The Impact of Cost Metric on Algorithm Configuration

Furong Ye | The Joint Lectures on Evolutionary Algorithms (JoLEA)

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Background

- Furong Ye, postdoc at the Leiden Institute of Advanced Computer Science (LIACS), working for DACCOMPLI project (Auto-ML for time series analysis).
- Obtained my PhD degree from Leiden University, under supervision of Thomas Bäck, Carola Doerr (CNRS and Sorbonne Université, France), and Hao Wang
- Thesis: *Benchmarking Discrete Optimization Heuristics: from building a sound experimental environment to algorithm configuration*

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Algorithm Configuration

Determine a well-performing parameter configuration of a given algorithm for a given problem (or a set of problem instances)

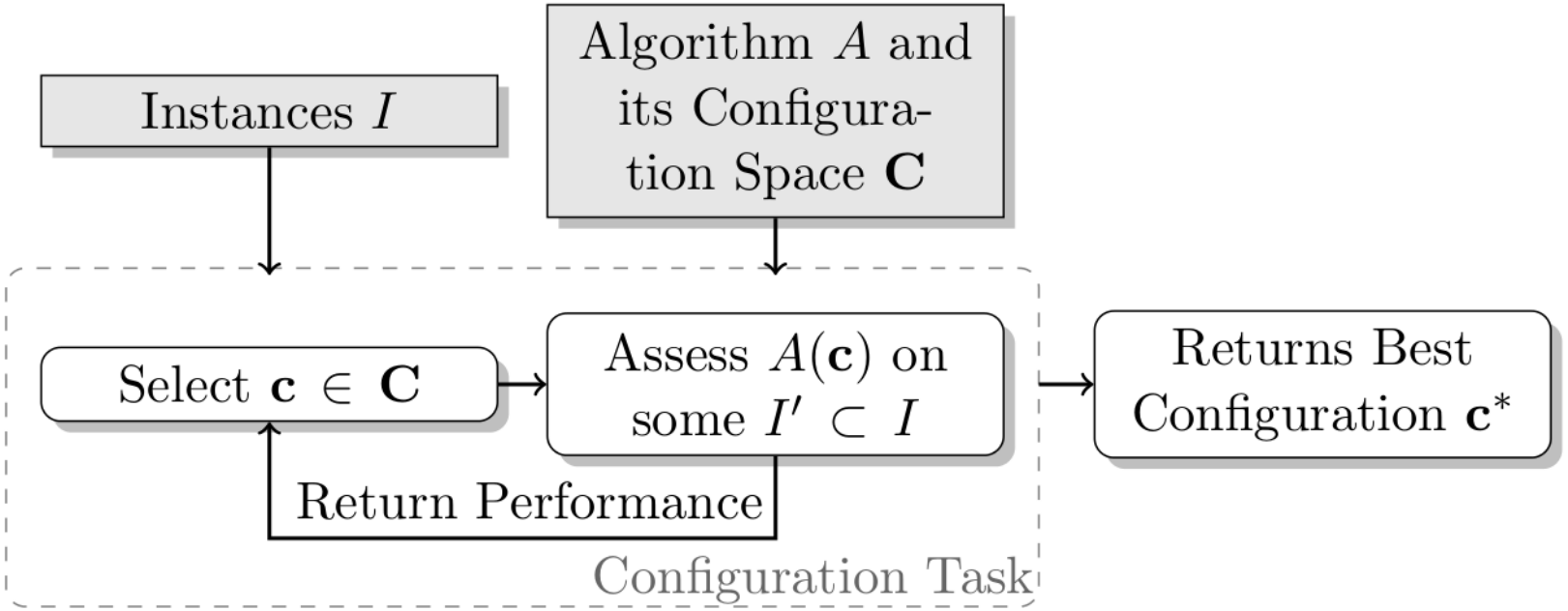
Parameterised algorithms

- Genetic Algorithms: population size, mutation rate, crossover probability, mutation operators, crossover operators, selection operators, …
- Artificial Neural Networks: number of layers, learning rate, momentum, training type, epoch, …
- Satisfiability Solvers, etc.

Algorithm Configurators

- Irace: https://iridia.ulb.ac.be/irace/
- MIP-EGO: https://github.com/wangronin/MIP-EGO
- SMAC: https://github.com/automl/SMAC3
- ParamILS: https://www.automl.org/automated-algorithm-design/algorithm-configuration/paramils/
- GGA: https://www.aaai.org/ocs/index.php/IJCAI/IJCAI15/paper/viewPaper/11435
- …

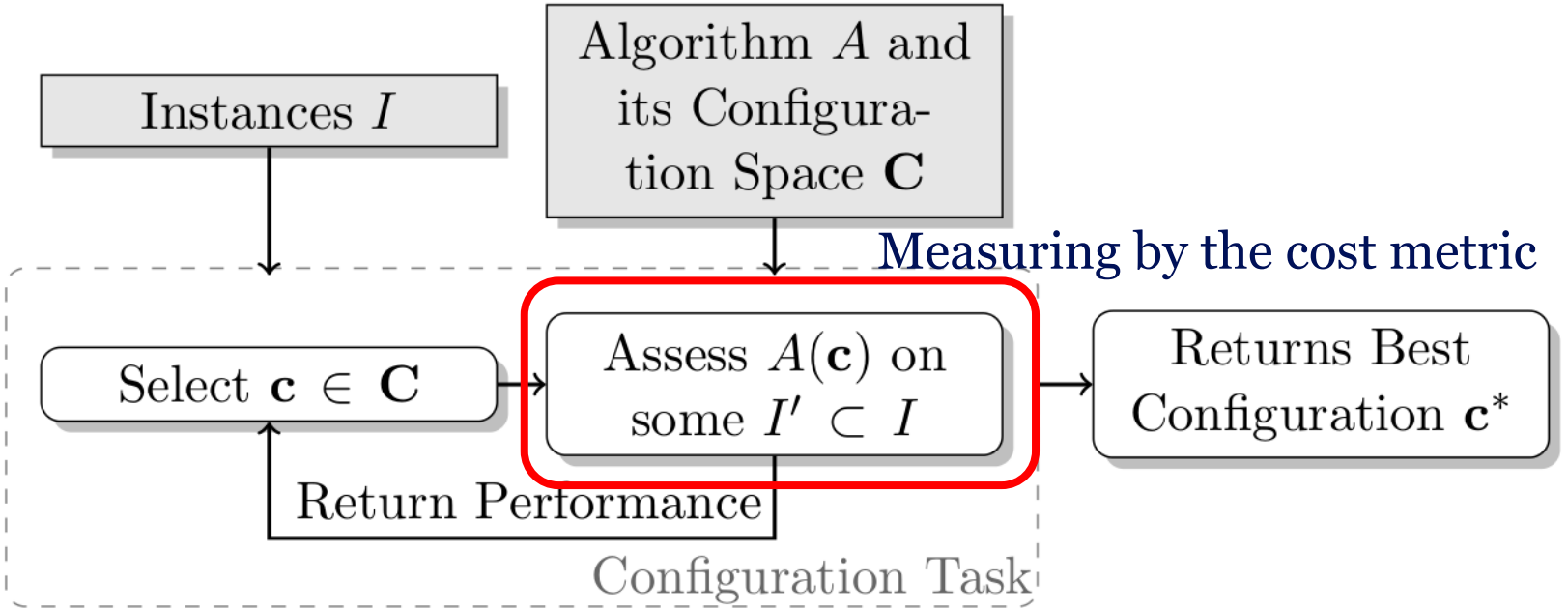
Algorithm Configuration



Workflow of Algorithm Configuration

The picture is taken from https://www.automl.org

Algorithm Configuration



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Cost Metric

- The optimisation time metric
  - How fast does an algorithm get a solution with required quality?

- The fitness-based metric
  - What solution quality can be achievend with a given budget?

The picture is taken from https://www.bradaronson.com/performance-measures/

Hall, G. T., Oliveto, P. S., & Sudholt, D. (2022). On the impact of the performance metric on efficient algorithm configuration. *Artificial Intelligence*, *303*, 103629.

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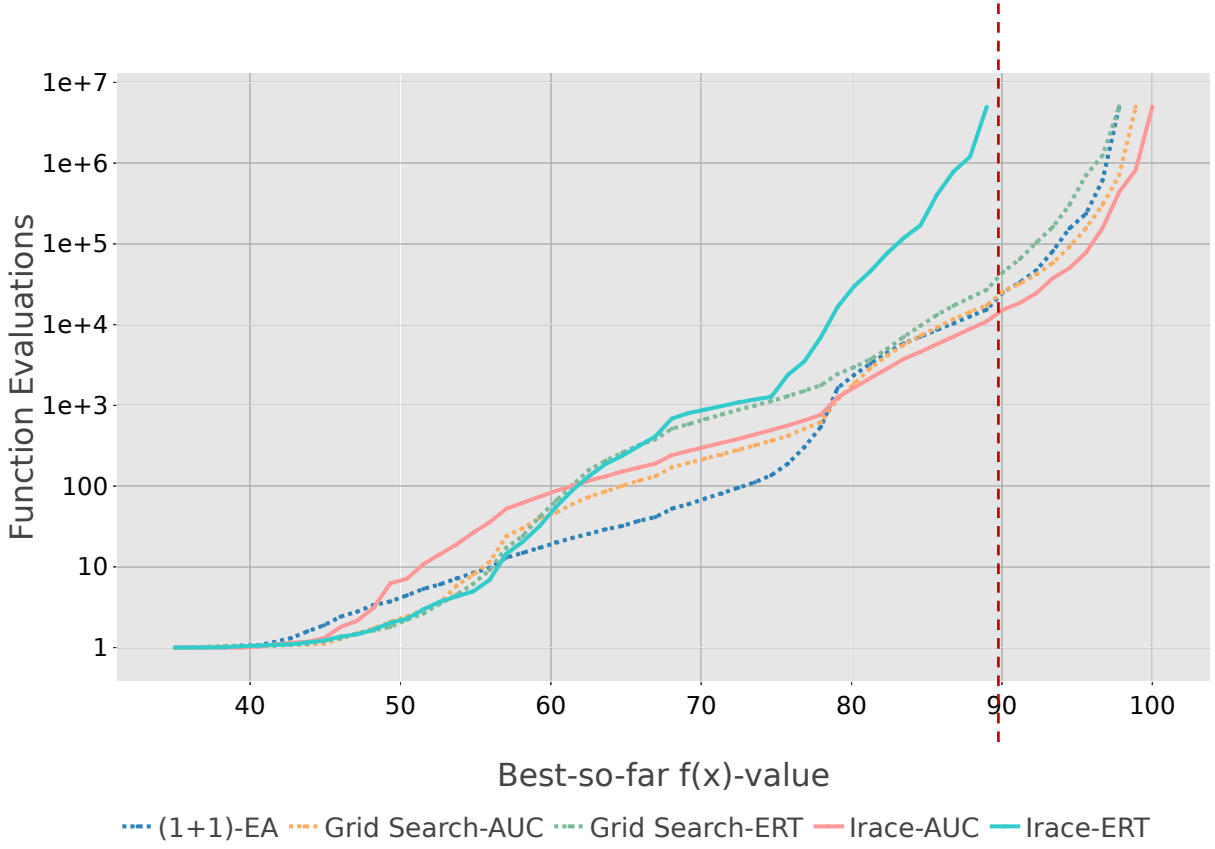
ERT

Expected runing time

Given a target value ϕ of problem P, the ERT value of the algorithm A given the budget of maximal function evaluations B for hitting ϕ is

$$\mathrm{ERT}(A, P, \phi) = \frac{\sum_{i=1}^{r} \min\{t_i(A, P, \phi), B\}}{\sum_{i=1}^{r} \mathbf{1}\{t_i(A, P, \phi) < \infty\}}$$



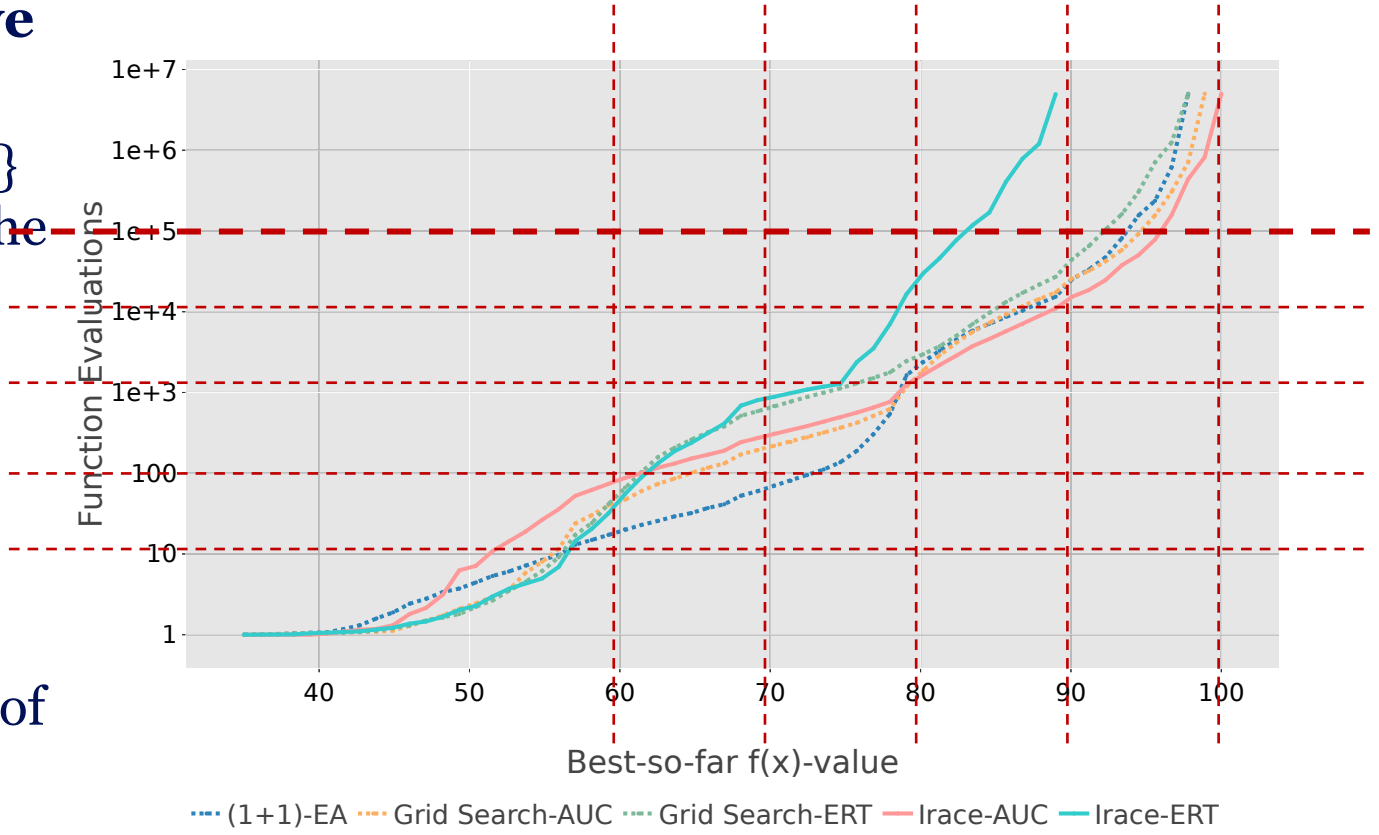
AUC

Area under the empirical cumulative distribution function

Given a target set $\Phi = \{\phi_i \in \mathbb{R} | \ i \in [1..m]\}$ and a budget set $T \in \{t_j \in \mathbb{N} \big| \ j \in [1..z]\}$, the AUC $\in [0,1]$ of algorithm A on problem P is

$$\mathrm{AUC}(A, P, \Phi, T) = \frac{\sum_{h=1}^{r} \sum_{i=1}^{m} \sum_{j=1}^{z} \mathbb{1}\{\phi_h(A, P, t_j) \geq \phi_i\}}{rmz}$$

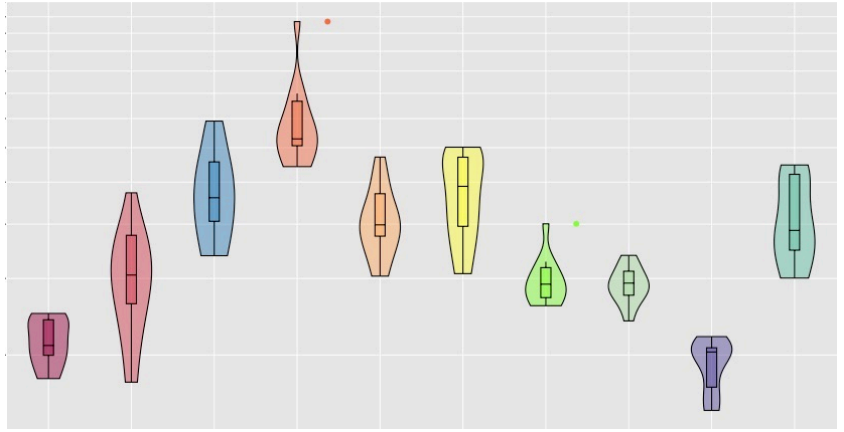
$\phi_h(A, P, t)$ denotes the best-found fitness of run h within the first t function evaluations, r is the number of independent runs



Two cost metrics

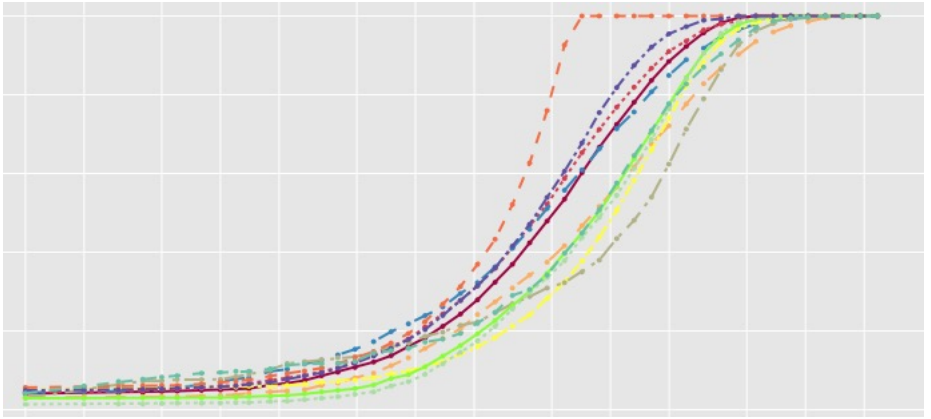
ERT – fixed-target performance

- concerns a single target value
- can be affected by the given budget



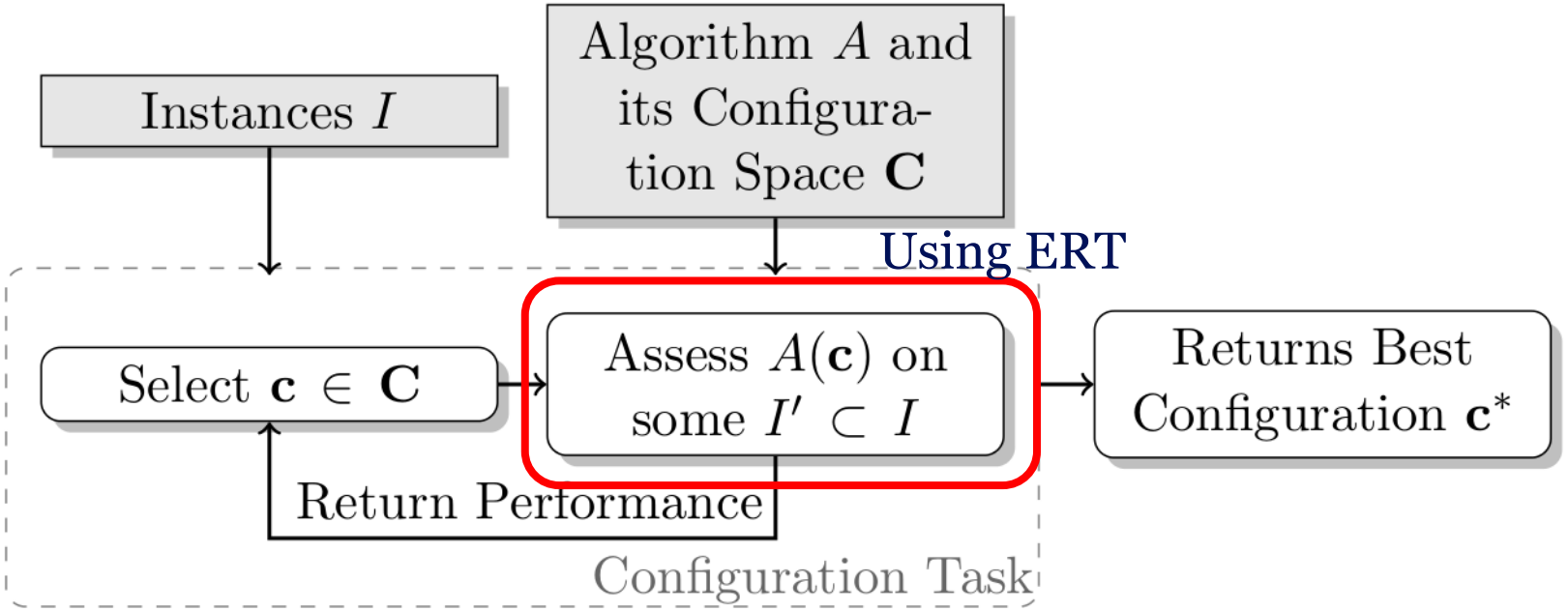
AUC – anytime performance

- concerns a set of target values
- concerns the performance across different used function evaluations



Goal: finding the algorithm configuration obtaining the best ERT

Algorithm Configuration



Workflow of Algorithm Configuration

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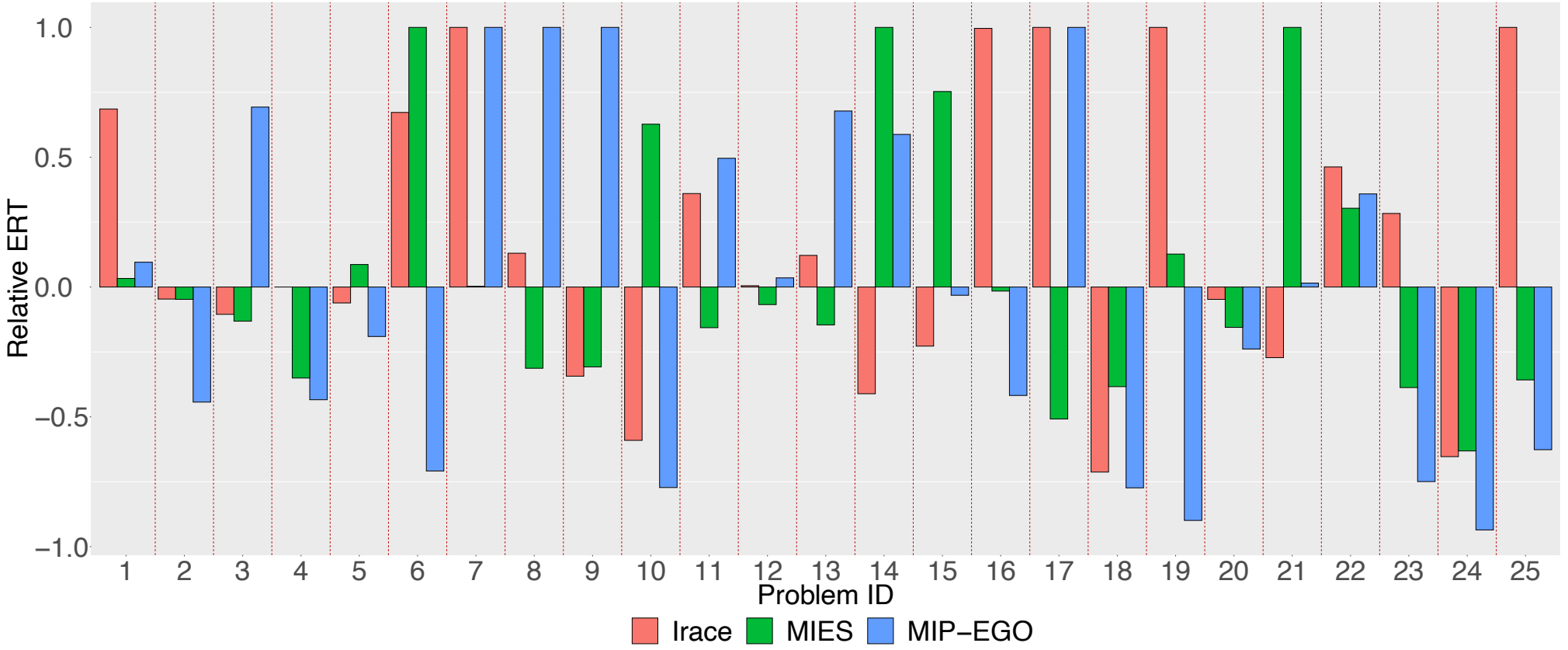
For some problems, tuning for AUC gives better ERT values than when directly tuning for ERT.

Ye, F., Doerr, C., Wang, H., & Bäck, T. (2022). Automated configuration of genetic algorithms by tuning for anytime performance. *IEEE Transactions on Evolutionary Computation*.

Comparison of the obtained genetic algorithm configurations between tuning for ERT and AUC

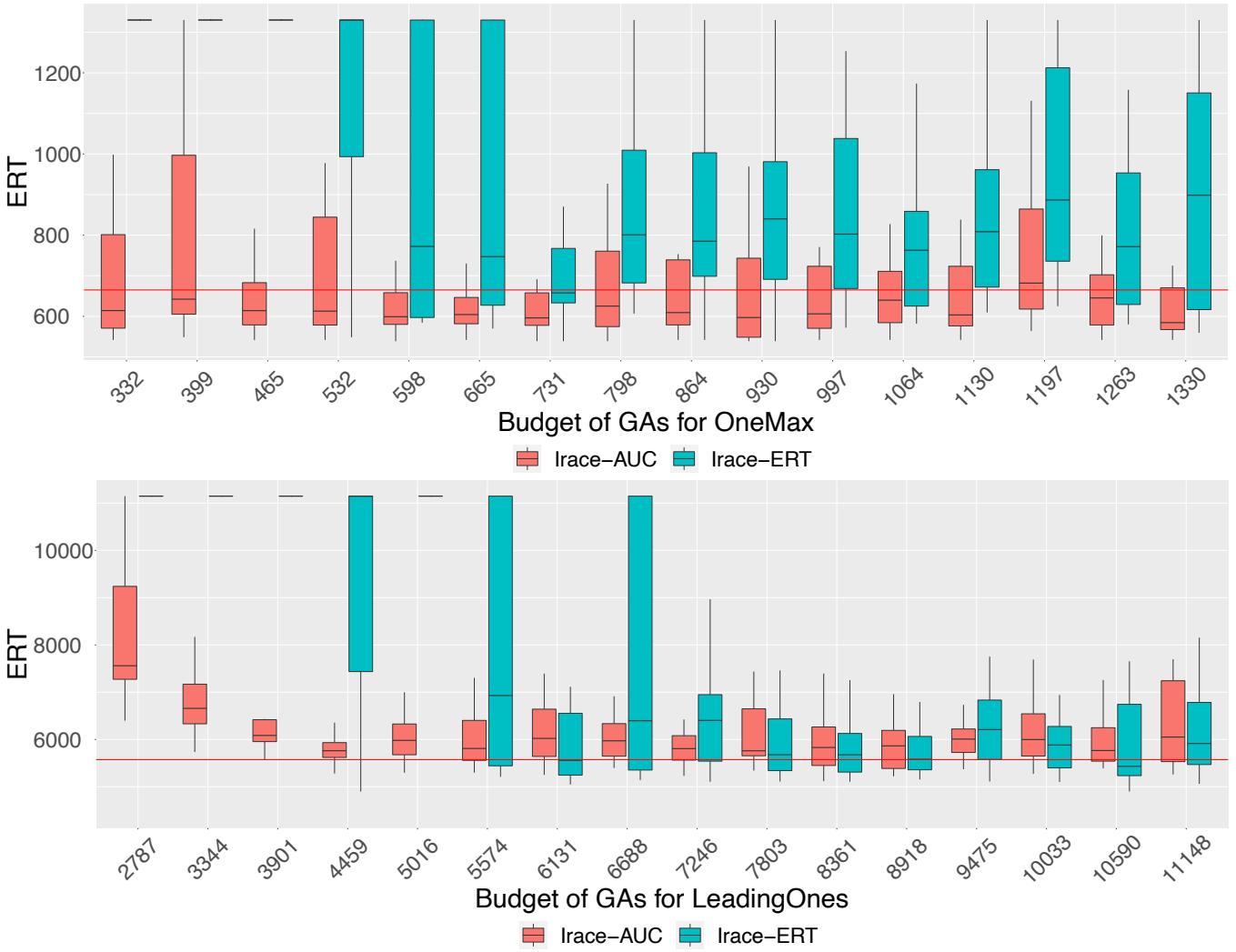
Positive results indicate that tuning for AUC performs better than tuning for ERT



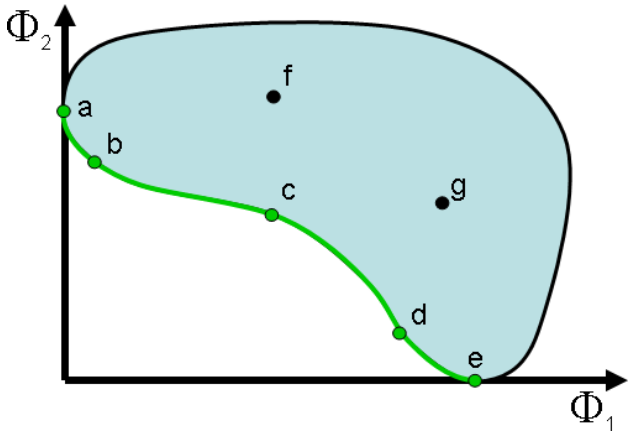
Detailed results: https://doi.org/10.5281/zenodo.4823492

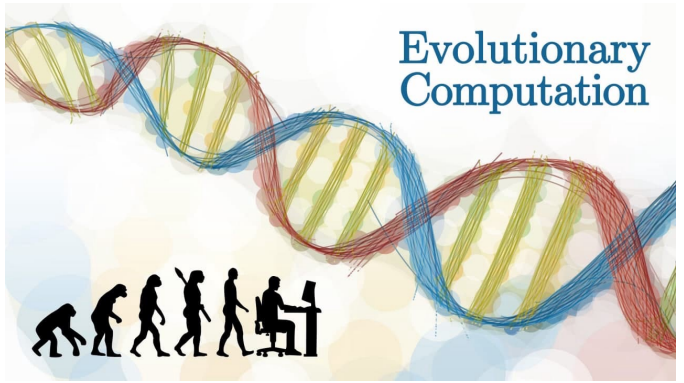
- For some problems, tuning for AUC gives better ERT values than when directly tuning for ERT.
- Using ERT as the cost metric is more sensitive to the given budget of algorithms, compared to using AUC

ERTs of the configurations obtained by Irace for OneMax and LeadingOnes.



Next steps





Bi-objective (multi-objective) Configuration

Pictures are taken from:
http://docs.ros.org/en/indigo/api/acado/html/example_008_1.png
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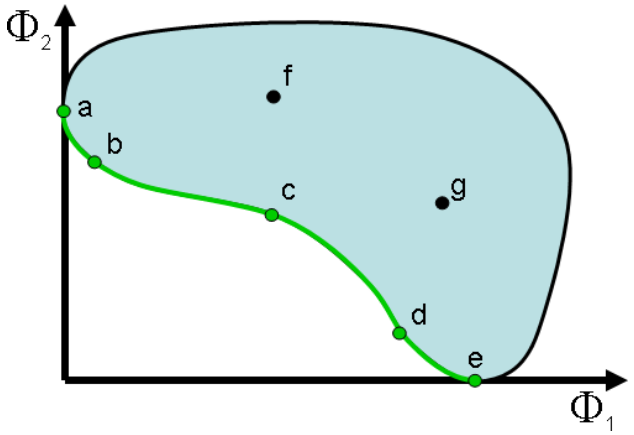
Next steps



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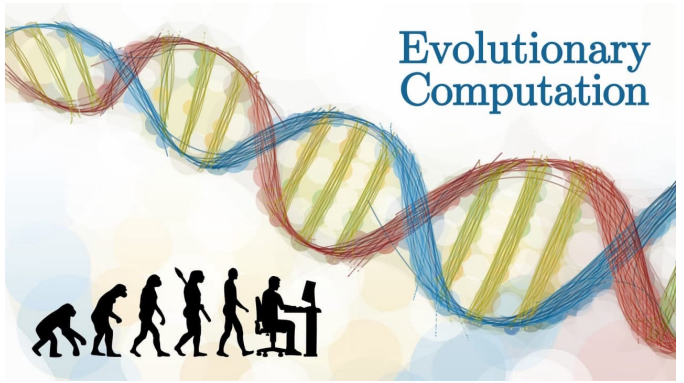

Better Configurators

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None of the algorithm configuration methods clearly outperforms all others.

For several problems, none of the methods can find configurations that outperform or perform on par with the (1+1) EA.

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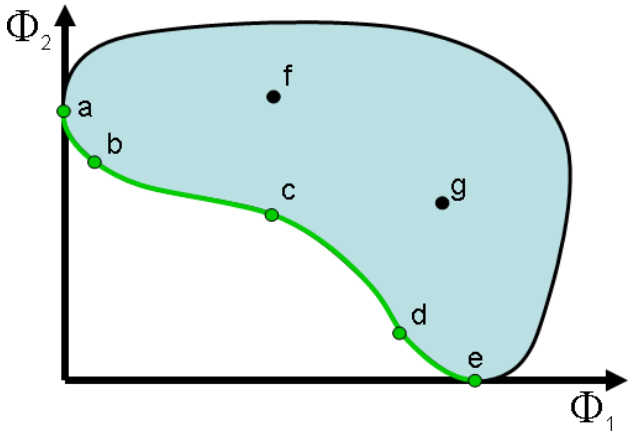
Better Configurators

- **Irace**
  - iterated racing
  - diverse selection
    - *Non-Elitist Selection among Survivor Configurations can Improve the Performance of Irace (PPSN 2022)*
- **SMAC, MIP-EGO**
  - Bayesian Optimization
- **ParamILS**
  - local search
- **Genetic Programming**

Next steps



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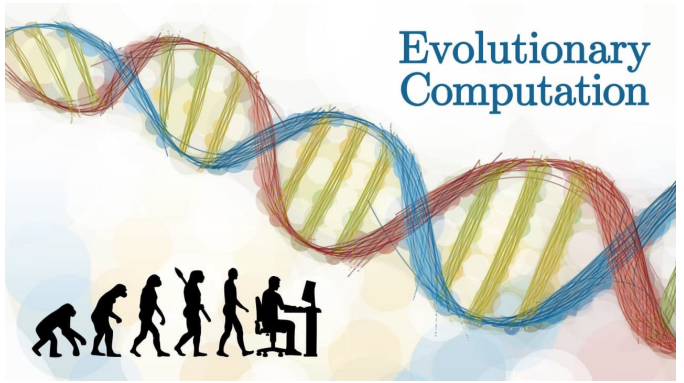

Better Configurators

AUTO-ML

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AUTO-ML

Pre-processing	Feature Engineering	Model Selection	Hyperparameter Optimization

Questions?

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