. **Optimization of cogeneration systems applying direct search methods**

Ana Ferreira (acferreira@dps.uminho.pt)
University of Minho, *Ana C. Ferreira, Manuel L. Nunes, Luís B. Martins, Senhorinha F. Teixeira*

High efficiency cogeneration systems based on Stirling engine was considered for optimization using performance and costs criteria. A thermal-economic model was developed so that the output power and thermal efficiency of the Stirling system with finite rate of heat transfer, regenerative heat loss and imperfect performance could be studied. The main objective of this work is the optimization of a renewable-based cogeneration system for residential, by using numerical optimization tools, based on direct search methods. An alpha Stirling engine is optimized by trying to disclose the best operational parameters for the Stirling engine for cogeneration applications, by using a software-code developed in the MatLab® environment. The paper discusses different combinations and number of decision variables, and analyses their relevance in the thermal-economic output of cogeneration system. The objective function corresponds to the balance between the incomes and costs from the system operation.

Keywords: Stirling engine CHP systems, thermal-economic optimization

2. **Derivative-free optimization of a 3D composite structure**

Ricardo Sá (sa.ricardof@gmail.com)
Institute of Polymers and Composites/I3N, Minho University, *A. Ismael F. Vaz, F. W. J. van Hattum, J. M. A. César de Sá , J. P. Nunes*

A case study corresponding to the design optimization of a gantry, a highly critical component of an Industrial Laser Cutting Machine (ILCM), is presented. The material and shape in which the new gantry will be produced must allow for adequate dynamic characteristics. Because of the flexibility in terms of shape and thickness allowed by composite materials, optimization algorithms have in this field a natural application, allowing for the production of lighter and cheaper structures. The objective will be to minimize the structure weight and cost, by varying its composite material thickness and orientations, while ensuring that the gantry allows for a pre-established degree of precision. Since the objective function evaluation

requests a time consuming simulation process, where derivatives are unavailable, a population-based derivative-free optimization algorithm is considered. Numerical results for a particular ILCM is to be presented.

Keywords: Composite structures, derivative-free optimization, industrial laser cutting machine

3. **An indoor location problem using fuzzy logic and direct search methods**

Aldina Correia (aic@estgf.ipp.pt) CIICESI-ESTGF-IPP, *Pedro Mestre, Carlos Serôdio, João Matias*

In this work Direct Search methods were used to tune the Fuzzy Logic parameters of the membership functions used in the location systems as well as the weights of the rules used in the online phase of Fingerprinting location method, minimizing the value of the precision. At each iteration of the optimization method, data from the FM (Fingerprint Map) and test data collected with mobile nodes are loaded, the patterns are created and the location estimation is made for all the points of the spatial domain under test. In this case the objective function to be minimized is the precision of the location system. As a result, the optimization method returns the values for the parameters for which the lower precision was obtained.

Keywords: Location, engineering optimization, fuzzy, direct Search methods

Tue.A.5, *Tuesday, July 29, 10:30-12:30, Room 5*

Convex Optimization

Session chair: *Philipp Hungerländer*

1. **KKT point and non-convexity**

Suvendu Ranjan Pattanaik (suvendu.pattanaik@gmail.com) NIT Rourkela

In this article we consider a convex feasible set described by inequality constraints that are continuous and not necessarily Lipschitz or convex. We show that if the Slater constraint qualification and a non-degeneracy condition are satisfied, then the Karush-Kuhn-Tucker type optimality condition is both necessary and sufficient. In this way we extend previous results which are proved for Lipschitz and differentiable inequalities.

Keywords: Convex optimization, KKT conditions, non-smooth functions

2. **Restricted area and collinear condition techniques for solving geometric shortest path problems**

Dinh Thanh Giang (dtgiang@math.ist.utl.pt) CEMAT/Instituto Superior Técnico, Lisbon and Institute of Mathematics, Hanoi, Vietnam, *An Phan Thanh, Le Hong Trang*

The problem of computing the geometric shortest path between two points in a domain in 2D or 3D (polygon or the surface of a polytope), is a classic of computational geometry. Computing such shortest paths is already presented by Lee and Preparata in 1984, Guibas, Hershberger, Leven, Sharir, and Tarjan in 1987, Agarwal, Sharir, and Varadarajan in 1998, Schreiber in 2007, etc. Most of them use a so-called sequential approach, i.e., at each step, the length of the present path is determined based on the the length of the previous path. In 2D their algorithms are based on triangulation of the polygon and in 3D usually based on the use of graphs on entire domain.

Relying on the idea of the method of orienting curves, introduced by Phu in 1987, an exact algorithm for solving some optimization problems, we introduce new algorithms for solving variants of geometric shortest pathproblem (convex hull, convex rope, Delaunay triangulation problems in 2D or 3D) without replying on triangulation. In addition, we use the multiple shooting approach, an approximate method for solving some optimization problems, to introduce new algorithms for solving Euclidean shortest path problems in 2D or 3D without con-

structing graphs on entire domain. In particular, “restricted area" technique originated from the method of orienting curves and “collinear condition", a matching condition type of multiple shooting approach, are used.

Our algorithms are implemented in C. Comparisons with previous algorithms on the running time, the accurate construction of shortest paths, and the use of memory are presented.

Keywords: Convex hull, Delaunay triangulation, multiple shooting, polyhedron, shortest path

3. **Non-parametric clustering with rank-constrained least-squares**

Stephane Chretien
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Laboratoire de Mathematiques,
Universite de Franche Comte

Unsupervised clustering is a problem of great practical importance, from genetics to marketing, extreme events modelling or even financial engineering. Although most available techniques perform well in practice, most of them require solving an NP-hard optimization problem or require to know the number of clusters ahead of time.

Our goal is to present a simple technique for fast joint estimation of the number of clusters and their respective center of mass, based on convex optimization. Assume that the data can be represented as a dxn matrix X=C+E, where C=MT, E is a matrix-noise, M is the center of mass matrix, and Tk,i=1 if Xi belongs to custer k and Tk,i=0 otherwise. This representation leads to searching for a low rank approximation of X. The rank of C is the number of clusters and is efficiently estimated using recent work in model selection. The approximation itself can be performed using nuclear-norm penalized least-squares.

Keywords: Convex relaxation, rank constraint, clustering

4. **An infeasible active set method with step size control for bound constrained convex problems**

Philipp Hungerländer
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University of Klagenfurt, *Fanz Rendl*

We extend the Kunisch-Rendl-Algorithm [K. Kunisch and F. Rendl. An infeasible active set method for convex problems with simple bounds. SIAM Journal on Optimization, 14(1):35-52, 2003.] for Bound Constrained Convex Problems by controlling the size of the steps taken. This allows us to ensure a decrease of the objective function for the projections of the primal iterates on the feasible region and at the same time a change of the active set.

The new approach inherits the preferable features of the Kunisch-Rendl-Algorithm, like simplicity, finding the exact numerical solution, insensitivity with respect to initialisation, lack of strict complementary and singularity and additionally overcomes its weakness by converging provable for any strictly convex objective function. Computational experience indicates that our approach also performs well in practice.

Keywords: Primal-dual active set methods, trust region, quadratic programming, box-constraints, convex programming

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Tue.B.1, *Tuesday, July 29, 15:00-16:30, Room 1*

Data Assimilation

Session organized by: *Serge Gratton*
Session chair: *Serge Gratton*

1. **Observation thinning in data assimilation computations**

Ehouarn Simon
(ehouarn.simon@enseeiht.fr) ENSEEIHT and IRIT, *Serge Gratton, Monserrat Rincon-Camacho, Ehouarn Simon, Philippe Toint*

We propose to use an observation-thinning method for the efficient numerical solution of

large-scale incremental four dimensional (4D-Var) data assimilation problems. This decomposition is based on exploiting an adaptive hierarchy of the observations. Starting with a low-cardinality set and the solution of its corresponding optimization problem, observations are successively added based on a posteriori error estimates. The particular structure of the sequence of associated linear systems allows the use of a variant of the conjugate gradient algorithm which effectively exploits the fact that the number of observations is smaller than the size of the vector state in the 4D-Var model. The new algorithm is tested on a 1D-wave equation and on the Lorenz-96 system.

Keywords: Data assimilation, numerical algorithms, multilevel optimization

2. **Preconditioning saddle point formulation of 4D-VAR**

Selime Gurol (gurol@cerfacs.fr) CERFACS, *Serge Gratton, Mike Fisher*

In this talk we will address the numerical solution of the saddle point system arising from four dimensional variational (4D-Var) data assimilation with an emphasis on a study of preconditioning with low-rank updates. The saddle point formulation of 4D-Var allows parallelization in the time dimension. Therefore, it represents a crucial step towards improved parallel scalability of 4D-Var. We will present numerical results obtained from the Object Oriented Prediction System (OOPS) developed by ECMWF.

Keywords: Preconditioning, saddle point system, data assimilation, parallelization

3. **Diffusion solvers for correlation modelling and localization in ensemble-variational data assimilation**

Jean Tshimanga Ilunga (jean.tshimanga@cerfacs.fr) CERFACS, Toulouse, France, *Anthony Weaver, Serge Gratton*

Differential operators derived from the explicit or implicit solution of a diffusion equation can be used to represent the action of a correlation matrix on a given vector. This can be exploited in large-scale applications of variational data assimilation to develop computationally efficient methods for modelling background-error correlations and/or for localizing correlation matrices estimated directly from a small sample of ensemble perturbations. In this study, we present theoretical and experimental results on the use of preconditioned linear solvers for an implicit formulation of a diffusion-based correlation operator. In particular, we focus our investigation on Krylov methods with Chebyshev acceleration.

Keywords: Linear solvers, Chebyshev acceleration, background-error correlations, data assimilation

■ Tue.B.2, *Tuesday, July 29, 15:00-16:30, Room 2*

Financial Optimization

Session chair: *Luís Alberto Coelho*

1. **Integrated planning of cash-flows and projects in a discrete-time model**

Francisco Lemos (chico.lemos@gmail.com) Master in Information Systems and Management, *Pedro Coimbra Martins*

Current day's financial crisis brought new challenges for governments, imposing narrower conditions for managing public expenses. We discuss and plan the annual budget to supply a local airfield, being entirely supported by public funds. The decision maker is intended to reduce the annual budget, along a 25 years stream,

such that a sustainability condition is met at the end of the planning horizon. To this purpose, a number of additional profitable infrastructures are required, demanding an initial investment cost covered by financement coming from loans, thus leaving the moldel the decision with an optimal planning strategy on when to lunch the construction of the facilities that could bring profits to cover financial and operational costs. We propose and discuss an integer programming discrete-time model that relates the two decision processes in a single framework.

Keywords: Mixed-integer programming, discrete-time financial planning, project planning

2. **Cumulative prospect theory for portfolio selection optimization in risk context**

Luís Alberto Coelho (lcoelho@uevora.pt)
CEFEGE-UE and Management Department, Évora University

The Cumulative Prospect Theory (CPT) is one of the most popular theories for evaluating the behavior of decision makers in the risk and uncertainty context. This theory emerged as a generalization of the Expected Utility Theory (EUT) and how is a relatively recent theory, its application has been somewhat reduced, especially when linked to portfolio optimization. This paper intends to analyze the behavior of CPT, with a power value function and a two parameters probability weighting function, as an objective function of a portfolio optimization model. The parameterization of the objective function coefficients allows us to analyze the composition of portfolios as the loss aversion, risk aversion and risk preference (in the negative part of the outputs) range. The results suggest that the loss aversion and risk aversion lead to the choice of portfolios with lower variability and that the risk preference in the negative part leads to the choice of portfolios with greater variability. The results obtained are also compared with the results obtained by the EUT and Rank Dependent Expected Utility. The optimization model with CPT, achieves more diversified solutions than other models and therefore more easily adjusted to the investors behavioral profile.

Keywords: Cumulative prospect theory, portfolio optimization, loss aversion, risk aversion

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■ **Tue.B.3**, *Tuesday, July 29, 15:00-16:30, Room 3*

Routing (II)

Session chair: *José Brandão*

1. **Combination of ant colony optimisation and exact methods applied to routing problems**

Samuel Carvalho (sdcc@inescporto.pt)
INESC TEC Porto, *Ana Maria Rodrigues, José Soeiro Ferreira*

An approach based on a combined strategy between Ant Colony Optimization (ACO) and Exact Optimisation Methods to deal with a special mixed capacitated arc routing problem, will be presented. The topic of mixing Metaheuristics and Mathematical Programming is also referred in the recent literature as Matheuristics. The situation under study, in the context of solid waste collection, comprises a heterogeneous fleet of vehicles and different points of collection with a limited number of visits to empty. The mathematical model linked to routing optimisation will be described. ACO is a population-based metaheuristic which has already revealed many interesting results, namely in routing problems. Computational results, some of which in connection with a real application, will be shown and discussed.

Keywords: Ant colony optimisation, metaheuristics, matheuristics, routing problems, solid waste collection

2. **Routes for solid waste collection - a real application**

Ana Maria Rodrigues
(amr@inescporto.pt) INESC TEC Porto / ISCAP - Instituto Politécnico do Porto,
José Soeiro Ferreira

This work was developed in cooperation with an environmental company and addressed a solid waste collection case arising in the north of Portugal. Two integrated phases are involved in the modelling and solution procedures: (a) sectorization, in which large municipalities are partitioned into small regions, and (b) routing, to construct routes for each sector. The presentation focus primarily on routing optimization, taking into account: a non-homogeneous fleet of vehicles starting and ending at a garage; the vehicles are emptied at different places, landfills and transfer stations; different types of containers some of which must be collected by specific vehicles; the transfer stations may have limitations related to the number of daily discharges. Three optimisation models and solution methods are described. The presentation also includes the computational results, part of which based on the real application.

Keywords: Waste collection, routing, sectoring, mixed capacitated arc routing problems

3. **Iterated local search algorithm for the open vehicle routing problem with time windows**

José Brandão (sbrandao@eeg.uminho.pt)
Universidade do Minho

The problem studied here is the open vehicle routing problem with time windows (OVRPTW). This problem is identical to the vehicle routing problem with time windows, except that the vehicles do not return to the distribution depot after delivering the goods to the customers. The OVRPTW has been solved using an iterated local search algorithm, taking as first objective to minimize the number of routes of the solution and as second objective minimizing the total distance travelled. In order to pursue the objective of minimizing the number of routes we used an ejection chain move, which is applied at the end of each iteration. The performance of the algorithm is tested using a large set of benchmark problems from the literature.

Keywords: Ejection chain, iterated local search, time windows, vehicle routing

Tue.B.4, *Tuesday, July 29, 15:00-16:30, Room 4*

Multiobjective Optimization (I)

Session chair: *João Paulo Costa*

1. **A Newton type method for constrained multiobjective optimization**

A. Ismael F. Vaz (aivaz@dps.uminho.pt)
University of Minho, *Joerg Fliege*

We propose a Newton type method for constrained nonlinear multiobjective optimization. The proposed algorithm considers a list of nondominated Pareto points, which is improved for spread and optimality by solving uniobjective constrained optimization problems. Under appropriate differentiability assumptions we provide theoretical considerations about the algorithm convergence to a local optimal Pareto front. Since the proposed algorithm can also be applied to unconstrained multiobjective optimization problems we provide numerical results for a set of unconstrained and constrained multiobjective optimization problems, in the form of performance and data profiles, where two performance metrics are used. The numerical results confirm the superiority of the proposed algorithm against a state-of-the-art multiobjective solver, either in the quality of the approximated Pareto front obtained as in computational work.

Keywords: Newton method, constrained multiobjective optimization

2. **Exploring neighbouring extreme efficient solutions in multiobjective mixed-integer linear programming**
Maria João Alves (mjalves@fe.uc.pt) Faculdade de Economia, Universidade de Coimbra / INESC-Coimbra, *João Paulo Costa*

Extreme efficient solutions (EES) of a multiobjective mixed-integer linear problem (MOMILP) are the supported efficient solutions whose objective points are vertices of the convex hull of the nondominated set. Although the EES constitute a subset of all efficient solutions, they can provide important insights about the whole efficient set because their objective points are on the boundary and delimit all nondominated points. In this work we propose a technique to explore EES and all their neighbouring relations in MOMILPs with two or three objective functions. The technique is based on the iterative computation of weight-space indifference subregions and the exploration of their adjacencies, which allows for the computation of all EES of a problem. A computer implementation is presented.

Keywords: Multiobjective optimization, mixed-integer programming

3. **Multiobjective integer linear fractional programming: a state-of-the-art**
João Paulo Costa (jpaulo@fe.uc.pt) Faculdade de Economia da Universidade de Coimbra, *Maria João Alves*

This communication aims to present the state-of-the-art in the practice of Multiobjective (mixed) Integer Linear Fractional Programming (MOILFP). The problems with an objective function that is a ratio of two linear functions have many applications when it is required the optimization of a ratio like debt/equity, output/employee, student/cost, doctor/patient, etc., subject to some constraints. If the constraints are linear, we obtain a linear fractional programming problem. Integer variables are usually necessary for modelling several real world issues. MOILFP problems are difficult to deal with and have not received much attention in the literature. We will present the last developments focusing on the attempts to solve MOILFP problems.

Keywords: Multiobjetive integer linear fractional programming, algorithms

Tue.B.5, *Tuesday, July 29, 15:00-16:30, Room 5*

Transportation Planning

Session chair: *Joao Luis Miranda*

1. **Optimization-based park & ride facility planning**
Joana Cavadas (joana.cavadas@hotmail.com) CITTA, Department of Civil Engineering, University of Coimbra, *António Pais Antunes*

Park & ride facilities (P&R) are parking lots located in the periphery of urban areas where commuters can transfer from cars to public transport in order to reach their final destinations, thus playing a potentially important role in decreasing traffic congestion in city centers. In this presentation, we describe an optimization model for assisting transport planners at determining the best locations and sizes for a set of P&R facilities as a function of the budget available for their construction and operation. The modal choice of commuters is assumed to depend on the generalized travel costs of each mode according to a logit model. The results that can be obtained through the model are illustrated through hypothetical examples inspired in real situations.

Keywords: Urban transport, modal choice, park & ride, optimization model

2. **Strategic planning model for free-floating car-sharing systems**
Miguel Gueifão Santos (msantos@dec.uc.pt) CITTA, Department of Civil Engineering, University of Coimbra, *António Pais Antunes*

Free-floating car-sharing is a recent type of shared mobility system whereby people pay for the use of a car that they can pick up and drop off anywhere within a given operating area (in a city). This type of system is quickly becoming popular, being already available in several cities worldwide, and especially in Germany. In this paper, we present an optimization model aimed to assist a free-floating carsharing company in its key strategic decisions - that is, the company's operating area or "geo-fence" and the cars' rental price or prices (if prices may vary with time of day and/or type of trip). The results that can be obtained through the model are illustrated for randomly-generated cities mimicking the essential features of real-world cities.

Keywords: Urban transport, free-floating car-sharing, pricing, optimization model

3. **International cooperation in higher education: decision support for a transportation network under expansion**
Joao Luis Miranda (jlmiranda@estgp.pt) ESTG/IPP, *James Uhomoibhi, Mariana Nagy*

The construction of the European higher education area considers the bilateral cooperation between high education institutions (HEI) as key subject. An international cooperation case on behalf of the Erasmus programme is presented: Decision Making topics are addressed and a learning module for decision support on Transportation and Capacity Expansion is developed. The module considers six lecturing hours in 3 sessions: (i) the introductory session with computational support, to focus on the basics of computational linear programming, integer programming, and Transportation typical problems; (ii) the advanced session, on the sequence, to consider uncertainty and also how to use multi-criteria decision making methods; (iii) the final session, to perform the evaluation of learning outcomes.

Keywords: Higher education, international cooperation, decision making, transportation, capacity expansion

Tue.C.1, *Tuesday, July 29, 17:00-19:00, Room 1*

Nonlinear Programming: theoretical and computational issues (I)

Session organized by: *Sandra Augusta Santos*

Session chair: *Sandra Augusta Santos*

1. **A new class of root-finding methods in Rn: the inexact Chebyshev-Halley tensor free class**
Ademir Alves Ribeiro (ademir.aribeiro@gmail.com) Federal University of Parana - Brazil, *Rodrigo Garcia Eustáquio, Miguel Angel Dumett*

This work introduces a new result about the Chebyshev-Halley Class for solving nonlinear systems. The methods in this class have third-order convergence rate In contrast, these methods are computationally expensive, requiring second-order derivatives. The result presented here is the introduction of a new class of methods, called Inexact Chebyshev-Halley tensor free Class, by not computing the second derivative tensor and by approximately solving two linear systems required for obtaining the necessary intermediate computations. Besides presenting the proof of convergence, we show that, depending on the assumptions, the methods of this class can have superlinear, quadratic, superquadratic or cubic convergence rates. We also show that these assumptions are quite reasonable. Finally, numerical evidence that shows significant improvement when using the inexact tensor free strategy (in the context of the classical methods of Chebyshev-Halley class) proposed in this work, is presented.

Keywords: Chebyshev-Halley class, tensor free, nonlinear systems of equations

2. **A flexible inexact restoration method and application to multiobjective constrained optimization**
Gabriel Haeser (ghaeser@ime.usp.br) University of Sao Paulo, *Luis Felipe Bueno, Martínez Jose Mario*

We introduce a new flexible Inexact-Restoration (IR) algorithm and an application to Multiobjective Constrained Optimization Problems (MCOP) under the weighted-sum scalarization approach. In IR methods each iteration has two phases. In the first phase one aims to improve feasibility and, in the second phase, one minimizes a suitable objective function. In the second phase we also impose bounded deterioration of the feasibility obtained in the first phase. Here we combine the basic ideas of the Fischer-Friedlander approach for IR with the use of approximations of the Lagrange multipliers. We present a new option to obtain a range of search directions in the optimization phase and we employ the sharp Lagrangian as merit function. Furthermore, we introduce a flexible way to handle sufficient decrease requirements and an efficient way to deal with the penalty parameter. We show that with the IR framework there is a natural way to explore the structure of the MCOP in both IR phases. Global convergence of the proposed IR method is proved and examples of the numerical behavior of the algorithm are reported.

Keywords: Nonlinear programming, inexact restoration, Lagrange multipliers, multiobjective optimization

3. **A new approach for the gradient sampling using nonmonotone line search**
Lucas Eduardo Azevedo Simões (simoes.lea@gmail.com) IMECC - Unicamp (Brasil), *Elias Salomão Helou, Sandra Augusta Santos*

An important tool for solving unconstrained optimization problems involving a nonsmooth function which is locally Lipschitz continuous is the Gradient Sampling (GS) algorithm. After its emergence, many variations of this algorithm have been developed to improve its performance or to overcome implementation issues. This study has the goal to use nonmonotone line search to improve upon the results of the original GS and to seek for an algorithm that does not need any kind of differentiability test during its execution. With these modifications we intend to reduce the gap between the theoretical and the implemented algorithm.

Keywords: Nonmonotone line search, gradient sampling methods, nonconvex optimization, nonsmooth optimization

4. **A quadratic regularization of Newton's method with algebraic rules**
Sandra Augusta Santos (sandra@ime.unicamp.br) University of Campinas , *Elizabeth W. Karas, Benar F. Svaiter*

The unconstrained minimization of a twice differentiable function with Lipschitz continuous Hessian is addressed. The proposed class of methods is based on the quadratic regularization of Newton's method, with algebraic explicit rules for computing the regularizing parameter. Global and local convergence properties of this class of methods are analyzed. Encouraging preliminary numerical experiments are presented.

Keywords: Smooth unconstrained minimization, Newton's method, regularization, global convergence, local convergence, computational results

Tue.C.2, *Tuesday, July 29, 17:00-19:00, Room 2*

Model-Predictive Control and Optimal Control

Session organized by: *Matthias Gerdts & Jürgen Pannek*
Session chair: *Mattias Gerdts*

1. Relaxation techniques for switching control of hyperbolic systems

Falk Hante (hante@math.fau.de)
University Erlangen-Nuremberg

We apply relaxation techniques to mixed-integer optimal control problems giverned by hyperbolic partial differential equations. We give a theoretical result on the size of the relaxation gap for semilinear systems with switching source terms and analyse a numerical method for providing epsilon-optimal switching controls. The method allows gradient computations using an adjoint calculus and therefore qualifies to the usage in context of model predictive control. As an application we study a traffic flow szenario, where we apply the above relaxation method to a hyperbolically relaxed model of conservation laws on networks to determine optimal switching between different flux functions to maximize the performance of the system.

Keywords: Mixed-integer optimal control, hyperbolic systems of PDEs, relaxation methods

2. Model predictive control with WORHP and TransWORHP for tracking problems

Matthias Knauer
(knauer@math.uni-bremen.de)
Universität Bremen, *Christof Büskens*

Optimal control problems can be found easily in many areas of application, e.g. in robotics, aerospace engineering, or the automotive industry. Mostly in mechanical systems, a trajectory has to be found bringing a system optimally from an initial to a final state.

However, the complete task for the process may not be known in advance, but develops after the initial time. Consider a system, which has to react in real-time to user input, but is too complex to apply feedback controllers.

In this talk, we will present techniques to solve this tracking problem as a problem of Model Predictive Control in real-time using the sparse NLP solver WORHP and the transcription method TransWORHP. The efficiency and robustness of our methods will be illustrated by an example of a crane system.

Keywords: Model predictive control, WORHP, crane system, real-time

3. Optimization of discrete switched and hybrid mechanical systems

Sina Ober-Blöbaum
(sinaob@math.upb.de) University of Paderborn, *Kathrin Flaßkamp, Maik Ringkamp, Sigrid Leyendecker*

Hybrid mechanical systems comprise continuous dynamics as well as discrete events. For example, structural changes in the system (discrete events) require a switch between different mathematical models (continuous dynamics). The switching law encoding the switching times and the sequence of modes serve as additional design parameters. For a fixed sequence of modes, switching time optimization is used to determine the optimal time switches in order to govern the system to a desired behavior. Is the sequence of modes part of the optimization, one is faced with a mixed-integer optimal control problem. In this talk, numerical switching time optimization and mixed integer optimal control methods especially tailored to hybrid mechanical systems are presented and demonstrated by examples.

Keywords: Optimal control, hybrid system, switching time optimization, mixed integer optimization

4. **Autonomous predictive driving utilizing car2car communication**
Jürgen Pannek
(pan@biba.uni-bremen.de) Universität Bremen

We consider a distributed non cooperative control setting in which systems are interconnected via state constraints. Each of these systems is governed by an agent which is responsible for exchanging information with its neighbours and computing a feedback law using a nonlinear model predictive controller to avoid violations of constraints. For this setting we present an algorithm which generates a parallelizable hierarchy among the systems. Moreover, we show both feasibility and stability of the closed loop using only abstract properties of this algorithm. To this end, we utilize a trajectory based stability result which we extend to the distributed setting. The scope of the results is illustrated using numerical simulations for crossroad, roundabout and takeover scenarios.

Keywords: Model predictive control, distributed control, suboptimality, stabilization, car-to-car communication

Tue.C.3, *Tuesday, July 29, 17:00-19:00, Room 3*

Integer Programming

Session chair: *Filipe Alvelos*

1. **Heuristics and relaxations for the diversity management problem**
Sérgio Marques (serolmar@hotmail.com) Universidade de Aveiro

New heuristic techniques to find and improve feasible solutions for the optimal diversity management problem are discussed. Feasible solutions are derived from the linear programming relaxation solution using rounding schemes. To solve the linear relaxation we use a decomposition approach that is based on the fact that the underlying graph is not connected, and show that this decomposition approach dominates the usual linear relaxation. The feasible solutions obtained from the linear relaxation are compared against the greedy solutions. Then the feasible solutions are improved using a Local Branching algorithm. All the computational tests are performed over a set of real instances.

Keywords: Optimal diversity management problem, hybrid heuristics, linear relaxations

2. **Capacitated single-allocation hub location problems with different types of products**
Isabel Correia (isc@fct.unl.pt) Centro de Matemática e Aplicações (CMA), Departamento de Matemática, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, *Stefan Nickel, Francisco Saldanha-da-Gama*

In this work, we extend the classical capacitated single-allocation hub location problem by considering that different types of products are to be shipped through the network. We propose a unified modeling framework for the situation in which no more than one hub can be located in each node. In particular, we consider the case in which all hubs are dedicated as well as the case in which all hubs can process all products. The objective is to minimize the total cost, which includes the cost for installing the hubs and the cost for routing the flow. Several models are proposed as well as additional inequalities for strengthening their linear relaxation. The results of a series of computational experiments performed are reported.

Keywords: Hub location, single-allocation, MILP formulations

3. **On a formulation for the (time-dependent) travelling salesman problem**

Luis Gouveia (legouveia@fc.ul.pt) Univ de Lisboa, DEIO, Centro de Investigação Operacional, *Maria Teresa Godinho, Pierre Pesneau*

We present a new formulation for the Time-Dependent Travelling Salesman Problem (TDTSP). We start by reviewing well known natural formulations with some emphasis on the formulation by Picard and Queyranne (1978). The main feature of this formulation is that it uses, as a subproblem, an exact description of the n-circuit problem. Then, we present a new formulation that uses more variables and is based on using, for each node, a stronger subproblem, namely a n-circuit subproblem with the additional constraint that the corresponding node is not repeated in the circuit. Although the new model has more variables and constraints than the original PQ model, the results given from our computational experiments show that the linear programming relaxation of the new model gives, for many of the instances tested, gaps that are close to zero. Thus, the new model is worth investigating for solving TDTSP instances. We also present an updated classification of formulations for the asymmetric travelling salesman problem (ATSP) where we "insert" the new time-dependet formulation presented in the first part of the talk.

Keywords: TSP, ILP reformulations

4. **Column generation heuristics**

Filipe Alvelos (falvelos@dps.uminho.pt) Algoritmi, DPS, Universidade do Minho

Column generation has been used for several decades in combination with branch-and-bound and branch-and-cut for attempting optimal solutions in integer programming / combinatorial optimization problems with a decomposable structure. In this presentation, we discuss the use of column generation for obtaining heuristic solutions. In particular, we discuss how column generation can be used to define restricted search spaces, constructive heuristics, local search and meta-heuristics, as well as matheuristics. We show computational results of different column generation heuristics and variants for some integer programming / combinatorial optimization problems.

Keywords: Integer programming, combinatorial optimization, column generation, heuristics

Tue.C.4, *Tuesday, July 29, 17:00-19:00, Room 4*

Metaheuristics and Benchmarking

Session chair: *José Fernando Gonçalves*

1. **Stochastic algorithms assessment using bootstrap performance profiles**

Lino Costa (lac@dps.uminho.pt) University of Minho, *Isabel Espírito Santo, Pedro Oliveira*

Optimization with stochastic algorithms has become a relevant research field. Due to its stochastic nature, its assessment is not straightforward and involves integrating accuracy and precision. Performance profiles for the mean do not show the trade-off between accuracy and precision, and parametric stochastic profiles require strong distributional assumptions and are limited to the mean performance for a large number of runs. In this work, bootstrap performance profiles are used to compare stochastic algorithms for different statistics. This technique allows the estimation of the sampling distribution of almost any statistic even with small samples. Multiple comparison profiles are presented for more than two algorithms. The advantages and drawbacks of each assessment methodology are discussed.

Keywords: Performance measures, stochastic algorithms, performance profiles

2. **A hybrid metaheuristic for the one-dimensional cutting stock problem**

Angelo Aliano Filho (angeloaliano@hotmail.com) Universidade Estadual de Campinas, *Antônio Carlos Moretti*

This work deals with the problem of the One-Dimensional Cutting Stock Problem. This problem is one of the most studied in Combinatorial Optimization and is highly complex to be solved, because of nature and number of variables involved, making the direct application of Branch type exact algorithms impractical. For this reason, we applied a hybrid metaheuristic named Genetic Algorithm with Simulated Annealing to solve it. Therefore, two heuristics to (i) build cutting patterns and (ii) to find initial solutions for the problem were developed. To validate them, we generated 1800 problems tests and compared the quality of the solutions of our method with the solution of the Integer Linear Problem, which are obtained with the patterns generated by the method Column Generation. The results showed a good performance and robustness of our algorithm, obtaining suboptimal solutions in a reasonable computational time.

Keywords: Combinatorial optimization, cutting stock problem, hybrid metaheuristic

3. **A biased random-key genetic algorithm for the shelf apace allocation problem in a supermarket chain**

Ana Carolina Janeiro (carolina.ccc91@gmail.com) INESC TEC, Faculty of Engineering, University of Porto, *Teresa Bianchi-Aguiar, José F. Oliveira*

Shelf space is one of the most valuable resources of a retail company. The challenge consists in distributing the scarce shelf space of a retail store among the different products to be displayed. Inspired by the case of a Portuguese supermarket chain, this project concerns the implementation of a Biased Random Key Genetic Algorithm (BRKGA) for the Shelf Space Allocation Problem. The BRKGA is a specific class of Genetic Algorithms (GA) that differs from common GA by its solution representation and the way it combines the individuals to create new generations. Using a BRKGA API, original ideas for solution decoders were designed, implemented and tested with real case study instances.

Keywords: Shelf space, genetic algorithm, retail

4. **A hybrid BRKGA and local search approach for the minimization of open stacks problem**

José Fernando Gonçalves (jfgoncal@fep.up.pt) Faculdade de Economia do Porto

This paper describes a hybrid biased random-key genetic algorithm (BRKGA) for the Minimization of Open Stacks Problem (MOSP). The MOSP arises in a production system scenario, and consists of determining a sequence of cutting patterns that minimizes the maximum number of opened stacks during the cutting process. The approach proposed combines a BRKGA and a local search procedure for generating the sequence of cutting patterns. A novel fitness function for evaluating the quality of the solutions is also developed. Computational tests are presented using available instances taken from the literature. The high-quality of the solutions obtained validate the proposed approach. Supported by Projects PTDC/EGE-GES/117692/2010 and NORTE-07-0124-FEDER-000057 financed by the North Portugal Regional Operational Programme (ON.2 - O Novo Norte), under the National Strategic Reference Framework (NSRF), through the European Regional Development Fund (ERDF), and by national funds, through the Portuguese funding agency, Fundação para a Ciência e a Tecnologia (FCT).

Keywords: Minimization of open stacks problem, cutting pattern, biased random-key genetic algorithm, random keys

Wed.A.1, *Wednesday, July 30, 11:00-12:30, Room 1*

Nonlinear Programming: theoretical and computational issues (II)

Session organized by: *Sandra Augusta Santos*

Session chair: *Sandra Augusta Santos*

1. **A new approach for linearly constrained semi-continuous quadratic programming problems**

Fernanda Maria Raupp (fernanda@lncc.br) Laboratório Nacional de Computação Científica - LNCC, *Wilfredo Sosa*

We show how to solve linearly constrained semi-continuous quadratic programming problems, when possible, through their associated convex dual problems, by applying the Fenchel-Moreau conjugation specifically for semi-continuous programming. Using an alternate conjugate dual space with finite dimension, we construct a dual problem as a linear programming one. The interesting aspect is that no hypothesis is needed for the Hessian of the quadratic objective function.

Keywords: Semi-continuous programming, quadratic programming, Fenchel-Moreau

2. **Combining implicit filtering and pattern search for linearly constrained noisy minimization**

Deise G. Ferreira (ra070609@ime.unicamp.br) University of Campinas, *Sandra A. Santos, Maria A. Diniz-Ehrhardt*

We investigate a new method for solving linearly constrained noisy minimization problems. This method builds on our previous work with a pattern-search approach applied to linearly constrained smooth minimization and it is combined with ideas from the implicit filtering algorithm proposed by Kelley. The implicit filtering framework added to the pattern-search approach provides for faster convergence, besides extending the range of applicability to noisy problems. Moreover, the method may address functions not defined at some of the points visited by the algorithm. Numerical experimentation put the proposed ideas into perspective.

Keywords: Pattern search, implicit filtering, linearly constrained noisy minimization

3. **The exact penalty map for nonsmooth and nonconvex optimization**

Alfredo N. Iusem (iusp@impa.br) Instituto de Matemática Pura e Aplicada, IMPA, *Regina Burachik, Jefferson Divino Melo*

Augmented Lagrangian duality provides zero duality gap and saddle point properties for nonconvex optimization. Hence, subgradient-like methods can be applied to the (convex) dual of the original problem, recovering the optimal value of the problem, but possibly not a primal solution.We prove that the recovery of a primal solution by such methods can be characterized in terms of the differentiability properties of the dual function, and the exact penalty properties of the primal-dual pair.

Keywords: Exact penalty, nonsmooth optimization, Lagrangian duality

Wed.A.2, *Wednesday, July 30, 11:00-12:30, Room 2*

Calculus of Variations and Optimal Control

Session chair: *Sofia Lopes*

1. **An Overview About the Solution Approximation of Some Delay - Advance Differential Equations**

M. Filomena Teodoro
(maria.teodoro@estsetubal.ips.pt) Dep. Matemática, ESTSetúbal, Instituto Politécnico de Setúbal/ CEMAT, Instituto Superior Técnico, Universidade de Lisboa

The mixed type functional differential equations (MTFDEs), equations with both delayed and advanced arguments, appear in many mathematical models in distinct contexts of applied sciences such as biology, physics, economy, control. Some analysis from delay differential equations can be extend case to MTFDEs. Algorithms relatively to autonomous and nonautonomous linear equations have been carried out and will be presented. Concerning to a special nonlinear equation which appears in nervous propagation, some schemes are proposed and computations have been carried out.

Keywords: mixed type functional differential equations

2. **Noether's first theorem for variational problems of Herglotz type with time delay**

Simão P.S. Santos (spsantos@ua.pt) Departamento de Matemática da Universidade de Aveiro, *Natália Martins, Delfim F.M. Torres*

The main goal of this talk is to present our extention of the DuBois-Reymond necessary optimality condition and Noether's first theorem to variational problems of Herglotz type with time delay. The DuBois-Reymond necessary optimality condition and the first Noether theorem for variational problems with time delay proved by Frederico and Torres in 2012 will be presented as corollaries.

Keywords: Euler-Lagrange differential equations, generalized calculus of variations, time delay, invariance, symmetries, constants of motion, DuBois-Reymond necessary optimality condition, Noether's Theorem

3. **Normal forms of necessary conditions of optimality: calculus of variations and optimal control problem**

Sofia Lopes
(sofialopes@math.uminho.pt)
Universidade do Minho, *Fernando Fontes*

There has been a longstanding interest in deriving conditions under which dynamic optimization problems are normal, that is, the necessary conditions of optimality (NCO) can be written with a nonzero multiplier associated with the objective function. When this happens, we ensure that the objective function is used to select candidates to minimizers. Normal forms of NCO are also needed to establish regularity proprieties of the minimizers and to deduce second order optimality conditions. The normal NCO that we present here may address problems with nonsmooth and less regular data. We also explore the particular case of calculus of variations problems to show a favorable comparison with existent results.

Keywords: Optimal control, calculus of variations, state constraints, maximum principle, normality

Wed.A.4, *Wednesday, July 30, 11:00-12:30, Room 4*

Multiobjective Optimization (II)

Session chair: *Carlos Henggeler Antunes*

1. **Multiobjective mathematical model for sizing and locating biogas plants: a case study from Entre-Douro-e-Minho Region, Portugal**

Sandra Silva (sandrasilva@esa.ipvc.pt) Instituto Politécnico de Viana do Castelo e INESC Coimbra, *Luís Alçada-Almeida, Luís C. Dias*

This work introduces a Multiobjective Mixed Integer Linear Programming approach to identify locations and capacities of biogas plants to process animal waste from dairy farms, and assign these farms to each opened biogas plant. Three criteria are considered in the mathematical model: minimizing plant costs (initial investment, operation and maintenance costs); minimizing transportation cost; and minimizing social rejection. The proposed model is tested with a case study of Biogas Plants sited in Entre-o-Douro-e-Minho Region. The approach provides as output a set of Pareto optimal solutions, each one achieving a unique combination of economic and social performance, that are represented by maps using a Geographic Information System.

Keywords:

2. **Component-based framework for multi-objective multidisciplinary design and optimization applied to engineering problems**

Marcos Proença de Almeida (marcospa@icmc.usp.br) ICMC/USP - Institute of Mathematics and Computer Sciences, University of São Paulo, Brazil, *António Gaspar-Cunha, Antonio Castelo Filho, Alexandre Cláudio Botazzo Delbem*

Real engineering problems which employ design and optimization techniques generally have a high degree of complexity and involve different knowledge areas. In some cases, they can be described, to some extent, by sophisticated computational tools, which generally require significant resources. The current technological capacity gain related to high performance computing and scientific advancement in some disciplines make it possible to progressively tackle more features of complicated problems.

Multi-Objective Multidisciplinary Design and Optimization (MO-MDO) can be understood as a technology, an environment, or a methodology used to design complex integrated engineering structures, which combines different disciplines to interact between the various subsystems. The use of approximation and decomposition techniques is a common feature in these systems and consist in to divide the problem into smaller partitions, that can be solved separately, using simpler models. The application of a MO-MDO, using Multi-Objective Evolutionary Algorithm, to solve multi-objective engineering problems should entail optimization together with engineering and design tools.

Computational tools to facilitate the connection between decomposed parts of the problem, within the MO-MDO methodology, can facilitate the search for appropriate solutions to complex problems in different contexts of science and engineering. Therefore, due to the absence in the literature of appropriated and free tools able to deal with this problems, a computational framework to integrate the MO-MDO methodology with customizable component based workflow was proposed. The framework manages the components which can be used in different applications and allows the workflow execution defined by the user.

Initial components have been developed for to incorporate the MO-MDO previously implemented approach to solve problems of the polymer processing type by employing tools that are able to deal with multiple objectives, decision

making and robustness of the solutions, among others.

Keywords: Multi-objective, evolutionary algorithms, multidisciplinary design and optimization, component-based software

3. **A multi-objective model for residential electrical load scheduling**

Carlos Henggeler Antunes
(ch@deec.uc.pt) University of Coimbra and INESC Coimbra, *Ana Soares, Álvaro Gomes, Carlos Oliveira*

Demand response is a valuable tool that can be used to compensate the volatility of output power in renewable energy sources while simultaneously helping to reshape end-user's consumption profile according to the available electricity generation and grid requests. A multi-objective evolutionary algorithm is used to solve a multi-objective model to optimize the time allocation of domestic load operation within a given planning period. The management of controllable domestic loads is aimed at minimizing the electricity bill and the end-user's dissatisfaction, taking into account the preferred time slots for load operation, the risk of interruption of the energy supply and dynamic tariffs.

Keywords: Multi-objective optimization, evolutionary algorithms, electricity demand

Tourism

History of Guimarães

Guimarães has its origins in the distant 10th century. It was at this time that the Countess Mumadona Dias, widow of Hermenegildo Mendes ordered the construction of a monastery which became the focal point for a settlement. For its defense she ordered a Castle to be built on a hill a short distance away, thus creating a second nucleus of development. A street grew-up linking one to the other - the Rua de Santa Maria.
Later the monastery became a chapter house and acquired great importance due to the privileges and donations by kings and nobility. It became a famous centre for pilgrimage attracting the prayers and promises of the faithful drawn from all quarters.
While the town continued to grow inside the walls which were erected to defend it, the orders of poor friars arrived in Guimarães and made their contribution to shaping the town. The twin nuclei subsequently merged into one so that by the 15th century the layout of the city within the walls had been established. Even after the construction of some churches, monasteries and palaces and the creation of Largo da Misericórdia, its alignment was not significantly altered.
Guimarães is recognized as the cradle of the nation and of Portuguese identity. Its magnificently preserved Historic Center was classified as a World Cultural Heritage site by UNESCO in December of 2011.

Museums

The Castle

In the 10th century the Countess Mumadona Dias, in her widowhood, ordered the construction of a monastery in her estates at Vimaranes - today Guimarães. The constant attacks by Moors and Normans led to the construction of a fort to guard and defend the monks and the Christian community which lived in its purlieus, giving shape to the original castle.
With the formation of the County of Portucalem in the 12th century Count D. Henrique and Countess D. Teresa came to live in Guimarães. They enlarged and strengthened the castle and according to tradition it was here that they took up residence. King Afonso Henriques was probably born here.
Between the 13 th and 15th centuries various kings contributed to further improve the

Castle. Throughout its history it was the place of dynastic conflicts, none more heroic than the leading to the foundation of the kingdom of Portugal at the Battle of S. Mamede in 1128; for this reason it is also known as the Founding Castle or as the Castle of St. Mamede. After losing its defensive function the Castle was abandoned to progressive decline until the 20th century when it was declared a National Monument and completely restored.

Opening hours
daily: 10 a.m. to 6 p.m.
Free entry

Chapel of S. Miguel

This small chapel of great simplicity was built at the beginning of the 12th century in Romanesque style probably at the order of Count Henry. It has a symbolic link to the founding of the nation as tradition states that King Afonso Henriques was baptised here. Inside, the floor is paved with the sepulchres attributed to the noble warriors who fought with him at the founding of the nation.
It is classified as a National Monument.

Opening hours
daily: 10 a.m. to 6 p.m.
Free entry

The Palace of the Dukes of Bragança

This majestic stately home was built in the 15th century at the order of the illegitimate son of King D. Joao I, Afonso, who was to become the Duke of Bragança. He lived here with his second wife Constança de Noronha. It is a unique example on the Iberian peninsula of a fortified house influenced by the manorial architecture of Northern Europe, typified by the steeply inclined roofs and cylindrical chimneys. From the 16th century onwards the palace suffered a progressive decline leading to its almost complete ruin by the 20th century. Rebuilding began in 1937 and continued until 1959, when it was transformed into a museum open to the public, housing a collection dating from the 17th and 18th centuries.
Of the present collection a set of copies of four tapestries by Pastrana are especially important in relation to the history of the Portuguese expansion. They narrate episodes from the subjugation of North Africa, namely the conquest of Arzila and Tangier. Ordered by the Portuguese king, Afonso V, the originals, which are now in Spain, were made in Toumais in the 15th century after drawings attributed to Nuno Gonçalves. These unique copies, executed by the Real Fabric de Tapices de Madrid, were acquired by the Portuguese state in 1957. There is also a collection of Flemish tapestries depicting episodes from the life of a roman consul. These tapestries, executed after drawings by Pieter Paul Rubens, are notable.
Furniture from the period following the Portuguese discoveries is on display. A group of cabinets fitted with multiple drawers classed as varguenos, an anglicised form of the Spanish designation bargeños, deserves special attention. They include examples of Indo-Portuguese manufacture in Mudéjar style, and some fine Spanish pieces. Ornamenting the furniture is a major collection of porcelain from the Companhia das Índias, and Portuguese faience from the main producers of the period: Prado, Viana, Rocha Soares and

Rato.

In one of the rooms there is a display of weapons including examples of daggers, fire-arms and parts of armour dating from the 15th and 16th centuries which were collected by the Viscount of Pindela and subsequently acquired by the state.

The Palace is classified as a National Monument.

Opening hours
daily: 10 a.m. to 6 p.m.
Free entry on Sunday morning

Museum Route at Santo António dos Capuchos Convent

The Museum Route at the Santo António dos Capuchos Convent was created by the Santa Casa da Misericórdia de Guimarães in 2008, aiming at the preservation and valorization of its artistic and cultural heritage. Located right on the Colina Sagrada (Sacred Hill), it occupies a space in the building that was erected as a convent in the 17th century, purchased by the Misericórdia in 1842, and later used as its Hospital. Some of the Institution's property is on display, and visitors are invited to walk along the corridors, yards and cloister of the edifice, as well as to visit the convent church and its magnificent 17th century sacristy.

Opening hours
daily: 10 a.m. to 5 p.m.

Alberto Sampaio Museum

The Alberto Sampaio Museum was created in 1928 to house the collection of the extinct Chapter house of Nossa Senhora da Oliveira (Our Lady) and the other churches and monasteries of Guimarães, which were at that time owned by the state. It is situated in the historical centre on the exact site where in the 10th century Mumadona founded her monastery and around which grew up the town of Guimarães. The museum occupies the space of the ancient priory and chapter house, the cloisters and the medieval rooms, which all once belonged to the Chapter house of Nossa Senhora da Oliveira and have a historic and artistic value of their own. The museum has important collections of architectural, figure and tomb sculptures covering the medieval and renaissance periods, extending as far as the 18th century. The collection of silverware is one of the finest in the country.

Outstanding is the chalice offered by King Sancho I, the 13th century image of St. Mary of Guimarães, processional crosses and the magnificent gothic altarpiece in gilded silver from the end of the 14th century representing the Nativity. One should also point out the tunic worn by King João I at the battle of Aljubarrota; the fresco from the 16th century depicting the beheading of St. John the Baptist, paintings from the 16th and 17th centuries in mannerist style, baroque carvings, embroidered vestments, tiles and faience.

Opening hours
Monday to Saturday: 10 a.m. to 6 p.m.
Closes Mondays and Public holidays
Free entry on Sunday mornings

Martins Sarmento Archaeological Museum

The invaluable collection of the Martins Sarmento Archaeological Museum belongs to the Martins Sarmento Society, a cultural institution founded in 1881. The museum was created in 1885 with objects of archaeological value, and a gallery was opened in the beautiful 14th century cloisters of St. Dominic which offered suitable conditions for their display. It is not only the main reference point for pre-roman culture in Portugal but it is also one of the most important European museums dedicated to this area.

Opening hours
Tuesday to Saturday: 9:30 a.m. to 12 p.m. / 2 p.m. to 5 p.m.
Closes Mondays and Public holidays

Vila Flor Palace and Cultural Centre

Built in the mid 17th century at the order of the Carvalho family, the palace is decorated with granite statues of the first kings of Portugal and surrounded by a beautiful garden on three terraces, embellished with a baroque fountain. Queen Maria II stayed here during her visit to Guimarães in 1852, and two years later it was the stage for the 1st Industrial and Trade Exhibition. The Palace was refurbished in 2005, when a Cultural Centre of the same name was also built. The Palace currently has several rooms that host temporary exhibitions and the Cultural Centre contains two auditoriums where shows and congresses are held, a concert café and a restaurant.

Gardens: may be visited free of charge

Guimarães cable-car

The cable-car extends over 1.7 km and climbs 400 m providing the passenger with an unforgettable ride between the city and Penha mountain lasting approximately 10 minutes. Penha mountain offers the visitor a wide range of services and spaces. Apart from the sanctuary there is a number of facilities including a camp-site, a guest-house, a mini-golf course, keep-fit circuits, a horse-riding centre, picnic areas, walks restaurants, bars and cafés. It is possible to explore numerous grottoes and enjoy the magnificent landscapes which the natural vantage-points allow.

More information

Further information may be found at the municipality official website:

http://www.guimaraesturismo.com

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Serge Gratton ..... Luís Nunes Vicente
Tim Kelley ..... A. Ismael F. Vaz
Nenad Mladenovic ..... Luís Gouveia
François Vanderbeck ..... J. M. Valério de Carvalho
Maarten H. Van der Vlerk ..... Francisco Saldanha-da-Gama

Session Chairs

Optimization 2014 Program Overview

	Sunday July 27	Monday July 28	Tuesday July 29	Wednesday July 30	
08:45 09:00		Opening			
09:00 10:00		Plenary Maarten H. Van der Vlerk	Plenary François Vanderbeck		
09:30 10:30				Plenary Nenad Mladenovic	
10:00 10:30		Coffee Break	Coffee Break		
10:30 11:00				Coffee Break	
10:30 12:30		Parallel Sessions Mon.A	Parallel Sessions Tue.A		
11:00 12:30				Parallel Sessions Wed.A	
12:30 14:00		Lunch	Lunch	Lunch	
12:30 14:00					
14:00 15:00		Plenary Serge Gratton	Plenary Masao Fukushima	Plenary Tim Kelley	
14:00 15:00					
15:00 16:30		Parallel Sessions Mon.B	Parallel Sessions Tue.B	Closing	
15:00					
16:30 17:00	Conference registration	Coffee Break	Coffee Break		
17:00 18:30		Parallel Sessions Mon.C	Parallel Sessions Tue.C	Conference Tour (15:15 - 19:45)	
18:30 19:00		Welcome Reception (18:30 - 19:30)			
			Conference Banquet (19:45-22:30)		

Optimization

Guimarães 2014