04461 Abstracts Collection
Practical Approaches to Multi-Objective Optimization
— Dagstuhl Seminar —

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Abstract. From 07.11.04 to 12.11.04, the Dagstuhl Seminar 04461 "Practical Approaches to Multi-Objective Optimization" was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. The first section describes the seminar topics and goals in general. Links to extended abstracts or full papers are provided, if available.

Keywords. Multi-objective optimization, evolutionary algorithms, decision support system

04461 Summary – Practical Approaches to Multi-Criterion Optimization

Jürgen Branke (Universität Karlsruhe, D)

Summary of the Dagstuhl Seminar 04461. Motivation, proceedings, achievements and feedback, future seminars.

Keywords: Multi-criterion Optimization, Classical and Evolutionary Approaches

Joint work of: Branke, Jürgen; Deb, Kalyanmoy; Miettinen, Kaisa; Steuer, Ralph E.

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/243

Optimizing Surface Profiles during Hot Rolling: A Genetic Algorithms based Multi-objective Analysis

Nirupam Chakraborti (Indian Institut of Technology, IND)

A hot rolled strip produced by any integrated steel plant would require satisfying some stringent requirements of its surface profile. Crown and Flatness are two industrially accepted quantifiers that relate to the geometric tolerances in the rolled strips.

This study attempts to regulate both crown and flatness within an acceptable limit, satisfying more than one objective at a time. Mathematically, this leads to a multi-objective optimization problem where the solution is no longer unique and a family of equally feasible solutions leads to the so called Pareto-Front, where each member is simply as good as the others. To implement this concept in the present context, one needs to realize that the surface deformation, which is ultimately imparted to the rolled sheets, comes from more than one source. The wear of the rolls, their thermal expansion, bending, and also deformation, contribute significantly towards the crown and flatness that is ultimately observed. During this study a detailed mathematical model has been worked out for this process incorporating all of these phenomena. Computation for the Pareto-optimality has been carried out using different forms of biologically inspired Genetic Algorithms, often integrated with an Ant Colony Optimization Scheme. Ultimately the model has been fine tuned for the hot rolling practice in a major integrated steel plant and tested against their actual operational data.

Keywords: Rolling, Hot Rolling, Crown, Flatness, Genetic Algorithms, Ant Colony Optimization, Multi-objective Optimization, Pareto Front, Multi-objective Evolutionary Computation

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/245

Current Status of the EMOO Repository, Including Current and Future Research Trends

Carlos A. Coello Coello (CINVESTAV - Mexico, MEX)

In this talk, I'll present some statistics of the EMOO repository (delta.cs.cinvestav.mx/∼ ccoello/EMOO/), emphasizing some of the trends that have been detected in terms of basic research and applications of multi-objective evolutionary algorithms. For example, I'll discuss the remarkable increase in PhD theses related to EMOO, as well as the number of journal papers and exposure of the area in evolutionary computation conferences. Finally, some (potential) future research trends will also be discussed.

Keywords: Evolutionary multiobjective optimization, multiobjective optimization, repository

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/250

A Tutorial on Evolutionary Multi-Objective Optimization (EMO)

Kalyanmoy Deb (Indian Inst. of Technology - Kanpur, IND)

Many real-world search and optimization problems are naturally posed as non-linear programming problems having multiple objectives.

Due to lack of suitable solution techniques, such problems are artificially converted into a single-objective problem and solved.

The difficulty arises because such problems give rise to a set of Pareto-optimal solutions, instead of a single optimum solution.

It then becomes important to find not just one Pareto-optimal solution but as many of them as possible. Classical methods are not quite efficient in solving these problems because they require repetitive applications to find multiple Pareto-optimal solutions and in some occasions repetitive applications do not guarantee finding distinct Pareto-optimal solutions. The population approach of evolutionary algorithms (EAs) allows an efficient way to find multiple Pareto-optimal solutions simultaneously in a single simulation run.

In this tutorial, we discussed the following aspects related to EMO:

1. The basic differences in principle of EMO with classical methods. 2. A gentle introduction to evolutionary algorithms with simple examples. A simple method of handling constraints was also discussed. 3. The concept of domination and methods of finding non-dominated solutions in a population of solutions were discussed. 4. A brief history of the development of EMO is highlighted. 5. A number of main EMO methods (NSGA-II, SPEA and PAES) were discussed. 6. The advantage of EMO methodologies was discussed by presenting a number of case studies. They clearly showed the advantage of finding a number of Pareto-optimal solutions simultaneously. 7. Three advantages of using an EMO methodology were stressed:

(i) For a better decision making (in terms of choosing a compromised solution) in the presence of multiple solutions (ii) For finding important relationships among decision variables (useful in design optimization). Some case studies from engineering demonstrated the importance of such studies.

(iii) For solving other optimization problems efficiently. For example, in solving genetic programming problems, the so-called 'bloating' problem of increased program size can be solved by using a second objective of minimizing the size of the programs. 8. A number of salient research topics were highlighted. Some of them are as follows:

(i) Development of scalable test problems (ii) Development of computationally fast EMO methods (iii) Performance metrics for evaluating EMO methods (iv) Interactive EMO methodologies (v) Robust multi-objective optimization procedures (vi) Finding knee or other important solutions including partial Pareto-optimal set (vii) Multi-objective scheduling and other optimization problems.

It was clear from the discussions that evolutionary search methods offers an alternate means of solving multi-objective optimization problems compared

to classical approaches. This is why multi-objective optimization using EAs is getting a growing attention in the recent years.

The motivated readers may explore current research issues and other important studies from various texts (Coello et al, 2003; Deb, 2001), conference proceedings (EMO-01 and EMO-03 Proceedings) and numerous research papers (http://www.lania.mx/∼ccoello/EMOO/).

References:

C. A. C. Coello, D. A. VanVeldhuizen, and G. Lamont. Evolutionary Algorithms for Solving Multi-Objective Problems. Boston, MA: Kluwer Academic Publishers, 2002.

K.Deb. Multi-objective optimization using evolutionary algorithms. Chichester, UK: Wiley, 2001.

C. Fonseca, P. Fleming, E. Zitzler, K. Deb, and L. Thiele, editors. Proceedings of the Second Evolutionary Multi-Criterion Optimization (EMO-03) Conference (Lecture Notes in Computer Science (LNCS) 2632). Heidelberg: Springer, 2003.

E. Zitzler, K. Deb, L. Thiele, C. A. C. Coello, and D. Corne, editors. Proceedings of the First Evolutionary Multi-Criterion Optimization (EMO-01) Conference (Lecture Notes in Computer Science (LNCS) 1993). Heidelberg: Springer, 2001.

Keywords: Multi-objective optimization, multi-criterion optimization, Pareto-optimal solutions, Evolutionary methods, EMO

AA New Adaptive Algorithm for Convex Quadratic Multicriteria Optimization

Jörg Fliege (Univ. of Birmingham, GB)

We present a new adaptive algorithm for convex quadratic multicriteria optimization. The algorithm is able to adaptively refine the approximation to the set of efficient points by way of a warm-start interior-point scalarization approach. Numerical results show that this technique is an order of magnitude faster than a standard method used for this problem.

Keywords: Multicriteria optimization, warm-start methods, interior-point methods, primal-dual algorithms

Joint work of: Fliege, Jörg; Heermann, Christoph; Weyers, Bernd

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/238

Multiobjective Optimization and Multiple Constraint Handling with Evolutionary Algorithms

Carlos Fonseca (University of Algarve, P)

In this talk, fitness assignment in multiobjective evolutionary algorithms is interpreted as a multi-criterion decision process. A suitable decision making framework based on goals and priorities is formulated in terms of a relational operator, characterized, and shown to encompass a number of simpler decision strategies, including constraint satisfaction, lexicographic optimization, and a form of goal programming. Then, the ranking of an arbitrary number of candidates is considered, and the effect of preference changes on the cost surface seen by an evolutionary algorithm is illustrated graphically for a simple problem.

The formulation of a multiobjective genetic algorithm based on the proposed decision strategy is also discussed. Niche formation techniques are used to promote diversity among preferable candidates, and progressive articulation of preferences is shown to be possible as long as the genetic algorithm can recover from abrupt changes in the cost landscape.

Finally, an application to the optimization of the low-pressure spool speed governor of a Pegasus gas turbine engine is described, which illustrates how a technique such as the Multiobjective Genetic Algorithm can be applied, and exemplifies how design requirements can be refined as the algorithm runs.

The two instances of the problem studied demonstrate the need for preference articulation in cases where many and highly competing objectives lead to a non-dominated set too large for a finite population to sample effectively.

It is shown that only a very small portion of the non-dominated set is of practical relevance, which further substantiates the need to supply preference information to the GA.

Keywords: Evolutionary algorithms, multiobjective optimization, preference articulation, interactive optimization

Joint work of: Fonseca, Carlos M.; Fleming, Peter J.

Extended Abstract: http://drops.dagstuhl.de/opus/volltexte/2005/237

Runtime Analysis of a Simple Multi-Objective Evolutionary Algorithm

Oliver Giel (Universität Dortmund, D)

Practical knowledge on the design and application of multi-objective evolutionary algorithms (MOEAs) is available but well-founded theoretical analyses of the runtime are rare.

Laumanns, Thiele, Zitzler, Welzel and Deb (2002) have started such an analysis for two simple mutation-based algorithms including SEMO.

These algorithms search locally in the neighborhood of their current population by selecting an individual and flipping one randomly chosen bit. Due to its local search operator, SEMO cannot escape from local optima, and, therefore, has no finite expected runtime in general.

In this talk, we investigate the runtime of a variant of SEMO whose mutation operator flips each bit independently. It is proven that its expected runtime is $O(n^n)$ for all objective functions f: $0,1^n- > R^m$, and that there are bicriteria problems among the hardest problem for this algorithm. Moreover, for each d between 2 and n, a bicriteria problem with expected runtime Theta(n^d) is presented. This shows that bicriteria problems cover the full range of potential runtimes of this variant of SEMO. For the problem LOTZ (Leading-Ones-Trailing Zeroes), the runtime does not increase substantially if we use the global search operator. Finally, we consider the problem MOCO (Multi-Objective-Counting-Ones).

We show that the conjectured bound $O((n^2)logn)$ on the expected runtime is wrong for both variants of SEMO. In fact, MOCO is almost a worst case example for SEMO if we consider the expected runtime; however, the runtime is $O((n^2)logn)$ with high probability. Some ideas from the proof will be presented.

Keywords: Runtime analysis, multi-objecive evolutionary algorithms

Extended Abstract: http://drops.dagstuhl.de/opus/volltexte/2005/271

Application Issues for Multiobjective Evolutionary Algorithms

Thomas Hanne (FhG ITWM - Kaiserslautern, D)

In the talk, various issues of the design and application of multiobjective evolutionary algorithms for real-life optimization problems are discussed. In particular, questions on problem-specific data structures and evolutionary operators and the determination of method parameters are treated. Three application examples in the areas of constrained global optimization (electronic circuit design), semi-infinite programming (design centering problems), and discrete optimization (project scheduling) are discussed.

Keywords: Multiobjective optimization, Pareto set, evolutionary algorithm, discrete optimization, continuous optimization, electronic circuit design, semi-infinite programming, scheduling

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/344

Effects of Crossover Operations on the Performance of EMO Algorithms

Hisao Ishibuchi (Osaka Prefecture University, J)

This paper visually demonstrates the effect of crossover operations on the performance of EMO algorithms through computational experiments on multiobjective 0/1 knapsack problems. In our computational experiments, we use the NSGA-II algorithm as a representative EMO algorithm. First we compare the performance of the NSGA-II algorithm between two cases: NSGA-II with/without crossover. Experimental results show that the crossover operation has a positive effect on the convergence of solutions to the Pareto front and a negative effect on the diversity of solutions. That is, the crossover operation decreases the diversity of solutions while it improves the convergence of solutions to the Pareto front. Next we examine the effects of recombining similar or dissimilar parents using a similarity-based mating scheme. Experimental results show that the performance of the NSGA-II algorithm is improved by recombining similar parents and degraded by recombining dissimilar ones. Finally we show that the recombination of extreme and similar parents using the similarity-based mating scheme drastically improves the diversity of obtained non-dominated solutions without severely degrading their convergence to the Pareto front. An idea of dynamically controlling the selection pressure toward extreme and similar parents is also illustrated through computational experiments.

Keywords: Evolutionary Multiobjective Optimization, Multiobjective 0/1 Knapsack Problems, Crossover Operations, Mating Restriction

Extended Abstract: http://drops.dagstuhl.de/opus/volltexte/2005/239

Bicriterial Magnetic Field Optimization

Johannes Jahn (Univ. Erlangen-Nürnberg, D)

The optimization of electromagnetic fields is an important future-oriented topic in electrical engineering and applied mathematics. Such problems arise in antenna design, for instance in the design of antennas with directed radiation, or in medical technology like in magnetic resonance.

In this talk we investigate, as a special example, the design of rod antennas of mobile phones. It is our aim to reduce the radiated energy absorbed by the head or body of the user and to increase the radiation intensity to other areas, especially to the receiver. The mathematical modelling of this problem leads to an infinite dimensional bicriterial optimization problem. It is shown that this optimization problem and a discretized version of this problem are solvable.

The relationship between the infinite and finite dimensional optimization problem is investigated. Numerical results are presented for mobile phones working with the GSM 900 and 1800 standards.

Keywords: Multiobjective Optimization, Antenna design

Hybrid representations for Evolutionary Multiobjective Optimization

Yaochu Jin (Honda Research Europe - Offenbach, D)

Defferent representations and genetic operators exhibit very different search behavior in evolutionary optimization. This talk shows that such kind of different search behavior make even a large difference when the EAs are applied to multiobjective optimization.

Keywords: Genetic algorithms, evolution strategies, Real-coded GA

Joint work of: Okabe, Tatsuya; Jin, Yaochu; Bernhard Sendhoff

Guiding and Comparing Approximations of the Nondominated Set: The Impact of Distance Measures

Kathrin Klamroth (Univ. Erlangen-Nürnberg, D)

Approximations of the nondominated set of bicriteria or multicriteria optimization problems are an attractive tool since they visualize the alternatives for the decision maker and provide valuable trade-off information in a simple and understandable way.

We propose an approximation approach using solutions of a series of scalarized subproblems selected in a problem-dependent way. Polyhedral distance functions based on the approximation itself are used to evaluate the quality of the approxiamtion and to guide the selection of the next scalarization. The functions auotmatically adapt to the problem structure and scaling which makes the approximation process unbiased and self-driven.

Keywords: Approximation; polyhedral gauge; nondominated set; quality indicator

Joint work of: Klamroth, Kathrin; Tind, Jørgen; Wiecek, Margaret M.

An Adaptive Scheme to Generate the Pareto Front based on the Epsilon-Constraint Method

Marco Laumanns (ETH Zürich, CH)

We discuss methods for generating or approximating the Pareto set of multi-objective optimization problems by solving a sequence of constrained single-objective problems.

The necessity of determining the constraint value a priori is shown to be a serious drawback of the original epsilon-constraint method. We therefore propose a new, adaptive scheme to generate appropriate constraint values during the run. A simple example problem is presented, where the running time (measured by the number of constrained single-objective sub-problems to be solved) of the original epsilon-constraint method is exponential in the problem size (number of decision variables), although the size of the Pareto set grows only linearly. We prove that — independent of the problem or the problem size — the time complexity of the new scheme is $O(k^{m-1})$, where k is the number of Pareto-optimal solutions to be found and m the number of objectives. Simulation results for the example problem as well as for different instances of the multiobjective knapsack problem demonstrate the behavior of the method, and links to reference implementations are provided.

Keywords: Multiple objective optimization, non-dominated set, Pareto set, epsilon-constraint method, generating methods

Joint work of: Laumanns, Marco; Thiele, Lothar; Zitzler, Eckart

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/246

Approximation and Visualization of Pareto Frontier in the Framework of Classical Approach to Multi-Objective Optimization

Alexander Lotov (Moscow State University, RUS)

This paper is devoted to a Pareto frontier generation technique, which is aimed at subsequent visualization of the Pareto frontier in an interaction with the user. This technique known as the Interactive Decision Maps technique was initiated about 30 years ago. Now it is applied for decision support in both convex and non-convex decision problems in various fields, from machinery design to environmental planning. The number of conflicting criteria explored with the help of the Interactive Decision Maps technique is usually between three and seven, but some users manage to apply the technique in the case of a larger number of criteria. Here we outline the main ideas of the technique, concentrating at nonlinear problems.

Keywords: Multi-objective optimization, Pareto frontier, visualization

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/235

SSPMO: A Scatter Search Procedure for Non-Linear Multiobjective Optimization

Julian Molina (Universidad de Malaga, E)

Abstract - We describe the development and testing of a metaheuristic procedure, based on the scatter search methodology, for the problem of approximating the efficient frontier of nonlinear multiobjective optimization problems with continuous variables. Recent applications of scatter search have shown its merit as a global optimization technique for single-objective problems. However, the application of scatter search to multiobjective optimization problems has not been explored fully in the literature. We test the proposed procedure on a suite of problems that have been used extensively in multiobjective optimization. Additional tests are performed on instances that are an extension of those considered classic. The tests indicate that our extension of the basic scatter search framework is a viable alternative for multiobjective optimization.

Keywords: Scatter Search, Non-Linear Multiobjective Optimization, Tabu Search

Joint work of: Molina, Julian; Laguna, Manuel; Martí, Rafael; Caballero, Rafael

A New Approach on Many Objective Diversity Measurement

Sanaz Mostaghim (ETH Zürich, CH)

In multi-objective particle swarm optimization (MOPSO) methods, selecting the best *local guide* (the global best particle) for each particle of the population from a set of Pareto-optimal solutions has a great impact on the convergence and diversity of solutions, especially when optimizing problems with high number of objectives. here, we introduce the Sigma method as a new method for finding best local guides for each particle of the population.

The Sigma method is implemented and is compared with another method, which uses the strategy of an existing MOPSO method for finding the local guides.

These methods are examined for different test functions and the results are compared with the results of a multi-objective evolutionary algorithm (MOEA).

Keywords: Multi-objective Optimization Particle Swarm Optimization

Joint work of: Mostaghim, Sanaz; Teich, Jürgen

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/254

Aspiration Level Methods in Interactive Multi-objecitve Programming and Generation Methods for Pareto Frontiers

Hirotaka Nakayama (Konan University - Kobe, J)

One of the most important tasks in multi-objective optimization is “trade-off analysis" which aims to make the total balance among objective functions. The trade-off relation among alternatives can be shown as Pareto frontier.

In cases with two or three objective functions, the set of Pareto optimal solutions in the objective function space (i.e., Pareto frontier) can be depicted relatively easily. Seeing Pareto frontiers, we can grasp the trade-off relation among objectives totally. Therefore, it would be the best way to depict Pareto frontiers in cases with two or three objectives. (It might be difficult to read the trade-off relation among objectives with three dimension, though). Although evolutionary algorithms are widely applied for this purpose, the author recently proposed new techniques using data envelopment analysis and support vector machines for generating Pareto frontiers.

In cases with more than three objectives, however, it is impossible to depict Pareto forntiers. Under this circumstance, interactive methods can help us to make local trade-off analysis showing a “certain" Pareto optimal solution. Along this line, aspiration level methods were developed, and have been observed to be effective in many practical problems in various fields. Satisficing Trade-off Method proposed by the author is one of aspiration level methods, and has several devices for making trade-off analysis, i.e., automatic trade-off and exact trade-off.

This paper discusses those methods for multi-objective optimization, in particular, applied to engineering design problems.

Keywords: Aspiration level methods, trade-off analysis, interactive programming methods, Pareto frontier, general data envelopment analysis, support vctor machines

Multi-objective Optimization and its Engineering Applications

Hirotaka Nakayama (Konan University - Kobe, J)

Many practical optimization problems usually have several conflicting objectives. In those multi-objective optimization, no solution optimizing all objective functions simultaneously exists in general. Instead, Pareto optimal solutions, which are “efficient" in terms of all objective functions, are introduced. In general we have many Pareto optimal solutions. Therefore, we need to decide a final solution among Pareto optimal solutions taking into account the balance among objective functions, which is called “trade-off analysis". It is no exaggeration to

say that the most important task in multi-objective optimization is trade-off analysis. Consequently, the methodology should be discussed in view of how it is easy and understandable for trade-off analysis.

In cases with two or three objective functions, the set of Pareto optimal solutions in the objective function space (i.e., Pareto frontier) can be depicted relatively easily. Seeing Pareto frontiers, we can grasp the trade-off relation among objectives totally. Therefore, it would be the best way to depict Pareto frontiers in cases with two or three objectives. (It might be difficult to read the trade-off relation among objectives with three dimension, though). In cases with more than three objectives, however, it is impossible to depict Pareto forntier. Under this circumstance, interactive methods can help us to make local trade-off analysis showing a "certain" Pareto optimal solution. A number of methods differing in which Pareto optimal solution is to be shown, have been developed. This paper discusses critical issues among those methods for multi-objective optimization, in particular applied to engineering design problems.

Keywords: Multi-Objective Optimization, Interactive Multi-Objective Optimization, Evolutionary Algorithms, Pareto Frontier

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/234

Population Dynamics in Evolutionary Multi-Objective Optimization

Tatsuya Okabe (Honda Research - Saitama, J)

Although the dynamics of single objective optimization are often discussed, it is rare to investigate the ones of multi-objective optimization. In this presentation, the dynamics of evolutionary multi-bjective optimization will be discussed empirically and theoretically.

Keywords: Population Dynamics, Evolutionary Multi-bjective Optimization

Supporting Implicit Learning via the Visualisation of COGA Multi-objective Data

Ian Parmee (University of the West of England - Bristol, GB)

Abstract - The presentation speculates upon the development of human-centric evolutionary conceptual design systems that support implicit learning through the succinct visual presentation of data relating to both variable and objective space. Various perspectives of multi-objective design information support a constantly improving understanding of both subjective and quantitative relationships between variables and objectives. This information emerges from cluster-oriented genetic algorithm (COGA) output and is further defined by appropriate data mining, processing and visualization techniques. The intention

is to support implicit learning and reduce complexity through the presentation of differing perspectives relating to solution / objective interaction and dependencies. It is proposed that the developing systems could support intuitional understanding of the problem domain. Further proposed agent-based support and interactive elements for the various processes are also introd

Keywords: Design, multi-objective cluster-oriented genetic algorithms; implicit learning

Joint work of: Parmee, Ian; Abraham, Johnson

NBI and MOGA-II, two complementary algorithms for Multi-Objective optimizations

Silvia Poles (ESTECO - Trieste, I)

The NBI-NLPQLP scheduler is tested on several multi-objective optimization problems. Its performance is compared to that of MOGA-II: since NBI-NLPQLP is based on the classical gradient-based NLPQLP, it is fast and accurate, but not as robust, in comparison with MOGA-II. Furthermore a discontinuous Pareto frontier can give rise to problems in the algorithm's convergence: in order to overcome this problem, a hybridization technique coupled with a partitioning method is proposed.

Keywords: Genetic Algorithms, Normal-Boundary Intersection, Designs optimizations

Joint work of: Poles, Silvia; Rigoni, Enrico

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/272

Visualization of Global Trade-Offs in Aerodynamic Problems by ARMOGAs

Daisuke Sasaki (Univ. of Southampton, GB)

Trade-offs is one of important elements for engineering design problems characterized by multiple conflicting design objectives to be simultaneously improved.

In many design problems such as aerodynamic design, due to computational reasons, only a limited number of evaluations can be allowed for industrial use. Efficient MOEAs, Adaptive Range Multi-Objective Genetic Algorithms (ARMOGAs), to identify trade-offs using a small number of function evaluations have been developed. In this study, ARMOGAs are applied to aerodynamic designs problems to identify trade-offs efficiently. In addition to identify trade-offs, trade-off analysis is also important to obtain useful knowledge about the design problem.

To analyze the high-dimensional data of aerodynamic optimization problem, Self-Organizing Maps are applied to understand the trade-offs.

Keywords: Aerodynamic optimization, MOEA, SOM, trade-off analysis

Joint work of: Sasaki, Daisuke; Obayashi, Shigeru

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/241

On Continuation Methods for the Numerical Treatment of Multi-Objective Optimization Problems

Oliver Schütze (Univ. Paderborn, D)

In this report we describe how continuation methods can be used for the numerical treatment of multi-objective optimization problems (MOPs): starting with a given Karush-Kuhn-Tucker point (KKT-point) x of an MOP, these techniques can be applied to detect further KKT-points in the neighborhood of x. In the next step, again further points are computed starting with these new-found KKT-points, and so on. In order to maintain a good spread of these solutions we use boxes for the representation of the computed parts of the solution set. Based on this background, we propose a new predictor-corrector variant, and show some numerical results indicating the strength of the method, in particular in higher dimensions. Further, the data structure allows for an efficient computation of MOPs with more than two objectives, which has not been considered so far in most existing continuation methods.

Keywords: Multi-objective optimization, continuation, k-manifolds

Joint work of: Schütze, Oliver; Dell'Aere, Alessandro; Dellnitz, Michael

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/349

On Properly Pareto Optimal Solutions

Pradyumn Kumar Shukla (TU Dresden, D)

In this paper we study ε-proper efficiency in multiobjective optimization. We introduce various new definitions of ε-proper efficiency, relate them with existing ones, study various concepts and develop very general necessary optimality conditions for a few of them.

Keywords: Proper efficiency, ε solutions

Joint work of: Shukla, Pradyumn Kumar; Dutta, Joydeep; Deb, Kalyanmoy

Extended Abstract: http://drops.dagstuhl.de/opus/volltexte/2005/240

Multi-criteria ranking of a finite set of alternatives using ordinal regression and additive utility functions - a new UTA-GMS method

Roman Slowinski (Politechnika Poznanska, PL)

UTA-GMS is a new method for assessment of strong or weak outranking relation in a problem of multi-criteria ranking, proposed by the authors. The ranking concerns a finite but relatively large set of alternatives A. We assume indirect preference information supplied by the decision maker (DM) in form of a complete preorder on a subset of reference alternatives R, called reference preorder. The preference model build from this information is an additive value function. The technique of passing from reference preorder to compatible additive value functions is called ordinal regression and it is well known from the UTA method proposed by Jacquet-Lagreze and Siskos in 1982. Unlike in the UTA method, we take into account all compatible value functions (instead of one or several most characteristic) at the stage of ranking the whole set A of alternatives. Moreover, we do not impose the additive value function to have piecewise-linear components but we accept any additive form. The resulting relations in A are twofold: strong outranking (if alternative x has greater value than y for all compatible value functions) and weak outranking (if alternative x has greater value than y for at least one compatible value function). Strong outranking is a partial preorder and weak outranking is a complete preorder in A. The strong outranking is of particular interest for the DM Ű it corresponds to dominance relation when the set of reference alternatives is empty, and to a complete preorder relation when the reference ranking is compatible with a single value function only. This approach has several interesting extensions useful for practical applications. The method has been implemented for a PC and will be presented together with an example of application.

Keywords: Multiple-criteria ranking, ordinal regression, partial preorder, UTA-like method

Joint work of: Slowinski, Roman; Greco, Salvatore; Mousseau, Vincent

Extended Abstract: http://drops.dagstuhl.de/opus/volltexte/2005/247

Classical and Evolutionary Approaches for Computing Nondominated Surfaces in Multi-Quadratic/Multi-Linear Multicriterion Optimization

Ralph E. Steuer (University of Georgia, USA)

In finance is the problem of portfolio selection. In standard form, there are only two objectives. ne is to minimize risk (commonly measured by variance x^TQx, a quadratic function).

The other is to maximize return (measured by mean $\mu^T x$, a linear function). The constraints are particularly simple – box constraints about each variable, an equality constraint requiring all variables to sum to one, and perhaps a few additional linear inequality constraints. Although formulated in the 1950s, it was hardly possible to compute the nondominated frontier of portfolio selection problems with dense covariance matrices Q until the early 1990s. Actually during the 70s and 80s, considerable research was expended, mostly centered about modifying or rationalizing a simpler structure for Q, to speed up solution times.

However, most of this research is no longer of great ,urgency as it is now possible to solve exactly standard-form portfolio optimization problems with dense covariance matrices Q with up to 3,000 variables in only a matter of hours (not days). This now gives headroom to incorporate into portfolio selection problems complex features that could not have been seriously considered earlier. Three cases are distinguished and strategies for computing or characterizing the nondominated in each case are discussed. The simplest case is when only additional linear objectives such as dividends and liquidity enter the problem. While the nondominated frontier of a standard-form portfolio optimization problem is piece-wise parabolic, the nondominated surface of a problem with only additional linear objectives is surface-wise paraboloidic (like the plates on the back of a turtle). Another case is when two or more criteria are quadratic with positive semi-definite covariance matrices. Discretized characterizations of such nondominated sets can be obtained by solving weighted-sums problems, but this could be quite time consuming. Finally, there is the case in which non-smooth objectives (such as to minimize the number of securities sold short) and/or constraints (such as semi-continuous variables) complicate the problem. The strategy discussed here is of a hybrid variety in which multiple criteria mathematical programming is used to obtain a high quality starting population of characterizing points, and then evolutionary algorithms are employed to move the population of points arbitrarily close to the non-smooth nondominated front.

Keywords: Multiple criteria mathematical programming, portfolio selection, covariance matrices, nondominated fronts, hybrid procedures, evolutionary algorithms

Joint work of: Steuer, Ralph E.; Qi, Yue ; Hirschberger,Markus

Hybrid Representations for Composition Optimization and Parallelizing MOEAs

Felix Streichert (Universität Tübingen, D)

We present a hybrid EA representation suitable to optimize composition optimization problems ranging from optimizing recipes for catalytic materials to cardinality constrained portfolio selection. On several problem instances we can show that this new representation performs better than standard repair mechanisms with Lamarckism.

Additionally, we investigate the a clustering based parallelization scheme for MOEAs. We prove that typical "divide and conquer" approaches are not suitable for the standard test functions like ZDT 1-6. Therefore, we suggest a new test function based on the portfolio selection problem and prove the feasibility of "divide and conquer" approaches on this test function.

Keywords: Multi-objective Evolutionary Algorithms (MOEAs); Solution Representation; Constrained Portfolio Selection Problem; Parallelizing MOEAs

Joint work of: Streichert, Felix; Ulmer, Holger; Zell, Andreas

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2005/251

Multiobjective Optimization Using Quality Indicators

Eckart Zitzler (ETH Zürich, CH)

This talk discusses how preference information of the decision maker can in general be integrated into multiobjective search. The main idea is to first define the optimization goal in terms of a binary performance measure (indicator) and then to directly use this measure in the selection process. To this end, we propose a general indicator-based evolutionary algorithm (IBEA) that can be combined with arbitrary indicators. In contrast to existing algorithms, IBEA can be adapted to the preferences of the user and moreover does not require any additional diversity preservation mechanism such as fitness sharing to be used. It is shown on several continuous and discrete benchmark problems that IBEA can substantially improve on the results generated by two popular algorithms, namely NSGA-II and SPEA2, with respect to different performance measures.

Joint work of: Zitzler, Eckart; Kuenzli, Simon