



Universiteit
Leiden
The Netherlands

Algorithm design for mixed-integer black-box optimization problems with uncertainty

Thomaser, A.M.

Citation

Thomaser, A. M. (2024, October 22). *Algorithm design for mixed-integer black-box optimization problems with uncertainty*. Retrieved from <https://hdl.handle.net/1887/4104741>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/4104741>

Note: To cite this publication please use the final published version (if applicable).

Bibliography

- [1] Ali Ahrari, Saber Elsayed, Ruhul Sarker, Daryl Essam, and Carlos A. Coello Coello. Revisiting Implicit and Explicit Averaging for Noisy Optimization. *IEEE Transactions on Evolutionary Computation*, 27(5):1250–1259, 2023.
- [2] Takuya Akiba, Shotaro Sano, Toshihiko Yanase, Takeru Ohta, and Masanori Koyama. Optuna: A Next-Generation Hyperparameter Optimization Framework. In *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, KDD '19, pages 2623–2631, New York, NY, USA, 2019. Association for Computing Machinery.
- [3] Satyajith Amaran, Nikolaos V. Sahinidis, Bikram Sharda, and Scott J. Bury. Simulation optimization: a review of algorithms and applications. *Annals of Operations Research*, 240(1):351–380, 2016.
- [4] Martin Andersson, Sunith Bandaru, Amos H.C. Ng, and Anna Syberfeldt. Parameter Tuned CMA-ES on the CEC'15 Expensive Problems. In *2015 IEEE Congress on Evolutionary Computation (CEC)*, pages 1950–1957, 2015.
- [5] Jarosław Arabas, Adam Szczepankiewicz, and Tomasz Wroniak. Experimental Comparison of Methods to Handle Boundary Constraints in Differential Evolution. In Robert Schaefer, Carlos Cotta, Joanna Kołodziej, and Günter Rudolph, editors, *Parallel Problem Solving from Nature, PPSN XI*, pages 411–420, Berlin, Heidelberg, 2010. Springer Berlin Heidelberg.
- [6] Dirk V. Arnold and Hans-Georg Beyer. Local Performance of the $(\mu/\mu_I, \lambda)$ -ES in a Noisy Environment. In Worthy N. Martin and William M. Spears, editors, *Foundations of Genetic Algorithms 6*, pages 127–141. Morgan Kaufmann, San Francisco, 2001.

-
- [7] Dirk V. Arnold and Hans-Georg Beyer. A general noise model and its effects on evolution strategy performance. *IEEE Transactions on Evolutionary Computation*, 10(4):380–391, 2006.
 - [8] Charles Audet and Warren Hare. *Derivative-Free and Blackbox Optimization*. Springer, Cham, 2017.
 - [9] Anne Auger and Nikolaus Hansen. A Restart CMA Evolution Strategy With Increasing Population Size. In *Proceedings of the IEEE Congress on Evolutionary Computation*, volume 2, pages 1769–1776, 2005.
 - [10] Anne Auger and Nikolaus Hansen. Performance Evaluation of an Advanced Local Search Evolutionary Algorithm. In *Proceedings of the IEEE Congress on Evolutionary Computation*, volume 2, pages 1777–1784, 2005.
 - [11] Thomas Bäck. Parallel Optimization of Evolutionary Algorithms. In Gerhard Goos, Juris Hartmanis, Jan Leeuwen, Yuval Davidor, Hans-Paul Schwefel, and Reinhard Männer, editors, *Parallel Problem Solving from Nature — PPSN III*, volume 866 of *Lecture Notes in Computer Science*, pages 418–427. Springer Berlin Heidelberg, Berlin, Heidelberg, 1994.
 - [12] Thomas Bäck, Christophe Foussette, and Peter Krause. *Contemporary Evolution Strategies*. Natural Computing Series. Springer Berlin Heidelberg, Berlin, Heidelberg, 1st ed. edition, 2013.
 - [13] Thomas Bäck, Anna V. Kononova, Bas van Stein, Hao Wang, Kirill A. Antonov, Roman T. Kalkreuth, Jacob de Nobel, Diederick Vermetten, Roy de Winter, and Furong Ye. Evolutionary Algorithms for Parameter Optimization—Thirty Years Later. *Evolutionary Computation*, 31(2):81–122, 2023.
 - [14] Thomas Bartz-Beielstein, Carola Doerr, Daan van den Berg, Jakob Bossek, Sowmya Chandrasekaran, Tome Eftimov, Andreas Fischbach, Pascal Kerschke, William La Cava, Manuel Lopez-Ibanez, Katherine M. Malan, Jason H. Moore, Boris Naujoks, Patryk Orzechowski, Vanessa Volz, Markus Wagner, and Thomas Weise. Benchmarking in Optimization: Best Practice and Open Issues. Technical report, 2020.
 - [15] Nacim Belkhir, Johann Dréo, Pierre Savéant, and Marc Schoenauer. Per Instance Algorithm Configuration of CMA-ES with Limited Budget. In Peter

-
- A. N. Bosman, editor, *Proceedings of the Genetic and Evolutionary Computation Conference*, ACM Digital Library, pages 681–688, New York, NY, USA, 2017. Association for Computing Machinery.
- [16] James Bergstra, Rémi Bardenet, Yoshua Bengio, and Balázs Kégl. Algorithms for Hyper-Parameter Optimization. In J. Shawe-Taylor, R. Zemel, P. Bartlett, F. Pereira, and K.Q. Weinberger, editors, *Advances in Neural Information Processing Systems*, volume 24. Curran Associates, Inc, 2011.
- [17] Hans-Georg Beyer and Hans-Paul Schwefel. Evolution Strategies – A Comprehensive Introduction. *Natural Computing*, 1(1):3–52, 2002.
- [18] Rafał Biedrzycki. Handling bound constraints in CMA-ES: An experimental study. *Swarm and Evolutionary Computation*, 52:100627, 2020.
- [19] Patrick L. Boyd. NHTSA’s NCAP Rollover Resistance Rating System. Technical report, National Highway Traffic Safety Administration, United States, 2004.
- [20] Jürgen Branke, Stephen E. Chick, and Christian Schmidt. Selecting a Selection Procedure. *Management Science*, 53(12):1916–1932, 2007.
- [21] Dima Brockhoff, Anne Auger, Nikolaus Hansen, Dirk V. Arnold, and Tim Hohm. Mirrored Sampling and Sequential Selection for Evolution Strategies. In Robert Schaefer, Carlos Cotta, Joanna Kołodziej, and Günter Rudolph, editors, *Parallel Problem Solving from Nature, PPSN XI*, Lecture Notes in Computer Science, pages 11–21. Springer, Berlin, 2010.
- [22] Chun-Hung Chen, S. David Wu, and Liyi Dai. Ordinal comparison of heuristic algorithms using stochastic optimization. *IEEE Transactions on Robotics and Automation*, 15(1):44–56, 1999.
- [23] E. Jack Chen. Using ordinal optimization approach to improve efficiency of selection procedures. *Discrete Event Dynamic Systems*, 14(2):153–170, 2004.
- [24] Jiecao Chen, Xi Chen, Qin Zhang, and Yuan Zhou. Adaptive Multiple-Arm Identification. Technical report, 2017.
- [25] Jennifer N. Dang. Preliminary results analyzing the effectiveness of electronic stability control (ESC) systems. Technical report, US Department of Transportation, National Highway Traffic Safety Administration, 2004.

- [26] Jacob de Nobel, Diederick Vermetten, Hao Wang, Carola Doerr, and Thomas Bäck. Tuning as a Means of Assessing the Benefits of New Ideas in Interplay with Existing Algorithmic Modules. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, GECCO '21, pages 1375–1384, New York, NY, USA, 2021. Association for Computing Machinery.
- [27] Isabelle D. Dourson. *KI-basierte virtuelle Vorapplikation in der Fahrdynamik-auslegung*. Master Thesis, RWTH Aachen University, Aachen, 2022.
- [28] David Eckman. *Reconsidering Ranking-and-Selection Guarantees*. Dissertation, Cornell University Library, 2019.
- [29] David J. Eckman and Shane G. Henderson. Posterior-Based Stopping Rules for Bayesian Ranking-and-Selection Procedures. *INFORMS Journal on Computing*, 34(3):1711–1728, 2022.
- [30] A. E. Eiben and S. K. Smit. Parameter tuning for configuring and analyzing evolutionary algorithms. *Swarm and Evolutionary Computation*, 1(1):19–31, 2011.
- [31] A. E. Eiben and James E. Smith. *Introduction to Evolutionary Computing*. Natural Computing Series. Springer, Berlin and Heidelberg, 2 edition, 2015.
- [32] Sebastian Ellmaier. *Uncertainty Management for Reduction of Simulation Costs in Virtual Application of Vehicle Dynamics Control*. Master Thesis, Technical University of Munich, Munich, 2023.
- [33] Alena Erke. Effects of electronic stability control (ESC) on accidents: a review of empirical evidence. *Accident Analysis & Prevention*, 40(1):167–173, 2008.
- [34] Leonard Evans. Antilock Brake Systems and Risk of Different Types of Crashes in Traffic. *Journal of Crash Prevention and Injury Control*, 1(1):5–23, 1999.
- [35] Matthias Feurer, Aaron Klein, Katharina Eggensperger, Jost Springenberg, Manuel Blum, and Frank Hutter. Efficient and Robust Automated Machine Learning. In C. Cortes, N. Lawrence, D. Lee, M. Sugiyama, and R. Garnett, editors, *Advances in Neural Information Processing Systems*, volume 28. Curran Associates, Inc, 2015.
- [36] J. Michael Fitzpatrick and John J. Grefenstette. Genetic Algorithms in Noisy Environments. *Machine Learning*, 3(2):101–120, 1988.

-
- [37] Christodoulos A. Floudas. *Nonlinear and Mixed-Integer Optimization: Fundamentals and Applications*. Oxford University Press, 1995.
- [38] Michael C. Fu. Optimization via simulation: A review. *Annals of Operations Research*, 53(1):199–247, 1994.
- [39] Michael Gallagher. Comparing Proportional Representation Electoral Systems: Quotas, Thresholds, Paradoxes and Majorities. *British Journal of Political Science*, 22(4):469–496, 1992.
- [40] Jean Dickinson Gibbons, Ingram Olkin, and Milton Sobel. *Selecting and ordering populations: A new statistical methodology*, volume 26 of *Classics in applied mathematics*. SIAM, Philadelphia, Pa., 1999.
- [41] J. P. Gram. Ueber die Entwicklung reeller Funktionen in Reihen mittelst der Methode der kleinsten Quadrate. *Journal für die reine und angewandte Mathematik*, 1883(94):41–73, 1883.
- [42] John Grefenstette. Optimization of Control Parameters for Genetic Algorithms. *IEEE Transactions on Systems, Man, and Cybernetics*, 16(1):122–128, 1986.
- [43] Matthew Groves and Juergen Branke. Sequential sampling for noisy optimisation with CMA-ES. In *Proceedings of the Genetic and Evolutionary Computation Conference*, GECCO ’18, pages 1023–1030, New York, NY, USA, 2018. Association for Computing Machinery.
- [44] Dae Woong Ham, Michael Lindon, Martin Tingley, and Iavor Bojinov. Design-Based Confidence Sequences: A General Approach to Risk Mitigation in Online Experimentation. *SSRN Electronic Journal*, 2023.
- [45] Ryoki Hamano, Shota Saito, Masahiro Nomura, and Shinichi Shirakawa. Benchmarking CMA-ES with Margin on the Bbob-Mixint Testbed. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, GECCO ’22, pages 1708–1716, New York, NY, USA, 2022. Association for Computing Machinery.
- [46] Ryoki Hamano, Shota Saito, Masahiro Nomura, and Shinichi Shirakawa. CMA-ES with Margin: Lower-Bounding Marginal Probability for Mixed-Integer Black-Box Optimization. In *Proceedings of the Genetic and Evolutionary Computation Conference*, GECCO ’22, pages 639–647, New York, NY, USA, 2022. Association for Computing Machinery.

-
- [47] Nikolaus Hansen. The CMA Evolution Strategy: A Comparing Review. In Jose A. Lozano, editor, *Towards a New Evolutionary Computation*, volume 192 of *Studies in Fuzziness and Soft Computing*, pages 75–102. Springer, Berlin and Heidelberg and New York, 2006.
 - [48] Nikolaus Hansen. Benchmarking a BI-Population CMA-ES on the BBOB-2009 Function Testbed. In *Proceedings of the 11th Annual Conference Companion on Genetic and Evolutionary Computation Conference: Late Breaking Papers*, ACM Conferences, pages 2389–2396, New York, NY, USA, 2009. Association for Computing Machinery.
 - [49] Nikolaus Hansen. A CMA-ES for Mixed-Integer Nonlinear Optimization: Research Report. Technical Report RR-7751, INRIA, 2011.
 - [50] Nikolaus Hansen. The CMA Evolution Strategy: A Tutorial. Technical report, 2016.
 - [51] Nikolaus Hansen, Youhei Akimoto, and Petr Baudis. CMA-ES/pycma on Github, 2019.
 - [52] Nikolaus Hansen and Anne Auger. Evolution Strategies and CMA-ES (Covariance Matrix Adaptation). In *Proceedings of the Companion Publication of the 2014 Annual Conference on Genetic and Evolutionary Computation*, GECCO Comp '14, pages 513–534, New York, NY, USA, 2014. Association for Computing Machinery.
 - [53] Nikolaus Hansen, Anne Auger, Dimo Brockhoff, and Tea Tušar. Anytime Performance Assessment in Blackbox Optimization Benchmarking. *IEEE Transactions on Evolutionary Computation*, 26(6):1293–1305, 2022.
 - [54] Nikolaus Hansen, Steffen Finck, Raymond Ros, and Anne Auger. Real-Parameter Black-Box Optimization Benchmarking 2009: Noiseless Functions Definitions: Research Report. Technical Report RR-6829, INRIA, 2009.
 - [55] Nikolaus Hansen, André S.P. Niederberger, Lino Guzzella, and Petros Koumoutsakos. A Method for Handling Uncertainty in Evolutionary Optimization With an Application to Feedback Control of Combustion. *IEEE Transactions on Evolutionary Computation*, 13(1):180–197, 2009.
 - [56] Nikolaus Hansen and Andreas Ostermeier. Adapting Arbitrary Normal Mutation Distributions in Evolution Strategies: The Covariance Matrix Adaptation. In

-
- Proceedings of the IEEE International Conference on Evolutionary Computation*, pages 312–317, 1996.
- [57] Nikolaus Hansen and Andreas Ostermeier. Completely Derandomized Self-Adaptation in Evolution Strategies. *Evolutionary Computation*, 9(2):159–195, 2001.
- [58] Y-C Ho, C. G. Cassandras, C-H Chen, and L. Dai. Ordinal optimisation and simulation. *Journal of the Operational Research Society*, 51(4):490–500, 2000.
- [59] L. Jeff Hong, Weiwei Fan, and Jun Luo. Review on ranking and selection: A new perspective. *Frontiers of Engineering Management*, 8(3):321–343, 2021.
- [60] Steven R. Howard and Aaditya Ramdas. Sequential estimation of quantiles with applications to A/B testing and best-arm identification. *Bernoulli*, 28(3), 2022.
- [61] Susan R. Hunter and Barry L. Nelson. Parallel Ranking and Selection. In Andreas Tolk, John Fowler, Guodong Shao, and Enver Yücesan, editors, *Advances in Modeling and Simulation: Seminal Research from 50 Years of Winter Simulation Conferences*, pages 249–275. Springer International Publishing, Cham, 2017.
- [62] Frank Hutter, Holger H. Hoos, and Kevin Leyton-Brown. Sequential Model-Based Optimization for General Algorithm Configuration. In Carlos A. Coello Coello, editor, *Learning and Intelligent Optimization*, volume 6683 of *Lecture Notes in Computer Science*, pages 507–523. Springer Berlin Heidelberg, Berlin, Heidelberg, 2011.
- [63] International Organization for Standardization. ISO 21994:2007 - Passenger cars - Stopping distance at straight-line braking with ABS - Open-loop test method, 2007.
- [64] International Organization for Standardization. ISO 19365:2016 - Passenger cars - Validation of vehicle dynamic simulation - Sine with dwell stability control testing, 2016.
- [65] Grahame A. Jastrebski and Dirk V. Arnold. Improving Evolution Strategies through Active Covariance Matrix Adaptation. In *IEEE International Conference on Evolutionary Computation*, pages 2814–2821, 2006.

- [66] Alexandre D. Jesus, Arnaud Liefoghe, Bilel Derbel, and Luis Paquete. Algorithm Selection of Anytime Algorithms. In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference*, GECCO '20, pages 850–858, New York, NY, USA, 2020. Association for Computing Machinery.
- [67] Haotian Jiang, Jian Li, and Mingda Qiao. Practical Algorithms for Best-K Identification in Multi-Armed Bandits. page arXiv:1705.06894, 2017.
- [68] Yaochu Jin and J. Branke. Evolutionary optimization in uncertain environments—a survey. *IEEE Transactions on Evolutionary Computation*, 9(3):303–317, 2005.
- [69] Ian T. Jolliffe. *Principal Component Analysis*. Springer eBook Collection Mathematics and Statistics. Springer, New York, NY, 1986.
- [70] Pascal Kerschke, Mike Preuss, Simon Wessing, and Heike Trautmann. Detecting Funnel Structures by Means of Exploratory Landscape Analysis. In *Proceedings of the 2015 Annual Conference on Genetic and Evolutionary Computation*, ACM Digital Library, pages 265–272, New York, NY, 2015. Association for Computing Machinery.
- [71] Pascal Kerschke, Mike Preuss, Simon Wessing, and Heike Trautmann. Low-Budget Exploratory Landscape Analysis on Multiple Peaks Models. In Frank Neumann, editor, *Proceedings of the Genetic and Evolutionary Computation Conference*, ACM Digital Library, pages 229–236, New York, NY, USA, 2016. Association for Computing Machinery.
- [72] Pascal Kerschke and Heike Trautmann. Automated Algorithm Selection on Continuous Black-Box Problems by Combining Exploratory Landscape Analysis and Machine Learning. *Evolutionary Computation*, 27(1):99–127, 2019.
- [73] Pascal Kerschke and Heike Trautmann. Comprehensive Feature-Based Landscape Analysis of Continuous and Constrained Optimization Problems Using the R-Package Flacco. In Nadja Bauer, Katja Ickstadt, Karsten Lübke, Gero Szepannek, Heike Trautmann, and Maurizio Vichi, editors, *Applications in Statistical Computing*, Studies in Classification, Data Analysis, and Knowledge Organization, pages 93–123. Springer, 2019.
- [74] Martin Klein, Tommy Wright, and Jerzy Wieczorek. A Joint Confidence Region for an Overall Ranking of Populations. *Journal of the Royal Statistical Society Series C: Applied Statistics*, 69(3):589–606, 2020.

-
- [75] Heinz-Jürgen Koch-Dücker and Ulrich Papert. Antilock braking system (ABS). In Konrad Reif, editor, *Brakes, Brake Control and Driver Assistance Systems*, Bosch professional automotive information, pages 74–93. Springer Vieweg, Wiesbaden, 2014.
- [76] Mykel J. Kochenderfer and Tim Allan Wheeler. *Algorithms for Optimization*. The MIT Press, Cambridge and London, 2019.
- [77] Anna V. Kononova, David W. Corne, Philippe de Wilde, Vsevolod Shneer, and Fabio Caraffini. Structural bias in population-based algorithms. *Information Sciences*, 298:468–490, 2015.
- [78] Friedrich Kost, Jürgen Schuh, Heinz-Jürgen Koch-Dücker, Frank Niewels, Thomas Ehret, Jochen Wagner, Ulrich Papert, Peter Eberspächer, and Frank Heinen. Electronic Stability Program (ESP). In Konrad Reif, editor, *Automotive Mechatronics: Automotive Networking, Driving Stability Systems, Electronics*, pages 378–393. Springer Fachmedien Wiesbaden, Wiesbaden, 2015.
- [79] Johannes Willem Kruisselbrink. *Evolution Strategies for Robust Optimization*. Doctoral Thesis, Leiden University, Leiden, 2012.
- [80] Arun Kumar Kuchibhotla and Qinqing Zheng. Near-Optimal Confidence Sequences for Bounded Random Variables. Technical report, 2020.
- [81] Anders Lie, Claes Tingvall, Maria Krafft, and Anders Kullgren. The effectiveness of electronic stability control (ESC) in reducing real life crashes and injuries. *Traffic injury prevention*, 7(1):38–43, 2006.
- [82] Marius Lindauer, Katharina Eggensperger, Matthias Feurer, André Biedenkapp, Difan Deng, Carolin Benjamins, Tim Ruhkopf, René Sass, and Frank Hutter. SMAC3: A Versatile Bayesian Optimization Package for Hyperparameter Optimization. *Journal of Machine Learning Research*, 23(54):1–9, 2022.
- [83] Fu Xing Long, Bas van Stein, Moritz Frenzel, Peter Krause, Markus Gitterle, and Thomas Bäck. Learning the Characteristics of Engineering Optimization Problems with Applications in Automotive Crash. In *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO ’22*, New York, NY, USA, 2022. Association for Computing Machinery.
- [84] Fu Xing Long, Diederick Vermetten, Bas van Stein, and Anna V. Kononova. BBOB Instance Analysis: Landscape Properties and Algorithm Performance

- Across Problem Instances. In João Correia, Stephen Smith, and Raneem Qadoura, editors, *Applications of Evolutionary Computation*, Lecture Notes in Computer Science, pages 380–395, Cham, 2023. Springer Nature Switzerland and Imprint Springer.
- [85] Monte Lunacek and Darrell Whitley. The Dispersion Metric and the CMA Evolution Strategy. In *Proceedings of the 8th Annual Conference on Genetic and Evolutionary Computation*, page 477. Association for Computing Machinery, 2006.
- [86] Katherine M. Malan. A Survey of Advances in Landscape Analysis for Optimisation. *Algorithms*, 14(2):40, 2021.
- [87] Katherine M. Malan and Andries P. Engelbrecht. A survey of techniques for characterising fitness landscapes and some possible ways forward. *Information Sciences*, 241:148–163, 2013.
- [88] Olaf Mersmann, Bernd Bischl, Heike Trautmann, Mike Preuss, Claus Weihs, and Günter Rudolph. Exploratory Landscape Analysis. In Pier Luca Lanzi, editor, *Proceedings of the 13th Annual Conference on Genetic and Evolutionary Computation*, ACM Conferences, pages 829–836, New York, NY, USA, 2011. ACM.
- [89] Olaf Mersmann, Mike Preuss, and Heike Trautmann. Benchmarking Evolutionary Algorithms: Towards Exploratory Landscape Analysis. In Robert Schaefer, Carlos Cotta, Joanna Kolodziej, and Günter Rudolph, editors, *Parallel Problem Solving from Nature, PPSN XI*, Lecture Notes in Computer Science, pages 73–82. Springer, Berlin, 2010.
- [90] Manfred Mitschke and Henning Wallentowitz. *Dynamik der Kraftfahrzeuge*. VDI-Buch. Springer Vieweg, Wiesbaden, 5., überarb. und erg. aufl. edition, 2014.
- [91] Mario A. Muñoz, Michael Kirley, and Saman K. Halgamuge. Exploratory Landscape Analysis of Continuous Space Optimization Problems Using Information Content. *IEEE Transactions on Evolutionary Computation*, 19(1):74–87, 2015.
- [92] Mario A. Muñoz, Yuan Sun, Michael Kirley, and Saman K. Halgamuge. Algorithm selection for black-box continuous optimization problems: A survey on methods and challenges. *Information Sciences*, 317:224–245, 2015.

-
- [93] Barry L. Nelson. Foundations of Ranking & Selection for Simulation Optimization. In Zdravko Botev, Alexander Keller, Christiane Lemieux, and Bruno Tuffin, editors, *Advances in Modeling and Simulation: Festschrift for Pierre L'Ecuyer*, pages 353–379. Springer International Publishing, Cham, 2022.
- [94] Barry L. Nelson and Linda Pei. Simulation Optimization and Sensitivity. In *Foundations and Methods of Stochastic Simulation: A First Course*, pages 231–285. Springer International Publishing, Cham, 2021.
- [95] Francesco Orabona and Kwang-Sung Jun. Tight Concentrations and Confidence Sequences From the Regret of Universal Portfolio. *IEEE Transactions on Information Theory*, 70(1):436–455, 2024.
- [96] Art B. Owen. Scrambling Sobol’ and Niederreiter–Xing Points. *Journal of Complexity*, 14(4):466–489, 1998.
- [97] Hans B. Pacejka and Egbert Bakker. The Magic Formula Tyre Model. *Vehicle System Dynamics*, 21(sup001):1–18, 1992.
- [98] S. Gopal Krishna Patro and Kishore Kumar Sahu. Normalization: A Preprocessing Stage. Technical report, 2015.
- [99] Yijie Peng, Chun-Hung Chen, Edwin K. P. Chong, and Michael C. Fu. A Review of Static and Dynamic Optimization for Ranking and Selection. In *2018 Winter Simulation Conference (WSC)*, pages 1909–1920, 2018.
- [100] Alejandro Piad-Morffis, Suilan Estévez-Velarde, Antonio Bolufé-Röhler, James Montgomery, and Stephen Chen. Evolution Strategies with Threshold Convergence. In *2015 IEEE Congress on Evolutionary Computation (CEC)*, pages 2097–2104, 2015.
- [101] Erik Pitzer and Michael Affenzeller. A Comprehensive Survey on Fitness Landscape Analysis. In Ryszard Klempous, editor, *Recent Advances in Intelligent Engineering Systems*, volume 378 of *Studies in Computational Intelligence Ser.*, pages 161–191. Springer Berlin Heidelberg, Berlin, Heidelberg, 2012.
- [102] Raphael P. Prager. pflacco: The R-package flacco in native Python code, 2023.
- [103] Mike Preuss. Improved Topological Niching for Real-Valued Global Optimization. In *Applications of Evolutionary Computation*, volume 7248 of *Lecture Notes in Computer Science*, pages 386–395. Springer, Berlin and Heidelberg, 2012.

-
- [104] Rajesh Rajamani. *Vehicle Dynamics and Control*. Mechanical engineering series. Springer, Boston, MA, 2 edition, 2012.
- [105] Pratyusha Rakshit, Amit Konar, and Swagatam Das. Noisy evolutionary optimization algorithms – A comprehensive survey. *Swarm and Evolutionary Computation*, 33:18–45, 2017.
- [106] Ingo Rechenberg. *Evolutionsstrategie: Optimierung technischer Systeme nach Prinzipien der biologischen Evolution*. Dissertation, Technical University of Berlin, 1971.
- [107] Quentin Renau, Carola Doerr, Johann Dreö, and Benjamin Doerr. Exploratory Landscape Analysis is Strongly Sensitive to the Sampling Strategy. In Thomas Bäck, Mike Preuss, André. Deutz, Hao Wang, Carola Doerr, Michael Emmerich, and Heike Trautmann, editors, *Parallel Problem Solving from Nature - PPSN XVI*, volume 12270 of *Lecture Notes in Computer Science*, pages 139–153. Springer International Publishing, Cham, 2020.
- [108] Justin Rising. An Order-Theoretic Perspective on Rank Estimation. 2023.
- [109] Sheldon M. Ross. *Introduction to Probability and Statistics for Engineers and Scientists*. Academic press, London, United Kingdom, 6 edition, 2021.
- [110] Günter Rudolph. An evolutionary algorithm for integer programming. In Yuval Davidor, Hans-Paul Schwefel, and Reinhard Männer, editors, *Parallel Problem Solving from Nature — PPSN III*, pages 139–148, Berlin, Heidelberg, 1994. Springer Berlin Heidelberg.
- [111] J. Jon Ryu and Alankrita Bhatt. On Confidence Sequences for Bounded Random Processes via Universal Gambling Strategies. Technical report, 2022.
- [112] Francisco J. Samaniego. *A Comparison of the Bayesian and Frequentist Approaches to Estimation*. Springer New York, New York, NY, 2010.
- [113] Erhard Schmidt. Zur Theorie der linearen und nichtlinearen Integralgleichungen. *Mathematische Annalen*, 63(4):433–476, 1907.
- [114] Dieter Schramm, Manfred Hiller, and Roberto Bardini. *Vehicle Dynamics: Modeling and Simulation*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2 edition, 2018.

-
- [115] Hans-Paul Schwefel. *Evolutionsstrategie und numerische Optimierung*. Dissertation, Technical University of Berlin, 1975.
- [116] Shubhanshu Shekhar, Ziyu Xu, Zachary Lipton, Pierre Liang, and Aaditya Ramdas. Risk-limiting financial audits via weighted sampling without replacement. *Uncertainty in Artificial Intelligence*, pages 1932–1941, 2023.
- [117] Jaehyeok Shin, Aaditya Ramdas, and Alessandro Rinaldo. Are sample means in multi-armed bandits positively or negatively biased? In H. Wallach, H. Larochelle, A. Beygelzimer, F. d’Alché-Buc, E. Fox, and R. Garnett, editors, *Advances in Neural Information Processing Systems*, volume 32. Curran Associates, Inc, 2019.
- [118] Jaehyeok Shin, Aaditya Ramdas, and Alessandro Rinaldo. On the Bias, Risk, and Consistency of Sample Means in Multi-armed Bandits. *SIAM Journal on Mathematics of Data Science*, 3(4):1278–1300, 2021.
- [119] Siemens Digital Industries Software. Tire Simulation & Testing.
- [120] Urban Škvorc, Tome Eftimov, and Peter Korošec. Understanding the problem space in single-objective numerical optimization using exploratory landscape analysis. *Applied Soft Computing*, 90, 2020.
- [121] I. M. Sobol’. On the distribution of points in a cube and the approximate evaluation of integrals. *Computational Mathematics and Mathematical Physics*, 7(4):86–112, 1967.
- [122] Peter F. Stadler. Fitness landscapes. In Michael Lässig and Angelo Valleriani, editors, *Biological evolution and statistical physics*, volume 585 of *Physics and astronomy online library*, pages 183–204. Springer, Berlin and Heidelberg, 2002.
- [123] The MathWorks, Inc. MATLAB and Simulink.
- [124] André Thomaser, Jacob de Nobel, Diederick Vermetten, Furong Ye, Thomas Bäck, and Anna V. Kononova. When to Be Discrete: Analyzing Algorithm Performance on Discretized Continuous Problems. In *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO ’23*, pages 856–863, New York, NY, USA, 2023. Association for Computing Machinery.

- [125] André Thomaser, Anna V. Kononova, Marc-Eric Vogt, and Thomas Bäck. One-Shot Optimization for Vehicle Dynamics Control Systems: Towards Benchmarking and Exploratory Landscape Analysis. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion*, GECCO '22, pages 2036–2045, New York, NY, USA, 2022. Association for Computing Machinery.
- [126] André Thomaser, Marc-Eric Vogt, Thomas Bäck, and Anna V. Kononova. Optimizing CMA-ES with CMA-ES. In *Proceedings of the 15th International Joint Conference on Computational Intelligence*, pages 214–221. SCITEPRESS - Science and Technology Publications, 2023.
- [127] André Thomaser, Marc-Eric Vogt, Thomas Bäck, and Anna V. Kononova. Real-World Optimization Benchmark from Vehicle Dynamics: Specification of Problems in 2D and Methodology for Transferring (Meta-)Optimized Algorithm Parameters. In *Proceedings of the 15th International Joint Conference on Computational Intelligence*, pages 31–40. SCITEPRESS - Science and Technology Publications, 2023.
- [128] André Thomaser, Marc-Eric Vogt, Anna V. Kononova, and Thomas Bäck. Transfer of Multi-objectively Tuned CMA-ES Parameters to a Vehicle Dynamics Problem. In Michael Emmerich, André Deutz, Hao Wang, Anna V. Kononova, Boris Naujoks, Ke Li, Kaisa Miettinen, and Iryna Yevseyeva, editors, *Evolutionary Multi-Criterion Optimization*, pages 546–560, Cham, 2023. Springer Nature Switzerland.
- [129] Ye Tian, Shichen Peng, Xingyi Zhang, Tobias Rodemann, Kay Chen Tan, and Yaochu Jin. A Recommender System for Metaheuristic Algorithms for Continuous Optimization Based on Deep Recurrent Neural Networks. *IEEE Transactions on Artificial Intelligence*, 1(1):5–18, 2020.
- [130] Tea Tušar, Dima Brockhoff, and Nikolaus Hansen. Mixed-Integer Benchmark Problems for Single- and Bi-Objective Optimization. In *Proceedings of the Genetic and Evolutionary Computation Conference*, GECCO '19, pages 718–726, New York, NY, USA, 2019. Association for Computing Machinery.
- [131] Sander van Rijn, Hao Wang, Matthijs van Leeuwen, and Thomas Bäck. Evolving the Structure of Evolution Strategies. In *2016 IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 1–8, 2016.

- [132] Sander van Rijn, Hao Wang, Bas van Stein, and Thomas Bäck. Algorithm Configuration Data Mining for CMA Evolution Strategies. In *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO '17*, pages 737–744, New York, NY, USA, 2017. Association for Computing Machinery.
- [133] VIRES Simulationstechnologie GmbH. Opencrg.
- [134] Hao Wang, Michael Emmerich, and Thomas Bäck. Mirrored Orthogonal Sampling with Pairwise Selection in Evolution Strategies. In *Proceedings of the 29th Annual ACM Symposium on Applied Computing, SAC '14*, pages 154–156, New York, NY, USA, 2014. Association for Computing Machinery.
- [135] Hongjian Wang and Aaditya Ramdas. Catoni-style confidence sequences for heavy-tailed mean estimation. *Stochastic Processes and their Applications*, 163:168–202, 2023.
- [136] Ian Waudby-Smith and Aaditya Ramdas. Estimating means of bounded random variables by betting. Technical report, 2020.
- [137] Simon Wessing. Repair Methods for Box Constraints Revisited. In Anna I. Esparcia-Alcázar, editor, *Applications of Evolutionary Computation*, pages 469–478, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.
- [138] Li Yang and Abdallah Shami. On hyperparameter optimization of machine learning algorithms: Theory and practice. *Neurocomputing*, 415:295–316, 2020.
- [139] Furong Ye, Carola Doerr, Hao Wang, and Thomas Bäck. Automated Configuration of Genetic Algorithms by Tuning for Anytime Performance. *IEEE Transactions on Evolutionary Computation*, 26(6):1526–1538, 2022.
- [140] Gongbo Zhang, Yijie Peng, Jianghua Zhang, and Enlu Zhou. Dynamic Sampling Policy For Subset Selection. In *2021 Winter Simulation Conference (WSC)*, pages 1–12, 2021.
- [141] Gongbo Zhang, Yijie Peng, Jianghua Zhang, and Enlu Zhou. Asymptotically Optimal Sampling Policy for Selecting Top-m Alternatives. *INFORMS Journal on Computing*, 35(6):1261–1285, 2023.
- [142] Meng Zhao and Jinlong Li. Tuning the hyper-parameters of CMA-ES with tree-structured Parzen estimators. In *2018 Tenth International Conference on Advanced Computational Intelligence (ICACI)*, pages 613–618, 2018.

List of Abbreviations

ABS	Antilock Braking System
AF	artificial function
ARP	Active Rollover Protection
AUC	Area Under the Curve
BBOB	Black-Box Optimization Benchmarking
BIPOP	bi-population
CI	Confidence Interval
CIS	Confidence Interval Sequence
CMA-ES	Covariance Matrix Adaptation Evolution Strategy
CMA-ESwM	CMA-ES with Margin
CRG	curved regular grid
CS	Confidence Set
CSA	cumulative step length adaptation
CV	characteristic value
DA	Dynamic Allocation
EA	Evolutionary Algorithm
ECDF	Empirical Cumulative Distribution Function
ELA	Exploratory Landscape Analysis
ERT	Expected Running Time
ES	Evolutionary Strategy
ESC	Electronic Stability Control
int-EA	Evolutionary Algorithm for Integer Programming
IPOP	increasing population
PCA	Principal Component Analysis
PCR	Probability of Correct Ranking

PCS	Probability of Correct Selection
RaS	Ranking and Selection
RCR	ratio of correct ranking
RI	Rank Interval
RQ	research question
SA	Static Allocation
SMAC	Sequential Model-based Algorithm Configuration
SMBO	sequential model-based optimization
SR	Success Rate
SWD	Sine with dwell
TPE	Tree-structured Parzen Estimator
UQiR	Uncertainty Quantification in Ranking
UQiRS	Uncertainty Quantification in Ranking and Selection
UQiS	Uncertainty Quantification in Selection
VDCS	vehicle dynamics control system
WoR	Without Replacement