Per-class algorithm selection for black-box optimisation

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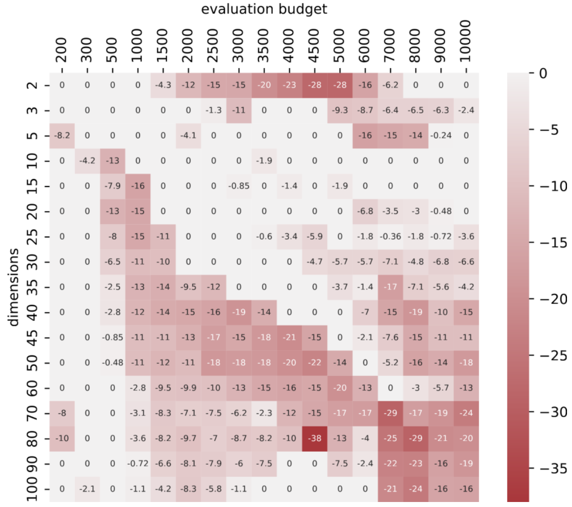
Summary

- Algorithm selection (AS) is great, e.g., for SAT → Mostly per-instance
- Black-box optimisation → No a priori instance-specific information
- Per-class AS → Use problem properties for AS over sets of instances

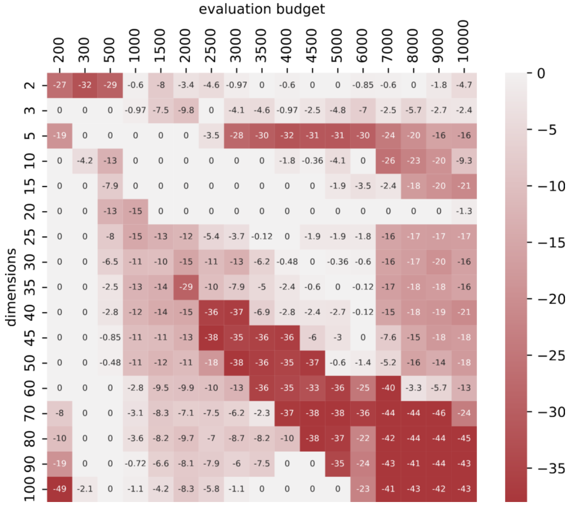
Summary

- General data-driven AS framework
  → Outperform hand-made SOTA system by Meta (NGOpt)
- Extensions to grey-box problems possible, to use more information

Data-driven



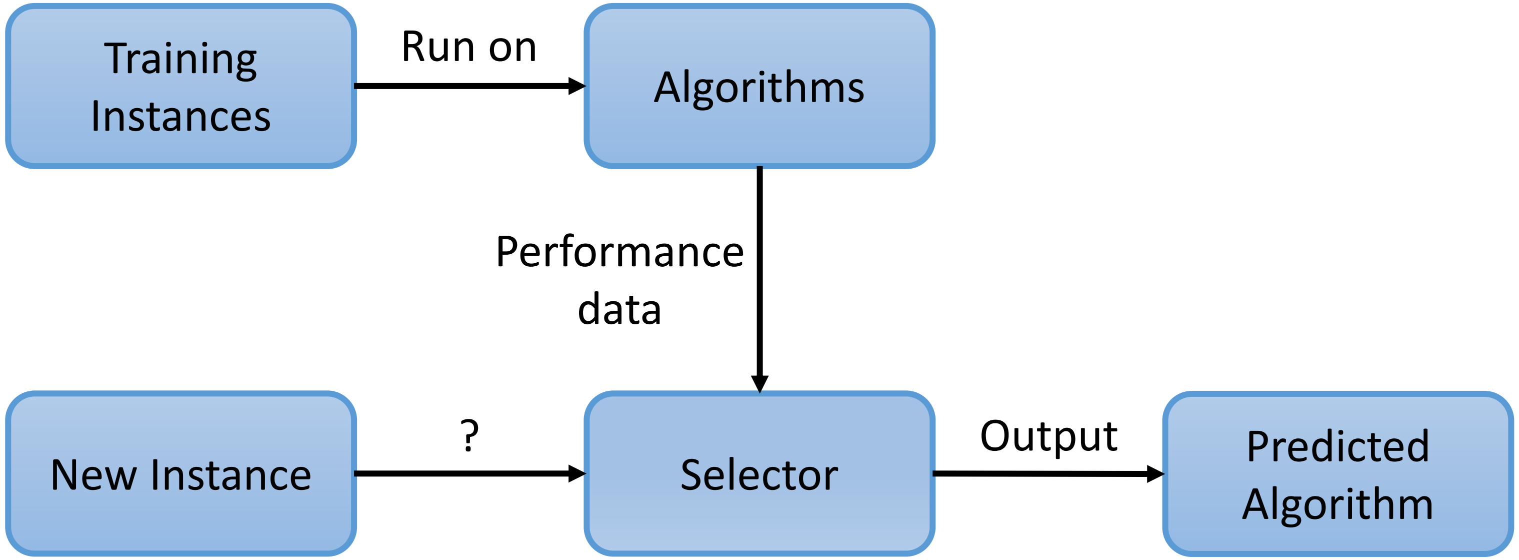
NGOpt39



This talk

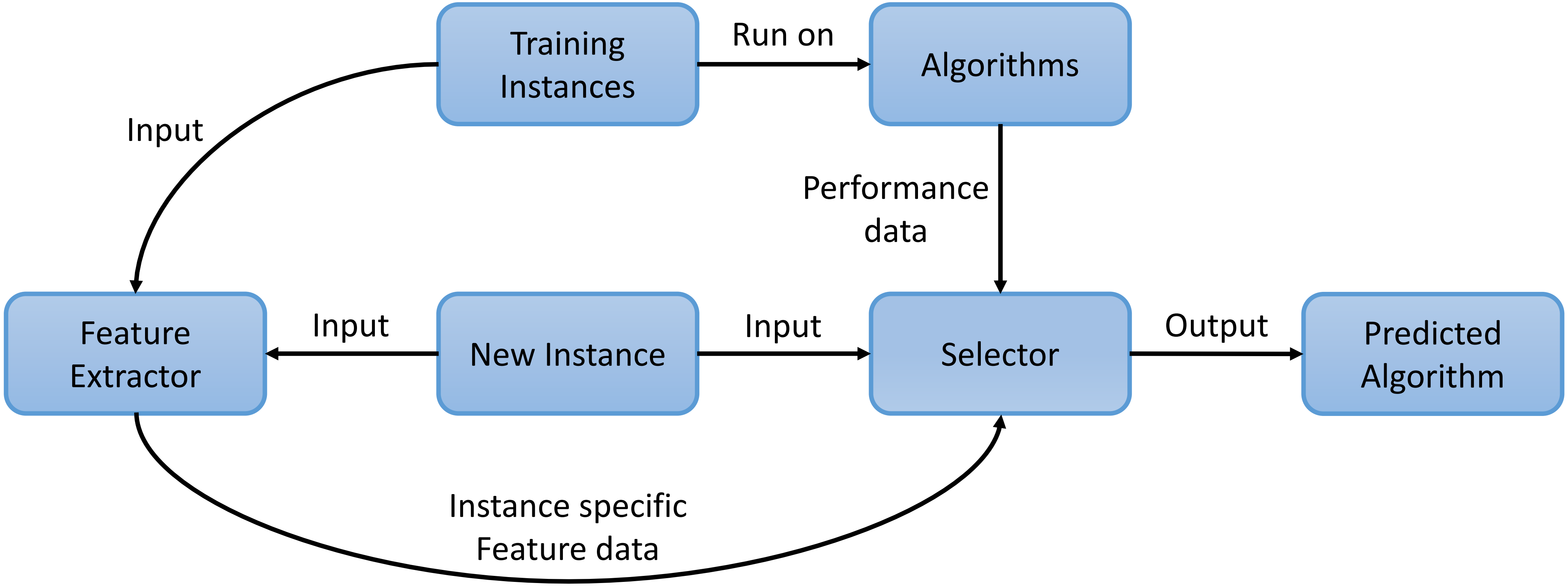
- Why we care about per-class algorithm selection
- How data-driven per-class algorithm selection works
- Comparison to hand-designed system
- Discussion of generality and extensibility

Algorithm selection [Rice, Adv. in Comp. 1976]



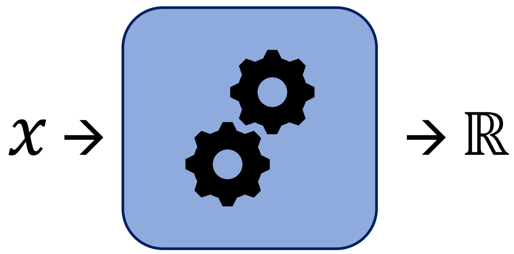
- No single algorithm is the best for every problem

Per-instance algorithm selection



Black-box optimisation

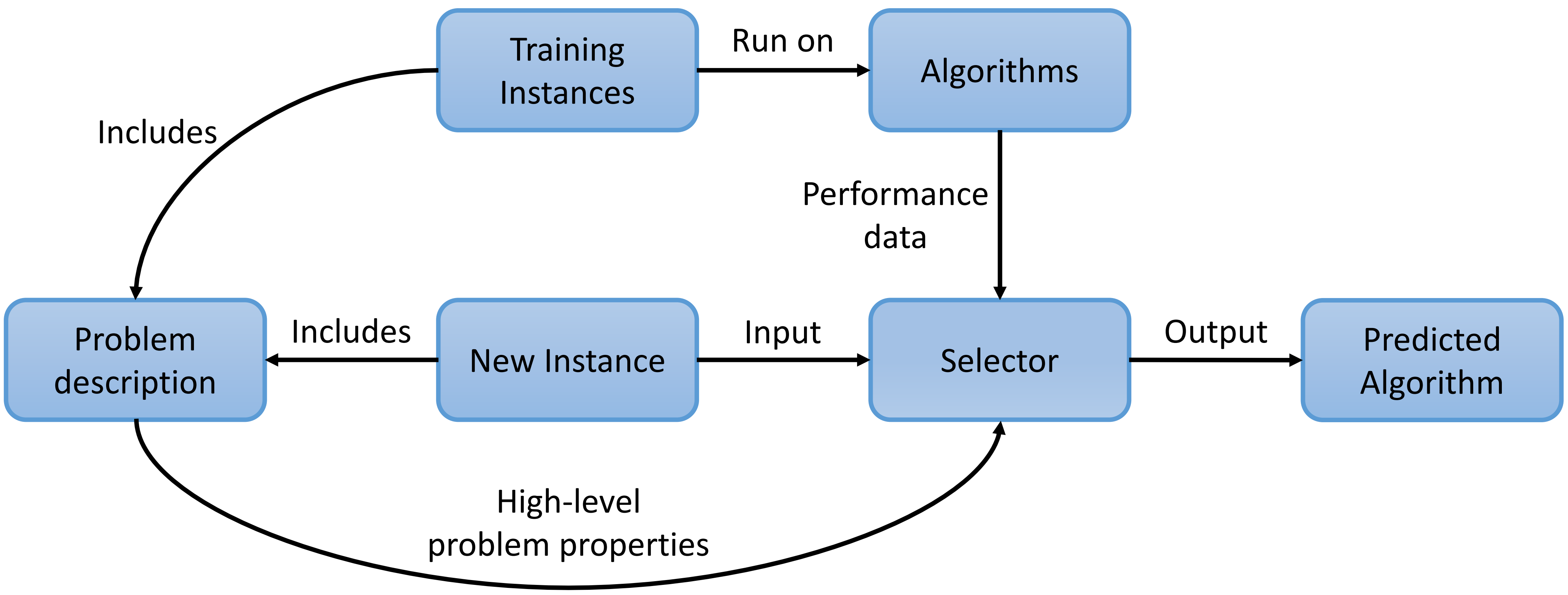
- Optimise a problem with unknown internals



- Use sampling strategy to find the optimum
  - Evolutionary algorithms
  - Bayesian optimisation
  - …

- No a priori instance specific → Costs function evaluations to compute
  - Description
  - Features

Per-class algorithm selection



Properties vs. features

- Features
  - Describe a problem instance
  - Differ across instances
  - Require function evaluations to determine

- Properties
  - Describe the higher level problem class or domain
  - Same across instances (in the same class/domain)
  - Known a priori

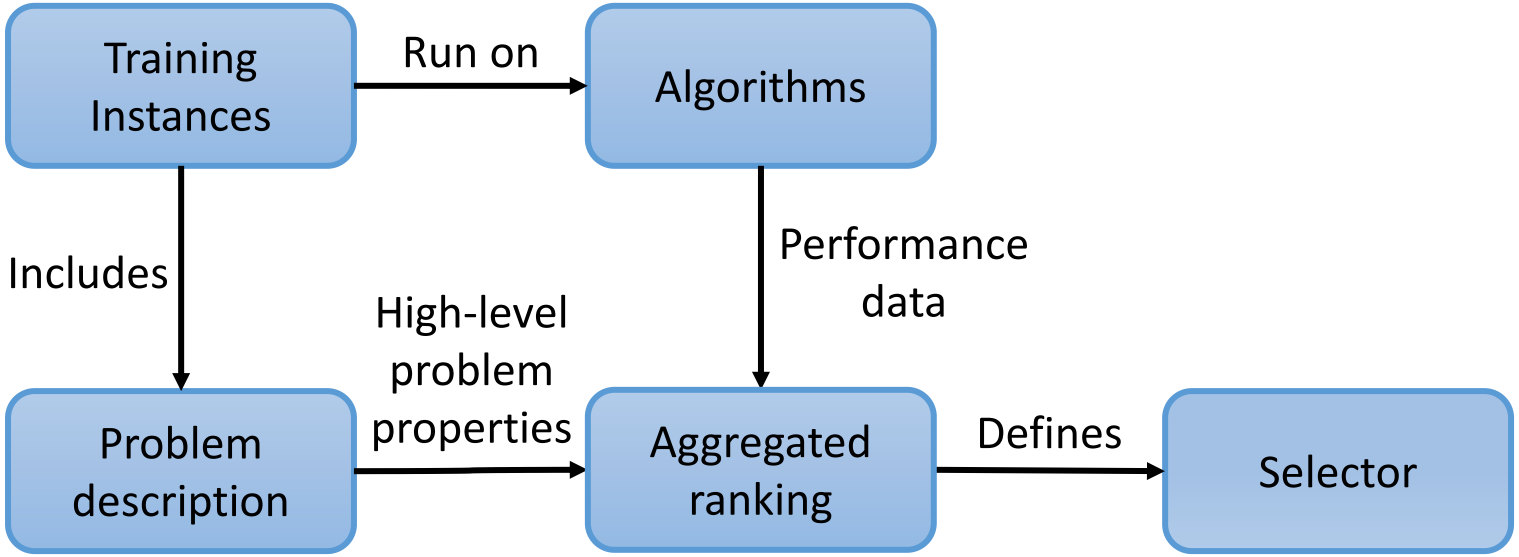
Pros and cons to per-class algorithm selection

- No per-instance selection, but for larger groups

- Pro
  - Free – Can make a decision before doing any evaluations
  - General – Don’t have to design features for each problem variant

- Con
  - Being less specific will usually mean lower performance

Data-driven selector – Basic idea



Considered problem properties

- Dimensions – Number of decision variables
- Budget – Number of function evaluations

- Properties we keep fixed
  - Variable type – Continuous
  - No constraints
  - No noise

Comparison

- NGOpt39 Nevergrad
  - Hand-designed competence map / selection wizard – “what is good where”
    [Meunier et al., TEVC 2022]

- Data-driven selector
  - Choose from the algorithms included in NGOpt39 based on performance data

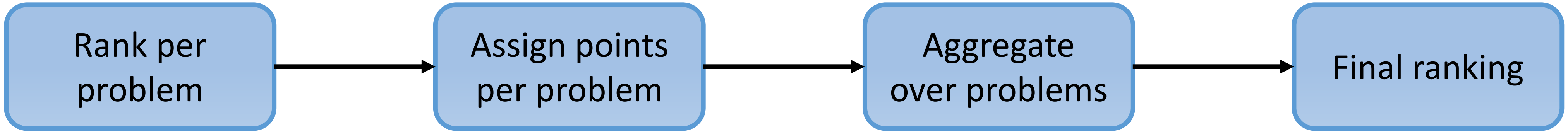
- Same algorithms + implementation, different selection method

Training

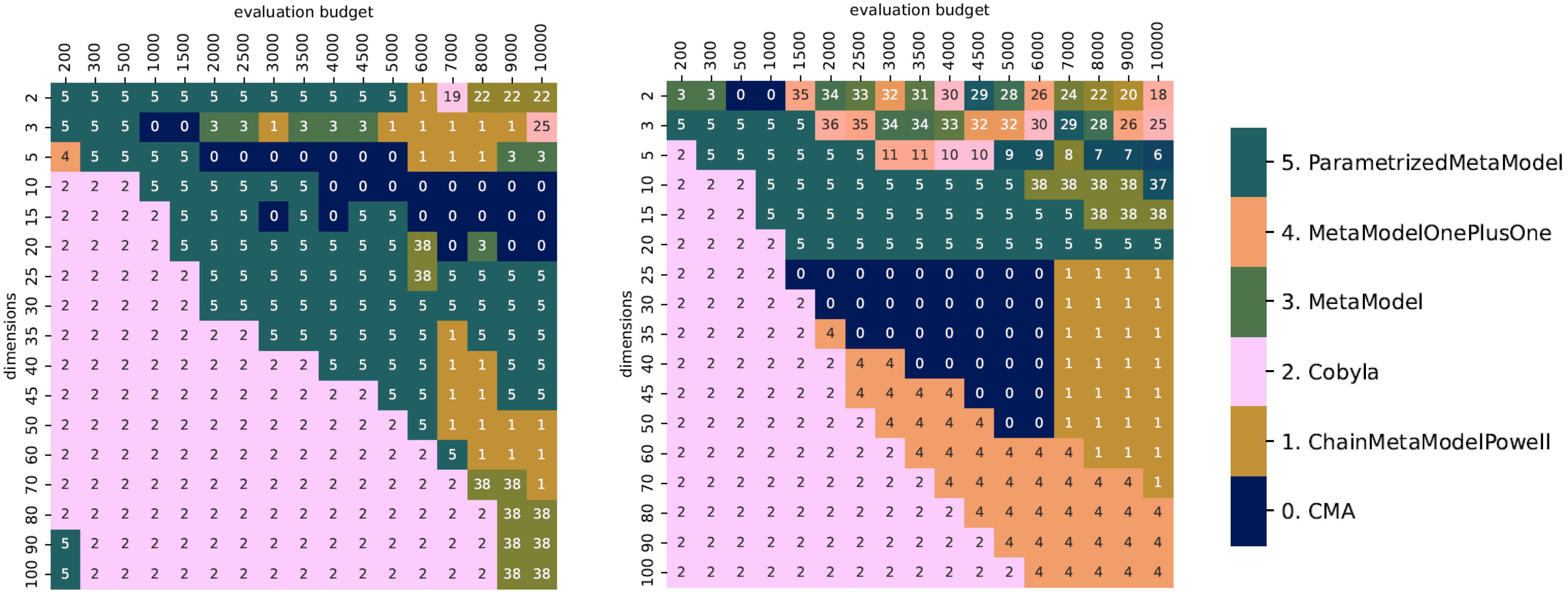
- Budgets: [1,…,<u>10000</u>]
- Dimensions: [1,…,100]
- Algorithms: All those used by NGOpt39 in this domain (34 total)
- Problems: 24 BBOB functions, instance 1, 25 repetitions each
  [Hansen et al. Tech. Rep. 2009]

Ranking

- Per budget-dimension pair
  - Give an algorithm 1 point for each run in the top 25 per problem
  - Runs below the top 25 tied with the 25^{th} best run are also awarded a point
  - Algorithm with most points is chosen for the budget-dimension pair



Data-driven vs. NGOpt39



Testing

- Budgets: [200, 300, 500, 1000, …, 5000, 6000, …, 10000]

- Dimensions: [2, 3, 5, 10, …, 50, 60, …, 100]

- Algorithms:
  - 5 per budget-dimension pair
  - All those chosen by NGOpt39, or in the top 4 performers (excluding NGOpt39)

- Problems: 828 MA-BBOB functions, 1 repetition each

MA-BBOB – Many affine combinations

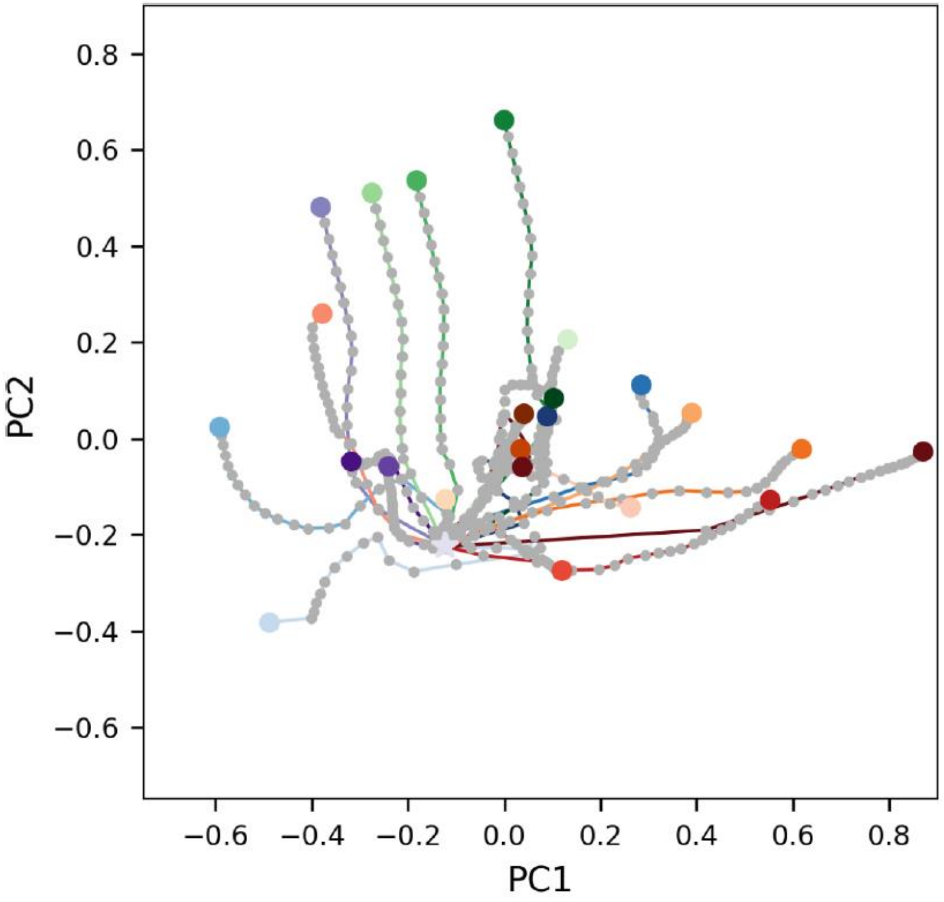


Fig. from [Dietrich and Mersmann, PPSN 2022]

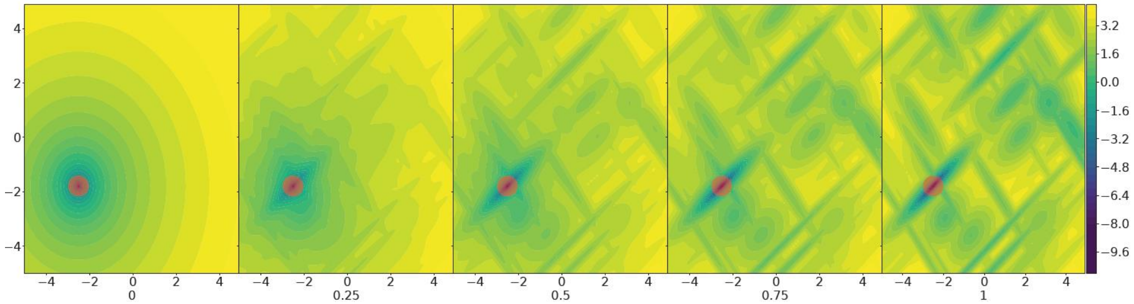
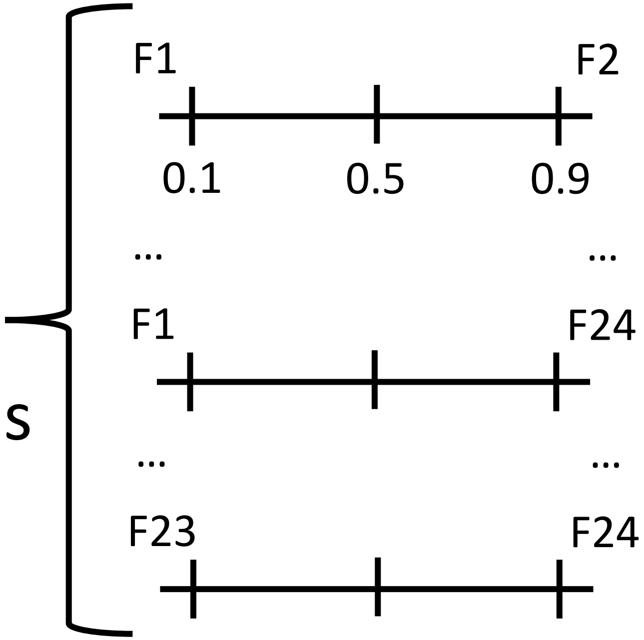


Fig. from [Vermetten et al., GECCO 2023]

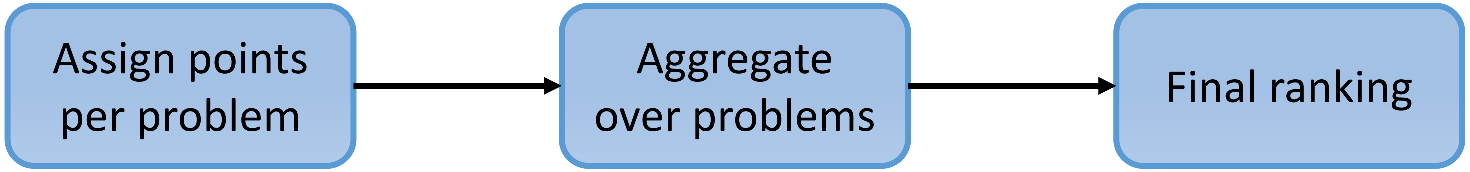
Our selection of combined BBOB functions



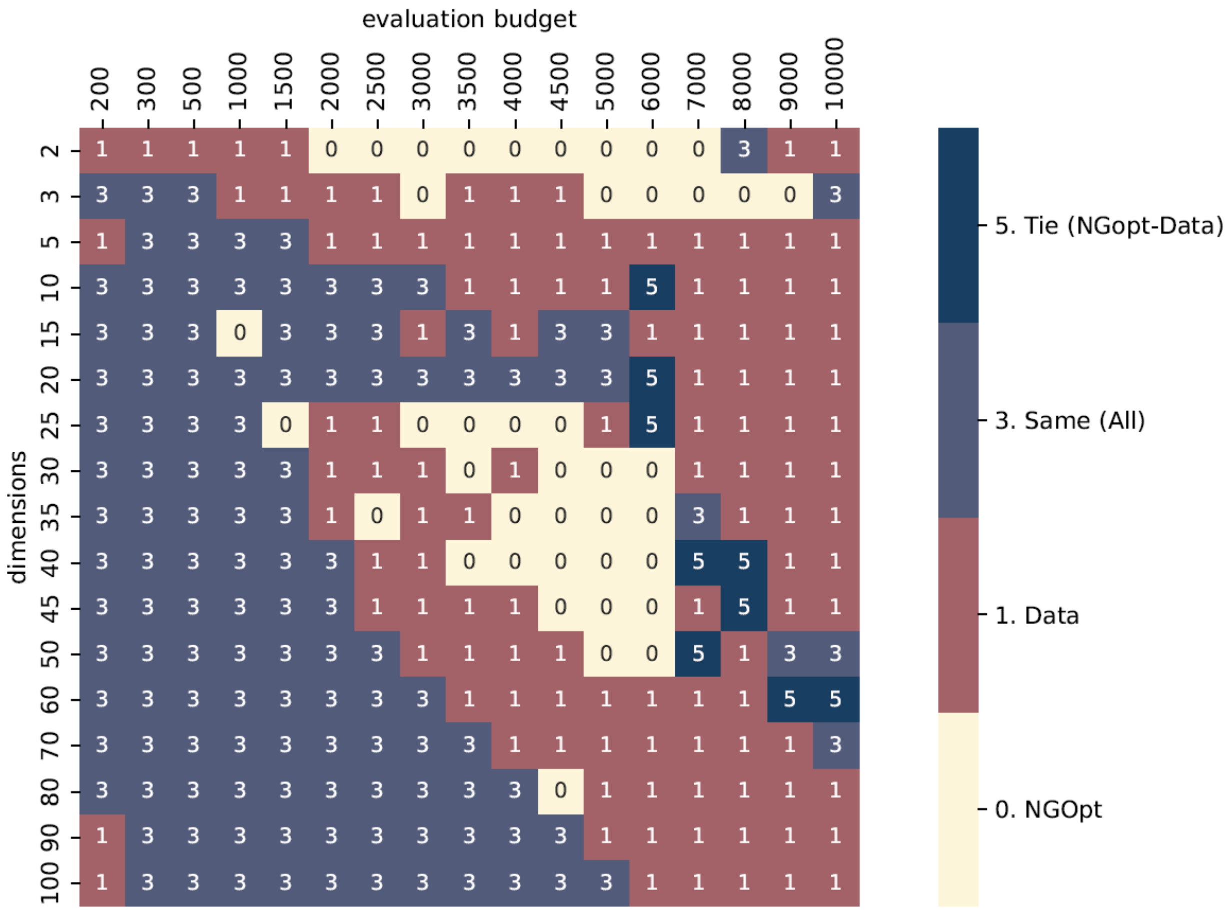
Test ranking

- One run per algorithm per problem

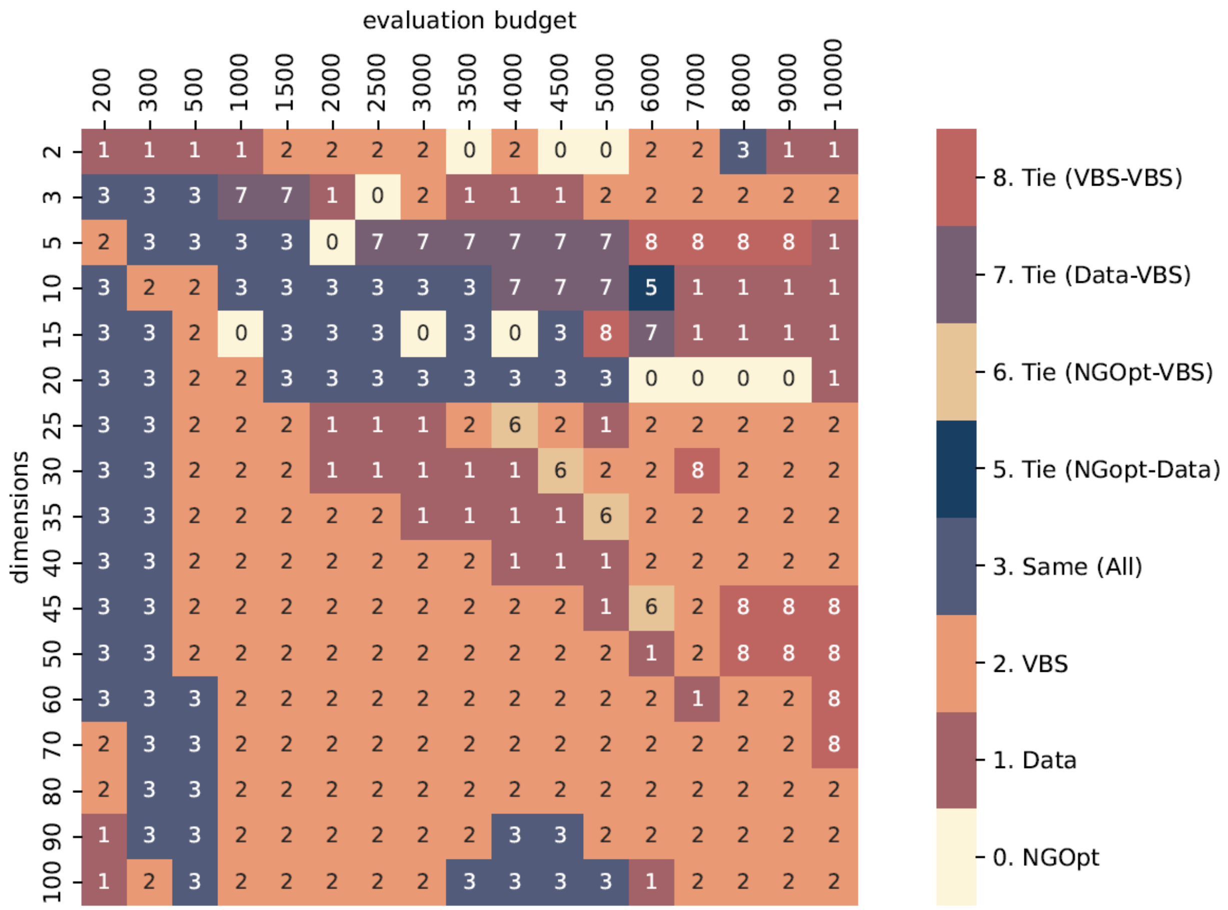
- Per budget-dimension pair
  - Give an algorithm 1 point for each problem where it is the best
  - Algorithms tied with the best algorithm on a problem also get a point
  - Algorithm with most points is chosen for the budget-dimension pair



Data-driven vs. NGOpt39 on MA-BBOB

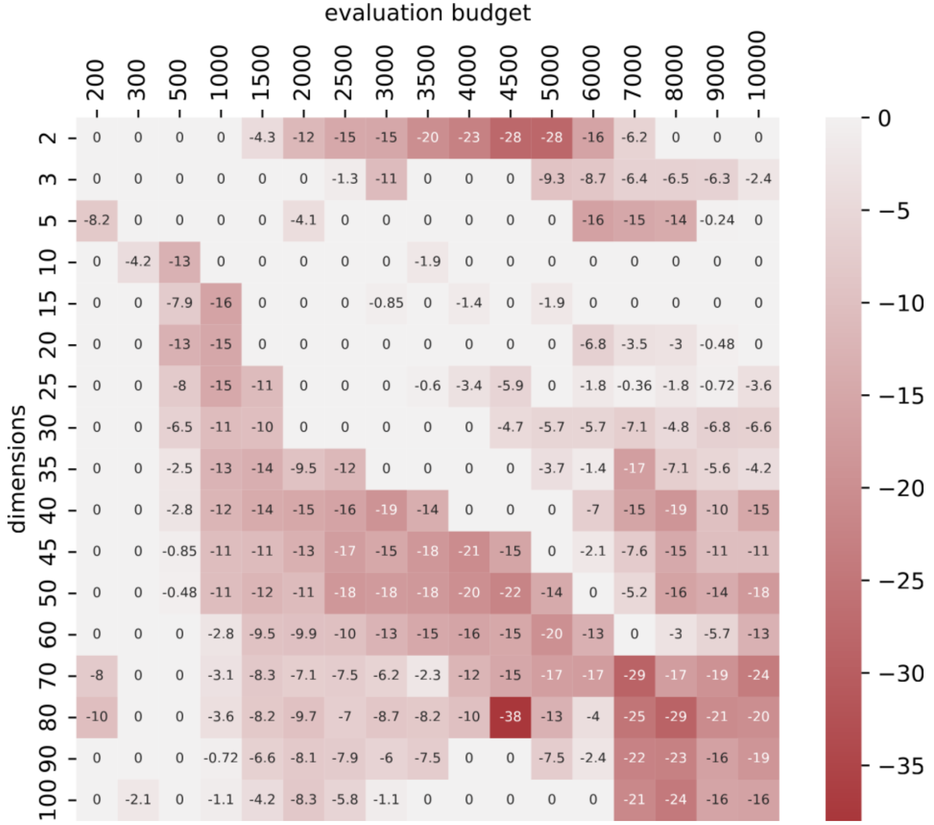


Wins compared to the VBS on MA-BBOB

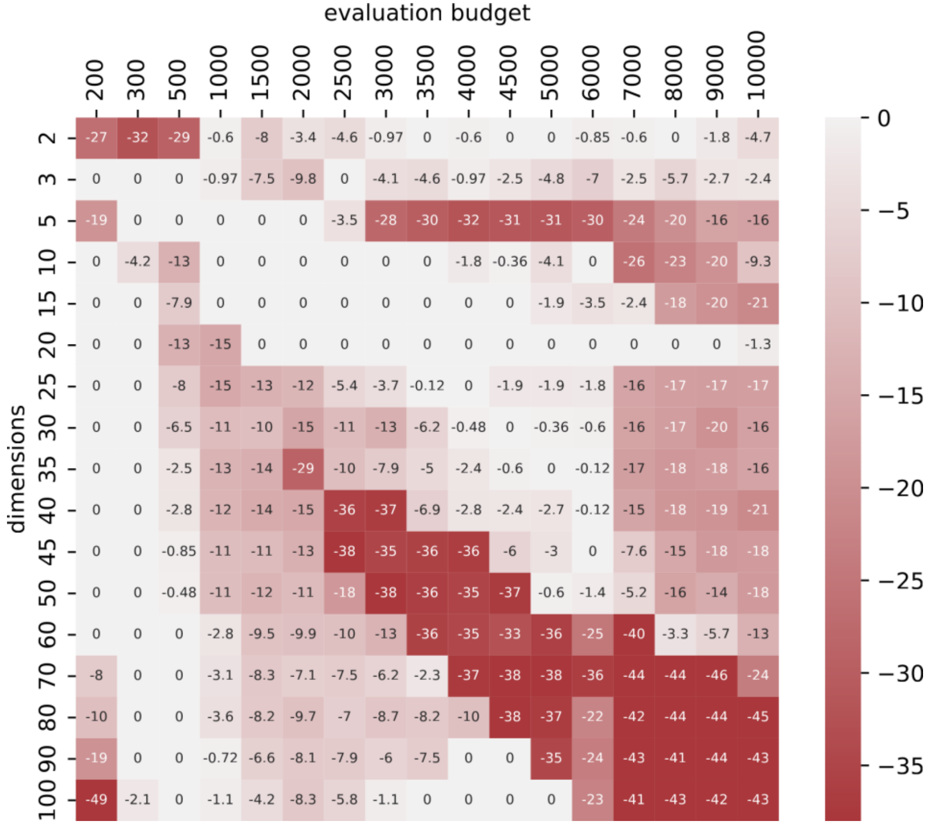


Loss to the VBS on MA-BBOB (% of problems)

Data-driven



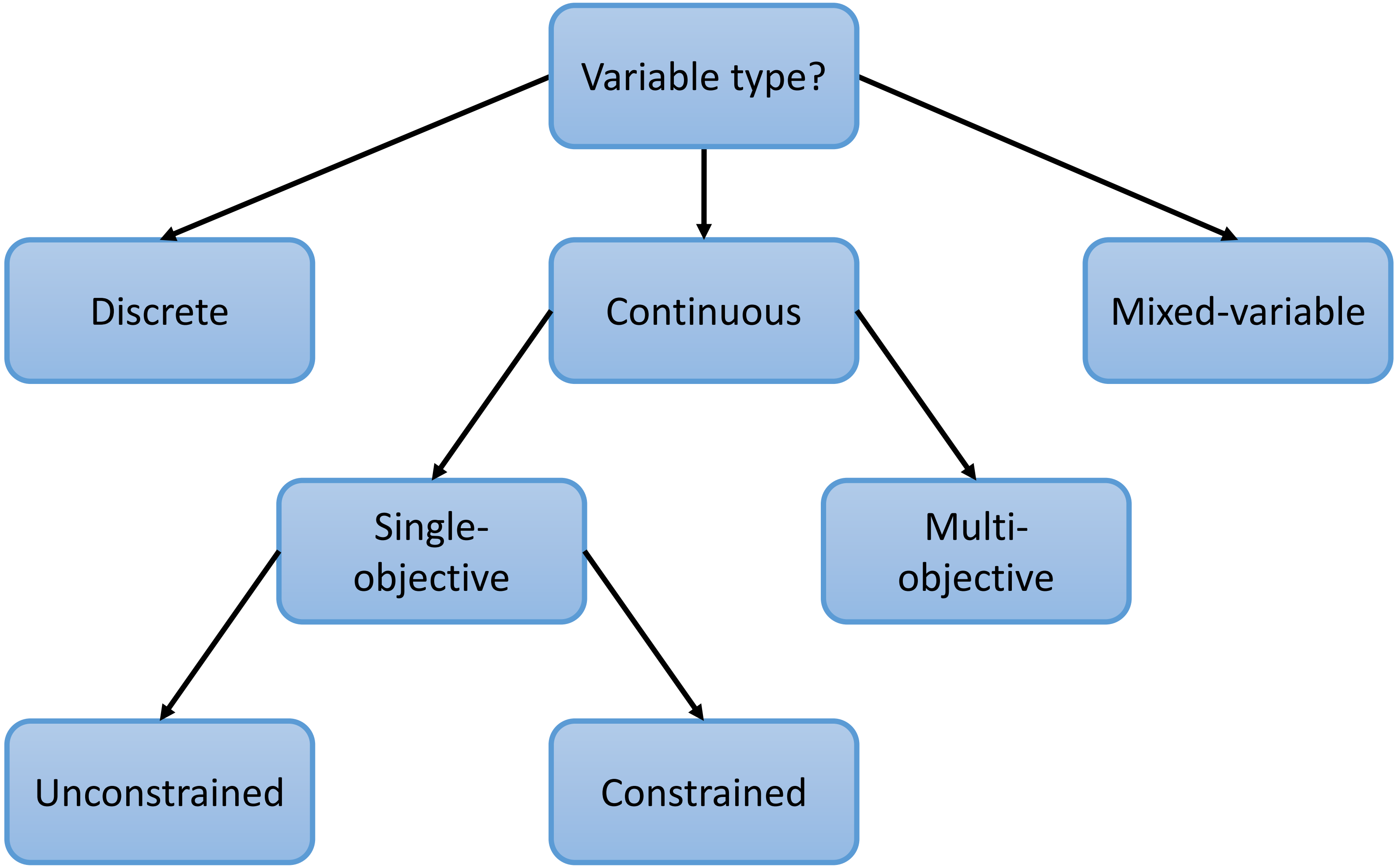
NGOpt39



Moving forward

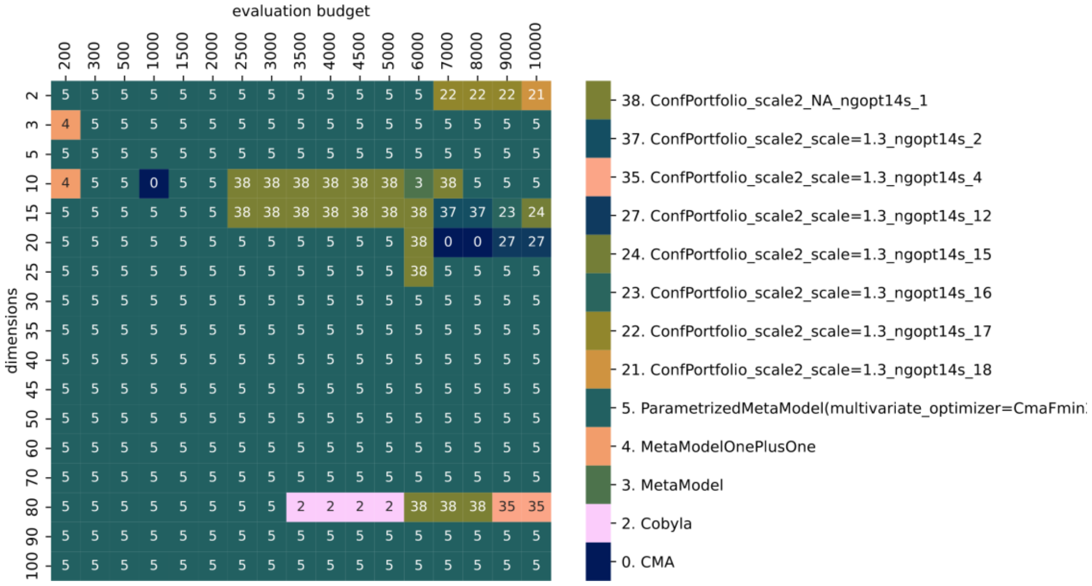
- Improve training instance set for generalisability
- Progressively add algorithms
- Evaluate different selection methods, e.g., for:
  - Worst case performance

Generalisation to other problem domains



Extension to grey-box setting

- Include user provided properties in the data-driven analysis
- Property needs to be known for the training data
- E.g., multimodal (F15-F24 in BBOB)



Take home

- Per-class algorithm selection for black-box optimisation works

- Data-driven system improves over hand-designed selectors

- General conceptual framework → No features, no problem
  - Problems with constraints, multiple objectives, … → No problem!

- Extendable to grey-box setting
  - Have a multimodal problem?
    → Selection based on multimodal problems in the data

References

- [Dietrich and Mersmann 2022] Dietrich, K., Mersmann, O. (2022). Increasing the Diversity of Benchmark Function Sets Through Affine Recombination. In: Rudolph, G., Kononova, A.V., Aguirre, H., Kerschke, P., Ochoa, G., Tušar, T. (eds) Parallel Problem Solving from Nature – PPSN XVII. PPSN 2022. Lecture Notes in Computer Science, vol 13398. Springer, Cham. https://doi.org/10.1007/978-3-031-14714-2_41
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