SIMCO

- Set-oriented and Indicator-based Multi-Criteria Optimization -

1 Organizers

All organizers are experts in set-oriented and indicator-based multicriteria optimization algorithms. The following lists only their expertise within the subfields relevant for the workshop:

- Michael Emmerich
  LIACS
  Leiden, The Netherlands
  Algorithm Design,
  Non-Standard Problems

- Boris Naujoks
  Cologne University of Applied Sciences
  Gummersbach, Germany
  Algorithm Design,
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- Dimo Brockhoff
  INRIA Lille - Nord Europe
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  Variation Operators,
  Theory of SIMCO

- André Deutz
  LIACS
  Leiden, The Netherlands
  Geometry,
  Convergence Theory

2 Scientific case

Multi-criteria optimization (MCO) problems occur frequently in many application fields such as engineering, economics, and medical sciences. Dealing with such problems, one is often interested in finding a *set* of solutions that shows the trade-offs between the conflicting optimization criteria. When designing a new product, for example, one might not only be interested in single solutions minimizing the costs or maximizing the performance. Compromise solutions in between these two extremes can also be of interest before making the final decision of which solution is going to be actually built and sold.

Evolutionary Algorithms improve a *population* of solutions (individuals) over time by recombination and mutation in terms of *random changes* and the process of *selecting* the best solutions for survival. They have the inherent advantage for solving MCO problems that they evolve a set of solutions over time. Those Evolutionary Multiobjective Optimization (EMO, [Deb, 2001, Coello Coello et al., 2007]) algorithms have been developed since the mid-1980s [Schaffer, 1985a, Schaffer, 1985b] and are applied frequently in industrial MCO applications [Coello Coello and Lamont, 2004].

Quite recently, a new viewpoint of solving MCO problems has been proposed [Zitzler et al., 2010]. As one is interested in finding a set of solutions in the case of EMO algorithms, one can formalize an MCO problem as a set problem and use indicator-based algorithms to solve it. In a set problem, the actual search space is the set of all possible solution sets and optimizing a so-called quality indicator, assigning each set of solutions a quality value, transforms the original MCO problem into a single-criteria problem. Instead of the previously formulated informal optimization goals of maximizing diversity and simultaneously converging to the Pareto front within the EMO field [Deb, 2001], the set- and indicator-based viewpoint allows for a clear mathematical description of the optimization goal, see for example [Auger et al., 2009, Auger et al., 2012] for details. First implementations of indicator-based EMO algorithms have been showing promising results and often outperform former state-of-the-art algorithms [Zitzler and Künzli, 2004, Beume et al., 2007, Igel et al., 2007, Bader and Zitzler, 2011]. Their potential, however, has not been fully explored, in particular with respect to set-based EMO algorithms, where the evolutionary operators of mutation and recombination are performed directly on sets and not on single solutions [Bader et al., 2009].

The proposed workshop on "Set-oriented and Indicator-based Multi-Criteria Optimization" aims at discussing new concepts of set- and indicator-based EMO algorithms in order to design more powerful algorithms for multi-criteria optimization problems. In particular, ideas for improved indicator-based selection mechanisms and variation operators operating on solution sets shall be discussed during the workshop. Moreover, it turns out that in set- and indicator-based algorithms, geometrical problems, such as the efficient computation of the volume of a union of hyperboxes (Klee's measure problem, see, e.g., [Overmars and Yap, 1991, Beume et al., 2009, Chan, 2010]) and of related measures (e.g. [Emmerich et al., 2011]) is an important research topic. Moreover, the computation of measures related to the Hausdorff distance and triangulation are recently explored in the EMO field [Trautmann et al., 2012].

To successfully solve such problems, EMO researchers slowly started to explore the already existing knowledge in the computational geometry community for which those problems might open up new challenging research directions outside the standard application areas of geometrical problems. Hence, the proposed workshop also aims at bringing together researchers from the EMO community and the computational geometry community to learn about each others' approaches and problems as well as to encourage collaboration between these two currently rather independent fields.

3 Preliminary program

The workshop is planned to last five days and four main topics have been identified beforehand to be discussed on the first four days. The following topics are heavily discussed research questions at current:

1) What are appropriate set preferences and indicators? In SIMCO, mainly the hypervolume indicator has been studied, which has favorable theoretical properties. However, it is computationally very expensive for problems with many objective functions (under standard complexity-theoretic asumptions) and furthermore requires a reference point. The open question to be adressed in the workshop is: Are there alternatives to the hypervolume indicator and if so, what are their pro's and con's?
2) How to design set-oriented variation operators? A topic that has been widely neglected in SIMCO is the interplay between selection and variation operators. The goal to find a set of solutions is inherently different from the goal to merely optimize a single criterion. Variation operators should adress this difference. What are appropriate design concepts for variation operators that interact well with existing set-oriented and indicator-based selection schemes?
3) What can be learned from (computational) geometry? There are many open questions in SIMCO that are closely related to (computational) geometry, for instance the efficient computation of indicators and the distribution of solution sets optimizing indicator values. By bringing together both experts from computational geometry and optimization algorithms, this workshop provides the opportunity to find answers to some of the fundamental questions.

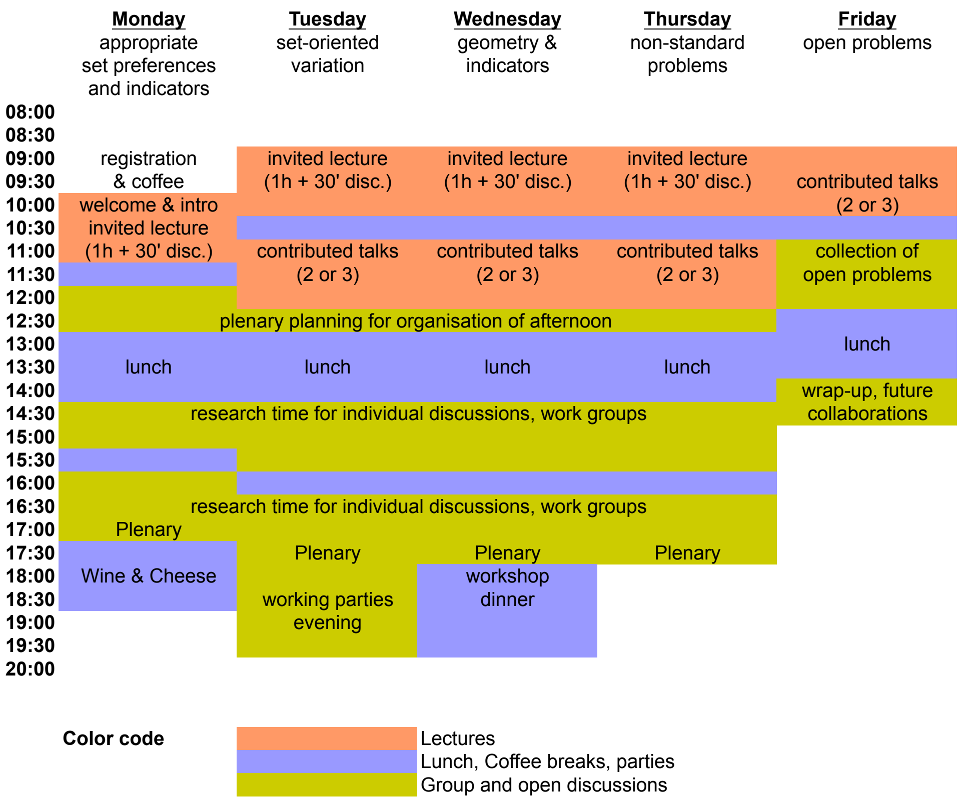

Figure 1: Tentative schedule for the SIMCO workshop.

4) How to deal with non-standard problems in MCO? When applying SIMCO in the real world, often additional difficulties arise. There is a demand to deal with constraints, costly function evaluations, as well as imprecise problem formulations or noise. How can SIMCO algorithms be properly extended to deal with such additional challenges?

It is planned to start each of the first four days with an invited talk on one of the topics above. The invited speakers will be asked to firstly provide a short introduction to the topic, secondly summarize basic findings and results, and thirdly provide there own subjective, possibly very critical opinion. At the end of each invited talk, a collection of about three key issues should be provided to encourage discussion after the talk and, possibly, for the rest of the day. These points should build the groundwork for the daily discussions and offer scientific perspectives. To this end, the invited speakers are strongly encouraged to recheck these points with the organizers beforehand.

Throughout the week, we plan to incorporate contributed talks in the workshop schedule which detail and possibly contrast the topics covered by the invited talks. To this end, we will invite all participants to submit a proposal for a talk related to the four workshop topics beforehand. The last day of the event is dedicated to finally discuss open questions and future research directions as well as to wrap-up the workshop.

In line with the Lorentz Center's philosophy, this preliminary planning (see Fig. 1) is expected to be subject to changes during the workshop. The organizers will foster open discussions that might be picked up during later (next days) time slots if this is desired by the participants. Consequently, (even small) groups of participants are encouraged to back out of the group discussions whenever they have identified an interesting research topic they want to discuss apart from the group's topic. Furthermore, we know that time slots during common conferences are always too short to deepen scientific exchange and therefore plan enough time for interactions and discussions.

Before the workshop is going to be held, a webpage should be setup and during the workshop it will be refined. The idea is to have after the workshop a platform where theoretical results, e.g. on complexity bounds, and software are collected and new findings are discussed in a blog, as well as new papers are announced.

We will compile a book of extended abstracts summarizing findings of the workgroups. This will be published after the workshop as a technical report with ISSN number.

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