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ECCOMAS Thematic Conference

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Invited Lectures

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Prof Thomas Baeck
Affiliation: Leiden Institute of Advanced Computer Science (LIACS), Head of the Natural Computing Research Group, The Nederlands.
Title: **Solving Optimization Problems in Industry**

Prof Marin Guenov
Affiliation: Cranfield University, Head of Centre for Aeronautics, Aircraft Design Group, Department of Aerospace Engineering, UK.
Title: Optimization of Complex Systems at Early Design Stage – Friend or Foe

Prof Olivier Pironneau
Affiliation: Emerit Professor at University of Pierre and Marie Curie, Jacques-Louis Lion Laboratory, France.
Title: Risk, Optimization and Meanfield Type Control

Dr Domenico Quagliarella
Affiliation: Italian Centre for Research in Aerospace (CIRA), Senior Researcher and head of the Multidisciplinary Analysis and Design Group of Fluid Mechanics Department, Italy.
Title: Value-at-risk and Conditional Value-at-risk in Optimization Under Uncertainty

Prof Oliver Schütze
Affiliation: CINVESTAV-IPN, México.
Title: Pareto Explorer: a Global/Local Exploration Tool for Many Objective Optimization Problems

Prof Karen Willcox
Affiliation: Massachusetts Institute of Technology, Department of Aeronautics & Astronautics, Co-director of the Center for Computational Engineering, USA.
Title: Multifidelity Methods for Design, Optimization and Uncertainty Quantification

Solving Optimization Problems in Industry

by Prof. Thomas Bäck

Abstract

Many industries use simulation tools for virtual product design, and there is a growing trend towards using simulation in combination with optimization algorithms. The requirements for optimization under such circumstances are often very strong, involving many design variables and constraints and a strict limitation of the number of function evaluations to a surprisingly small number (often around one thousand or less).

Tuning optimization algorithms for such challenges has led to very good results obtained by variants of evolution strategies. Evolutionary algorithms are nowadays standard solvers for such applications. In the presentation, sample cases from industry are presented, their challenges are discussed in more detail. Results of an experimental comparison of contemporary evolution strategies on the BBOB test function set for a small number of function evaluations are presented and discussed, and further enhancements of contemporary evolution strategies are outlined.

Our practical examples are motivated by industrial applications. A typical challenge is to find innovative solutions to a design optimization task. Based on a suitable definition of innovative solutions, an application of this concept to an airfoil design optimization task is discussed in the presentation.

Discussing these applications and the variants of evolution strategies applied, the capabilities of these algorithms for optimization cases with a small number of function evaluations are illustrated.

Biography

Thomas Bäck is full professor of computer science at the Leiden Institute of Advanced Computer Science (LIACS), Leiden University, The Netherlands, since 2004.

He received his Ph.D. in Computer Science (under supervision of Hans-Paul Schwefel) from Dortmund University, Germany, in 1994, and then worked for the Informatik Centrum Dortmund (ICD) as department leader of the Center for Applied Systems Analysis. From 2000 - 2009, Thomas was President of NuTech Solutions GmbH and CTO of NuTech Solutions, Inc. In 2009, he founded divis intelligent solutions GmbH. The company provides data mining and optimization software and services to customers such as BMW, Daimler, Ford, Honda, and many others.

Thomas Bäck has more than 200 publications as well as a book on evolutionary algorithms, entitled Evolutionary Algorithms: Theory and Practice, and is co-editor of the Handbook of Evolutionary Computation and the Handbook of Natural Computing, and co-author of the book Contemporary Evolution Strategies (Springer, 2013). He is editorial board member of a number of journals and has served as program chair for major conferences in evolutionary computation. He received the best dissertation award from the Gesellschaft für Informatik (GI) in 1995 and is an elected fellow of the International Society for Genetic and Evolutionary Computation for his contributions to the field. In 2015, he received the IEEE Evolutionary Computation Pioneer Award for his contributions in synthesizing evolutionary computation.

Optimization of Complex Systems at Early Design Stage – Friend or Foe

by Prof. Marin Guenov

Abstract

Early design is a crucial stage of the product development process since the decisions taken during this period commit the majority of the lifecycle costs. While most of these decisions are taken under a great deal of uncertainty, it is also true that early design stage offers the greatest scope for innovation.Our research in the aerospace industry during the last decade has found that although involving a lot of talent and producing great results, the early design processes could still be improved. For example, the relevant process information is spread in tools, manuals, brains and sites (and suppliers), and in some cases the computational models incorporate 'hardwired' assumptions from other disciplines. Thus the result of a design study may depend on the way it was produced. On the other hand, innovation may be restrained by the confinement to known cases since the process starts from existing configurations, often implicit in the computational code. Thus a need was identified for a:

- new approach, allowing to merge numeric and geometric design and to facilitate a component-driven modularisation of the disciplines
- collaborative environment to support the exchange of models and simulation data in order to perform an overall design optimisation process with robust and flexible computational workflows.

In this context, the presentation will cover the research and development of a new generation design tools for the synthesis and exploration of design sets and spaces at early product development stage. Such tools incorporate key enablers, including dynamically configurable computational workflows and appropriate numerical treatments allowing more interactivity and better visualisation. Illustrative examples will be presented. Future work is outlined, including the integration with architectural design.

Biography

Professor Marin D. Guenov has over 25 years industrial and research experience in the fields of Engineering Design and Multidisciplinary Design, Analysis and Optimisation (MDO) across the materials handling, marine and aerospace sectors. He holds the Chair of Engineering Design at Cranfield University where he founded the Advanced Engineering Design Group in 1997. In 2010 he was appointed as Head of the Aerospace Engineering Department and in 2013 became the inaugural Head of the University's Centre of Excellence in Aeronautics. Professor Guenov is an active researcher and directs Industrial, UK and EC funded research projects, contributing to novel design methods and tools for future aircraft configurations, and advanced modelling and simulation concepts such as the Digital Behavioural Aircraft.He is a Senior Member of the American Institute of Aeronautics and Astronautics, a Fellow of the Institution of Mechanical Engineers, a Fellow of the Royal Aeronautical Society, and a Chartered Engineer. He is the Chairman of the Cranfield Branch of the Royal Aeronautical Society.

Risk, Optimization and Meanfield Type Control

by Prof. Olivier Pironneau

Abstract
Risk is usually a global criteria which involves the world's state; for instance the strategy to extract oil from a well depends on the price of oil which in turn depends on how much the world's oil extractors produce. Optimization of system design where one of the criteria is cost or risk can involve a very large number of players who optimize the same criteria. Then price is the result of a global optimization problem, which is coupled with the system design problem where price appears as a passive variable. Mean-field type control is a tool, which can help solve such problem in the presence of randomness, which is essential for the concept of risk. We shall give a few examples and compare solutions by calculus of variations plus gradient algorithms with extended dynamic programming and fixed point.

Value-at-risk and Conditional Value-at-risk in Optimization Under Uncertainty

by Dr. Domenico Quagliarella

Abstract
The application to optimization under uncertainty of value-at-risk (VaR) and conditional value-at-risk (CVaR), also called quantiles and superquantiles in scientific literature, is here illustrated. The concepts of value-at-risk and conditional value-at-risk originated in the area of financial engineering, but they are indeed very well and naturally suited to reliability-based design optimization problems and they are a possible alternative to traditional approaches to robust design based on the optimization of statistical moments. Approaches based on VaR and CVaR are described and compared, and the advantages offered by the latter are discussed and analyzed.

Biography
Dr. Domenico Quagliarella is Senior Researcher and Head of the Multidisciplinary Analysis and Design Group of Fluid Mechanics Department at the Italia Centre for Aerospace Research (CIRA). He earned on July 1993 a Ph.D. in Aerospace Engineering at University "Federico II" in Naples, Italy, and he got a research engineer position at CIRA in July 1988. His main current research interest is the application of multi-objective optimisation methods to aerodynamic and multidisciplinary design problems, giving particular attention to hybrid optimization techniques such as genetic algorithms coupled with gradient based local search methods. Other fields of active research are approximate fitness evaluators for efficiency improvement of the evolutionary optimization process, and uncertainty incorporation and quantification methods into optimization algorithms for robust and reliability based design.

Pareto Explorer: a Global/Local Exploration Tool for Many Objective Optimization Problems

by Prof. Oliver Schuetze

Abstract

In many applications the problem arises that several objectives have to be optimized leading to a multi-objective optimization problem (MOP). One important haracteristic of a MOP is that its solution set, the so-called Pareto set, is typically not given by a single solution as for 'classical' scalar optimization problems. Instead it forms under certain mild assumptions on the model a (k-1)-dimensional object, where k is the number of objectives involved in the problem. After the huge success of the consideration of MOPs in many applications e.g. coming from engineering or finance in the recent past, and since the decision making process is getting more and more complex in many applications there is a recent trend to consider more objectives. Problems of that kind with four and more objectives are called many objective optimization problems (MaOPs). The numerical treatment of such problems differs from the treatment of MOPs (i.e., $k<4$) as a finite size representation of the entire Pareto set can not be computed any more with sufficient approximation quality. On the other hand, the computation of single solutions (e.g, via scalarization methods) very unlikely yields the desired 'optimal' trade off solution as the solution of such a problem depends on several factors.

In this talk, we present the Pareto Explorer, a global/local exploration tool for the effective treatment of MaOPs. The Pareto Explorer consists of 2 stages: first, a solution is selected via a global searcher such as an evolutionary algorithm. In the next step, the search is refined (locally) by steering the search along the solution set into a certain direction given by the decision maker, where this direction can be specified either in decision or in objective space. For this guided search we utilize the recently proposed multi-objective continuation method Pareto Tracer that possesses these steering features. We demonstrate the strength of the novel approach on several examples, including a 14 objective MaOP that arises in the design of a laundry system. Finally, we give some hints of how the ideas of the continuation method can be extended for the design of specialized evolutionary algorithms that aim to perform such exploration steps.

Biography

Oliver Schütze received a Ph.D. in Mathematics from the University of Paderborn, Germany, in 2004. He is currently Professor at the Cinvestav-IPN in Mexico City (Mexico). His research interests focus on numerical and evolutionary optimization where he addresses scalar and multi-objective optimization problems. He has co-edited 5 books and is co-author of more than 90 papers published in books, journals, and conference proceedings. Google Scholar reports more than 1,300 citations and a Hirsch index of 21. Dr. Schütze has co-organized several scientific events and is a co-founder of the SON (Set Oriented Numerics) and founder of the NEO (Numerical and Evolutionary Optimization) workshop series. During his career he received several prices and awards. For instance, he is co-author of two papers that won the IEEE CIS Outstanding Paper Award (for the IEEE TEC papers of 2010 and 2012).

Multifidelity Methods for Design, Optimization and Uncertainty Quantification

by Prof. Karen Willcox

Abstract
Multifidelity modeling refers to the situation where we have available several numerical models that describe a system of interest. These numerical models typically vary in "fidelity" or "skill", as well as in computational costs. Different models may arise from a choice to resolve the physics at different scales and/or from invoking different modeling assumptions; they may also include derived surrogates such as reduced-order models. A multifidelity approach seeks to exploit optimally all available models and data, using cheap models where possible but maintaining the quality of higher-fidelity information and associated guarantees of convergence. This talk describes our recent work in developing multifidelity methods for optimization and uncertainty quantification of large-scale problems in engineering design.

Biography
Karen Willcox is Professor of Aeronautics & Astronautics in the Aerospace Computational Design Laboratory at MIT. She is also Co-Director of the MIT Center for Computational Engineering. She holds a Bachelor of Engineering Degree from the University of Auckland, New Zealand, and master's and Ph.D. degrees from MIT. Before joining the faculty at MIT, she worked at Boeing Phantom Works with the Blended-Wing-Body group. Professor Willcox's research and teaching interests lie in computational simulation and optimization of engineering systems with two major research focuses. The first is model reduction for large-scale systems with applications in unsteady aerodynamics, flow control, uncertainty quantification, inverse problems, decision under uncertainty, and multifidelity design methods. The second is aircraft system design and optimization with particular emphasis on multifidelity modeling.