Seminar on **Evolutionary Computation**

Kickoff Meeting

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RWTH AACHEN UNIVERSITY

Challenges in optimisation

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- $\mathcal{NP}$-hard
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- of black-box nature
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- computationally expensive to evaluate
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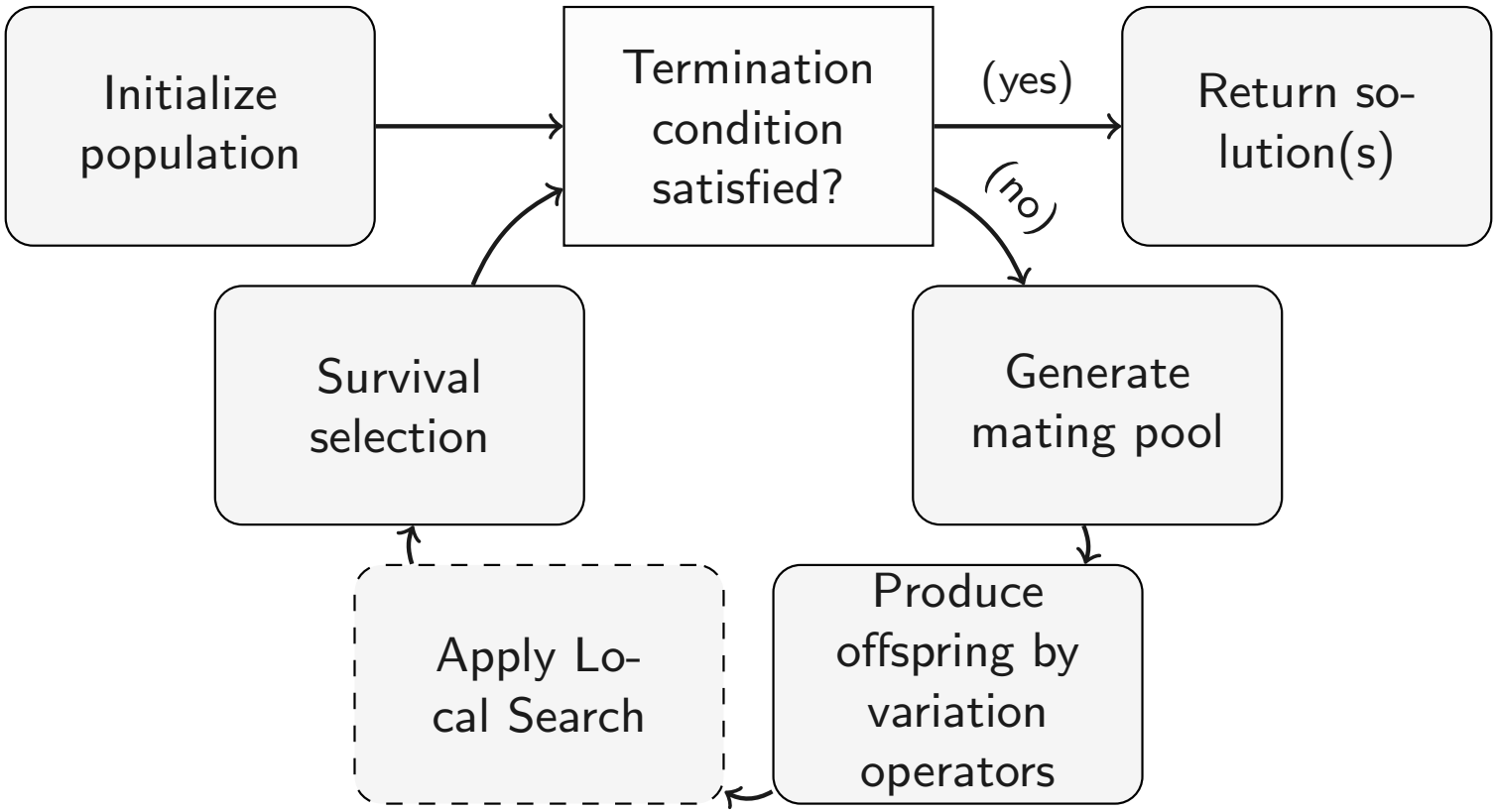
$\rightsquigarrow$ Need for heuristic approaches!

Generic Evolutionary Algorithm



Optimisation of a two-phase nozzle

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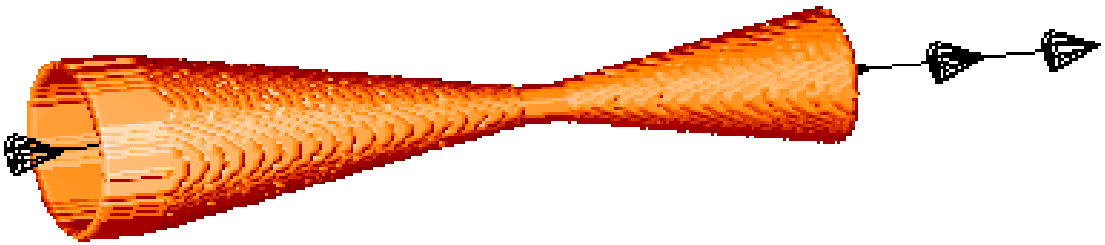

Initial nozzle (top) und final nozzle (bottom) [KS70].

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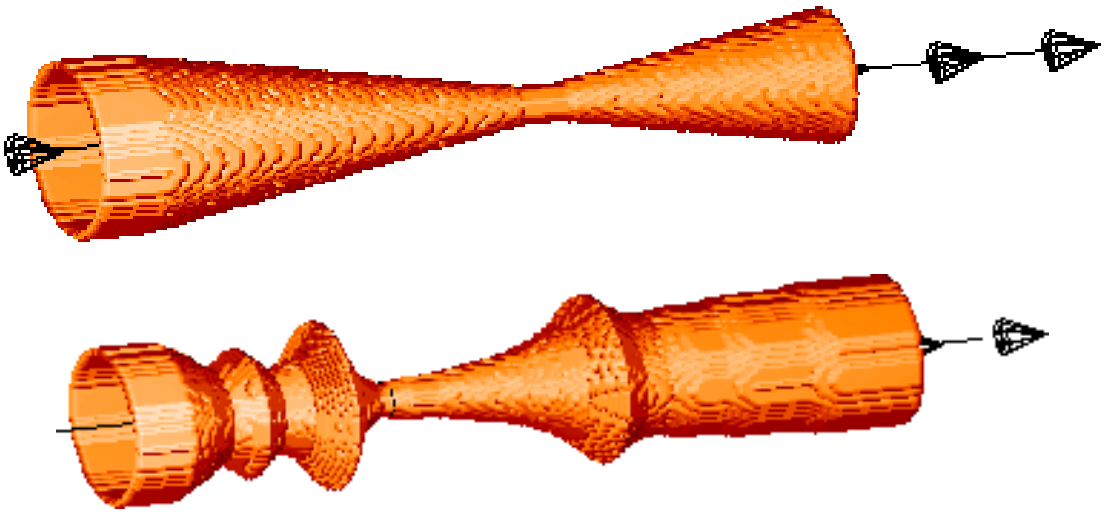

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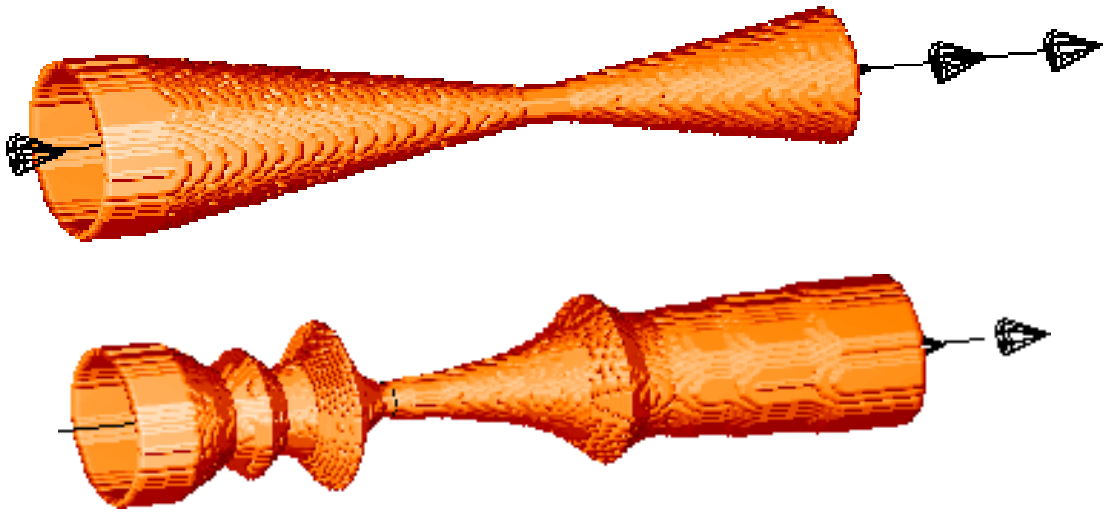
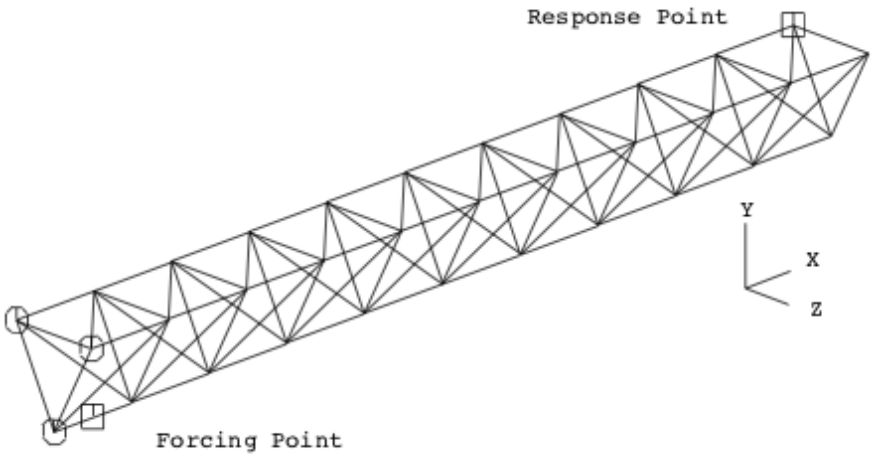


Initial nozzle (top) und final nozzle (bottom) [KS70].

"The result was a rather strange nozzle contour." [KS70].

Optimising the structure of a satellite dish holder boom



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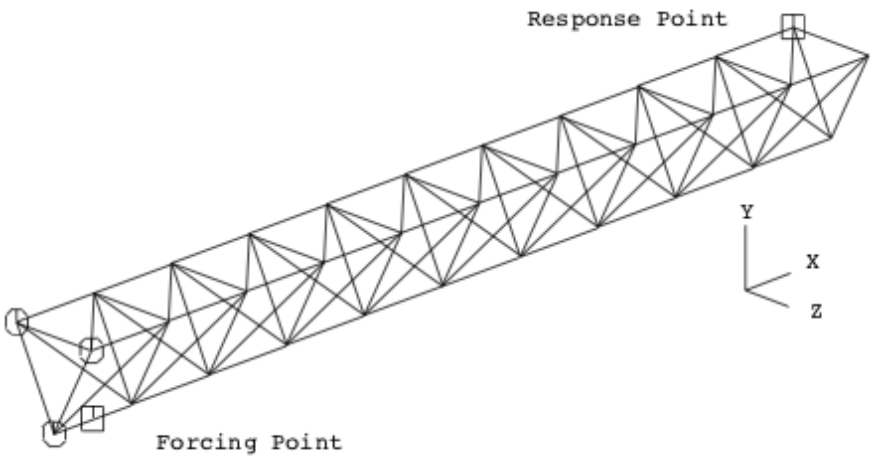

Initial solution (left) und final solution of a GA (right) [Kea96].

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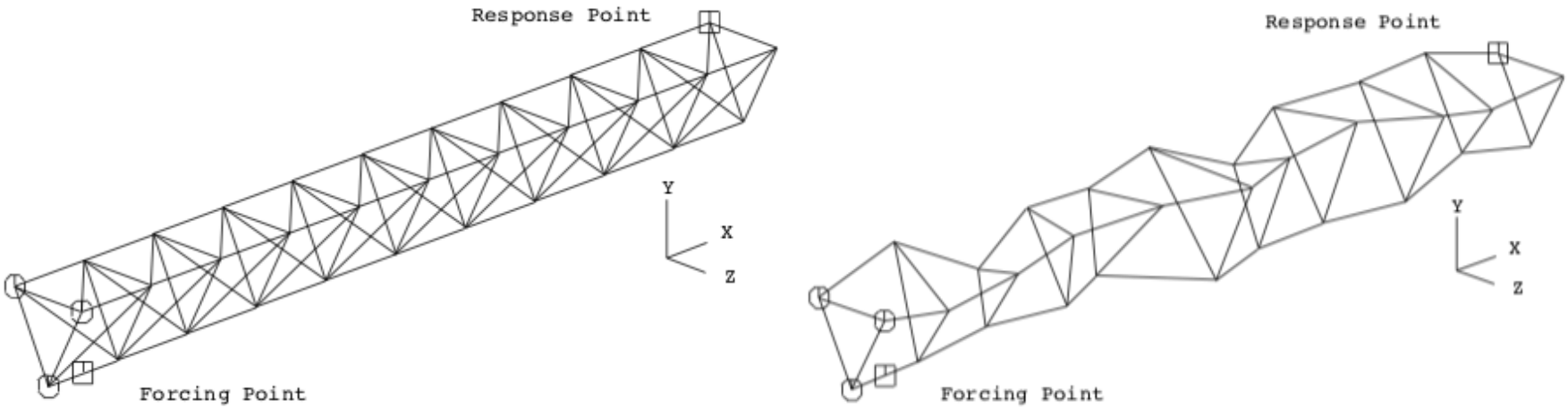

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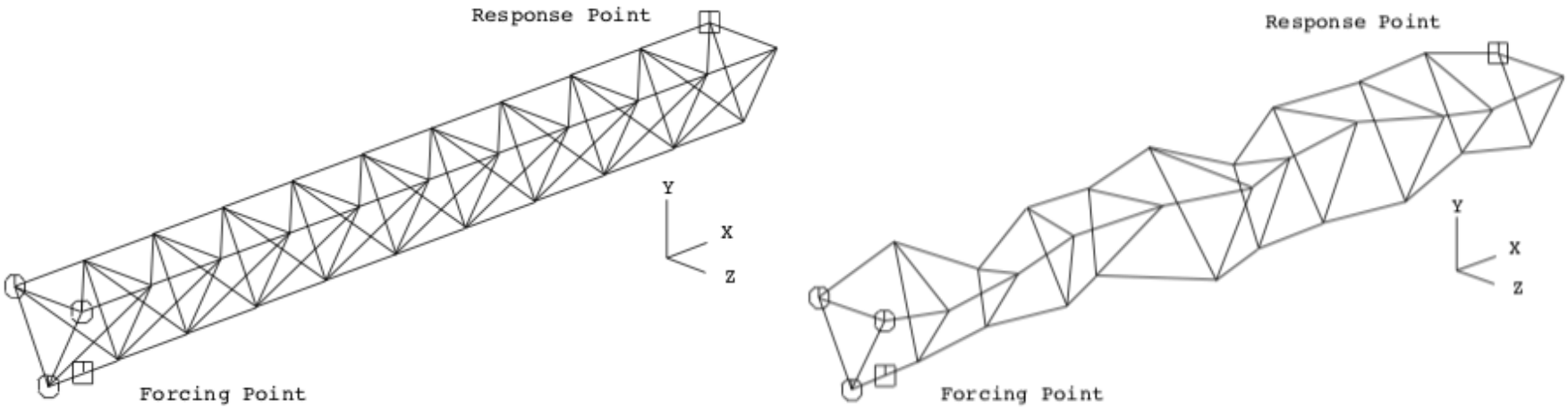

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Improvement over initial (traditionally symmetric) solution?
a) 24% b) 239% c) 1 448%

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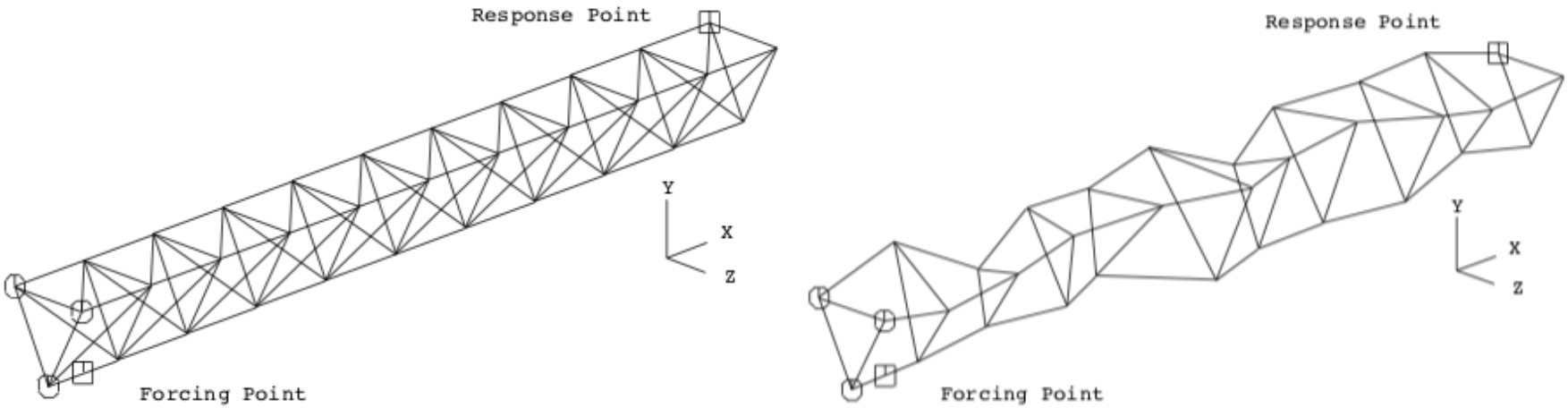

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Dr. Jakob Bossek

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Chair for AI Methodology (AIM)
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RWTH Aachen University

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Website: http://www.jakobbossek.de/

Research interests

- Heuristic Optimisation (in particular Evolutionary Algorithms)
- Combinatorial (Multi-Objective) Optimisation
- Evolutionary Diversity Optimisation (EDO) and Quality Diversity (QD)
- Theory of randomised search heuristics
- Sequential Model-Based Optimisation (SMBO)
- Automated Artificial Intelligence

Prof. Dr. Holger H. Hoos

Alexander von Humboldt Professor
Chair for AI Methodology (AIM)
Department of Computer Science
RWTH Aachen University

E-Mail: hh@aim.rwth-aachen.de
Website: https://hoos.ca/

Research interests

- Intersection of machine learning, automated reasoning and optimisation
- Automated design and analysis of algorithms: performance prediction, algorithm configuration, algorithm selection and construction of parallel algorithm portfolios
- Iterated Local Search (ILS) algorithms
- Bio-inspired optimisation, in particular Ant Colony Optimization (ACO)
- Bioinformatics and computer music

Registration

- Registration at RWTHonline open from today until 14 November.
- Once registered you will get access to the RWTHmoodle room.

Criteria for successfull completion

- Preparation of a seminar report in LaTeX
  (max. 20 pages, using the prescribed format, PDF)
- 30 minute presentation + 30 minutes discussion
- Meeting all deadlines
- Attendance of all mandatory meetings
- **Grading**: 60% report, 30% presentation incl. answers to questions and 10% participation in discussions on other presentations.

Other important dates (take note!)

Progress update (via e-mail, bullet points are OK, but do give us some details): 18 November 2022, 18:00 CEST (**hard deadline!**)

Final report PDF via e-mail: 27 January 2023, 18:00 CEST (**hard deadline!**)

Block seminar Two-day workshop-style. In person attendance preferred. Exact time tba.

Groups and topics I

PAR Simon Paul Levin Mainz, Elias Müllers

Topic: Parameter Control

A.E. Eiben and S.K. Smit. "Parameter tuning for configuring and analyzing evolutionary algorithms". In: *Swarm and Evolutionary Computation* 1.1 (2011), pp. 19–31. DOI: https://doi.org/10.1016/j.swevo.2011.02.001

DP Brian Schiller, Philipp Christoph Schneider

Topic: Diversity Preservation

Maury Meirelles Gouvêa Jr. and Aluizio Fausto Ribeiro Araújo. "Diversity-Based Adaptive Evolutionary Algorithms". In: *New Achievements in Evolutionary Computation*. Ed. by Peter Korosec. Rijeka: IntechOpen, 2010. Chap. 1. DOI: 10.5772/8046

Groups and topics II

EDO Dominic Wittner, Tobias Richter
Topic: Evolutionary Diversity Optimisation
Jakob Bossek and Frank Neumann. "Evolutionary diversity optimization and the minimum spanning tree problem". In: *GECCO*. ACM, 2021, pp. 198–206

NSQD Dominik Lazar, Adam Haman
Topic: Novelty Search & Quality Diversity
Justin K. Pugh, Lisa B. Soros, and Kenneth O. Stanley. "Quality Diversity: A New Frontier for Evolutionary Computation". In: *Frontiers Robotics AI* 3 (2016), p. 40

B Erik Schwarz, Nadim Khaded Nezar Adham
Topic: Benchmarking of Stochastic Optimisation Algorithms
Thomas Bartz-Beielstein et al. *Benchmarking in Optimization: Best Practice and Open Issues*. 2020. DOI: 10.48550/ARXIV.2007.03488

Groups and topics III

MOO-1 Jakob Leonhard Kapfenberger, Ritabrate Sanyal
Topic: Dominance-Based EMOAs
K. Deb et al. "A fast and elitist multiobjective genetic algorithm: NSGA-II". In: *IEEE Transactions on Evolutionary Computation* 6.2 (2002), pp. 182–197. DOI: 10.1109/4235.996017

MOO-2 Daniel Tebart, Edwin-Daniel Özdemir
Topic: Decomposition-Based EMOAs
Qingfu Zhang and Hui Li. "MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition". In: *IEEE Transactions on Evolutionary Computation* 11.6 (2007), pp. 712–731. DOI: 10.1109/TEVC.2007.892759

Groups and topics IV

MOO-3 Jana Lemke, Marc Flemming Thiemann

Topic: Haman Many-Objective Optimisation

Shelvin Chand and Markus Wagner. "Evolutionary many-objective optimization: A quick-start guide". In: *Surveys in Operations Research and Management Science* 20.2 (2015), pp. 35–42. ISSN: 1876-7354. DOI: https://doi.org/10.1016/j.sorms.2015.08.001

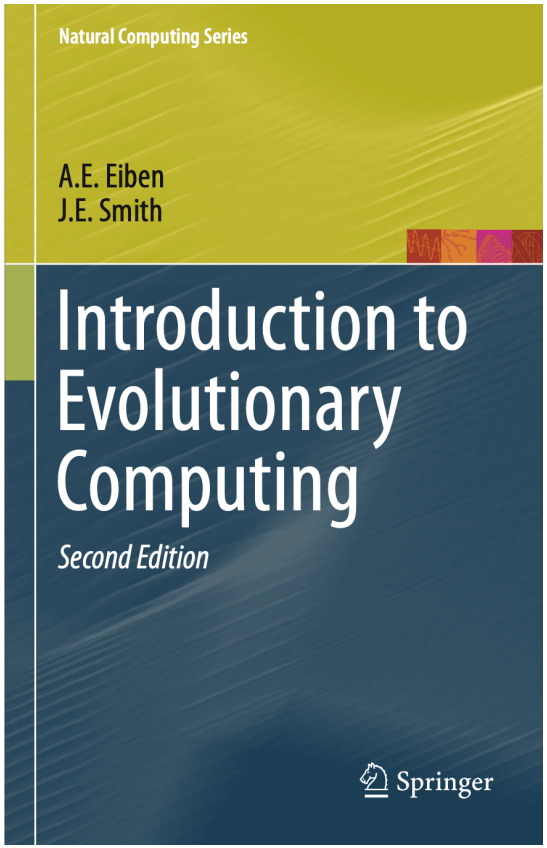
EA-TSP Marko Goldschmidt

Topic: EA for the Travelling Salesperson Problem

Yuichi Nagata and Shigenobu Kobayashi. "A Powerful Genetic Algorithm Using Edge Assembly Crossover for the Traveling Salesman Problem". In: *INFORMS Journal on Computing* 25.2 (2013), pp. 346–363. DOI: 10.1287/ijoc.1120.0506

Introductory literature

First five chapters of *Introduction to Evolutionary Computation* by Eiben & Smith [ES15]:



Take-home messages

- Evolutionary computation methods very successful in various domains: multi-obj. optimisation, black-box optimisation
- This seminar will cover a wide range of EC methods including novel branches, e.g., quality diversity
- I am here to help – do not hesitate to contact me if you have questions

References I

[KS70] J. Klockgether and H. P. Schwefel. "Two-phase nozzle and hollow core jet experiments". In: *Proc. 11th Symp. Engineering Aspects of Magnetohydrodynamics*. 1970, pp. 141–148.

[Kea96] Andy J. Keane. "The design of a satellite boom with enhanced vibration performance using genetic algorithm techniques". In: 1996.

[ES11] A.E. Eiben and S.K. Smit. "Parameter tuning for configuring and analyzing evolutionary algorithms". In: *Swarm and Evolutionary Computation* 1.1 (2011), pp. 19–31. DOI: https://doi.org/10.1016/j.swevo.2011.02.001.

[JA10] Maury Meirelles Gouvêa Jr. and Aluizio Fausto Ribeiro Araújo. "Diversity-Based Adaptive Evolutionary Algorithms". In: *New Achievements in Evolutionary Computation*. Ed. by Peter Korosec. Rijeka: IntechOpen, 2010. Chap. 1. DOI: 10.5772/8046.

[BN21] Jakob Bossek and Frank Neumann. "Evolutionary diversity optimization and the minimum spanning tree problem". In: *GECCO*. ACM, 2021, pp. 198–206.

References II

[PSS16] Justin K. Pugh, Lisa B. Soros, and Kenneth O. Stanley. "Quality Diversity: A New Frontier for Evolutionary Computation". In: *Frontiers Robotics AI* 3 (2016), p. 40.

[Bar+20] Thomas Bartz-Beielstein et al. *Benchmarking in Optimization: Best Practice and Open Issues*. 2020. DOI: 10.48550/ARXIV.2007.03488.

[Deb+02] K. Deb et al. "A fast and elitist multiobjective genetic algorithm: NSGA-II". In: *IEEE Transactions on Evolutionary Computation* 6.2 (2002), pp. 182–197. DOI: 10.1109/4235.996017.

[ZL07] Qingfu Zhang and Hui Li. "MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition". In: *IEEE Transactions on Evolutionary Computation* 11.6 (2007), pp. 712–731. DOI: 10.1109/TEVC.2007.892759.

[CW15] Shelvin Chand and Markus Wagner. "Evolutionary many-objective optimization: A quick-start guide". In: *Surveys in Operations Research and Management Science* 20.2 (2015), pp. 35–42. ISSN: 1876-7354. DOI: https://doi.org/10.1016/j.sorms.2015.08.001.

References III

[NK13] Yuichi Nagata and Shigenobu Kobayashi. "A Powerful Genetic Algorithm Using Edge Assembly Crossover for the Traveling Salesman Problem". In: *INFORMS Journal on Computing* 25.2 (2013), pp. 346–363. DOI: 10.1287/ijoc.1120.0506.

[ES15] A. E. Eiben and James E. Smith. *Introduction to Evolutionary Computing*. 2nd. Springer Publishing Company, Incorporated, 2015. ISBN: 3662448734.