Course: Natural Computing
*8 Exploratory Landscape Analysis

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Overview

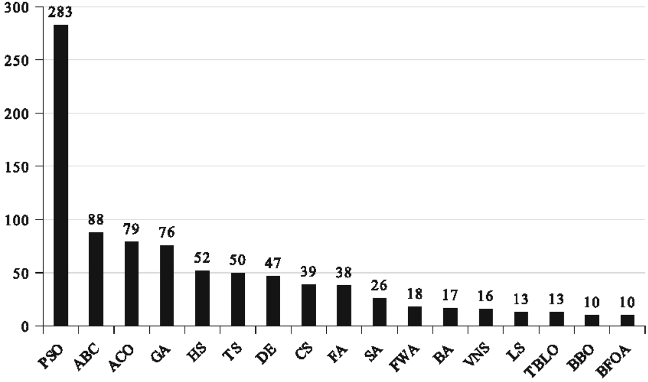
- Types and applications of MHO algorithms
- Landscape analysis
- Automated algorithm selection

Domains of metaheuristic applications

1222 publications from year 1983 to 2016

Hussain, Kashif et al. Metaheuristic research: A comprehensive survey. *AI Review* **52**:4 (2019) 2191. [1]

Number of publications per algorithm

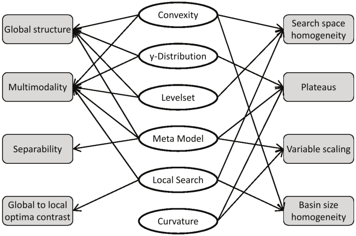


GP?

Hussain, Kashif et al. Metaheuristic research: A comprehensive survey. *AI Review* **52**:4 (2019) 2191. [1]

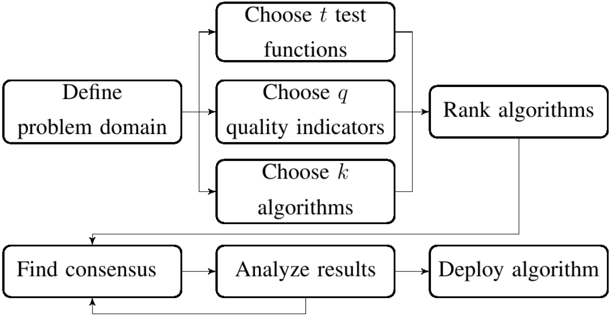
Classification of problems

- Exploratory landscape analysis [3] $\longrightarrow$
- Classification of problems to be optimized [4, 6]
- Problem is implied by a fitness function $f : X \to \mathbb{R}$



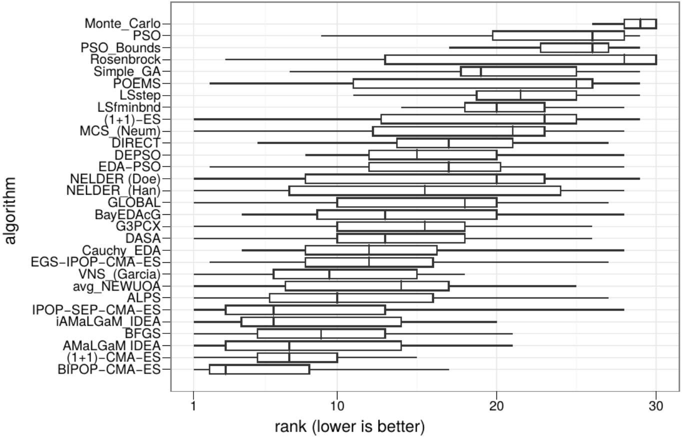
Level of classification

- Instances or templates (or sets) of instances (SAT, TSP, ...)
- Types of prior knowledge (see figure from [3])
- Amount of available knowledge and respective costs
- Generating or evolving of additional problem instances



O. Mersmann ea. (2010) Benchmarking evolutionary algorithms: Towards exploratory landscape analysis.

Ranking



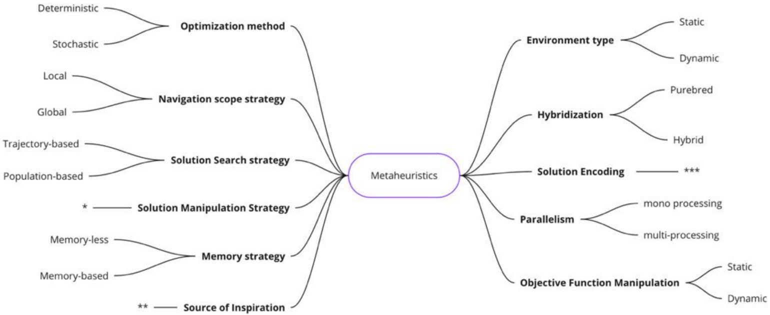
Search in 5, 10, 20 dimensions averaged over 24 benchmark functions

O. Mersmann ea. (2010) Benchmarking evolutionary algorithms: Towards exploratory landscape analysis.

ELA

- ELA aims at finding a relation between problems (fitness functions) and algorithms based on landscape features which can be extracted by suitable methods
- There may be more direct or comprehensive ways to identify *alignement* (see NFL theorem) between algorithms and problems.

Classification of algorithms



* Solution manipulation refers to algorithm details: Best suited for classification.
** The source of inspiration may be irrelevant and is often not even unique.
*** Encoding is crucial in practical applications; this may help for re-use of algorithms.

Peres, F. and Castelli, M.: Combinatorial Optimization Problems and Metaheuristics: Review, Challenges, Design, and Development. *Applied Sciences* 11:14 (2021) 6449.

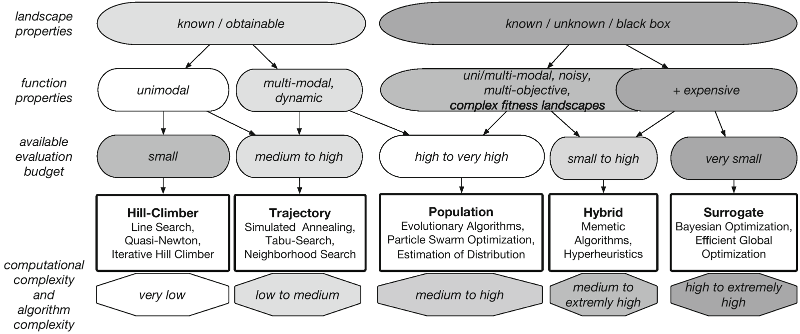
Matching of algorithms and problems

- Ideally: Alignment (see NFL theorem)
- Hyperheuristic algorithms (ibid.)
- Algorithm selection (next slides)

Decisions based on performance measures

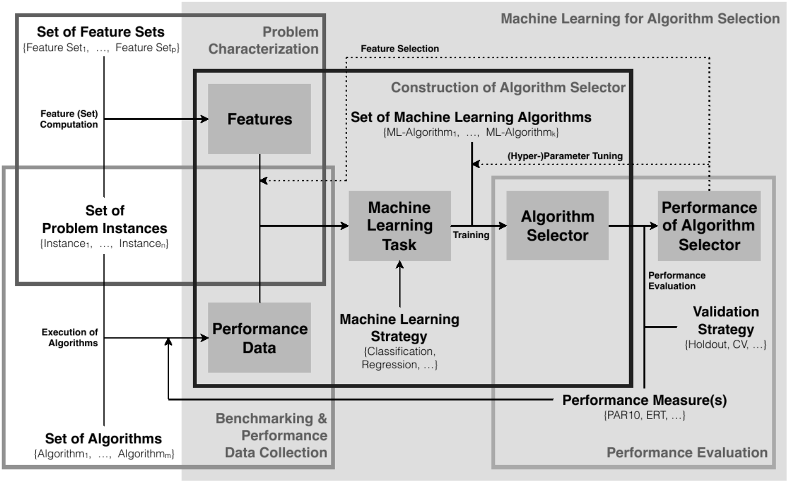
- Resources or runtime needed for given solution quality
- Solution quality obtainable by given budget
- Robustness (stochasticity of the algorithm's search behaviour, complexity of fitness landscape, problem noise)
- Performance relative to problem class
- Time course of performance (e.g. slower for hyperheuristics)
- Deviation of fitness from estimate by a surrogate model

Algorithm selection guideline



Stork e.a.: A new taxonomy of global optimization algorithms. *Natural Computing* (2020) 1-24.[5]

Automated algorithm selection



Kerschke e.a.: Automated algorithm selection: Survey and perspectives. *Evol. Comp.* **27**:1 (2019) 3-45.

Remarks: Automated algorithm selection

- Algorithm selection (AS) for portfolio selection
  - Specialised: SATzilla [7] or
  - More general: AutoFolio [2] for speed-up
  - Algorithm schedules [Lindauer 2014, 2016]
  - Machine learning: Bag of landscape features [Shirakawa & Nagao, 2016]
  - See review [Kerschke e.a., 2019]
- No clear winner: AS for AS or hyper-hyperheuristics?
- Background knowledge on problem instance or problem class can be more useful than automated AS

DIY

- moPLOT landscape explorer: Visualizing Multi-Objective Optimization Problems
- ParadisEO: Heuristic Optimization Framework (S. Cahon (2004) Paradiseo: A framework for the reusable design of parallel and distributed metaheuristics. *Journal of Heuristics* **10**:3 ,357-380)
- irace: Automated algorithm configuration tool (M. López-Ibáñez et al. (2016) The *irace* package: Iterated racing for automatic algorithm configuration. *Operations Research Perspectives* **3**, 43-58)
- IOHprofiler: Experimental platform (C. Doerr et al. (2018) IOHprofiler: A benchmarking and profiling tool for iterative optimization heuristics. arXiv:1810.05281)

Conclusions

- Landscape analysis is suggestive, but perhaps not easier than optimisation itself.
- Other attempts with huge numbers of features have been made.
- AAS is an advanced form of hyperheuristics.
- Evolved into automatic algorithm composition based on neural networks

Kashif Hussain, Mohd Najib Mohd Salleh, Shi Cheng, and Yuhui Shi.
Metaheuristic research: a comprehensive survey.
Artificial Intelligence Review, 52(4):2191–2233, 2019.

Marius Lindauer, Holger H Hoos, Frank Hutter, and Torsten Schaub.
Autofolio: An automatically configured algorithm selector.
Journal of Artificial Intelligence Research, 53:745–778, 2015.

Olaf Mersmann, Bernd Bischl, Heike Trautmann, Mike Preuss, Claus Weihs, and Günter Rudolph.
Exploratory landscape analysis.
In *Proceedings of the 13th Annual Conference on Genetic and Evolutionary Computation*, pages 829–836. ACM, 2011.

Helena Stegherr, Michael Heider, and Jörg Hähner.
Classifying metaheuristics: Towards a unified multi-level classification system.
Natural Computing, pages 1–17, 2020.

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A new taxonomy of global optimization algorithms.
Natural Computing, pages 1–24, 2020.

El-Ghazali Talbi.
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ACM Computing Surveys (CSUR), 54(6):1–32, 2021.

Lin Xu, Frank Hutter, Holger H Hoos, and Kevin Leyton-Brown.
Satzilla: portfolio-based algorithm selection for sat.
Journal of artificial intelligence research, 32:565–606, 2008.