

# Research Internship: Design and Analysis of Evolutionary Algorithms

This is an offer for a 3-month research internship in the 2023 call for SPECIES scholarships <http://species-society.org/scholarships-2023/>. Please see that webpage for all formalities.

**Host institution:** Laboratoire d'informatique de l'École polytechnique (LIX), Palaiseau, Île de France, France.

**Supervisors:** Benjamin Doerr, Martin Krejca (LIX, École Polytechnique), [firstname.lastname@polytechnique.edu](mailto:firstname.lastname@polytechnique.edu)

**Keywords:** Evolutionary algorithms, heuristic optimization, artificial intelligence, theory.

**Context: Runtime analysis of evolutionary algorithms.** Evolutionary algorithms such as genetic algorithms, genetic programming, estimation-of-distribution algorithms or ant colony optimizers are successfully used in many application areas. Their theoretical understanding, which could guide the design of such algorithms, is still little developed. Nevertheless, for a good twenty years now there have been increased attempts to shed some light on the working principles of evolutionary algorithms, mostly with the methods that have been used successfully in classic algorithms for more than hundred years [NW10, AD11, Jan13, DN20]. The fruits of these efforts have become visible in the last years. Not only we understand much better how evolutionary algorithms work, we also have some rigorous advice how to choose their parameters. Based on theoretical considerations, even new algorithms have been developed.

**Topic of this internship:** In this internship, we shall try to continue this recent line of research of first analyzing a particular aspect of evolutionary computation and then using the new understanding to improve the existing algorithms or designing superior ones. Since on the one hand in this young and fast-changing area it is difficult to decide on a research topic far ahead and on the other hand there is much work to be done in different subareas, we shall decide the particular topic of the internship together with the student at the start of the internship, taking into account the student's background and interests as well as what are at that moment the most interesting research questions. Areas in which the supervisors have successfully worked and supervised student projects include evolutionary multi-objective algorithms (EMO), estimation-of-distribution algorithms (EDAs), and self-adjusting parameter settings. Examples of recent papers stemming from student projects or

internships include [BDK23, DQ23a, DQ23b, CDH<sup>+</sup>23, DDHW23, DW23], most of which can also be found on the arXiv preprint server.

**Prerequisites:** As should be clear from the description above, this is a topic with a strong connection to recent research. As such, the intern should have a keen interest in doing excellent research, and consequently, a pronounced scientific curiosity. A solid background in computer science, mathematics, or applied mathematics is necessary. Having attended an algorithms course with joy and very good marks is a clear indication that this is a suitable topic for your internship.

**Research environment:** This research internship will be carried out in the *Algorithms and Complexity (AlCo) team* of the computer science lab (LIX) of the French École Polytechnique. The AlCo team consists of five permanent full-time researchers and professors from four different countries, all conducting research of the highest international level on various topics of classic algorithms, evolutionary algorithms, and complexity theory. We always have several interns and PhD students. The default language in the team is English, but all permanent members are also happy to speak French or German. We are well-connected internationally. In the area of this internship we had recent collaborations, among others, with DTU Copenhagen, Hasso-Plattner-Institut Potsdam, SUSTECH Shenzhen, and ETH Zurich.

## References

- [AD11] Anne Auger and Benjamin Doerr, editors. *Theory of Randomized Search Heuristics*. World Scientific Publishing, 2011.
- [BDK23] Firas Ben Jedidia, Benjamin Doerr, and Martin S. Krejca. Estimation-of-distribution algorithms for multi-valued decision variables. In *Genetic and Evolutionary Computation Conference, GECCO 2023*. ACM, 2023. To appear.
- [CDH<sup>+</sup>23] Sacha Cerf, Benjamin Doerr, Benjamin Hebras, Jakob Kahane, and Simon Wietheger. The first proven performance guarantees for the Non-Dominated Sorting Genetic Algorithm II (NSGA-II) on a combinatorial optimization problem. In *International Joint Conference on Artificial Intelligence, IJCAI 2023*. ijcai.org, 2023. To appear.
- [DDHW23] Matthieu Dinot, Benjamin Doerr, Ulysse Hennebelle, and Sebastian Will. Runtime analyses of multi-objective evolutionary algorithms in the presence of noise. In *International Joint Conference on Artificial Intelligence, IJCAI 2023*. ijcai.org, 2023. To appear.
- [DN20] Benjamin Doerr and Frank Neumann, editors. *Theory of Evolutionary Computation—Recent Developments in Discrete Optimization*. Springer, 2020. Also available at [http://www.lix.polytechnique.fr/Labo/Benjamin.Doerr/doerr\\_neumann\\_book.html](http://www.lix.polytechnique.fr/Labo/Benjamin.Doerr/doerr_neumann_book.html).
- [DQ23a] Benjamin Doerr and Zhongdi Qu. From understanding the population dynamics of the NSGA-II to the first proven lower bounds. In *Conference on Artificial Intelligence, AAI 2023*. AAAI Press, 2023. To appear.

- [DQ23b] Benjamin Doerr and Zhongdi Qu. Runtime analysis for the NSGA-II: Provable speed-ups from crossover. In *Conference on Artificial Intelligence, AAAI 2023*. AAAI Press, 2023. To appear.
- [DW23] Benjamin Doerr and Simon Wietheger. A mathematical runtime analysis of the Non-dominated Sorting Genetic Algorithm III (NSGA-III). In *International Joint Conference on Artificial Intelligence, IJCAI 2023*. ijcai.org, 2023. To appear.
- [Jan13] Thomas Jansen. *Analyzing Evolutionary Algorithms – The Computer Science Perspective*. Springer, 2013.
- [NW10] Frank Neumann and Carsten Witt. *Bioinspired Computation in Combinatorial Optimization – Algorithms and Their Computational Complexity*. Springer, 2010.

## Short Curriculum Vitae: Benjamin Doerr

**Area of expertise:** Algorithms, randomized search heuristics, evolutionary computation.

### Employment history:

**07/2013–** Full professor (professeur de classe exceptionnelle) at École Polytechnique, France.

**2005–2013** Senior researcher (W2 level) at the Max Planck Institute for Informatics, Saarbrücken, Germany. Tenured in 2007 in response to offers for professorships at RWTH Aachen and TU Dortmund.

**2001–2005** Research assistant, University of Kiel, Germany. Research stays at New York University (3 months) and at the Rényi Institute of the Hungarian Academy of Sciences (2 months).

### Education:

**2005** Habilitation in Mathematics, University of Kiel, Germany. Thesis: *Integral Approximation*.

**2000** PhD in Mathematics, University of Kiel, Germany. Thesis: *Multi-Color Discrepancies*.  
Referees: Prof. Dr. Anand Srivastav, Prof. Dr. Dieter Betten, Prof. Dr. Joel Spencer.

**1998** Diploma in Mathematics, University of Kiel, Germany. Thesis: *Nichtauflösbare  $J(T)$ -Komponenten* (Algebra). Advisor: Prof. Dr. Bernd Stellmacher.

**Selected current service:** Executive board member of the doctoral school of IP Paris, coordinator of the habilitations in the CS department of IP Paris.

**Teaching:** Design and analysis of algorithms (undergraduate), randomized methods in computer science (graduate), search heuristics (MPRI Master program, with E. Bampis and C. Doerr).

**Editorial boards:** *Artificial Intelligence*, *Evolutionary Computation*, *Information Processing Letters*, *Journal of Complexity*, *Natural Computing*, *RAIRO—Theoretical Informatics and Applications*, and *Theoretical Computer Science*. Advisory Board of Springer’s Natural Computing Series.

**Recent program committees:** Algorithms and complexity (small committees): ESA 2015 and 2021, ICALP 2014 and 2016, SEA 2014. Evolutionary computation, artificial intelligence (large committees): GECCO, CEC, FOGA, PPSN, EvoStar (each year for a long time), AAAI (2019, 2020, 2021, 2023), IJCAI (since 2020). Area chair AutoML 2022, 2023. Program chair of the theory track at GECCO 2007-2009 (co-founder with Frank Neumann and Ingo Wegener), 2014, 2023.

**Selected invited talks:** SEMCCO-FANCCO 2019, SSSI 2016, KolKom 2008, Diskrete Mathematik 2002. Regular tutorial speaker at GECCO, CEC, and PPSN.

**PhD students:** Quentin Yang (2022), Denis Antipov (2020, Digiteo-Digicosme dissertation award, dissertation award of the CS department of IP Paris, 2021 SIGEVO dissertation award (runner-up)), Jing Yang (2018), Anatolii Kostrygin (2017), Marvin Künnemann (2016, awarded with the *Otto-Hahn-Medal* of the Max-Planck society), Christian Klein (2014), Mahmoud Fouz (2012, awarded with the *Dr. Eduard Martin prize*, nominated for the *GI-Dissertation Award 2012*), Carola Winzen (2011, awarded with the *Otto-Hahn-Medal* of the Max-Planck society, nominated for the *GI-Dissertation Award 2011*), Anna Huber (2010), Daniel Johannsen (2010), Edda Happ (2009), Tobias Friedrich (2007, nominated for the *GI-Dissertation Award 2007*).

**Publications:** More than 120 journal publications and 180 conference publications in selective international venues. Please consult <http://dblp.uni-trier.de/pers/hd/d/Doerr:Benjamin.html> (some mathematical works missing) or <http://scholar.google.de/citations?user=aXWFB2UdJUUC&hl=de&oi=ao> for the details.

**Best paper awards:** GECCO 2022, GECCO 2020, EvoCOP 2020, GECCO 2019, GECCO 2017, GECCO 2015, GECCO 2013, GECCO 2012, GECCO 2010, GECCO 2008, GECCO 2007.

# Short Curriculum Vitae: Martin Krejca

**Area of expertise:** Random processes, randomized search heuristics.

## Employment history:

**Since 09/2022** Assistant professor at École Polytechnique, France.

**2021–2022** Postdoctoral researcher at Sorbonne University, France.

**2019–2020** Postdoctoral researcher at Hasso Plattner Institute, Germany.

## Education:

**2019** PhD (Dr. rer. nat.) in computer science from Hasso Plattner Institute, University of Potsdam, Germany. Thesis: *Theoretical Analyses of Univariate Estimation-of-Distribution Algorithms*.  
Advisor: Prof. Dr. Tobias Friedrich  
Honorable mention at the ACM SIGEVO Best-Dissertation Award 2020.

**2014** M.Sc. in computer science from Friedrich Schiller University Jena. Thesis: *Special Model Checking Problems for Computation Tree Logic* (in German).  
Advisor: Prof. Dr. Martin Mundhenk

**2012** B.Sc. in computer science from Friedrich Schiller University Jena. Thesis: *Bounded Tiling—An Alternative Base Problem in the Class NP* (in German).  
Advisor: Dr. Jörg Vogel

**Selected current service:** Vice-chair of the working group for sustainable development at the computer science laboratory of École Polytechnique, chair of the theory task force *Theoretical Foundations of Bio-inspired Computation* of the IEEE Computational Intelligence Society.

**Teaching:** Assistant in the undergraduate courses *Design and Analysis of Algorithms*, *Object-Oriented Programming*, and *Algorithms for Data Analysis in C++*.

**Program committees:** Evolutionary computation and artificial intelligence: GECCO 2016–2023, FOGA 2017–2023 (biennially), PPSN 2018–2022 (biennially), AutoML 2023.

**Invited talks:** IEEE SSCI 2021.

**Publications:** More than 40 publications (roughly two thirds at conferences and one third in journals) in selective international venues.

**Best-paper awards:** GECCO 2022, PPSN 2022, GECCO 2021, EvoCOP 2020, GECCO 2015.