09041 Abstracts Collection
Hybrid and Robust Approaches to Multiobjective Optimization
— Dagstuhl Seminar —

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Abstract. The seminar "Hybrid and Robust Approaches to Multiobjective Optimization" was a sequel to two previous Dagstuhl seminars (04461 in 2004 and 06501 in 2006). The main idea of this seminar series has been to bring together two contemporary fields related to multiobjective optimization – Evolutionary Multiobjective Optimization (EMO) and Multiple Criteria Decision Making (MCDM) – to discuss critical research and application issues for bringing the entire field further and for fostering future collaboration.
This particular seminar was participated by 53 researchers actively working in multiobjective optimization. The purpose of the seminar was to discuss two fundamental research topics related to multiobjective optimization: interactive methods requiring optimization and decision making aspects to be integrated for a practical implementation and robust multiobjective methodologies dealing with uncertainties in problem parameters, objectives, constraints and algorithms. The seminar was structured to have more emphasis on working group discussions, rather than individual presentations, so that the open and free environment and facilities of Schloss Dagstuhl could be fully utilized.

Keywords. Multi-objective optimization, multiple criteria decision making, evolutionary multi-objective optimization, robust optimization, interactive optimization

09041 Summary – Hybrid and Robust Approaches to Multiobjective Optimization

In this document, we describe the working group topics, participants, and keywords. There were two rounds of group discussions. In the first round, there were

four groups and in the second round there were two groups each having a number of subgroups. The detailed outcome of the group discussions of both rounds can be found from the Dagstuhl seminar web site http://www.dagstuhl.de.

The abstracts of the invited talks are appended thereafter. The presentation slides of these talks can be found from the Dagstuhl web site.

Finally, abstracts of research works proposed by some of the participants are presented.

Keywords: Multi-objective optimization, multiple criteria decision making, evolutionary multi-objective optimization, robust optimization, interactive optimization

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2005

09041 Working Group on MCDM for Robust and Interactive Multiobjective Optimization (1st Round)

We were looking at robustness and related issues in the context of interactive MCDM, in different stages of the decision process.

Keywords: Interactive methods, robustness, MCDM, objectivity, subjectivity

Joint work of: Ehrgott, Matthias; Hakanen, Jussi; Ishibuchi, Hisao; Loehne, Andreas; Luque, Mariano; Miettinen, Kaisa; Ogryczak, Wlodek; Romanko, Olexandr; Stewart, Theodor; Wierzbicki, Andrzej

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2001

09041 Working Group on MCDM for Robust Multiobjective Optimization (1st Round)

This group explored MCDM techniques for robust multiobjective optimization.

Keywords: Robust multiobjective optimization

Joint work of: Figueira, Jos; Geiger, Martin; Greco, Salvatore; Jahn, Johannes; Klamroth, Kathrin; Inuiguchi, Masahiro; Mousseau, Vincent; Sayin Serpil; Slowinski, Roman; Wiecek, Margaret; Witting, Katrin

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2002

09041 Working Group on EMO for Interactive Multiobjective Optimization (1st Round)

This group explored the use of EMO in an interactive manner to solve multiobjective optimization problems.

Keywords: Interactive multiobjective optimization

Joint work of: Fonseca Carlos; Gandibleux, Xavier; Korhonen, Pekka; Marti, Luis; Naujoks, Boris; Thiele, Lothar; Wallenius, Jyrki; Zitzler, Eckart

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2004

09041 Working Group on EMO for Robust Multiobjective Optimization (1st Round)

This group explored various robust methodologies for multiobjective optimization.

Keywords: Robust multiobjective optimization

Joint work of: Fliege, Joerg; Beume, Nicola; Branke, Juergen; Braun, Heinrich; Chakraborti, Nirupam; Deb, Kalyanmoy; Helwig, Sabine; Knowles, Joshua; Middendorf, Martin; Mostaghim, Sanaz; Poles, Silvia; Salazar, Daniel; Shukla, Pradymn; Talbi, El-Ghazli

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2003

Working Group Presentations on EMO+MCDM for Interactive Multiobjective Optimization (2nd Round)

The working group on Interactivity was divided into three subgroups: Interaction styles and preference models in transfer from MCDM to EMO, Many objectives in interactive methods and Multi-objective trajectory Optimisation.

Keywords: Interaction styles, preference models

Joint work of: Gandibleux, Xavier; Hakanen, Jussi; Ishibuchi, Hisao; Jaszkiewicz, Andrzej; Jin, Yaochu; Luque, Mariano; Miettinen, Kaisa; Naujoks Boris; Ruuska, Sauli; Teghem, Jacques; Tiele, Lothar; Wallenius, Jyrki; Zitzler, Eckart

Working Group Presentations on EMO+MCDM for Robust Multiobjective Optimization (2nd Round)

This group explored combined EMO and MCDM topics on robust multiobjective optimization.

Keywords: robust multiobjective optimization, EMO, MCDM

Joint work of: Deb, Kalyanmoy; Greco, Salvatore and others (see two 1st round reports on robust methodologies)

Abstracts of Invited Talks

Robustness and Reliability in EMO

Jürgen Branke (Universität Karlsruhe (TH), DE)

This talk surveyed the work on robustness and reliability in evolutionary multi-objective optimization, and discussed open research questions.

It started with general definitions of robustness, reliability, flexibility and noise as related concepts. Then, it highlighted the particular challenges, when these concepts are to be used in the presence of multiple objectives. Two applications and successful approaches are discussed in more detail: 1. Reliability based optimal design using evolutionary multiobjective optimization. Here it was shown how integrate standard techniques from reliability based optimal design into EMO, opening up completely new possibilities. 2. Worst-case multiobjective optimization. This has been shown to pose completely new challenges, because for different decision makers, different scenarios may represent the worst case in a multiobjective setting. First approaches to tackle this problem have also been presented.

The talk concluded with a summary and a list of future challenges. and worst-case multi-objective optimization.

Keywords: Evolutionary multiobjective optimization, reliability, robustness

Fuzzy/possibilistic programming approaches in relations with MCDM, RMO, EMO and IMO

Masahiro Inuiguchi (Osaka University, JP)

In this talk, we review possibilistic programming approaches focusing mainly on treatments of fuzziness in relation to multiple objective programming problems. The possibility and necessity measures are introduced as basis of possibilistic programming. We classify possibilistic programming approaches into three categories: the optimization approach, the satisficing approach and the two-stage approach. Because the third approach has not yet been very developed, we focus on the other two approaches. First we review the optimization approach. We show that possibly and necessarily optimal solutions to single objective programming problems with uncertain objective functions are very similar to weak efficient and completely optimal solutions in multiple objective programming problems, respectively. This similarity implies that we may utilize evolutionary multiobjective optimization algorithms to single objective programming problems with uncertain objective functions. Because possibly and necessarily optimal solutions are two extremes, intermediate solution concepts are introduced. Since the problems for computing intermediate solutions are nonconvex programming

problems, the application of evolutionary computation can be expected. The concepts of possibly and necessarily optimal solutions are extended to multiple objective programming problems with uncertain coefficients. They are possibly efficient solutions and necessarily efficient solutions. Some results about those solutions are described. Necessarily efficient solutions would be reasonable and practical. One of promising approaches to the computation of necessarily efficient solutions would be the extended EMO approaches. Then we move to satisficing approaches. Modality constrained programming and modality goal programming approaches are introduced.

The similarity and differences between models of modality constrained programming problems and models of chance constrained programming problems which may be called robust programming problems are described.

Moreover two kinds of modality goal programming approaches are introduced. Finally, conceivable interactions with decision makers in the framework of modality constrained programming and modality goal programming problems are described. By the interaction, we may elicit the target values of objective functions as well as the level of robustness.

Keywords: Fuzzy/possibilistic programming, necessarily optimal solution, minimax regret solution, modality constrained programming, modality goal programming

What is Robust Optimization?

Joshua D. Knowles (Univ. of Manchester, GB)

This talk is intended to kick off discussions about robust multiobjective optimization and EMO. I begin by noting a distinction between robustness as referring to the solutions we seek, from robustness of methods, e.g. meaning repeatability, generality, etc., and suggest to concentrate on the former only. A number of diverse applications are summarised to give a flavour of the robust field, including examples of multi-stage, highly-constrained, combinatorial and multiobjective problems with various sources of uncertainty. Approaches to robust optimization in the EA community are briefly reviewed, including a couple of multiobjective ones. At the end some open questions are given.

A Polynomial Chaos Approach to Robust Multiobjective Optimization

Silvia Poles (Enginsoft - Padova, IT)

Robust design optimization is a modeling methodology, combined with a suite of computational tools, which is aimed to solve problems where some kind of uncertainty occurs in the data or in the model.

This paper explores robust optimization complexity in the multiobjective case, describing a new approach by means of Polynomial Chaos expansions (PCE). The aim of this paper is to demonstrate that the use of PCE may help and speed up the optimization process if compared to standard approaches such as Monte Carlo and Latin Hypercube sampling.

Keywords: Uncertainty Quantification, Multiobjective Robust Design, Monte Carlo, Latin Hypercube, Polynomial Chaos

Joint work of: Poles, Silvia; Lovison, Alberto

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/2000

A New Robust Interactive Evolutionary Multiobjective Optimization Method

Roman Slowinski (Poznan University of Technology, PL)

See the attached abstract

Keywords: Robust Multiobjective Optimization, Evolutionary Multiobjective Optimization, Interactive Method, Dominance-based Rough Set Approach, Decision Rules

Decomposition and Coordination for Multiobjective Complex Systems

Margaret M. Wiecek (Clemson University, US)

Complex systems are modeled as collections of multiobjective programs each representing a subsystem (or component) of the overall system. The subsystems interact with each other in various ways adding to the complexity of the overall problem. Since the calculation of efficient sets of these complex systems presents a challenging problem, it is desirable to decompose the overall system into component multiobjective programs that are more easily solvable and then construct the efficient set of the overall system. Selected cases of complex system are presented and relationships between their efficient sets the efficient sets of their subsystems are given.

Keywords: Multiobjective programs, complex systems, efficient set, decomposition, coordination

Joint work of: Wiecek, Margaret M.; Gardenghi, Melissa

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2009/1999

Abstracts Proposed by Some Participants

Multi-objective vehicle routing: Presentation of a solution framework, its computer implementation and experimental verification

Martin Josef Geiger (University of Southern Denmark - Odense, DK)

In the joint work with Wolf Wenger, we present an adaptive hybrid planning system for the interactive solution of multi-objective vehicle routing problems. A general framework was built, being able to handle various components of general vehicle routing problems, e.g. the simultaneous consideration of six optimization criteria. Solutions are constructed and improved in real time allowing the user to adapt his articulated preference information interactively. Results simulating different types of decision makers are reported, focusing on the adaptability of the system and the quality of the obtained solutions.

In brief, we are able to observe and demonstrate the suitability of the system to different types of decision makers, focussing on cost- or service-oriented criteria, or maintaining a balanced view on the two areas.

Keywords: Interactive multi-objective optimization, vehicle roting, interactive planning

Joint work of: Geiger, Martin Josef; Wenger, Wolf

Full Paper:
http://dx.doi.org/10.1109/HIS.2008.91

See also: Proceedings of the 8th International Conference on Hybrid Intelligent Systems HIS 2008, September 10-12, Barcelona, Spain, pp. 302-307. IEEE Computer Society. ISBN 978-0-7695-3326-1.

Robustness, risk aversion, multiple equitable criteria

Wlodek Ogryczak (Warsaw Univ. of Technology, PL)

The precise concept of robustness depends on the way the uncertain data domains and the quality or stability characteristics are introduced. Typically, in robust analysis one does not attribute any probability distribution to represent uncertainties. Data uncertainty is rather represented by non-attributed scenarios. Since one wishes to optimize results under each scenario, robust optimization might be in some sense viewed as a multiobjective optimization problem where objectives correspond to the scenarios.

However, despite of many similarities of such robust optimization concepts to multiobjective models, there are also some significant differences. Actually, robust optimization is a problem of optimal distribution of objective values under

several scenarios with risk aversion preferences rather than a standard multiobjective optimization model.

This can be formalized with the multiple criteria equitable optimization leading to various specific aggregations allowing to optimize combined performances under the worst case scenario together with the performances under the second worst scenario, the third worst and so on. Such an approach exploits better the entire distribution of objective vectors in search for robust solutions and, more importantly, it introduces some tools for modeling robust preferences.

On Ordered Weighted Enhancement of the Reference Point Method

Wlodek Ogryczak (Warsaw Univ. of Technology, PL)

The Reference Point Method (RPM) provides the decision maker (DM) with a tool for an open analysis of the efficient frontier.

The interactive analysis of the multiple criteria optimization problems is navigated with the commonly accepted control parameters expressing reference levels for the individual objective functions. The component achievement functions quantify the DM satisfaction from the individual outcomes with respect to the given reference levels. The final scalarizing achievement function is built as the augmented max-min aggregation of component achievements which means that the worst individual achievement is essentially maximized but regularized with the term representing the average achievement. In order to avoid inconsistencies caused by the regularization, the max-min solution may be regularized by the Ordered Weighted Averages (OWA) with monotonic weights which combines all the component achievements allocating the largest weight to the worst achievement, the second largest weight to the second worst achievement, the third largest weight to the third worst achievement, and so on. Further following the concept of the Weighted OWA (WOWA) the importance weighting of several achievements may be incorporated into the RPM. Such a WOWA RPM approach uses importance weights to affect achievement importance by rescaling accordingly its measure within the distribution of achievements rather than by straightforward rescaling of achievement values.

The WOWA RPM can be quite effectively implemented as an extension of the original constraints and criteria with simple linear inequalities.

Keywords: Multicriteria Decision Making, Aggregation Methods, Reference Point Method, OWA, WOWA

Professor

Theodor J. Stewart (Univ. of Cape Town, ZA)

Interests are in problem structuring of multicriteria problems, both for discrete choice and mathematical programming problems.

Have applied combinations of value measurement and interactive reference point approaches to the solution of such problems. In most cases the applications deal with natural resource management problems

Keywords: Value measurement, reference points, natural resources

Objective Ranking and Classification: Its Applications and Robustness

Andrzej Wierzbicki (National Institute of Telecommunications - Warsaw, PL)

The issue of objective ranking appeared tacitly in the theory of multi-objective optimization since a long time; explicitly, however, it was investigated only since several years. The paper recalls this issue and quotes the discussion of the issue of objectivity versus subjectivity, stressing that while an absolute objectivity is not attainable, nevertheless trying to be as objective as possible constitutes a higher value, necessary for hard science and technology. Then we turn to the problem of subjective versus objective decision analysis and ranking. While all classical decision theory aims at a rational analysis and support of subjective decisions, there are important application cases, e.g., in managerial problems, in negotiation support, in contemporary network technology, when the decision maker prefers to avoid specifying her/his preferences and needs decision analysis e.g., ranking of decision options; that is as objective as possible. An approach to decision support that might be easily adapted for such objective ranking is the reference point methodology; its application is shown on several examples, including managerial, negotiation support and contemporary network technology. The examples show also the robustness of objective ranking. The example of IP QoS routing in network technology illustrates also the need for transparency in decision processes. General conclusions concerning desirable features of decision making processes and their relation to robustness are drawn.

Keywords: Subjective ranking, objective ranking, reference point approaches, objectivity, robustness, transparency of decision processes

Robustness in parameter-dependent multiobjective optimization problems

Katrin Witting (Universität Paderborn, DE)

We consider multiobjective optimization problems depending on an external scalar parameter. Our aim is to identify Pareto points which hardly vary under the variation of the parameter. To compute such "robust points", we have combined techniques from multiobjective optimization and numerical path following. Numerical path following allows to compute the solutions of parameter-dependent systems of equations.

In particular, multiobjective optimization and numerical path following can be combined by means of the Kuhn-Tucker necessary condition.

Based on this idea we developed specific predictor-corrector-methods and have proven related regularity conditions.

Keywords: Parameter-dependent multiobjective optimization, robust Pareto points

Joint work of: Witting, Katrin; Dellnitz, Michael

See also: M. Dellnitz, K. Witting: Computation of Robust Pareto Points, accepted to Int. J. Computing Science and Mathematics (IJCSM), 2008