Dagstuhl Seminar 08051

Theory of Evolutionary Algorithms

Executive Summary

January 27 - February 1, 2008

1 Motivation and Goals

Evolutionary algorithms (EAs) are randomised heuristics for search and optimisation that are based on principles derived from natural evolution. Mutation, recombination, and selection are iterated with the goal of driving a population of candidate solutions toward better and better regions of the search space. Since the underlying idea is easy to grasp and almost no information about the problem to be optimised is necessary in order to apply it, EAs are widely used in many practical disciplines, mainly in computer science and engineering.

It is a central goal of theoretical investigations of EAs to assist practitioners with the tasks of selecting and designing good strategy variants and operators. Due to the rapid pace at which new strategy variants and operators are being proposed, theoretical foundations of EAs still lag behind practice. However, EA theory has gained much momentum over the last few years and has made numerous valuable contributions to the field of evolutionary computation.

EA theory today consists of a wide range of different approaches. Run-time analysis, facet-wise analysis that concentrates on the one-step behaviour of EAs (e.g., the well-known schema theory), analysis of the dynamics of EAs, and systematic empirical analysis all consider different aspects of EA behaviour. Moreover, they employ different methods and tools for attaining their goals, such as Markov chains, infinite population models, or ideas based on statistical mechanics or population dynamics.

The focus of the 2006 Dagstuhl Seminar on the "Theory of Evolutionary Algorithms" was to find common ground among the multitude of theoretical approaches and identify open questions central to the field as a whole. In the ensuing discussions during the seminar it became clear that the existence of a wide variety of approaches can be considered evidence of the richness of the field, and that each stream has its own raison d'être. For example, rigorous analysis yields exact results, but can only deal with relatively simple problems. Purely experimental analysis can deal with much more complicated problems, but does not generalise well.

The goals of the 2008 seminar were twofold. The first goal was to gain a systematic understanding of

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what the capabilities and limitations of the different methodological approaches are, and how they can assist and complement each other. The second goal was to address some of the central open questions identified during the previous seminar, and to establish what the various theoretical approaches can contribute to answering them with a focus on issues related to design and analysis of EAs. For situations where a complete theoretical analysis is out of reach, the goal was to establish a rigorous framework for empirical studies.

2 Participants and Results

The seminar brought together 47 researchers from nine countries, and from across the spectrum of EA theory. Talks were arranged into eight sessions, grouped loosely around common themes, such as hardness and complexity, multi-objective optimisation, coevolution, and continuous optimisation.

Thomas Jansen (Technische Universität Dortmund)
Bit flip mutations vs. local search: An open problem presentation

Frank Neumann (MPI für Informatik, Saarbrücken)
Making problems easier by multi-objective optimization

Holger Hoos (University of British Columbia, Vancouver)
Automated tuning, configuration and synthesis of complex stochastic local search algorithms

Alden Wright (University of Montana)
Does a temporally or spatially varying environment speed up evolution?

Dirk V. Arnold (Dalhousie University)
Step length adaptation on ridge functions

Steffen Finck (Fachhochschule Vorarlberg)
Performance of evolution strategies on PDQFs

Olivier Teytaud (Université Paris Sud)
Complexity lower bounds for evolution strategies

Christian Igel (Ruhr-Universität Bochum)
Efficient covariance matrix update for evolution strategies

Dirk Sudholt (Technische Universität Dortmund)
Runtime analysis of binary PSO

Benjamin Doerr (MPI für Informatik, Saarbrücken)
A non-artificial problem where crossover provably helps

Ingo Wegener (Technische Universität Dortmund)
Tight bounds for blind search on the integers

Yossi Borenstein (University of Essex)
Kolmogorov complexity and hardness

Darrell Whitley (Colorado State University)
Relating experiments and theory

Adam Prügel-Bennett (University of Southampton)
Solving problems with critical variables

Jonathan E. Rowe (University of Birmingham)
Representation-invariant crossover and mutation operators

Anthony Bucci (Icosystem)
Solution concepts and the subdomain representation

Elena Popovici (Icosystem)
Monotonic convergence and memory requirements of algorithms for "interactive" search problems

R. Paul Wiegand (University of Central Florida, Orlando)
Conditions for the robustness of compositional coevolution

Jonathan L. Shapiro (Manchester University)
Convergence in co-adapting agents with opponents modelling

Eckart Zitzler (ETH Zürich)
Approximating the pareto set using set preference relations: A new perspective on evolutionary multiobjective optimization

Jürgen Branke (Universität Karlsruhe)
Evolutionary multi-objective worst case optimization

Nicholas Freitag McPhee (University of Minnesota, Morris)
N-gram GP: Early result and questions

Anton Eremeev (Sobolev Institute of Mathematics, Omsk)
NP-hard cases of optimal recombination

Nikolaus Hansen (INRIA Futurs, Orsay)
Toward a convergence proof for CMA-ES — and beyond

Alexander Melkozerov (Fachhochschule Vorarlberg)
Weighted multirecombination evolution strategy with mutation strength self-adaptation on the quadratic sphere

Olivier Francois (TIMC Laboratory)
Evolution strategies with random numbers of offspring

Jun He (University of Birmingham)
A theoretical analysis to an experimental comparison of GAs using penalty function methods and repairing methods

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Boris S. Mitavskiy (University of Sheffield)
Estimating the stationary distributions of Markov chains modeling evolutionary algorithms using quotient construction method

Lothar M. Schmitt (The University of Aizu)
Banach space techniques for the analysis of evolutionary algorithms

Riccardo Poli (University of Essex)
Bye, bye, bloat

Kenneth A. De Jong (George Mason University)
Closing discussion

Many of the presentations and discussions were dedicated to identifying the limitations of the various approaches, shedding light on their complementarity, and arriving at a wider consent with regard to advantages and disadvantages of the different techniques. A new theme that had been largely absent from previous Dagstuhl seminars on the "Theory of Evolutionary Algorithms" and that recurred again and again during the present seminar was a discussion of how experimental work can complement and inspire theoretical analysis. Further themes that were discussed and that are expected to have an impact on future research are the adaptation of mutation distributions in continuous search spaces, and how tools for investigating the stability of Markov chains can be used for the analysis of adaptive algorithms. Finally, important steps were made toward the goal of applying the tools and techniques that have been developed for the runtime analysis of evolutionary algorithms to other modern search heuristics, such as ant colony optimisation and swarm intelligence approaches.

3 Conclusion

Besides the presentations, and as at past Dagstuhl seminars on "Theory of Evolutionary Algorithms", fruitful and stimulating discussions among varying groups of participants occurred throughout the week. The Dagstuhl seminars are firmly established in the community as a biannual event, and we hope to be able to build on this success and continue to promote discussions between researchers in different areas of EA theory at further workshops in the future.

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