



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).

Algorithm Design for Mixed-Integer Black-Box Optimization Problems with Uncertainty

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op dinsdag 22 oktober 2024
klokke 11:30 uur

door

André Thomaser

geboren te München, Duitsland
in 1996

Promotor:

Prof.dr. T.H.W. Bäck

Co-promotor:

Dr. A.V. Kononova

Promotiecomissie:

Prof.dr. M.M. Bonsangue

Prof.dr. A. Plaat

Dr. N. van Stein

Dr. E. Raponi

Prof.dr. B. Sendhoff (Technical University Darmstadt, Germany)

Prof.dr. K.M. Malan (University of Pretoria, South Africa)

Copyright © 2024 André Thomaser

This thesis was written as part of the research project newAIDE under the consortium leadership of BMW AG with the partners Altair Engineering GmbH, divis intelligent solutions GmbH, MSC Software GmbH, Technical University of Munich, TWT GmbH. The project is financially supported by the Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a decision of the German Bundestag.

To my parents.

“No problem can withstand the assault of sustained thinking.”

Voltaire, 1694 - 1778

Contents

1	Introduction	1
1.1	Background	1
1.2	Research Questions	2
1.3	Contribution and Structure of the Thesis	3
1.4	Publications	4
2	Preliminaries	7
2.1	Optimization	7
2.2	Evolutionary Algorithms	8
2.3	Evolution Strategies	9
2.4	Covariance Matrix Adaption Evolution Strategy	10
2.4.1	Variants	12
2.4.2	Box Constraint Handling	14
2.4.3	Integer Handling	16
2.5	Objective Function Landscape	17
2.5.1	Objective Function Properties	17
2.5.2	Exploratory Landscape Analysis	18
2.6	Benchmarking and Tuning	20
2.6.1	Benchmark Problems	20
2.6.2	Performance Metric	21
2.6.3	Parameter Tuning	23
2.7	Uncertainty Quantification	24
2.7.1	Static and Dynamic Allocation	25
2.7.2	Dynamic Allocation for Ranking and Selection	26
2.7.3	Confidence Interval Sequences	27
2.7.4	Uncertainty Quantification in Ranking and Selection	31

3 Engineering Problems	35
3.1 Antilock Braking System	36
3.2 Active Rollover Protection	38
3.3 Vehicle Dynamics Modeling and Simulation	39
3.4 ABS Benchmark Dataset	40
4 Tuning CMA-ES Parameters	43
4.1 Methodology	45
4.1.1 Similarity Quantification	46
4.1.2 Artificial Functions	47
4.2 Analysis of Landscape Similarities	48
4.2.1 Experimental Setup	48
4.2.2 Results	49
4.2.3 Conclusion	55
4.3 Brute Force Search	56
4.3.1 Experimental Setup	56
4.3.2 Results	58
4.3.3 Summary	63
4.4 Meta-Optimization	64
4.4.1 Experimental Setup	65
4.4.2 Results	66
4.5 Tuning for Higher Dimensional Problems	68
4.5.1 Experimental Setup	68
4.5.2 Results	69
4.6 Comparison of Meta-Optimization Algorithms	71
4.6.1 Experimental Setup	72
4.6.2 Results	73
4.7 Conclusion	75
5 Handling Discretization	77
5.1 Function Discretization	77
5.2 EA for Integer Programming	80
5.3 Experimental Setup	81
5.4 Results	81
5.4.1 Success Rates	83
5.4.2 ECDF	87
5.5 Conclusion	90

6 Uncertainty Quantification	91
6.1 Noisy Test Function	92
6.2 Methodology	94
6.2.1 Dynamic Allocation Policy	95
6.2.2 Top- μ Selection and Ranking	97
6.2.3 CMA-ES and Bound Adaption for UQiS	101
6.2.4 CMA-ES Convergence	103
6.2.5 Conclusion	109
6.3 Application to Real-World Problems	110
7 Conclusion and Outlook	115
Bibliography	i
List of Abbreviations	xvii
Samenvatting	xix
Summary	xxi
Curriculum Vitae	xxiii

