

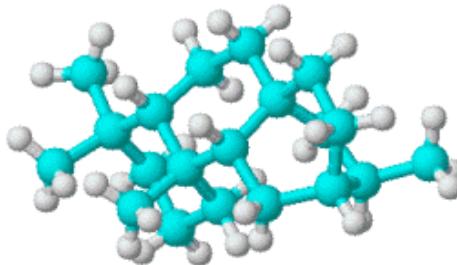
7th GECCO Workshop on Blackbox Optimization Benchmarking (BBOB): Welcome and Introduction to COCO/BBOB

The BBOBies

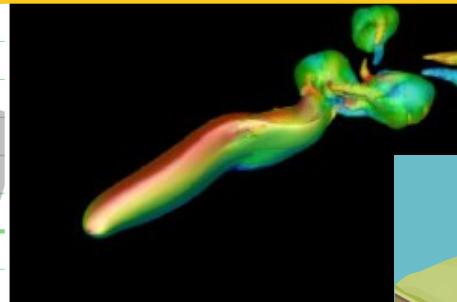
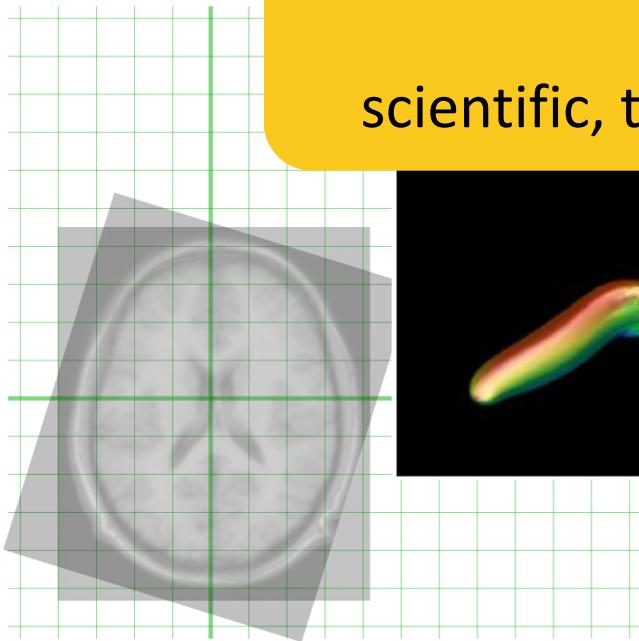
<https://github.com/numbbo/coco>



slides based on previous ones by A. Auger, N. Hansen, and D. Brockhoff

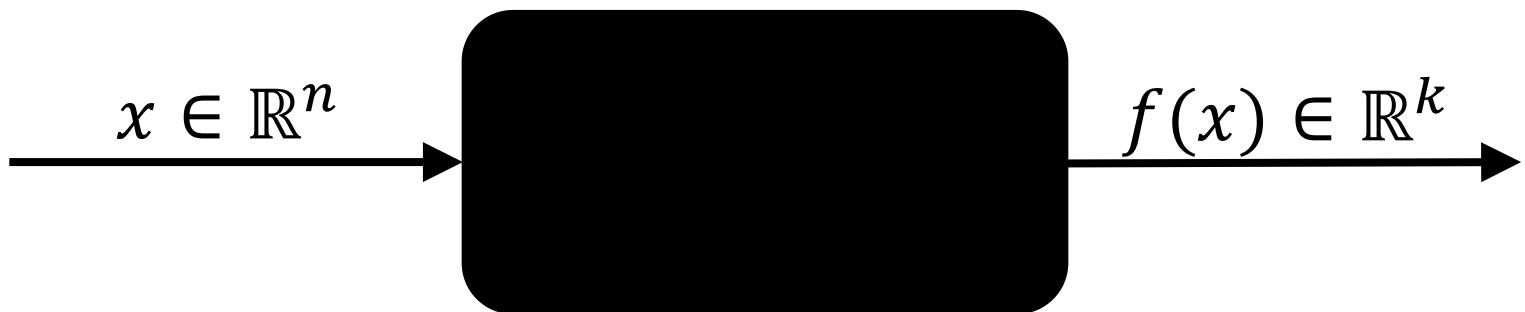


challenging optimization problems
appear in many
scientific, technological and industrial domains



Numerical Blackbox Optimization

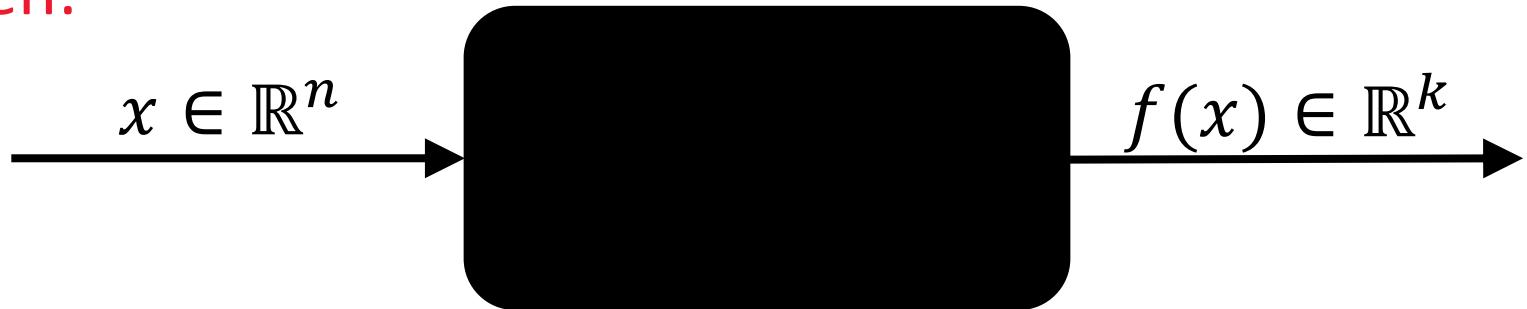
Optimize $f: \Omega \subset \mathbb{R}^n \mapsto \mathbb{R}^k$



derivatives not available or not useful

Practical Blackbox Optimization

Given:



Not clear:

which of the many algorithms should I use on my problem?

Numerical Blackbox Optimizers

Deterministic algorithms

Quasi-Newton with estimation of gradient (BFGS) [Broyden et al. 1970]

Simplex downhill [Nelder & Mead 1965]

Pattern search [Hooke and Jeeves 1961]

Trust-region methods (NEWUOA, BOBYQA) [Powell 2006, 2009]

Stochastic (randomized) search methods

Evolutionary Algorithms (continuous domain)

- Differential Evolution [Storn & Price 1997]
- Particle Swarm Optimization [Kennedy & Eberhart 1995]
- **Evolution Strategies, CMA-ES** [Rechenberg 1965, Hansen & Ostermeier 2001]
- Estimation of Distribution Algorithms (EDAs) [Larrañaga, Lozano, 2002]
- Cross Entropy Method (same as EDA) [Rubinstein, Kroese, 2004]
- [Holland 1975, Goldberg 1989]

Simulated annealing [Kirkpatrick et al. 1983]

Simultaneous perturbation stochastic approx. (SPSA) [Spall 2000]

Numerical Blackbox Optimizers

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- choice typically not immediately clear
- although practitioners have knowledge about which difficulties their problem has (e.g. multi-modality, non-separability, ...)

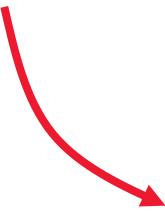
Need: Benchmarking

- understanding of algorithms
- algorithm selection
- putting algorithms to a standardized test
 - simplify judgement
 - simplify comparison
 - regression test under algorithm changes

Kind of everybody has to do it (and it is tedious):

- choosing (and implementing) problems, performance measures, visualization, stat. tests, ...
- running a set of algorithms

that's where COCO and BBOB come into play



Comparing Continuous Optimizers Platform

<https://github.com/numbbo/coco>

automatized benchmarking

How to benchmark algorithms with COCO?

<https://github.com/numbbo/coco>

Screenshot of a GitHub repository page for 'numbbo/coco'.

The page shows the following details:

- Repository Name:** numbbo / coco
- Issues:** 133
- Pull requests:** 1
- Projects:** 9
- Settings:** Settings
- Insights:** Insights

The main content area displays the following information:

- Commits:** 16,007
- Branches:** 11
- Releases:** 31
- Contributors:** 15

A red box highlights the **Clone or download** button in the top right corner of the commit list header.

The commit list shows the following recent commits:

Commit	Message	Date
brockho committed on GitHub	Merge pull request #1352 from numbbo/development	Latest commit 4b1497a on 20 Apr
code-experiments	A little more verbose error message when suite regression test fails	a month ago
code-postprocessing	Hashes are back on the plots.	a month ago
code-preprocessing	Fixed preprocessing to work correctly with the extended biobjective s...	3 months ago
howtos	Update create-a-suite-howto.md	4 months ago
.clang-format	raising an error in bbbob2009_logger.c when best_value is NULL. Plus s...	2 years ago
.hgignore	raising an error in bbbob2009_logger.c when best_value is NULL. Plus s...	2 years ago
AUTHORS	small correction in AUTHORS	a year ago
LICENCE	Update LICENCE	11 months ago

<https://github.com/numbbo/coco>

The screenshot shows the GitHub repository page for `numbbo/coco`. The top navigation bar includes links for "Most Visited", "Getting Started", "COCO-Algorithms", "numbbo/numbbo", "RandOpt", "CMAP", "Inria GitLab", and "RER B from lab". The repository header shows "16,007 commits", "11 branches", "31 releases", and "15 contributors". A dropdown menu for "Clone with HTTPS" is open, showing the URL `https://github.com/numbbo/coco.git` and a red box highlighting the "Download ZIP" button, which was last updated "4 months ago".

GitHub, Inc. (US) | https://github.com/numbbo/coco

This repository Search Pull requests Issues Marketplace Gist

Unwatch 15 Unstar 38 Fork 24

Code Issues 133 Pull requests 1 Projects 9 Settings Insights

Numerical Black-Box Optimization Benchmarking Framework <http://coco.gforge.inria.fr/>

Add topics

16,007 commits 11 branches 31 releases 15 contributors

Branch: master New pull request Create new file Upload files Find file Clone or download

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AUTHORS small correction in AUTHORS

LICENSE Update LICENSE

Clone with HTTPS Use SSH
https://github.com/numbbo/coco.git

Open in Desktop Download ZIP 4 months ago

2 years ago 2 years ago a year ago 11 months ago

https://github.com/numbbo/coco

The screenshot shows a GitHub repository page for 'numbbo/coco'. The repository has 16,007 commits, 11 branches, 31 releases, and 15 contributors. A dropdown menu is open over a commit, specifically for commit #1352 by brockho, which merges a pull request from 'numbbo/development'. The dropdown includes options for 'Clone with HTTPS' (selected), 'Use SSH', 'Open in Desktop', and 'Download ZIP'. The 'Download ZIP' button is highlighted with a red rectangle. The commit was made 4 months ago. The commit message indicates a fix for a verbose error message in a regression test and updates to howto files.

Numerical Black-Box Optimization Benchmarking Framework <http://coco.gforge.inria.fr/>

Add topics

Branch: master ▾ New pull request Create new file Upload files Find file Clone or download ▾

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numbbo/coco: Comparing Continuous Optimizers

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Most Visited Getting Started COCO-Algorithms [numbbo/numbbo · Gi...](#) RandOpt CMAP Inria GitLab RER B from lab

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This code reimplements the original Comparing Continuous Optimizer platform, now rewritten fully in `ANSI c` with other languages calling the `c` code. As the name suggests, the code provides a platform to benchmark and compare continuous optimizers, AKA non-linear solvers for numerical optimization. Languages currently available are

- `C/C++`
- `Java`
- `MATLAB/Octave`

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Contributions to link further languages (including a better example in C++) are more than welcome.

For more information,

- read our [benchmarking guidelines introduction](#)
- read the [COCO experimental setup description](#)

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- see the [bbob-biobj](#) and [bbob-biobj-ext](#) COCO multi-objective functions testbed documentation and the [specificities of the performance assessment for the bi-objective testbeds](#).
- consult the [BBOB workshops series](#),
- consider to [register here](#) for news,
- see the previous COCO home page [here](#) and
- see the [links below](#) to learn more about the ideas behind CoCo.

<https://github.com/numbbo/coco>

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Getting Started

0. Check out the [Requirements](#) above.
1. Download the COCO framework code from github,
 - either by clicking the [Download ZIP button](#) and unzip the `zip` file,
 - or by typing `git clone https://github.com/numbbo/coco.git`. This way allows to remain up-to-date easily (but needs `git` to be installed). After cloning, `git pull` keeps the code up-to-date with the latest release.

The record of official releases can be found [here](#). The latest release corresponds to the [master branch](#) as linked above.

2. In a system shell, `cd` into the `coco` or `coco-<version>` folder (framework root), where the file `do.py` can be found.
Type, i.e. execute, one of the following commands once

```
python do.py run-c  
python do.py run-java  
python do.py run-matlab  
python do.py run-octave  
python do.py run-python
```

depending on which language shall be used to run the experiments. `run-*` will build the respective code and run the example experiment once. The build result and the example experiment code can be found under `code-experiments/build /<language>` (`<language>=matlab` for Octave). `python do.py` lists all available commands.

3. On the computer where experiment data shall be post-processed, run

```
python do.py install-postprocessing
```

requirements & download

<https://github.com/numbbo/coco>

The screenshot shows a web browser window with the URL <https://github.com/numbbo/coco> in the address bar. The page content is the 'Getting Started' section of the COCO repository. It contains the following steps:

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A red callout box highlights the command `python do.py run-c`.

installation I: experiments

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3. On the computer where experiment data shall be stored, run:

`python do.py install-postprocessing`

installation II: postprocessing

to (user-locally) install the post-processing. From here on, `do.py` has done its job and is only needed again for updating the builds to a new release.

4. Copy the folder `code-experiments/build/YOUR-FAVORITE-LANGUAGE` and its content to another location. In Python it is sufficient to copy the file `example_experiment.py`. Run the example experiment (it already is compiled). As the details vary, see the respective read-me's and/or example experiment files:

- C [read me](#) and [example experiment](#)
- Java [read me](#) and [example experiment](#)
- Matlab/Octave [read me](#) and [example experiment](#)
- Python [read me](#) and [example experiment](#)

If the example experiment runs, connect your favorite algorithm to Coco: replace the call to the random search optimizer in the example experiment file by a call to your algorithm (see above). Update the output `result_folder`, the `algorithm_name` and `algorithm_info` of the observer options in the example experiment file.

Another entry point for your own experiments can be the `code-experiments/examples` folder.

5. Now you can run your favorite algorithm on the `bbob` suite (for single-objective algorithms) or on the `bbob-biobj` and `bbob-biobj-ext` suites (for multi-objective algorithms). Output is automatically generated in the specified data `result_folder`. By now, more suites might be available, see below.

<https://github.com/numbbo/coco>

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coupling algo + COCO

example_experiment.c (slightly simplified)

```
/* Iterate over all problems in the suite */
while ((PROBLEM = coco_suite_get_next_problem(suite, observer)) != NULL)
{
    size_t dimension = coco_problem_get_dimension(PROBLEM);

    /* Run the algorithm at least once */
    for (run = 1; run <= 1 + INDEPENDENT_RESTARTS; run++) {

        size_t evaluations_done = coco_problem_get_evaluations(PROBLEM);
        long evaluations_remaining =
            (long) (dimension * BUDGET_MULTIPLIER) - (long)evaluations_done;

        if (... || (evaluations_remaining <= 0))
            break;

        my_random_search(evaluate_function, dimension,
                         coco_problem_get_number_of_objectives(PROBLEM),
                         coco_problem_get_smallest_values_of_interest(PROBLEM),
                         coco_problem_get_largest_values_of_interest(PROBLEM),
                         (size_t) evaluations_remaining,
                         random_generator);
    }
}
```

numbbo/coco at develop... + GitHub, Inc. (US) https://github.com/numbbo/coco/tree/development Search Most Visited Getting Started COCO-Algorithms numbbo/numbbo · Gi... RandOpt CMAP Inria GitLab RER B from lab Another entry point for your own experiments can be the `code-experiments/examples` folder.

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6. Postprocess the data from the results folder by typing

```
python -m cocopp [-o OUTPUT_FOLDERNAME] YOURDATA
```

running the experiment

Any subfolder in the folder arguments will be searched for different folders collected under a single "root" `YOURDATAFOLDER` folder. We can also compare more than one algorithm by specifying several data result folders generated by different algorithms.

A folder, `ppdata` by default, will be generated, which contains all output from the post-processing, including an `index.html` file, useful as main entry point to explore the result with a browser. Data might be overwritten, it is therefore useful to change the output folder name with the `-o OUTPUT_FOLDERNAME` option.

A summary pdf can be produced via LaTeX. The corresponding templates can be found in the `code-postprocessing/latex-templates` folder. Basic html output is also available in the result folder of the postprocessing (file `templateBBOBarticle.html`).

7. Once your algorithm runs well, increase the budget in your experiment script, if necessary implement randomized independent restarts, and follow the above steps successively until you are happy.

8. The experiments can be parallelized with any re-distribution of single problem instances to batches (see `example_experiment.py` for an example). Each batch must write in a different target folder (this should happen automatically). Results of each batch must be kept under their separate folder as is. These folders then must be

<https://github.com/numbbo/coco>

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6. Postprocess the data from the results folder by typing

```
python -m cocopp [-o OUTPUT_FOLDERNAME] YOURDATAFOLDER [MORE_DATAFOLDERS]
```

Any subfolder in the folder arguments will be searched for logged data. That is, experiments from different batches can be in different folders collected under a single "root" `YOURDATAFOLDERS`, specifying several data result folders generated by different algorit...

postprocessing

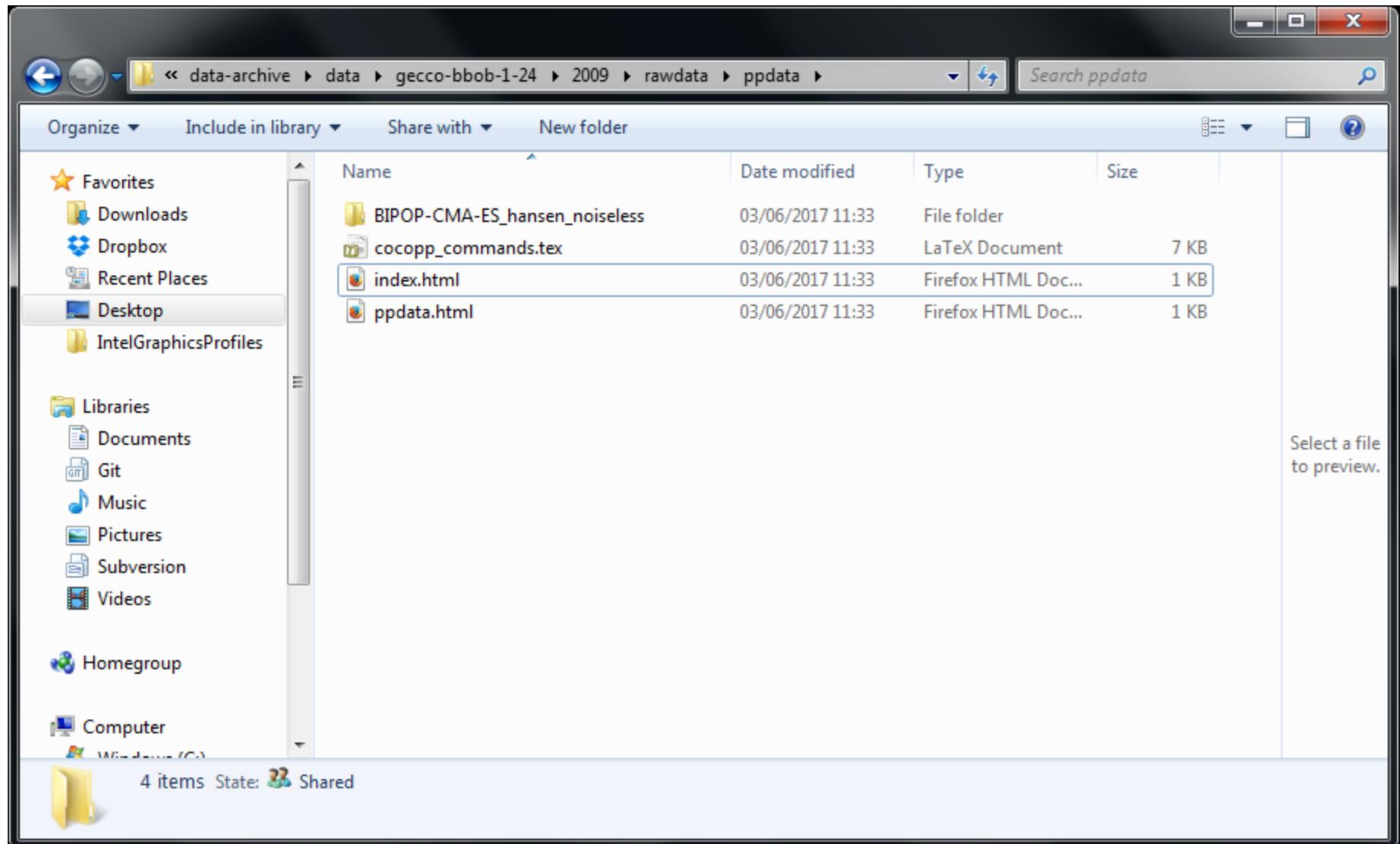
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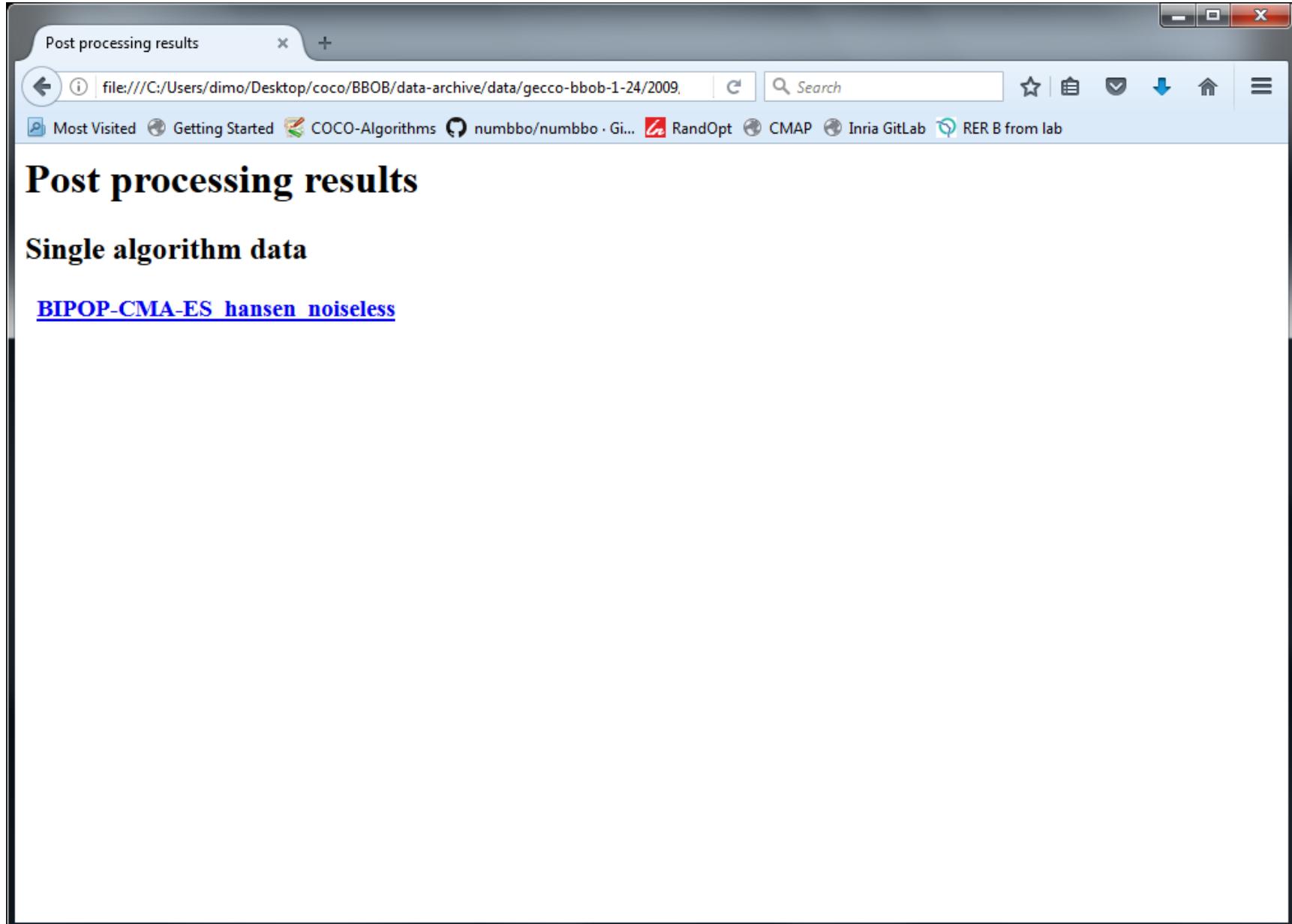
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Result Folder



Automatically Generated Results



Automatically Generated Results

BIPOP-CMA-ES, templateBBOB... +

file:///C:/Users/dimo/Desktop/coco/BBOB/data-archive/data/gecco-bbob-1-24/2009. C Search

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BIPOP-CMA-ES

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[Runtime distributions \(ECDFs\) per function](#)

[Runtime distributions \(ECDFs\) summary and function groups](#)

[Scaling with dimension for selected targets](#)

[Tables for selected targets](#)

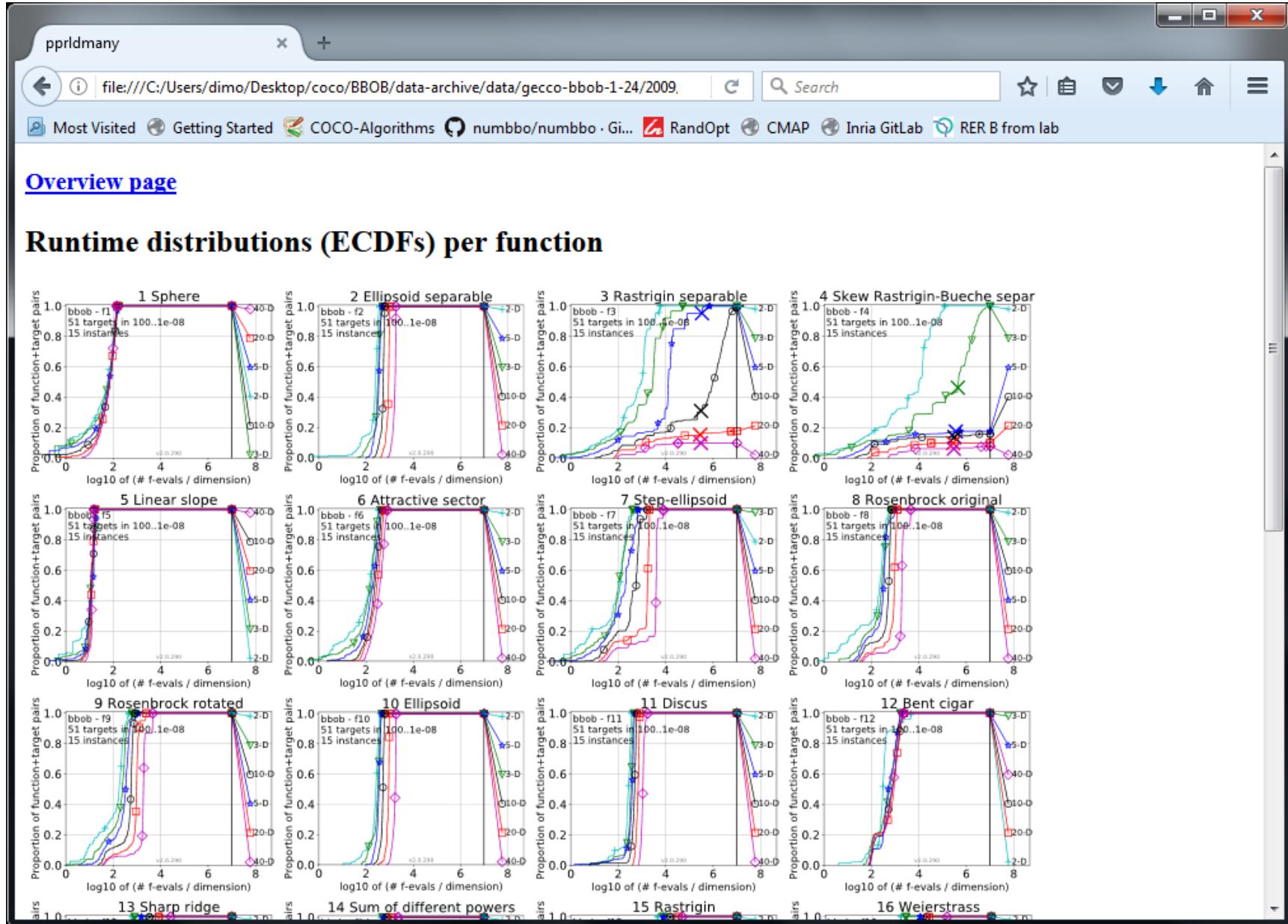
[Runtime distribution for selected targets and f-distributions](#)

[Runtime loss ratios](#)

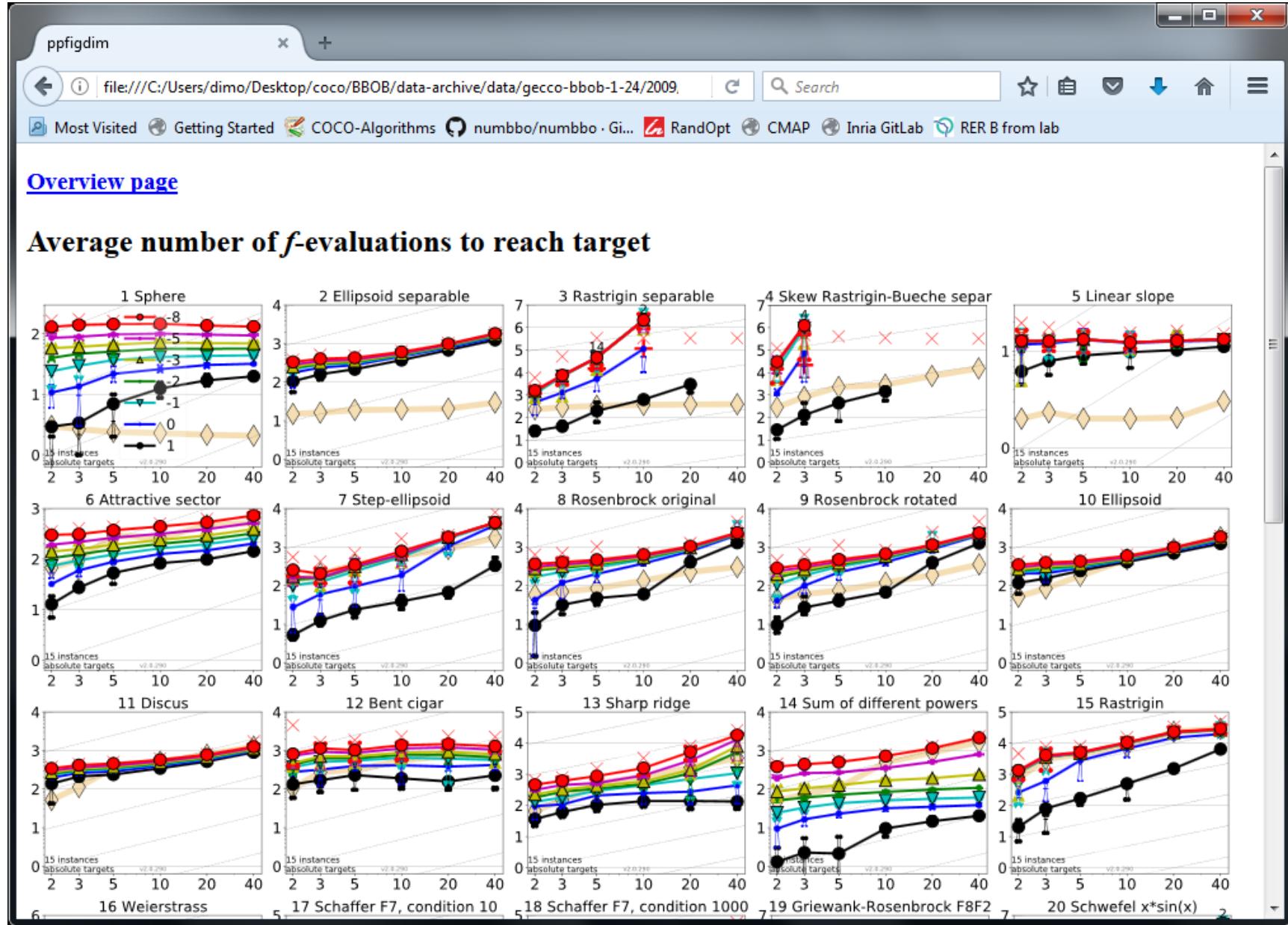
Runtime distributions (ECDFs) over all targets

The figure is a plot of the Empirical Cumulative Distribution Function (ECDF) for BIPOP-CMA-ES. The y-axis is labeled "function+target pairs" and ranges from 0.6 to 1.0. The x-axis represents the rank of the target functions. The legend indicates three dimensions: 2-D (black circles), 3-D (green inverted triangles), and 5-D (blue stars). A text box in the upper left corner provides context: "bbob - f1-f24", "51 targets in 100.1e-08", and "15 instances". The curves show that for most targets, the 2-D case performs best, followed by 3-D, and then 5-D. The 5-D curve shows a significant drop-off at higher ranks, indicating slower convergence for some targets.

Automatically Generated Results



Automatically Generated Results



doesn't look too complicated, does it?

[the devil is in the details ☺]

so far (i.e. incl. BBOB-2017):

data for about 170 algorithm variants
(some of which on noisy or multiobjective test functions)
145 workshop papers
by 101 authors from 28 countries

Measuring Performance

On

- real world problems
 - expensive
 - comparison typically limited to certain domains
 - experts have limited interest to publish
- "artificial" benchmark functions
 - cheap
 - controlled
 - data acquisition is comparatively easy
 - problem of representativeness

Test Functions

- define the "scientific question"
the relevance can hardly be overestimated
- should represent "reality"
- are often too simple?
remind separability
- a number of testbeds are around
- account for **invariance properties**
prediction of performance is based on “similarity”,
ideally equivalence classes of functions

Available Test Suites in COCO

• bbob	24 noiseless fcts	140+ algo data sets
• bbob-noisy	30 noisy fcts	40+ algo data sets
• bbob-biobj	55 bi-objective fcts	15 algo data sets

Under development:

- extended bi-objective suite (bbob-biobj-ext)
- large-scale version of bbob (bbob-largescale)
- constrained test suite (bbob-constrained)

Long-term goals:

- combining difficulties
- almost real-world problems
- real-world problems

How Do We Measure Performance?

Meaningful quantitative measure

- quantitative on the ratio scale (highest possible)
"algo A is two *times* better than algo B" is a meaningful statement
- assume a wide range of values
- meaningful (interpretable) with regard to the real world
possible to transfer from benchmarking to real world

runtime or **first hitting time** is the prime candidate
(we don't have many choices anyway)

How Do We Measure Performance?

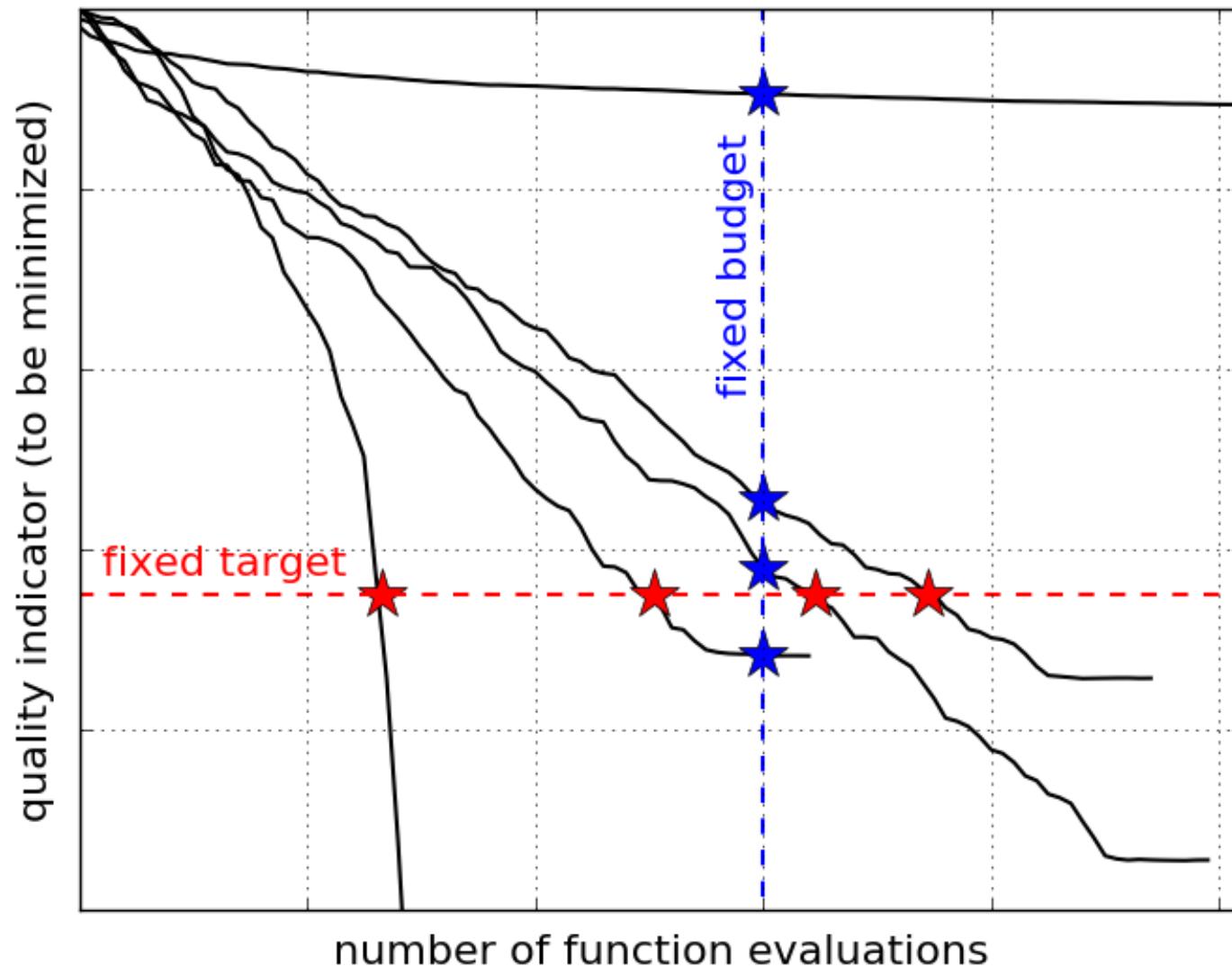
Two objectives:

- Find solution with small(est possible) function/indicator value
- With the least possible search costs (number of function evaluations)

For measuring performance: fix one and measure the other

Measuring Performance Empirically

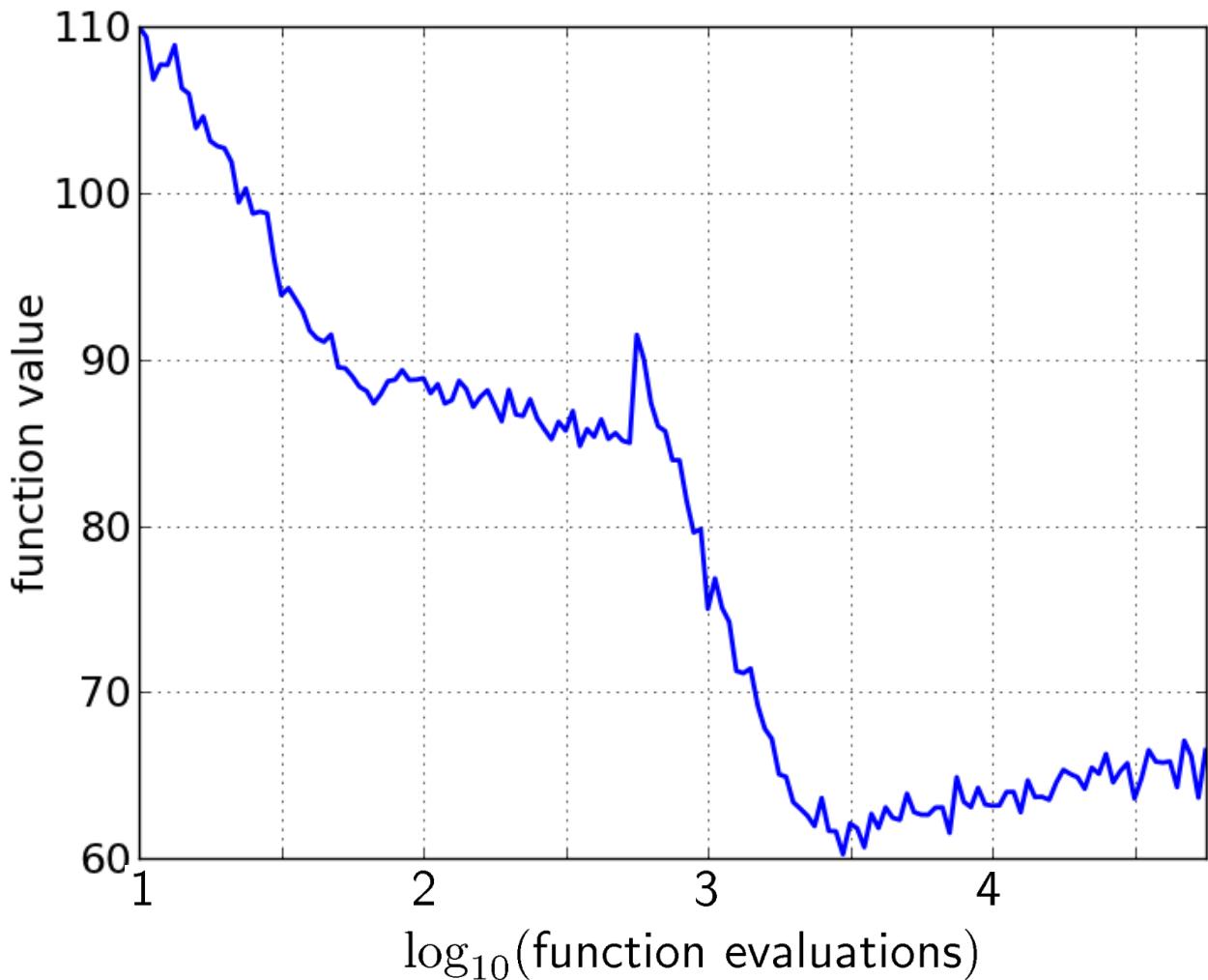
convergence graphs is all we have to start with...



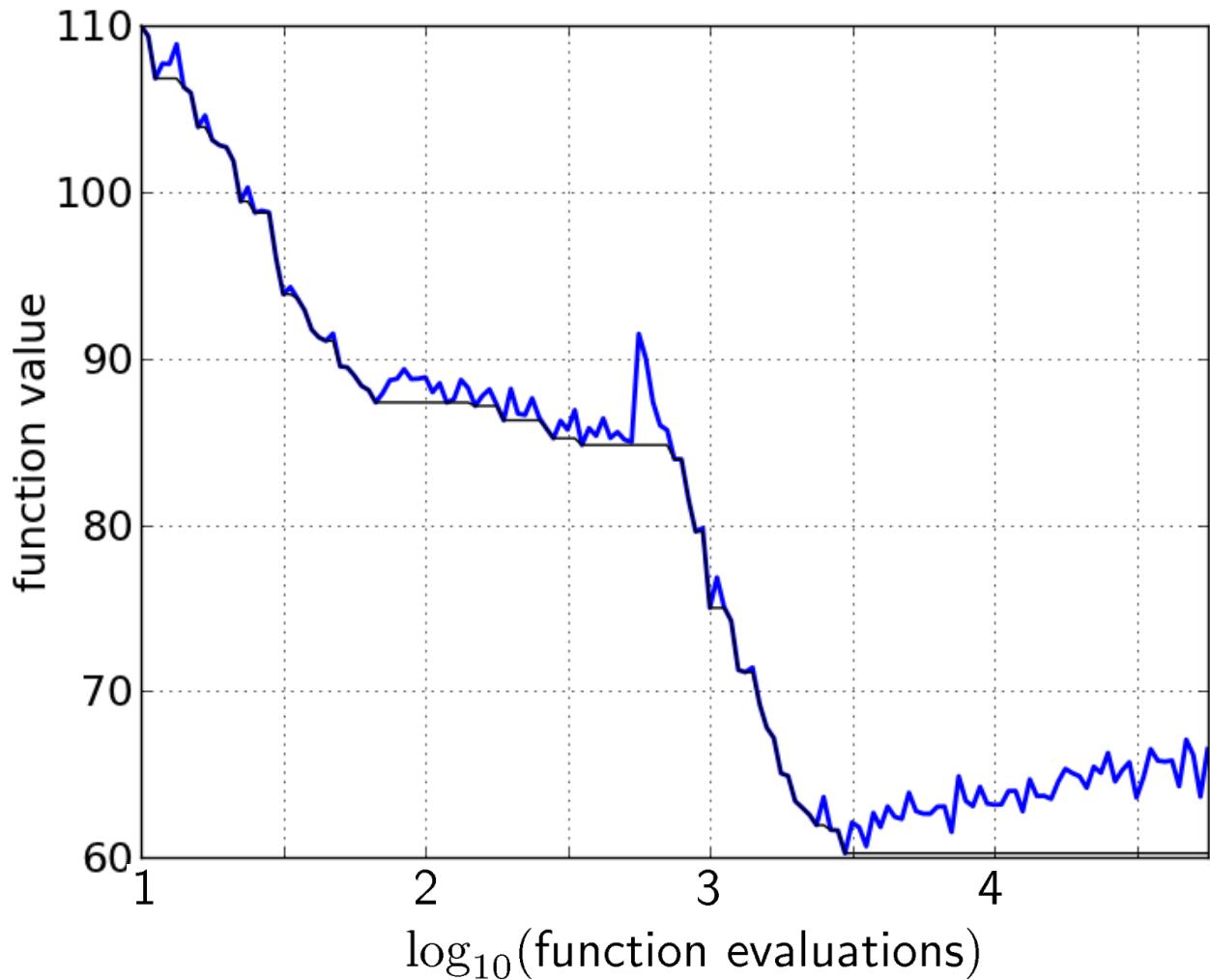
ECDF:

Empirical Cumulative Distribution Function of the Runtime
[aka data profile]

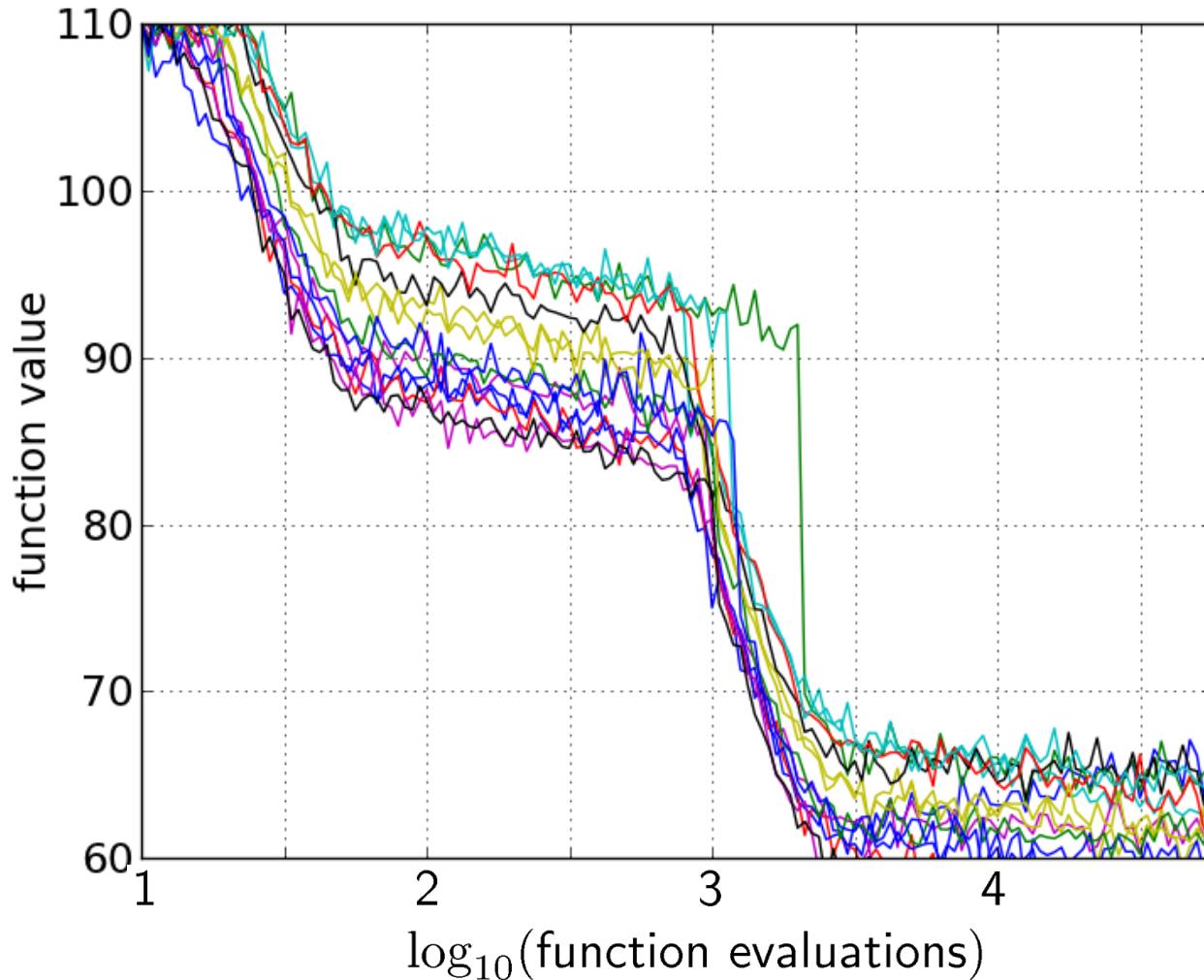
A Convergence Graph



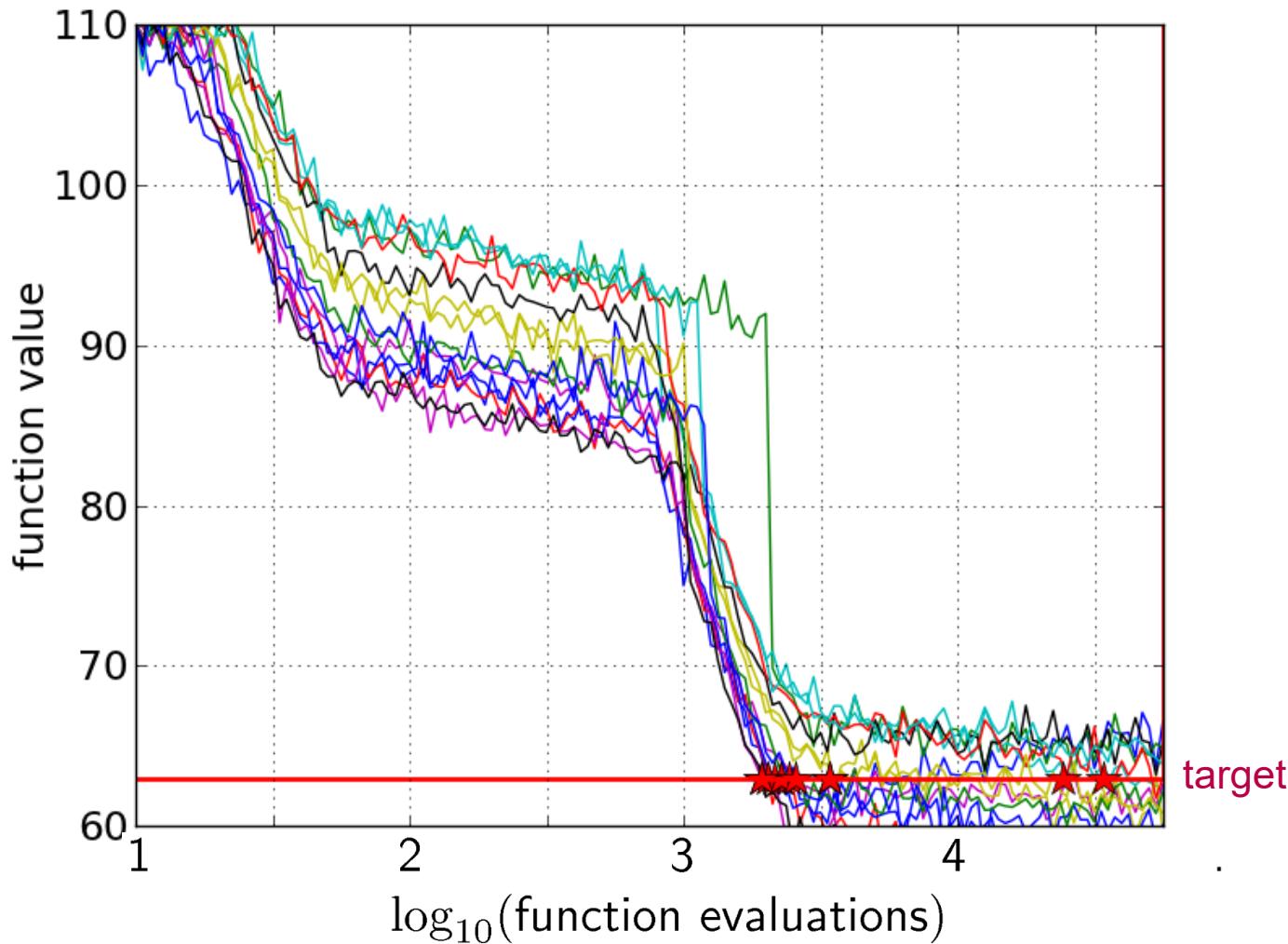
First Hitting Time is Monotonous



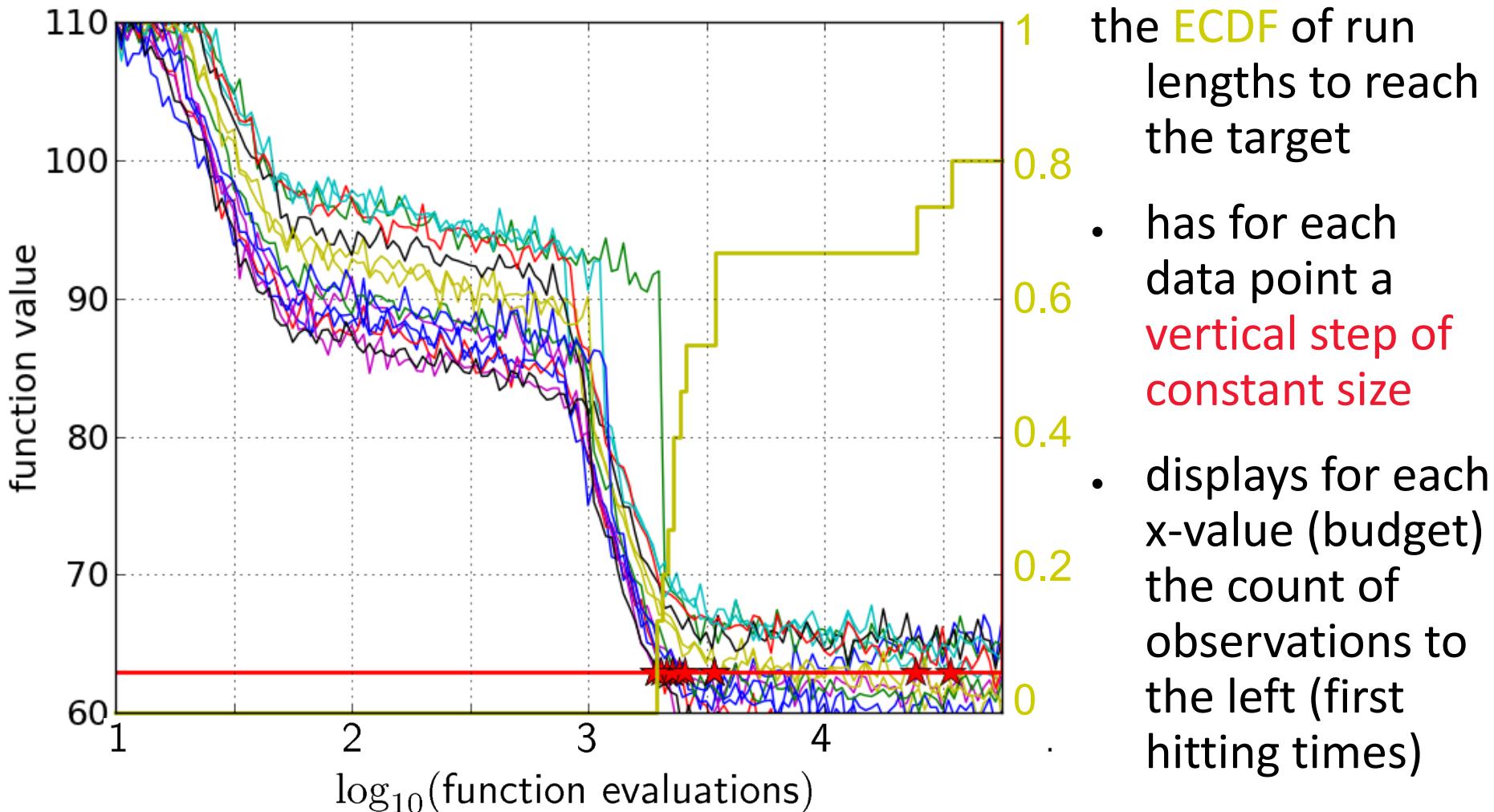
15 Runs



15 Runs ≤ 15 Runtime Data Points

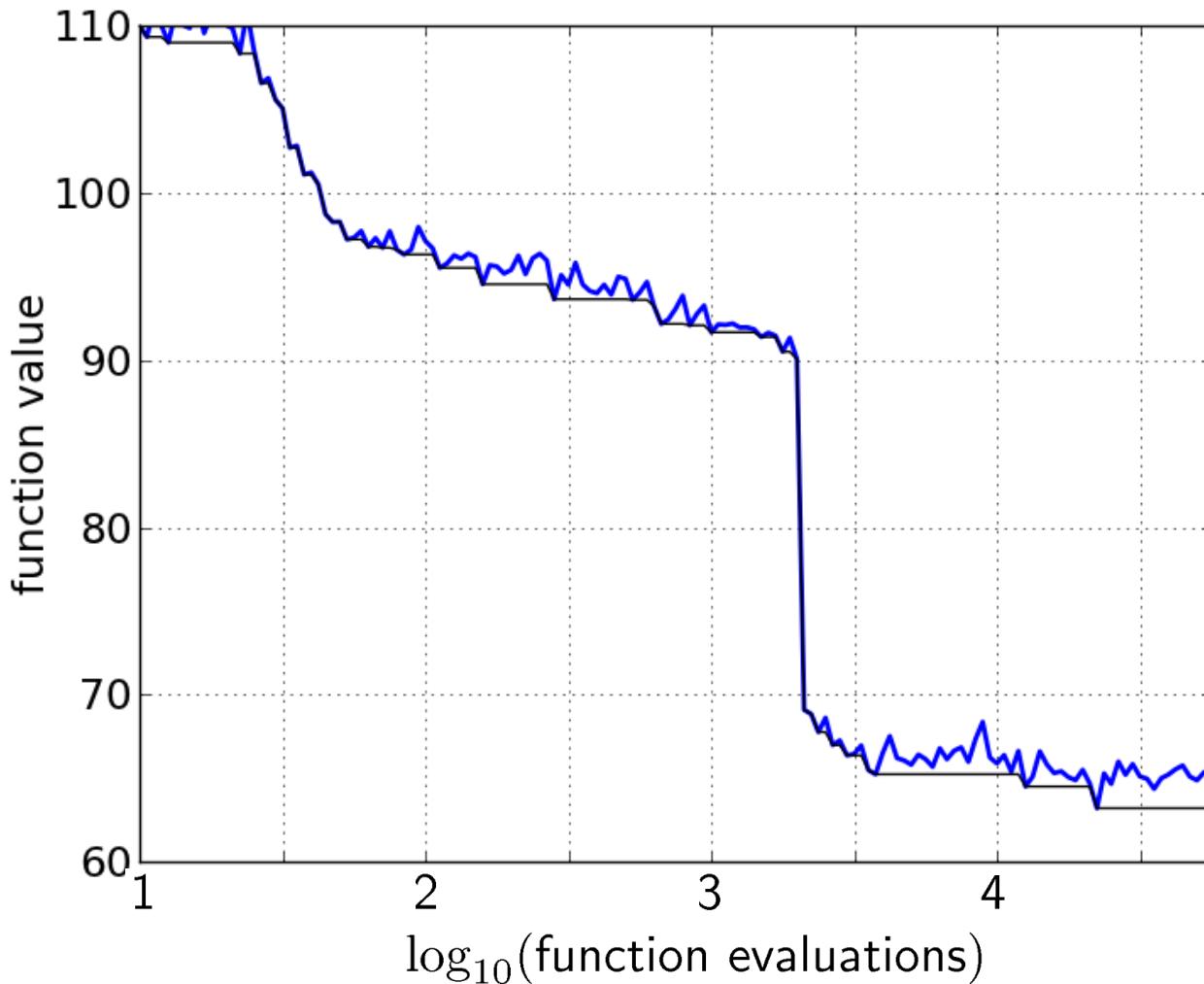


Empirical Cumulative Distribution

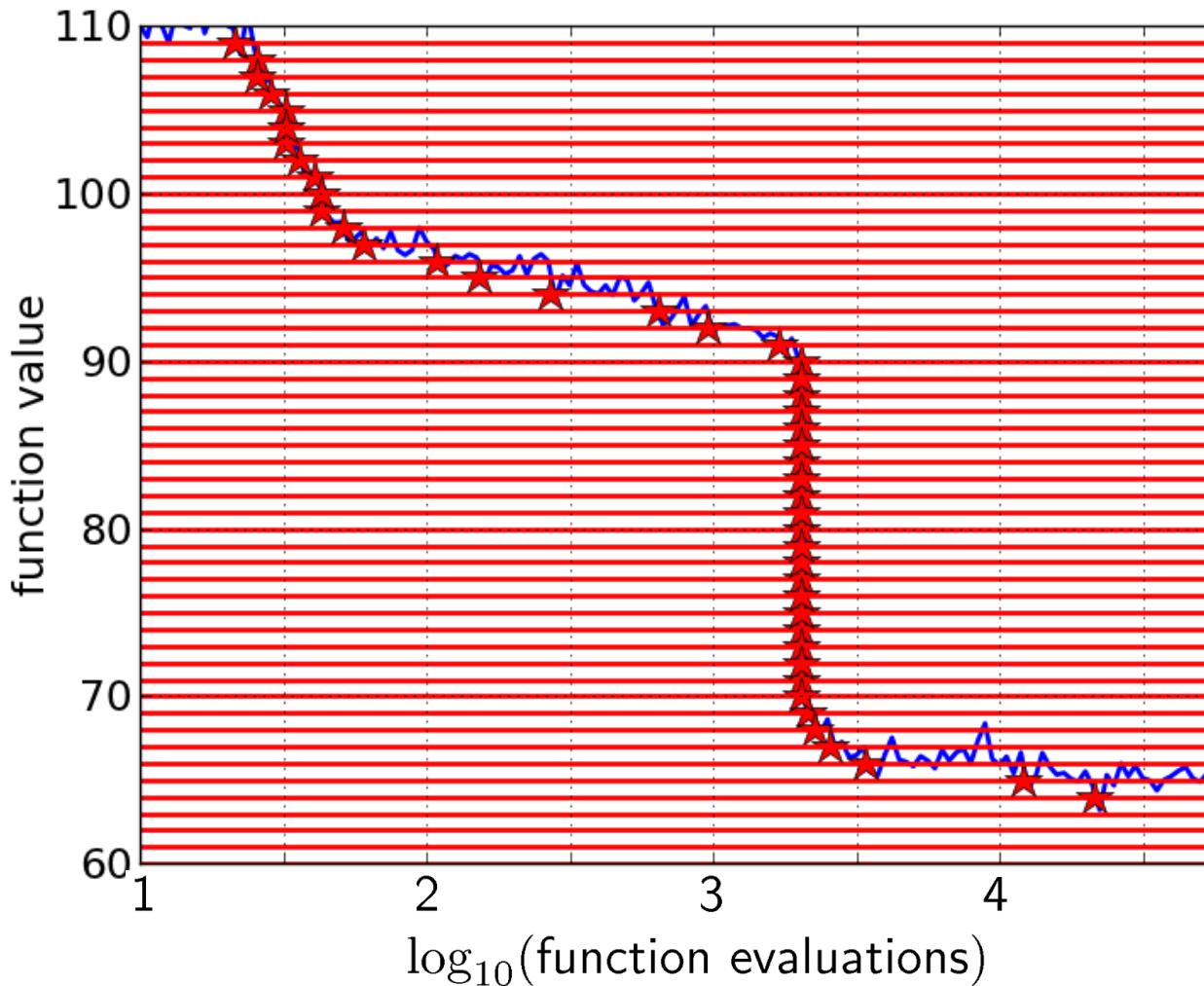


e.g. 60% of the runs need between 2000 and 4000 evaluations
80% of the runs reached the target

Reconstructing A Single Run

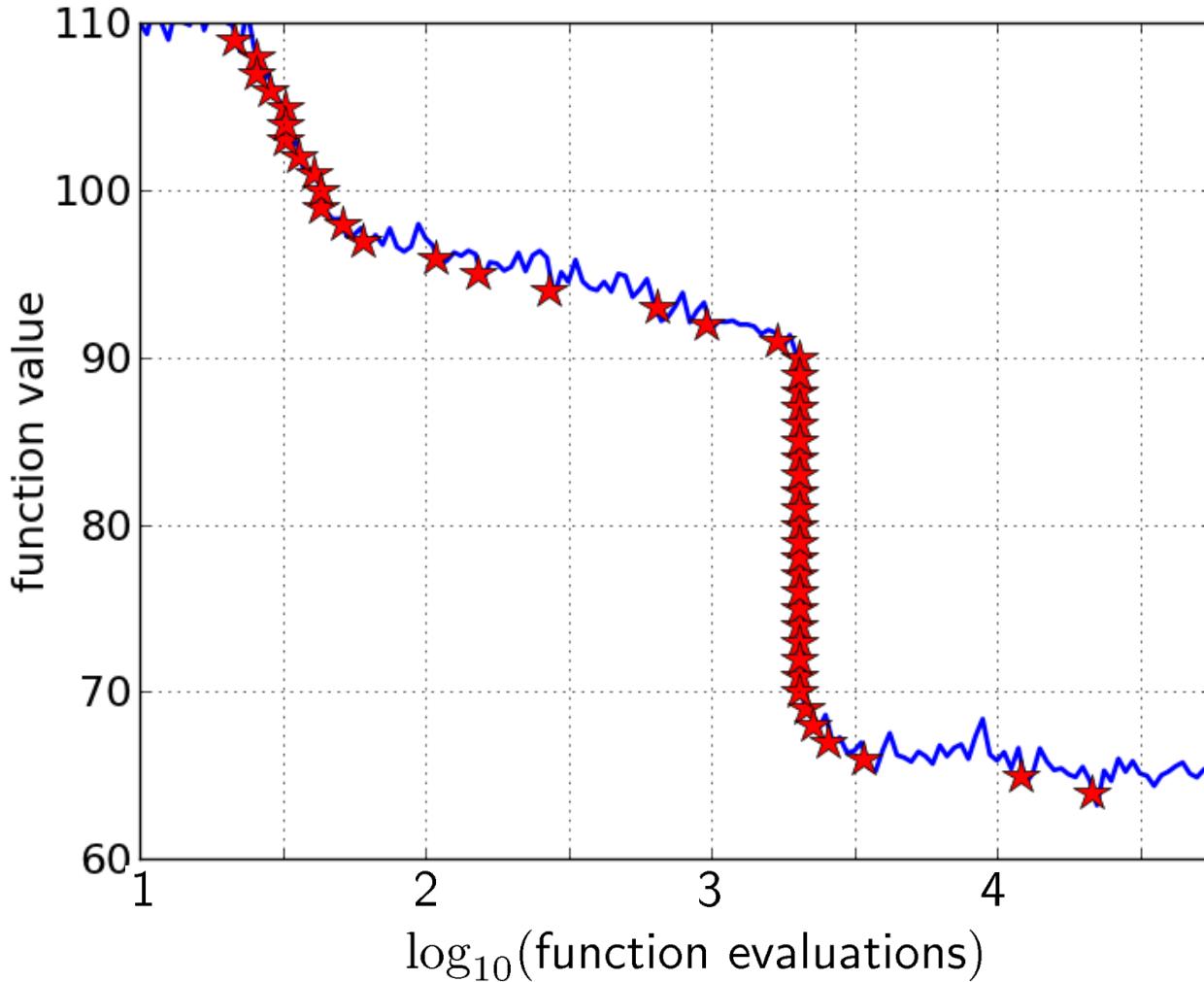


Reconstructing A Single Run

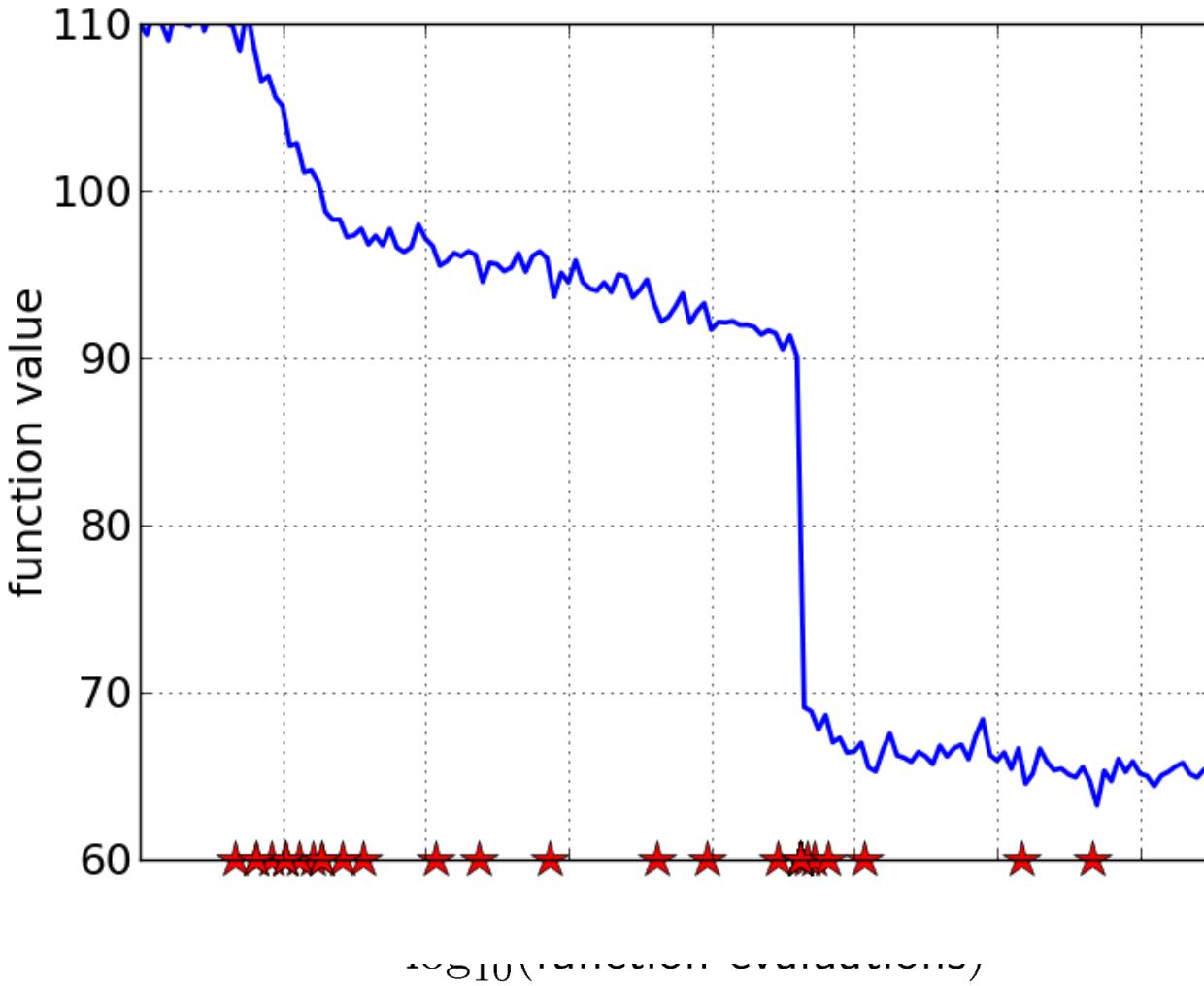


50 equally
spaced targets

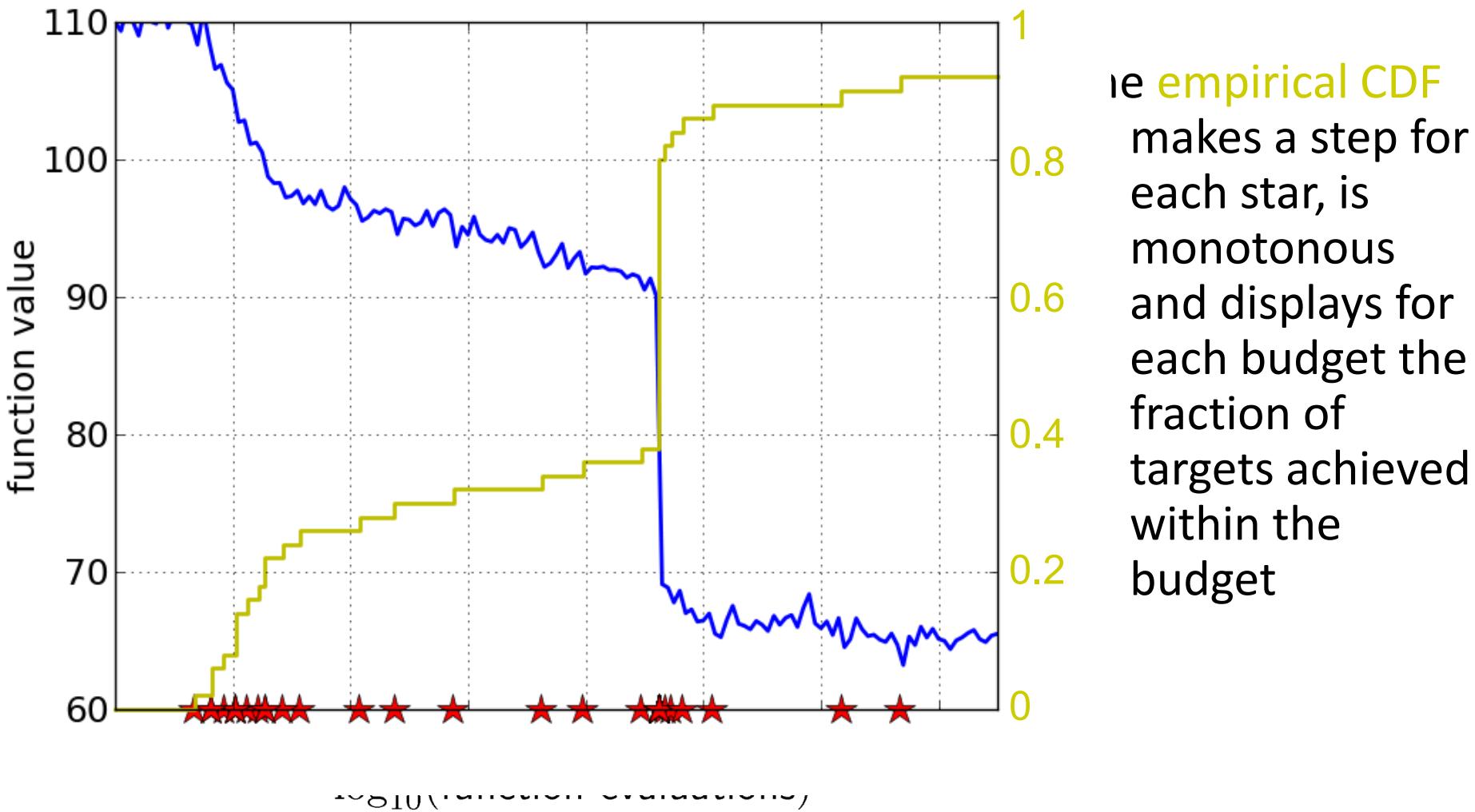
Reconstructing A Single Run



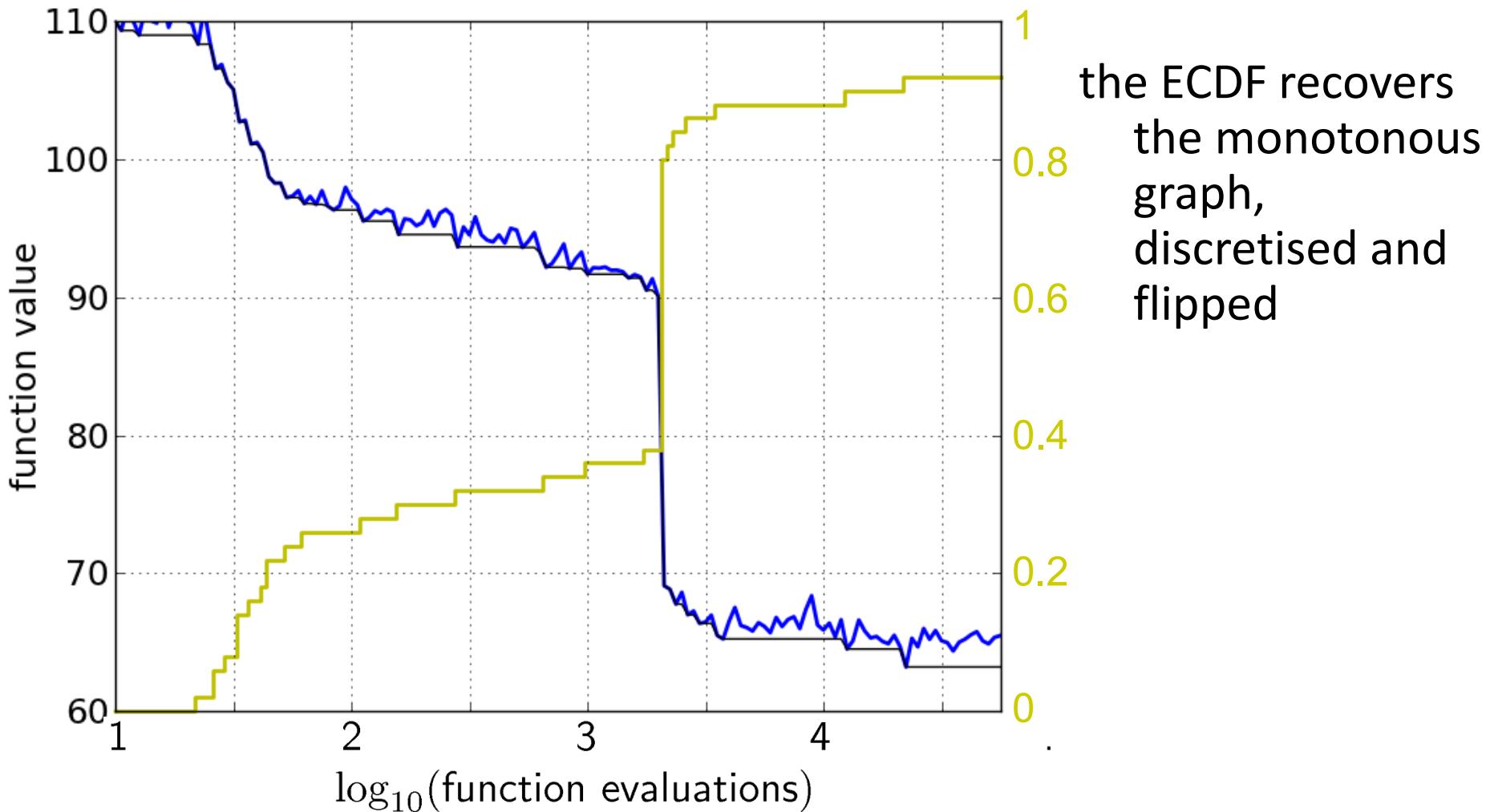
Reconstructing A Single Run



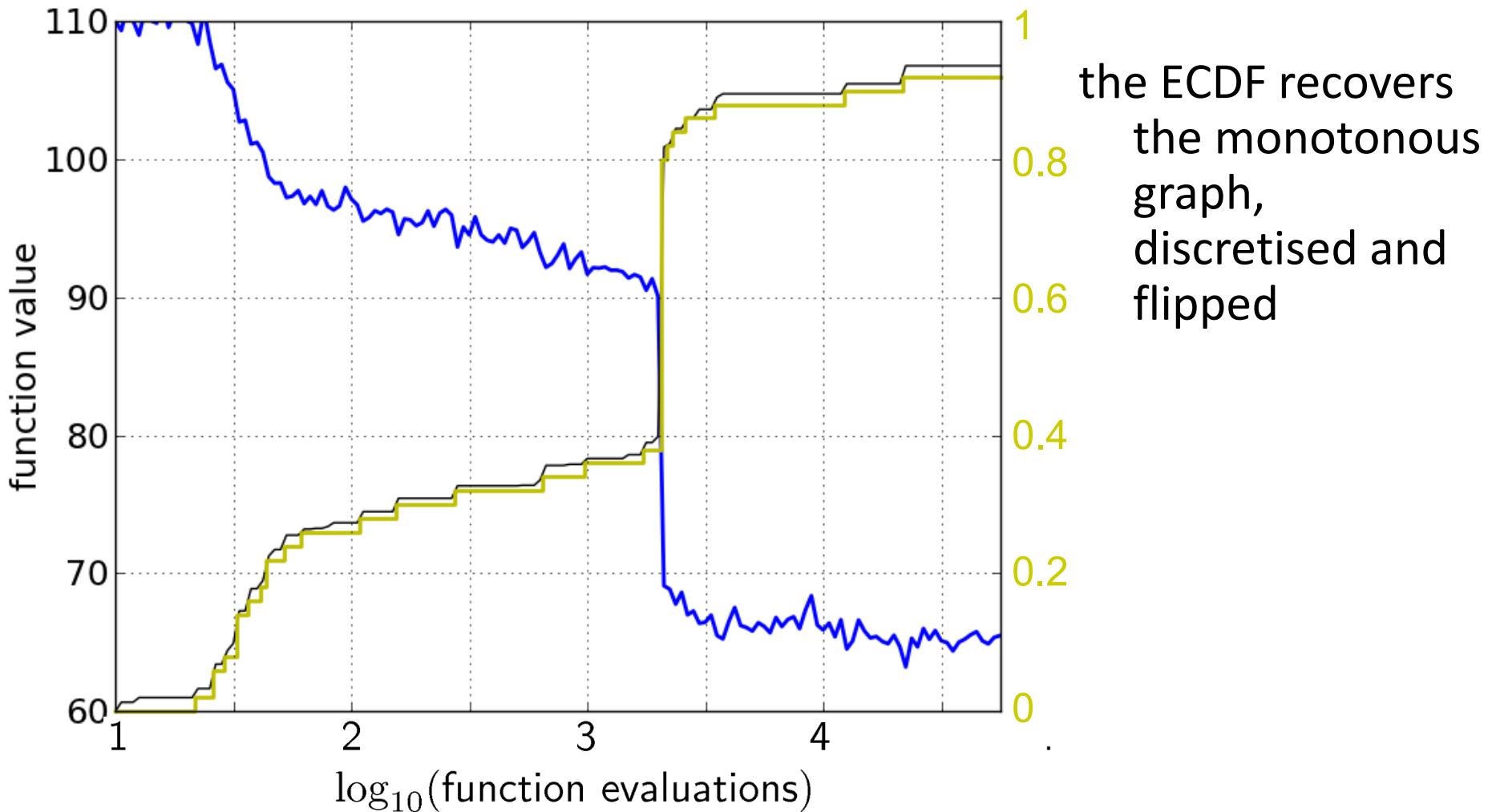
Reconstructing A Single Run



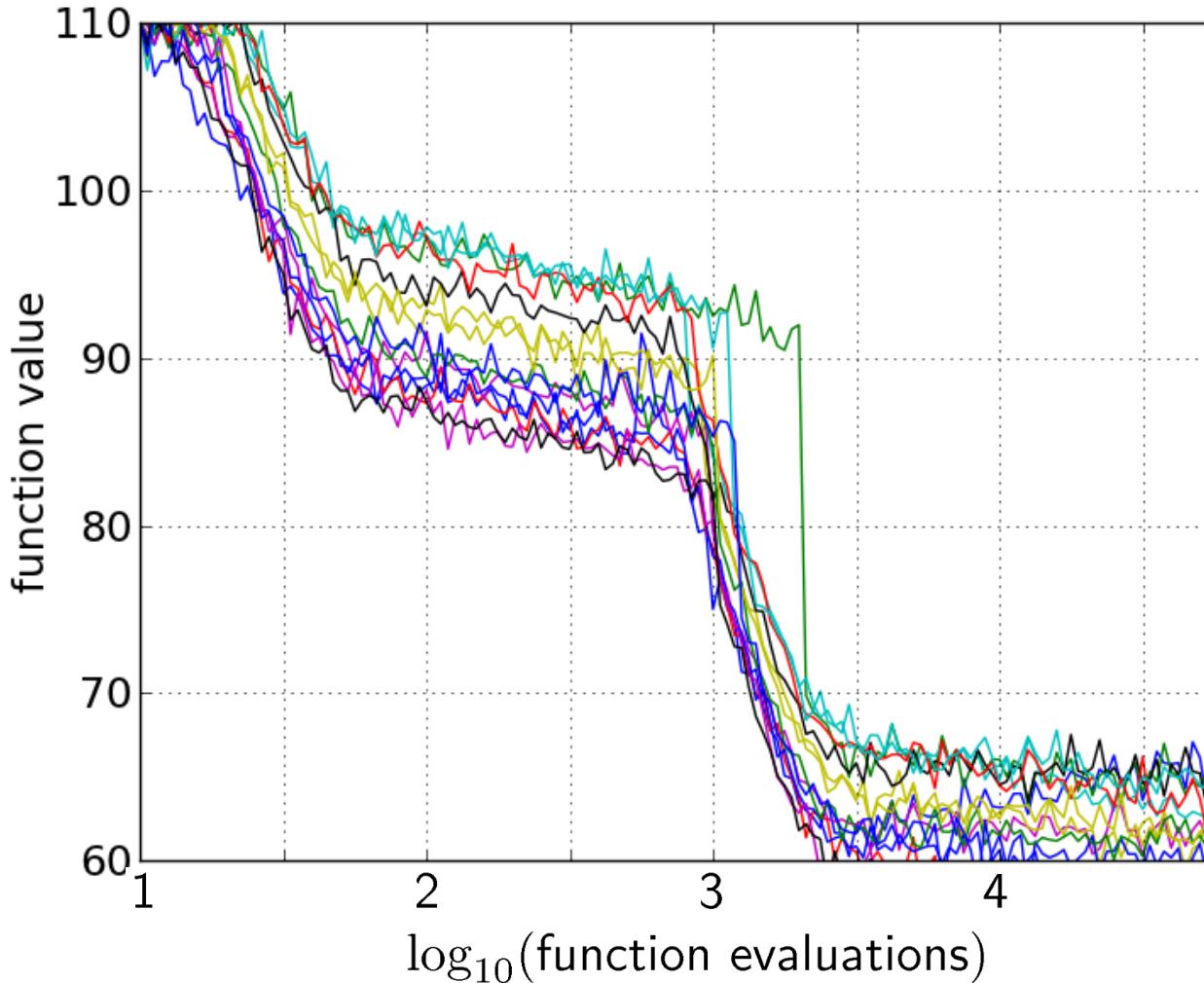
Reconstructing A Single Run



Reconstructing A Single Run

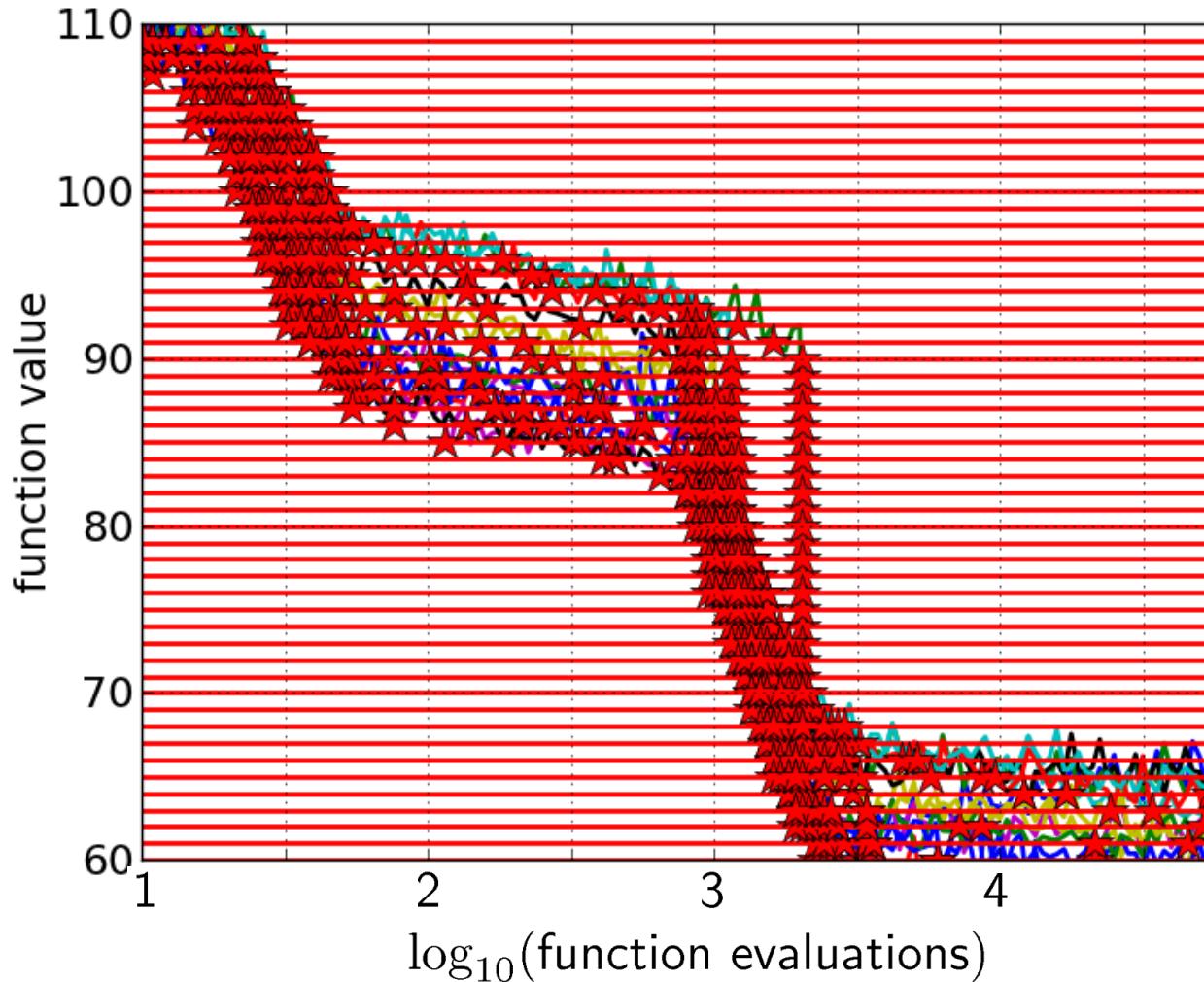


Aggregation



15 runs

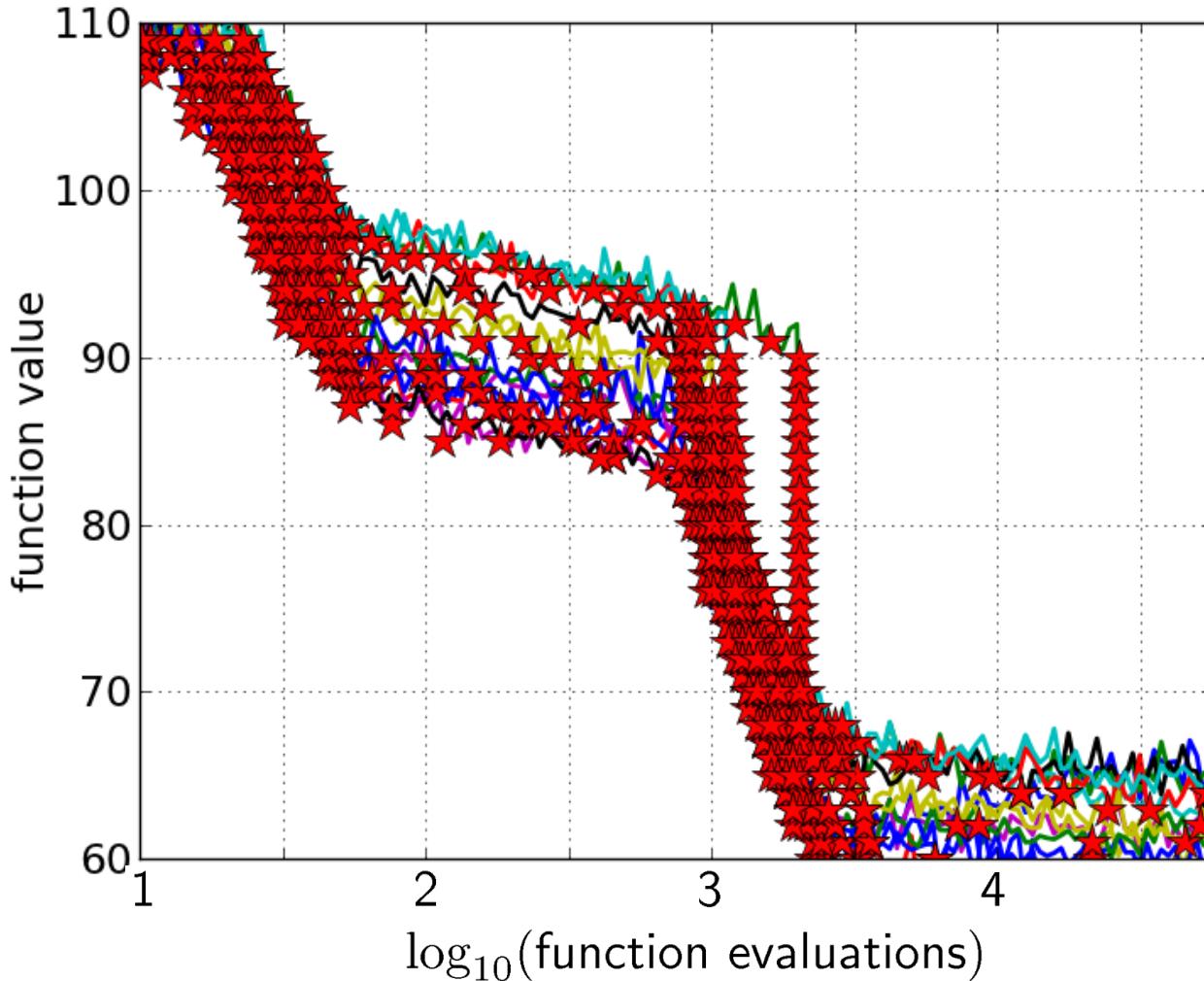
Aggregation



15 runs

50 targets

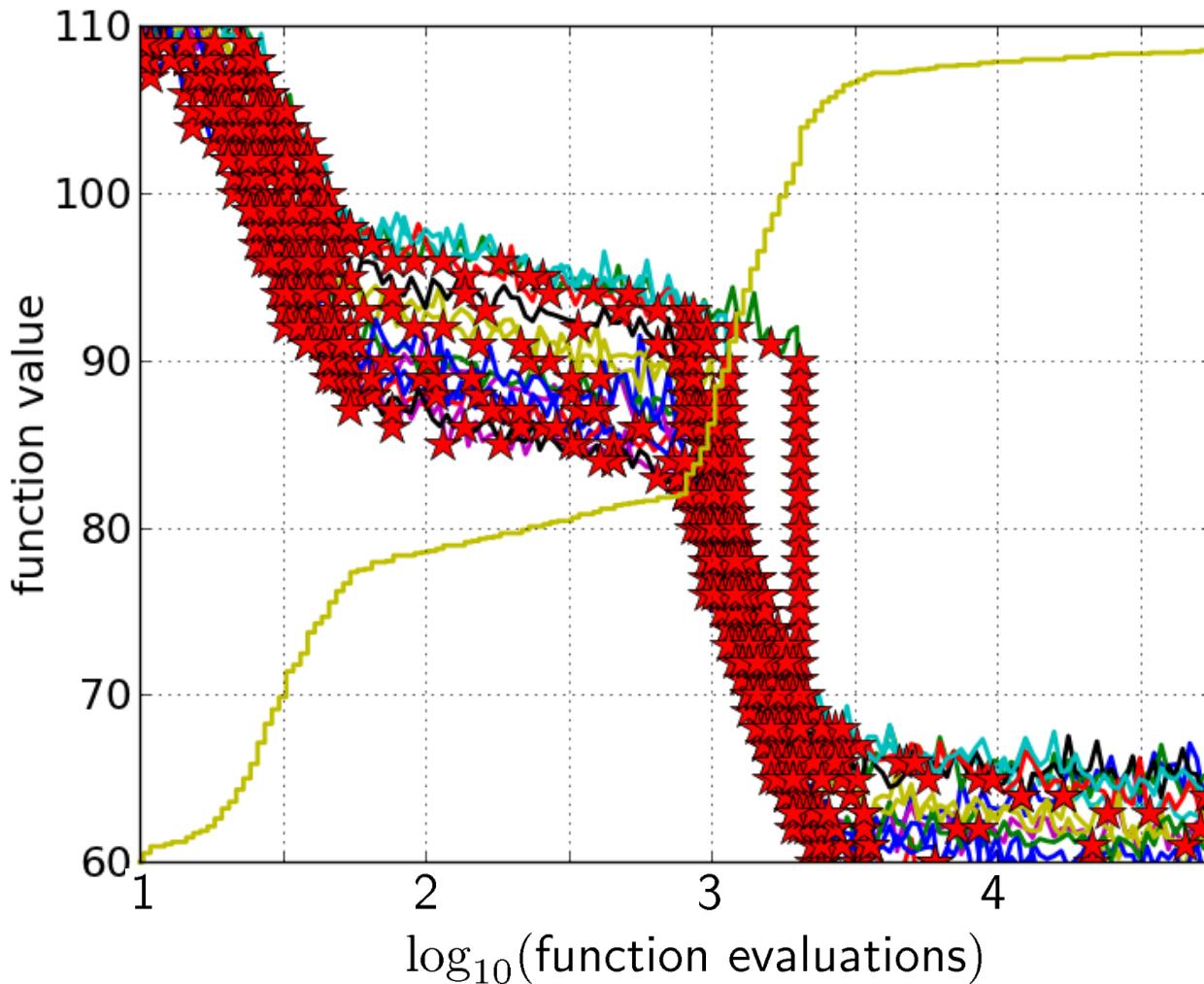
Aggregation



15 runs

50 targets

Aggregation

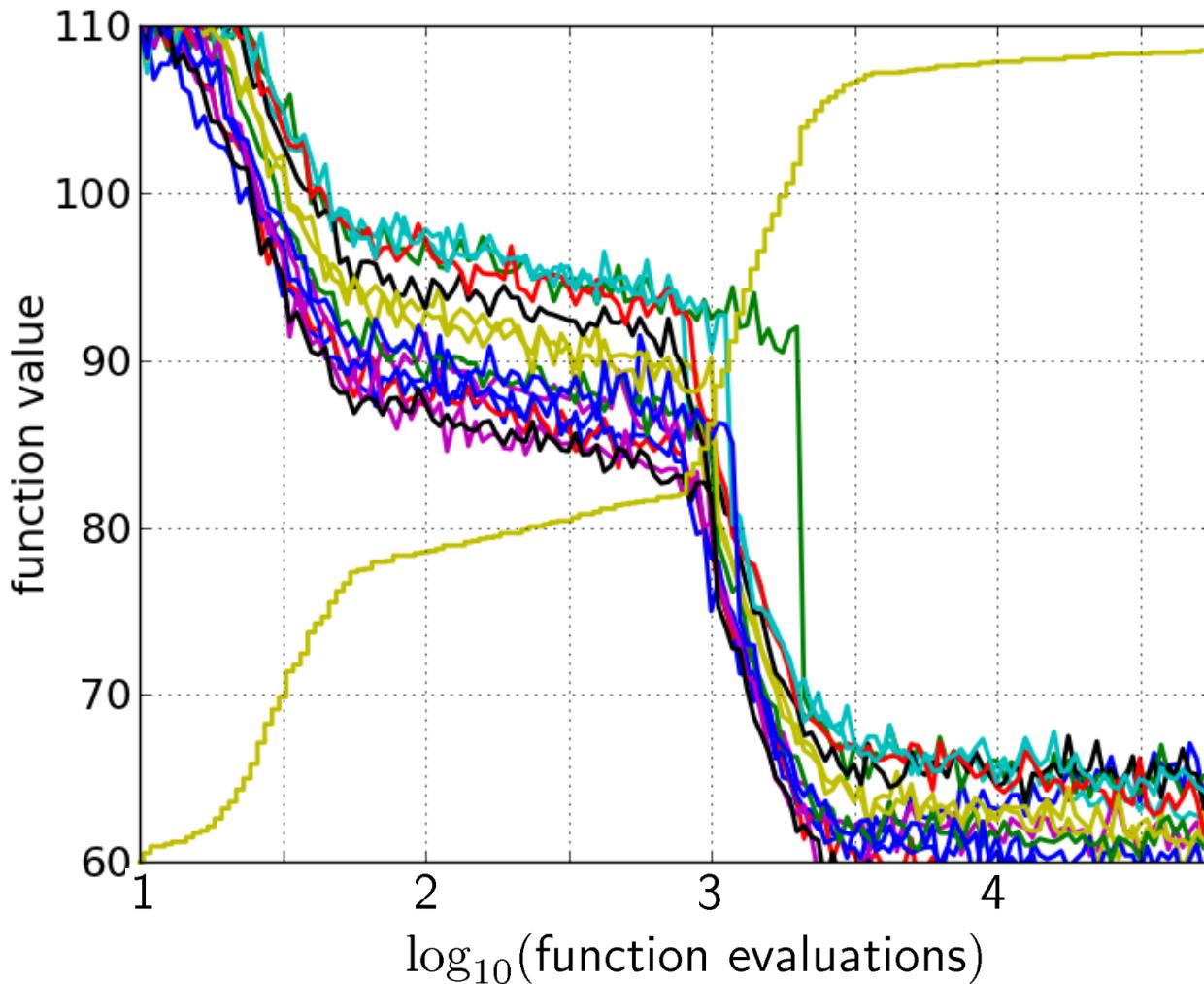


15 runs

50 targets

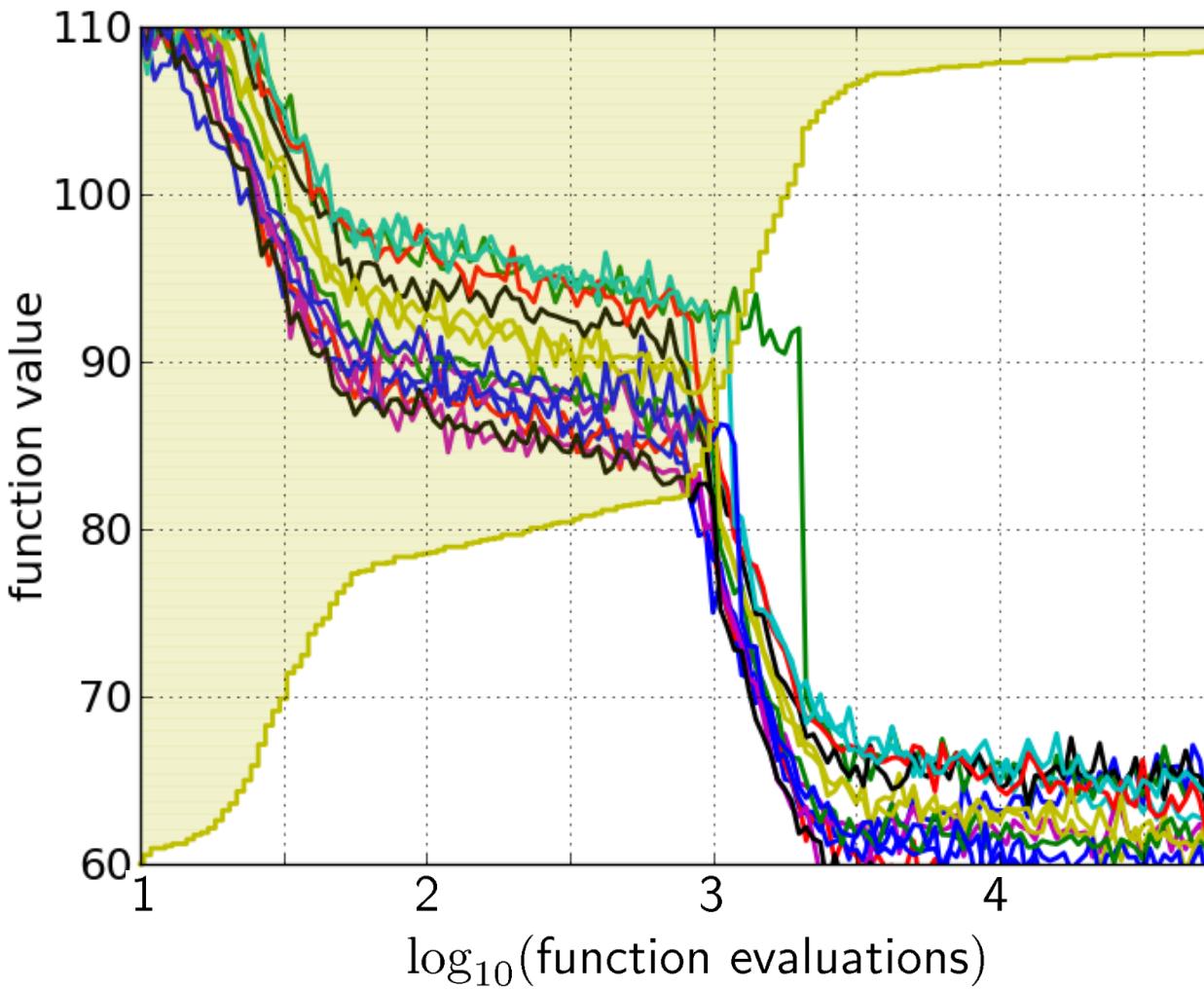
ECDF with 750
steps

Aggregation



50 targets from
15 runs
...integrated in a
single graph

Interpretation



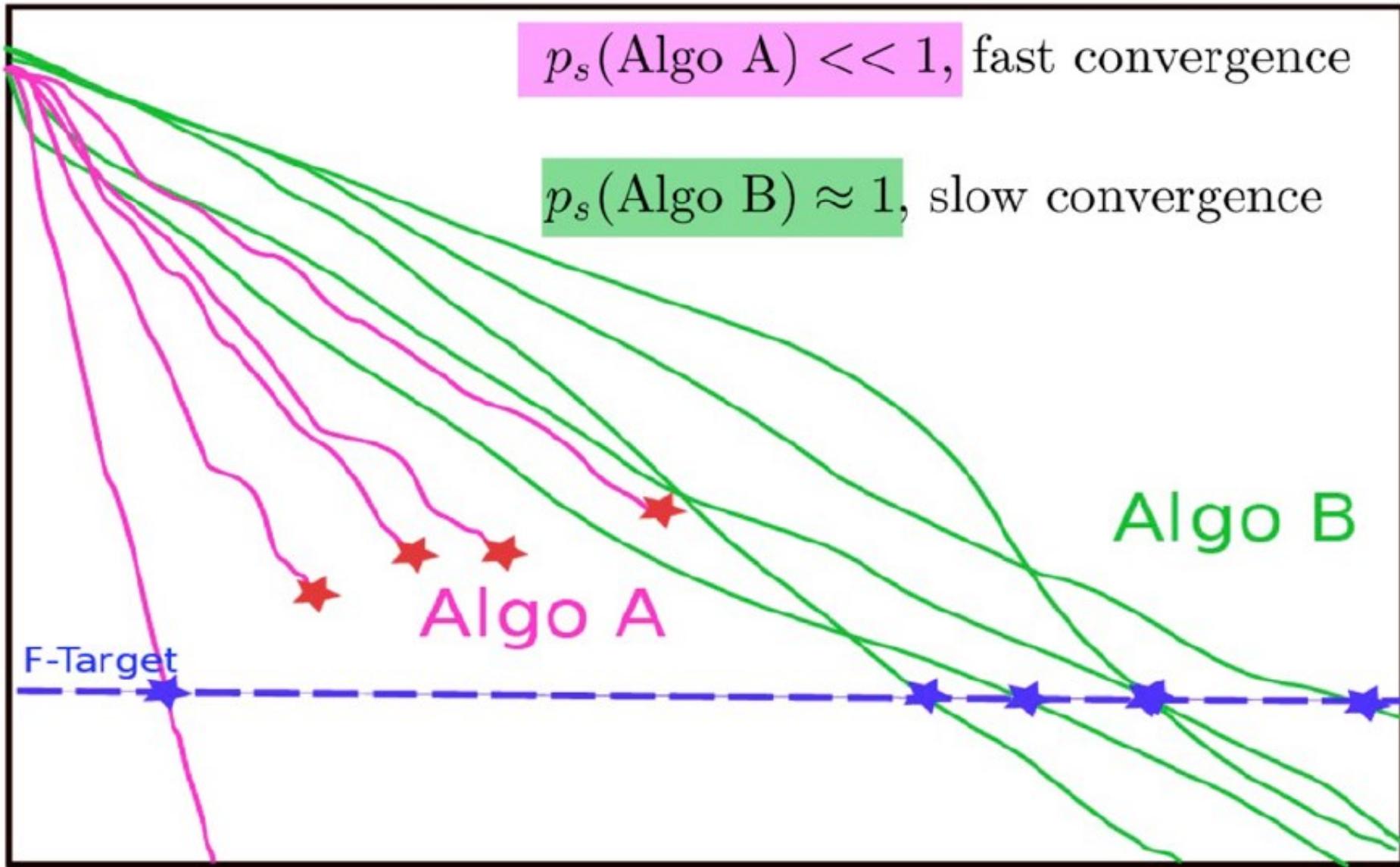
50 targets from
15 runs
integrated in a
single graph

area over the ECDF
curve

=

average log runtime
(or geometric avg.
runtime) over all
targets (difficult and
easy) and all runs

Fixed-target: Measuring Runtime



Fixed-target: Measuring Runtime

- Algo Restart A:



- Algo Restart B:



Fixed-target: Measuring Runtime

- Expected running time of the restarted algorithm:

$$E[RT^r] = \frac{1 - p_s}{p_s} E[RT_{unsuccessful}] + E[RT_{successful}]$$

- Estimator average running time (aRT):

$$\hat{p}_s = \frac{\text{\#successes}}{\text{\#runs}}$$

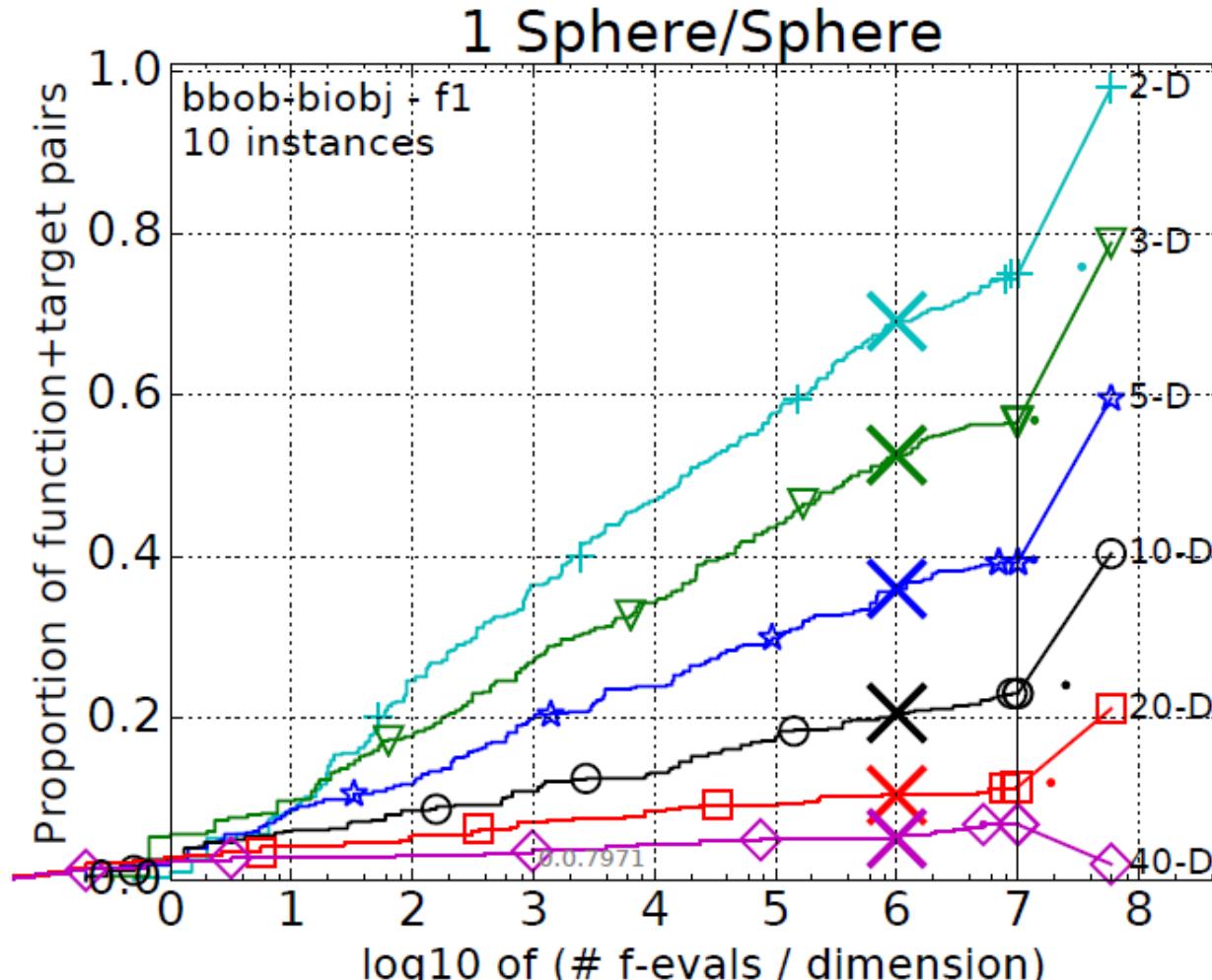
\widehat{RT}_{unsucc} = Average evals of unsuccessful runs

\widehat{RT}_{succ} = Average evals of successful runs

$$aRT = \frac{\text{total \#evals}}{\text{\#successes}}$$

ECDFs with Simulated Restarts

What we typically plot are ECDFs of the simulated restarted algorithms:

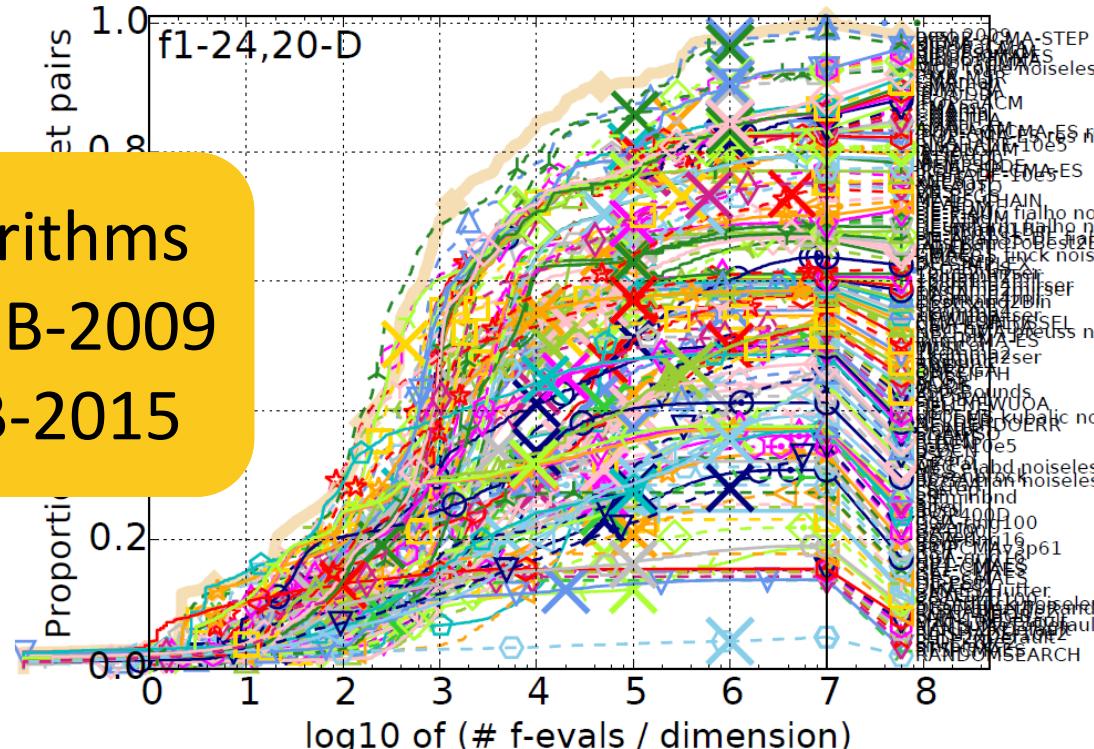


Worth to Note: ECDFs in COCO

In COCO, ECDF graphs

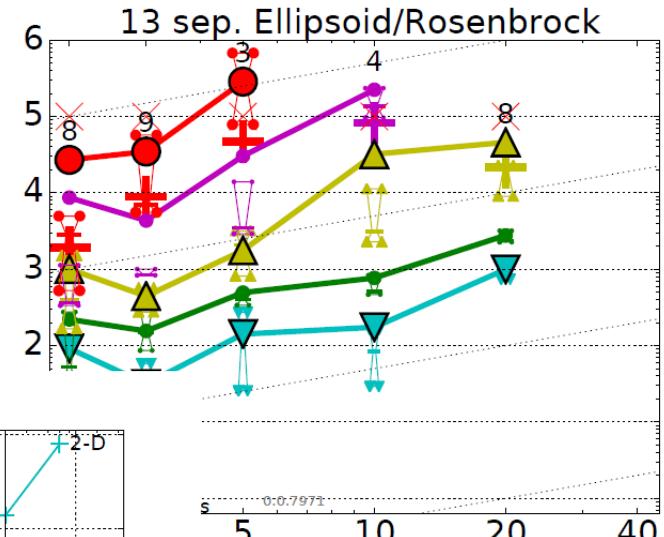
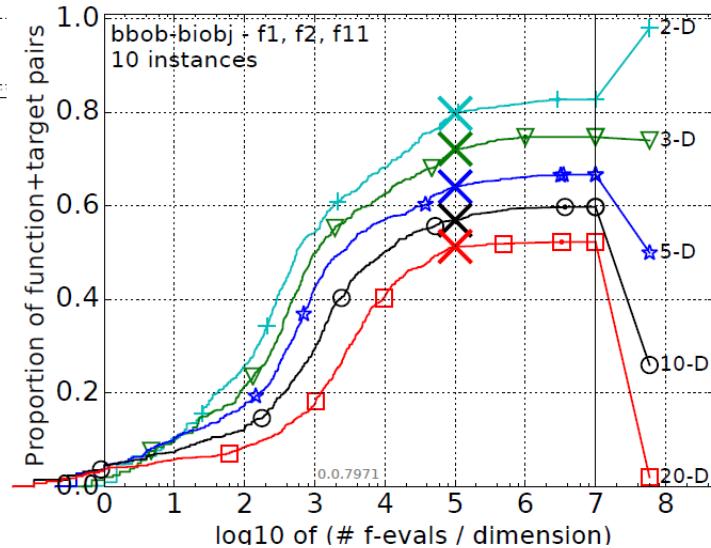
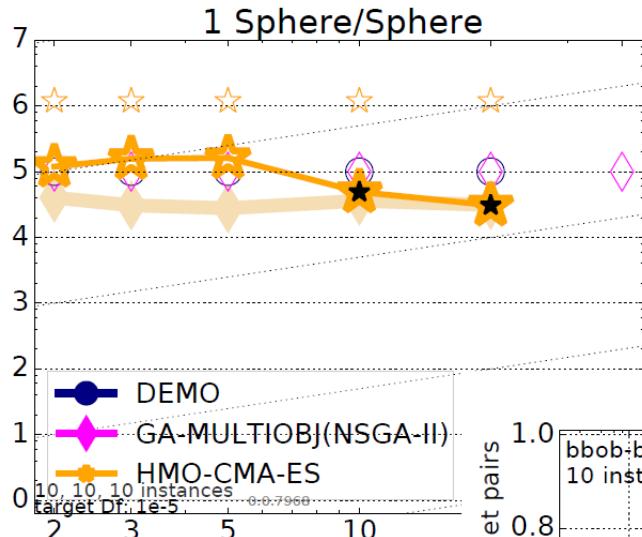
- never aggregate over dimension
 - but often over targets and functions
- can show data of more than 1 algorithm at a time

150 algorithms
from BBOB-2009
till BBOB-2015



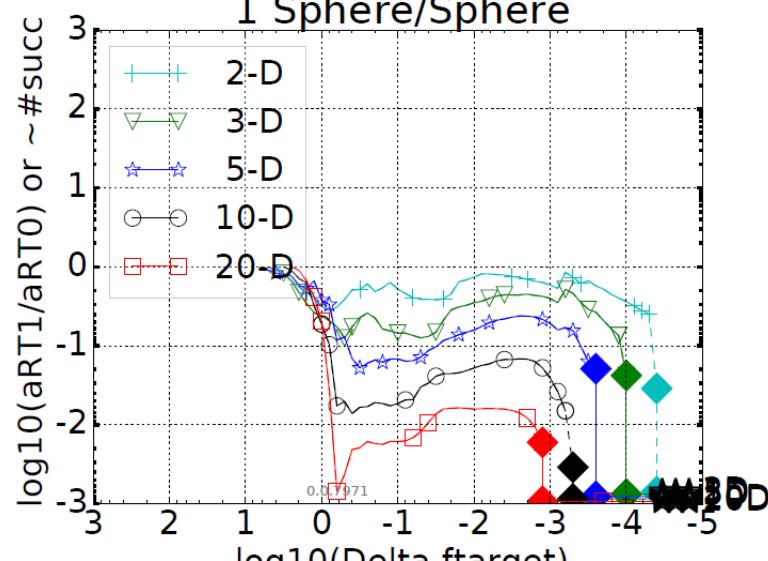
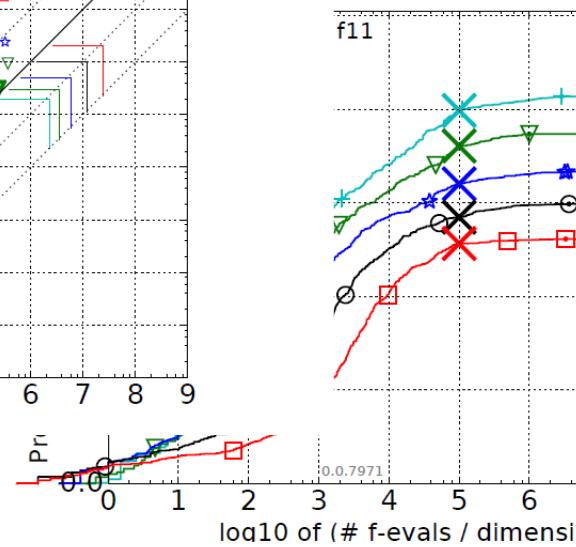
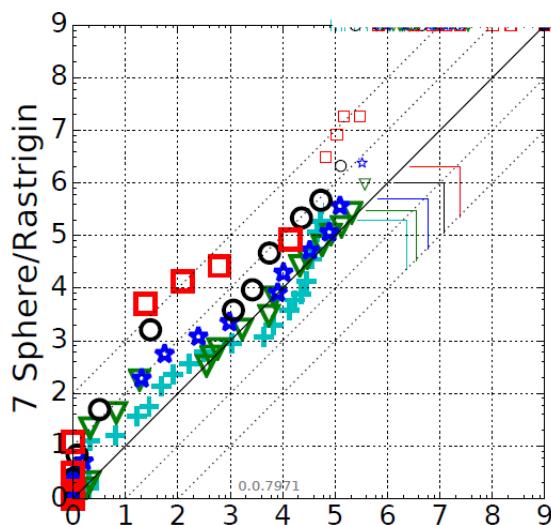
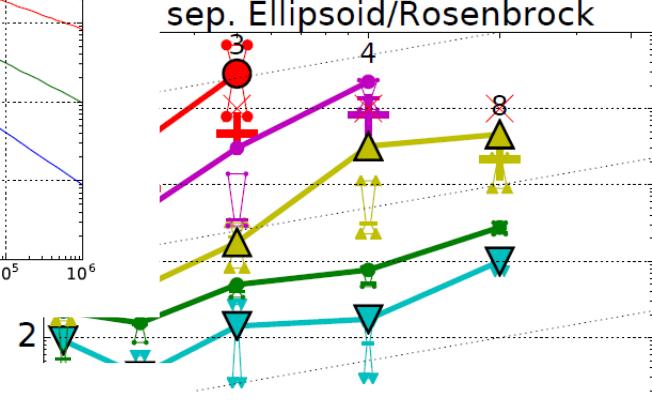
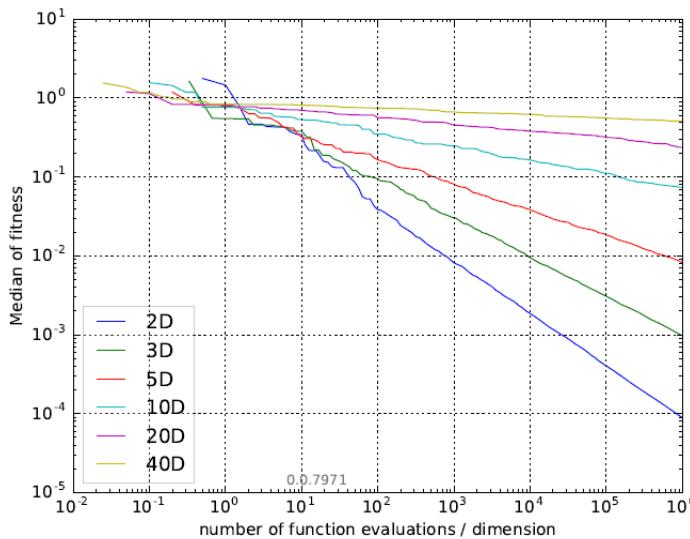
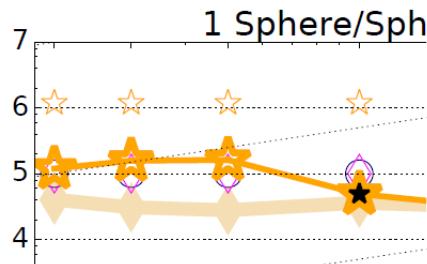
More Automated Plots...

...but no time to explain them here 😞



More Automated Plots...

...but no time t



The BBOB functions

bbob Testbed

- 24 functions in 5 groups:

1 Separable Functions	
f1	Sphere Function
f2	Ellipsoidal Function
f3	Rastrigin Function
f4	Büche-Rastrigin Function
f5	Linear Slope
2 Functions with low or moderate conditioning	
f6	Attractive Sector Function
f7	Step Ellipsoidal Function
f8	Rosenbrock Function, original
f9	Rosenbrock Function, rotated
3 Functions with high conditioning and unimodal	
f10	Ellipsoidal Function
f11	Discus Function
f12	Bent Cigar Function
f13	Sharp Ridge Function
f14	Different Powers Function
4 Multi-modal functions with adequate global structure	
f15	Rastrigin Function
f16	Weierstrass Function
f17	Schaffers F7 Function
f18	Schaffers F7 Functions, moderately ill-conditioned
f19	Composite Griewank-Rosenbrock Function F8F2
5 Multi-modal functions with weak global structure	
f20	Schwefel Function
f21	Gallagher's Gaussian 101-me Peaks Function
f22	Gallagher's Gaussian 21-hi Peaks Function
f23	Katsuura Function
f24	Lunacek bi-Rastrigin Function

- 6 dimensions: 2, 3, 5, 10, 20, (40 optional)

Notion of Instances

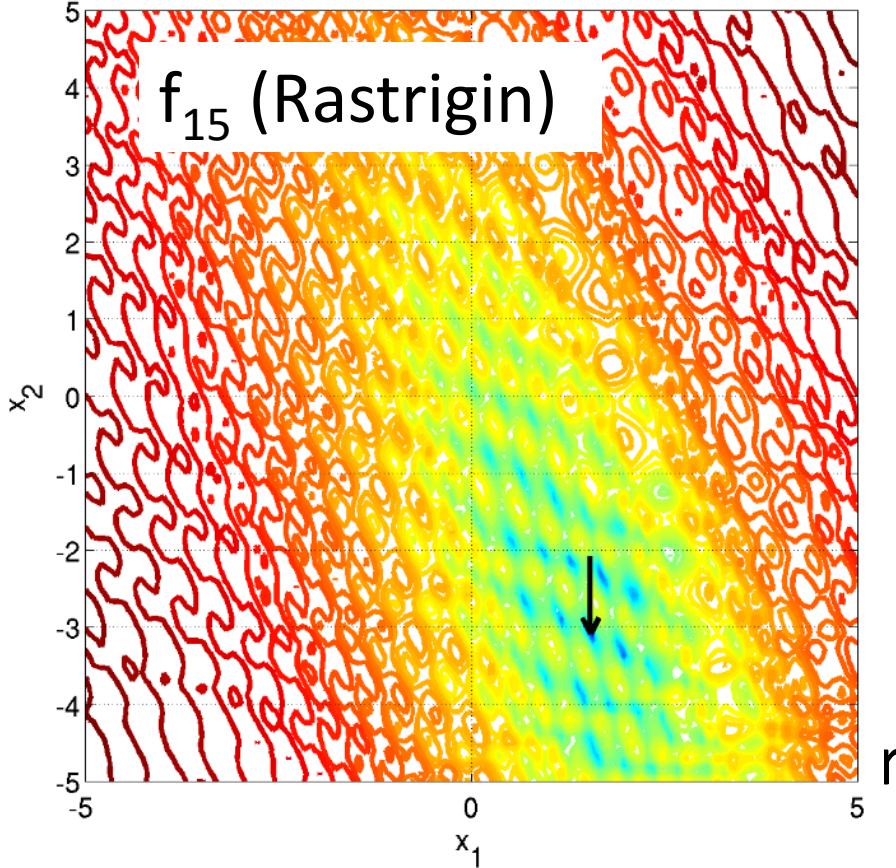
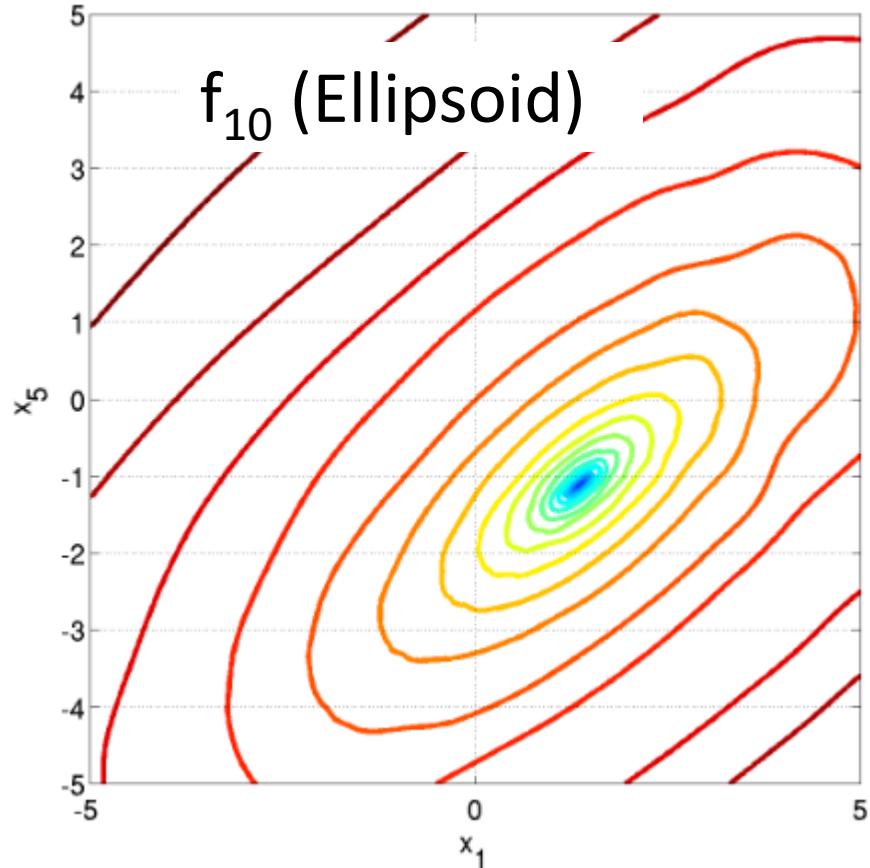
- All COCO problems come in form of instances
 - e.g. as translated/rotated versions of the same function
- Prescribed instances typically change from year to year
 - avoid overfitting
 - 5 instances are always kept the same

Plus:

- the bbob functions are locally perturbed by non-linear transformations

Notion of Instances

- All 8000 problems come in form of instances



bbob-noisy Testbed

- 30 functions with various kinds of noise types and strengths
 - 3 noise types: Gaussian, uniform, and seldom Cauchy
 - Functions with moderate noise
 - Functions with severe noise
 - Highly multi-modal functions with severe noise
 - **bbob** functions included: Sphere, Rosenbrock, Step ellipsoid, Ellipsoid, Different Powers, Schaffers' F7, Composite Griewank-Rosenbrock
- 6 dimensions: 2, 3, 5, 10, 20, (40 optional)

bbob-biobj Testbed

- 55 functions by combining 2 b_{bbob} functions

1 Separable Functions	
f1	Sphere Function ✓
f2	Ellipsoidal Function ✓
f3	Rastrigin Function
f4	Büche-Rastrigin Function
f5	Linear Slope
2 Functions with low or moderate conditioning	
f6	Attractive Sector Function ✓
f7	Step Ellipsoidal Function
f8	Rosenbrock Function, original ✓
f9	Rosenbrock Function, rotated
3 Functions with high conditioning and unimodal	
f10	Ellipsoidal Function
f11	Discus Function
f12	Bent Cigar Function
f13	Sharp Ridge Function ✓
f14	Different Powers Function ✓
4 Multi-modal functions with adequate global structure	
f15	Rastrigin Function ✓
f16	Weierstrass Function
f17	Schaffers F7 Function ✓
f18	Schaffers F7 Functions, moderately ill-conditioned
f19	Composite Griewank-Rosenbrock Function F8F2
5 Multi-modal functions with weak global structure	
f20	Schwefel Function ✓
f21	Gallagher's Gaussian 101-me Peaks Function ✓
f22	Gallagher's Gaussian 21-hi Peaks Function
f23	Katsuura Function
f24	Lunacek bi-Rastrigin Function

bbob-biobj Testbed

- 55 functions by combining 2 **bbob** functions

Bi-objective Performance Assessment

algorithm quality =

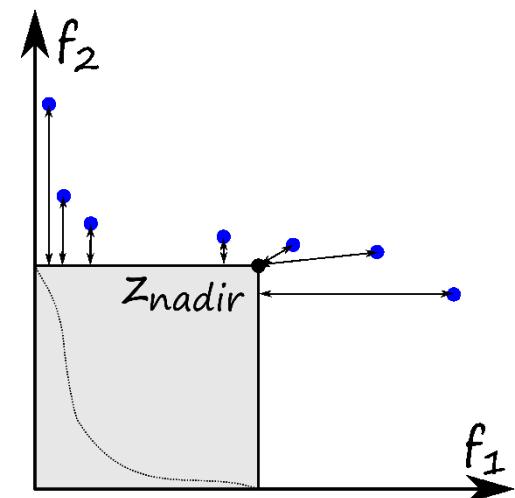
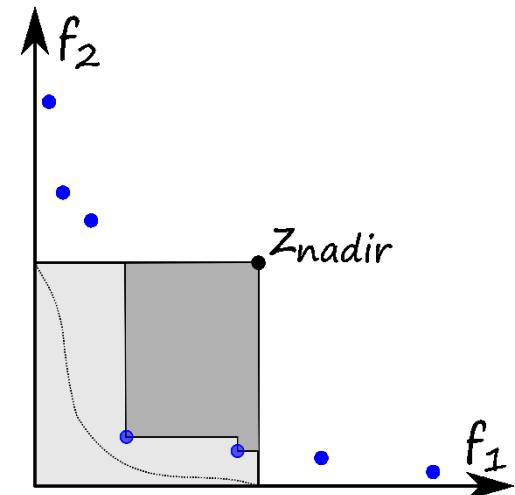
normalized* hypervolume (HV)
of all non-dominated solutions

if a point dominates nadir

closest normalized* negative distance
to region of interest $[0,1]^2$

if no point dominates nadir

* such that ideal=[0,0] and nadir=[1,1]



Bi-objective Performance Assessment

We measure runtimes to reach (HV indicator) targets:

- relative to a **reference set**, given as the best Pareto front approximation known (since exact Pareto set not known)
current_best values incl. all non-dominated points found by the 15 workshop algos of BBOB-2016
- actual **absolute hypervolume targets** used are
 $HV(\text{refset}) - \text{targetprecision}$
with 58 **fixed** targetprecisions between 1 and -10^{-4} (same for all functions, dimensions, and instances) in the displays

and now?

BBOB-2017

Session I

08:30 - 09:05	The BBOBies: Introduction to Blackbox Optimization Benchmarking
09:05 - 09:30	Simon Wessing*: Benchmarking the SMS-EMOA with Self-adaptation on the bbob-biobj Test Suite
09:30 - 09:55	Mario García-Valdez* and Juan-J. Merelo: Benchmarking a Pool-Based Execution with GA and PSO Workers on the BBOB Noiseless Testbed
09:55 - 10:20	Zbynek Pitra*, Lukas Bajer, Jakub Repicky, and Martin Holena: Comparison of Ordinal and Metric Gaussian Process Regression as Surrogate Models for CMA Evolution Strategy

Session II

10:40 - 10:50	The BBOBies: Session Introduction
10:50 - 11:15	Dogan Aydin* and Gurcan Yavuz: Self-adaptive Search Equation-Based Artificial Bee Colony Algorithm with CMA-ES on the Noiseless BBOB Testbed
11:15 - 11:40	Duc Manh Nguyen and Nikolaus Hansen*: Benchmarking CMAES-APOP on the BBOB Noiseless Testbed
11:40 - 12:05	Takahiro Yamaguchi and Youhei Akimoto*: Benchmarking the Novel CMA-ES Restart Strategy Using the Search History on the BBOB Noiseless Testbed
12:05 - 12:30	The BBOBies: Wrap-up and Open Discussion

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COMPARING CONTINUOUS OPTIMISERS: COCO

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COCO (COmparing Continuous Optimisers) is a platform for systematic and sound comparisons of real-parameter global optimisers. COCO provides benchmark function testbeds, experimentation templates which are easy to parallelize, and tools for processing and visualizing data generated by one or several optimizers. The COCO platform has been used for the Black-Box-Optimization-Benchmarking (BBOB) workshops that took place during the GECCO conference in 2009, 2010, 2012, 2013 and 2015. It was also used at the IEEE Congress on Evolutionary Computation (CEC'2015) in Sendai, Japan. The COCO source code is available at the [downloads](#) page.

- Black-Box Optimization Benchmarking (BBOB) 2016
- Black-Box Optimization Benchmarking (BBOB) 2015
- CEC'2015 special session on Black-Box Optimization Benchmarking (CEC-BBOB 2013)
- Black-Box Optimization Benchmarking (BBOB) 2013
- Black-Box Optimization Benchmarking (BBOB) 2012
- Black-Box Optimization Benchmarking (BBOB) 2010
- Black-Box Optimization Benchmarking (BBOB) 2009
- Downloads and documentations

To subscribe to (or unsubscribe from) the bbbob discussion mailing list follow this link <http://lists.lri.fr/cgi-bin/mailman/listinfo/bbbob-discuss>.

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