Benchmarking Continuous Multiobjective Optimization Algorithms — PhD proposal —

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Abstract. In its *Campagne Doctorants 2012* CORDI (http://www.inria.fr/en/institute/recruitment/offers/phd/campaign-2012), the French national research institute for computer science and control (Inria) is searching for excellent candidates to start their PhD studies in October 2012. The DOLPHIN team at Inria's Lille - Nord Europe research center is proposing a PhD on the topic of benchmarking continuous multiobjective optimization algorithms. The application deadline is May 4, 2012.

Keywords Optimization, Algorithms, Benchmarking, Multiple Objectives

1 Motivation and Context

The need for optimizing multiple objective functions simultaneously occurs frequently in industrial design and management tasks. In the design phase of a new product, for example, the engineer does not only want to minimize the cost but probably also to maximize the performance, minimize the weight, or maximize the life time of the product. As the objective functions are typically in conflict with each other, no single optimal design exists and one is rather interested in finding a good set of solutions showing the trade-offs among the objectives (the so-called Pareto-optimal or efficient solutions) from which the engineer can then pick a desired solution [1, 6]. In practice, the objective functions are often not given in a closed form but are defined only implicitly, for example as the outcome of a simulation. In such a case, one can model the problem as a black box and use general-purpose (randomized) search heuristics such as evolutionary algorithms to solve the problem. The advantage of those methods is that, in particular when the search space is continuous, every general-purpose multiobjective black box algorithm can be applied off-the-shelf to any optimization problem without the need to tune the algorithm to the specific problem. However, many existing algorithms are available and it is a non-trivial task for a user to decide on which algorithm to apply for a new, unknown problem. This is where algorithm benchmarking comes into play. If the difficulties observed in practical problems are covered by a set of well-understood test problems with formalized characteristics, algorithms can be compared on this benchmark in order to investigate which algorithms perform better than others andeven more importantlyto understand why they are better and how the results can be generalized to new

real-world problems. A decent benchmarking should also allow to see where the currently available algorithms have their deficiencies in order to improve their performance while not deteriorating it on any of the investigated problems. For single-objective problems in continuous domain, a recent effort has been put into understanding the difficulties that occur in continuous real-world problems (non-separability, multi-modality, noise, ...) and the design of a decent benchmarking exerciseresulting in a corresponding software tool with visualization and post-processing tools to ease the process of benchmarking black box optimization algorithms (http://coco.gforge.inria.fr/) [3]. For the multiobjective case, such a benchmarking framework is currently not available and recent comparisons of multiobjective black box algorithms focused on competitions [4, 7] rather than on the understanding of the algorithm performances and the design of test problems with well-understood difficulties that stem from practical problems.

2 Job Offer Description

In this PhD project, the doctoral candidate will work on transferring, adapting, and extending the available concepts and ideas in single-objective optimization benchmarking to the multiobjective, continuous case. To this end, several open research questions have to be tackled. Not only has one to decide on how to compare multiobjective optimization algorithms and their outcomes of solution sets ("what is a good algorithm?", "what do we want to measure?") but also to carefully design test instances such that they cover a wide list of possible difficulties observed in practical problems. The first topic covers the general aspects of performance assessment of multiobjective algorithms for which the foundations have been already laid [11, 10]. One idea is thereby to transform the multiobjective optimization problem into a single-objective *set problem* where the search space is the set of all solution sets of a fixed size and the quality of the sets, given by a unary quality indicator such as the hypervolume indicator [8], is then optimized. Hence, the benchmarking of multiobjective optimizers can be studied in a similar fashion than for single-objective algorithms but the transfer of important ideas such as the computation of the expected runtime (ERT) and the visualization of performance profiles [3] has not been done yet and can be a first starting point for the proposed PhD project. The solution set size as well as the number of objectives are thereby additional parameters and increase the complexity of the benchmarking in the multiobjective case—which has to be addressed. The second aspect of the thesis, and which is equally important in practice, is the definition of a well-balanced and well-understood test suite. Several benchmarking suites have been already proposed [9, 2, 5], but their focus was mainly to have easy-to-describe Pareto-optimal solutions or specific characteristics in the objective space (disconnected Pareto fronts, concavity/convexity of the Pareto front, etc.) rather than covering a wide variety of difficulties on the search space side as in the state-of-the-art single-objective benchmarks (non-separability, multi-modality, ill-conditioning, ridges, plateaus, ...). Combining standard single-objective test functions to multiobjective problems and analyzing their characteristics within this thesis work will be a first step towards a decent benchmarking exercise for multiobjective optimizers. The final goal of this thesis is to integrate the research on benchmarking continuous multiobjective optimizers into a software tool that on the one hand can be used by

researchers to compare and understand their algorithms. On the other hand, the data obtained with this tool can serve the practitioner by assisting in the selection of the most efficient and robust algorithm for a given application.

This research project is going to be carried out in close collaboration with TU Dortmund University in Dortmund, Germany and the TAO team at INRIA Saclay — Ile-de-France in Paris, France. Besides the actual research, the three-year PhD project includes the task of disseminating the obtained research results at the top international conferences in the field of multiobjective optimization. There are no teaching duties attached to this position, but the participation in tutoring exercise classes (TA) might be arranged depending on the applicants interests.

3 Skills and Profile

Required is a Master's degree in applied mathematics, computer science, operations research, or a related field from a university abroad or at least from outside Lille (a requirement of Inria's CORDI positions). A background in (continuous/stochastic/multiobjective) optimization and knowledge in software development in Python, MATLAB, Java, or C are highly welcome. The working language in the DOLPHIN project-team is English and fluency in spoken and written English therefore mandatory. Knowledge of French is a plus. Note that Inria provides language classes as well as support in obtaining visa and work permits.

4 About Inria and the Job

Inria is France's national research institute for computer science and control (`www.inria.fr`) and hosts 3,400 researchers in its eight research centers which are located throughout France. With its resolutely international outlook, Inria is at the forefront of conducting top-quality research in computer science, control theory, and applied mathematics. The Inria Lille - Nord Europe research centre, where the successful PhD candidate will integrate into the DOLPHIN project-team, employs 300 people in its 14 research teams–including 200 researchers. The main objectives of the DOLPHIN project-team itself (http://dolphin.lille.inria.fr) are the modeling and resolution of large multiobjective optimization problems using parallel and distributed hybrid techniques. They are at the heart of one of Inrias five strategic research topics of numerical systems which includes the development of "new methods for modeling, simulation, optimization, and large-scale problem solving in engineering, economics, medicine, biology and the environment". The proposed PhD project on benchmarking continuous multiobjective optimization algorithms integrates smoothly into this strategic research topic and the interests of the DOLPHIN team members in particular.

5 Further Information

Benefits:

Duration: 36 months
expected starting date of the contract: October 2012, 15th
Salary: 1957,54€ (gross) the first two years and 2058,84€ the third year which equals around 1590€ after taxes the first two years and 1670€ the third year (social security included).
Possibility of French courses
Help for housing
Participation for transportation
Scientific resident card and help to obtain visa (for both you and your spouse)

Important dates: The campaign ends on May 4, 2012 (strict deadline). By then, every candidate needs to register her or his application via Inria's web page (`http://www.inria.fr/en/institute/recruitment/offers/phd/campaign-2012`). The final selection of the candidates will be around mid-June.

Before applying, please contact Dimo Brockhoff by e-mail (`dimo.brockhoff@inria.fr`), preferably before the end of April.

Security and defense procedure: In the interests of protecting its scientific and technological assets, Inria is a restricted-access establishment. Consequently, it follows special regulations for welcoming any person who wishes to work with the institute. The final acceptance of each candidate thus depends on applying this security and defense procedure.

Supervisors and Contacts The PhD will be co-supervised by Dimo Brockhoff, CR2, at INRIA Lille - Nord Europe and El-Ghazali Talbi, professor at the Université Lille 1.

References

1. K. Deb. *Multi-Objective Optimization Using Evolutionary Algorithms*. Wiley, Chichester, UK, 2001.
2. K. Deb, L. Thiele, M. Laumanns, and E. Zitzler. Scalable Test Problems for Evolutionary Multi-Objective Optimization. In A. Abraham, R. Jain, and R. Goldberg, editors, *Evolutionary Multiobjective Optimization: Theoretical Advances and Applications*, chapter 6, pages 105–145. Springer, 2005.
3. N. Hansen, A. Auger, S. Finck, and R. Ros. Real-Parameter Black-Box Optimization Benchmarking 2009: Experimental Setup. INRIA Research Report RR-6828, INRIA Saclay—Ile-de-France, May 2009.
4. V. L. Huang, A. K. Qin, K. Deb, E. Zitzler, P. N. Suganthan, J. J. Liang, M. Preuss, and S. Huband. Problem Definitions for Performance Assessment of Multi-objective Optimization Algorithms. Technical report, Nanyang Technological University, 2007. Special Session on Constrained Real-Parameter Optimization.
5. S. Huband, P. Hingston, L. Barone, and L. While. A Review of Multiobjective Test Problems and a Scalable Test Problem Toolkit. *IEEE Transactions on Evolutionary Computation*, 10(5):477–506, 2006.

6. R. E. Steuer. *Multiple Criteria Optimization: Theory, Computation, and Application*. Wiley, New York, NY, USA, 1986.
7. Q. Zhang, A. Zhou, S. Zhao, P. N. Suganthan, W. Liu, and S. Tiwari. Multiobjective Optimization Test Instances for the CEC 2009 Special Session and Competition. CES 487, The School of Computer Science and Electronic Engieering, University of Essex, April 2009.
8. E. Zitzler, D. Brockhoff, and L. Thiele. The Hypervolume Indicator Revisited: On the Design of Pareto-compliant Indicators Via Weighted Integration. In S. Obayashi et al., editors, *Conference on Evolutionary Multi-Criterion Optimization (EMO 2007)*, volume 4403 of *LNCS*, pages 862–876, Berlin, 2007. Springer.
9. E. Zitzler, K. Deb, and L. Thiele. Comparison of Multiobjective Evolutionary Algorithms: Empirical Results. *Evolutionary Computation*, 8(2):173–195, 2000.
10. E. Zitzler, L. Thiele, and J. Bader. On Set-Based Multiobjective Optimization. *IEEE Transactions on Evolutionary Computation*, 14(1):58–79, 2010.
11. E. Zitzler, L. Thiele, M. Laumanns, C. M. Fonseca, and V. Grunert da Fonseca. Performance Assessment of Multiobjective Optimizers: An Analysis and Review. *IEEE Transactions on Evolutionary Computation*, 7(2):117–132, 2003.