Benchmarking State-of-the-art DIRECT-type Methods on the BBOB Noiseless Testbed

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Introduction

- In recent years, there has been significant progress in the development of new DIRECT-type algorithms for black-box optimization problems.
- We evaluate three well-performing DIRECT-type methods from a recent extensive numerical study on the BBOB noiseless testbed in dimensions 2, 3, 5, 10, and 20.
- In the paper, we discuss the strengths and weaknesses of these algorithms on different classes of functions and provide a comparison with the original DIRECT method, as well as with three other well-established methods: RL-SHADE, L-BFGS-B, and SLSQP.

- The original DIRECT (which is an acronym of DIviding RECTangles) algorithm was introduced in 1993 and extended the classical Lipschitz optimization techniques by eliminating the need for the Lipschitz constant.
- The algorithm performs a division of the search space into non-overlaping hyper-rectangles and the point in the middle of each hyperrectangle (called the base point) is evaluated.
- In each iteration, the algorithm chooses which of the existing hyper-rectangles should be split.
- This choice is based on the function values in the rectangles and the size of the rectangles.

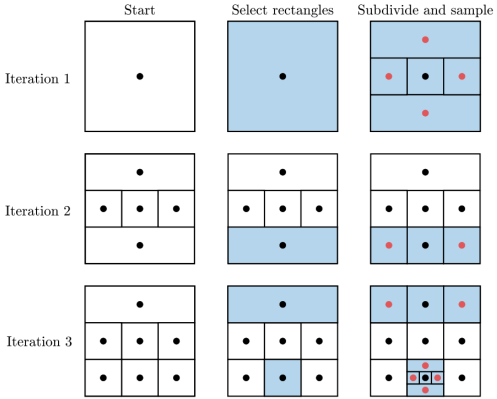


Figure: First iteration of the DIRECT algorithm on 2D problem[1].

[1]R.D. Jones and J.R.A.A. Martins. 2021. The DIRECT algorithm: 25 years Later. Journal of Global Optimization.

- Many different DIRECT-type algorithms have been proposed over the years, but almost all share the same basic structure of selection, evaluation, and partitioning.
- For performing the numerical comparison, we selected the best-performing methods from a recent extensive numerical study[2], which evaluated 64 derivative-free algorithms on the test problems from the DIRECTGOLib[3] and from the GKLS generator.

[2]Linas Stripinis and Remigijus Paulavičius. 2022. An extensive numerical benchmark study of deterministic vs. stochastic derivative-free global optimization algorithms. arXiv preprint arXiv:2209.05759 (2022)

[3]Linas Stripinis and Remigijus Paulavičius. 2022. DIRECTGOLib - Global Optimization test problems Library. `https://github.com/blockchain-group/DIRECTGOLib`.

Selected DIRECT-type Methods

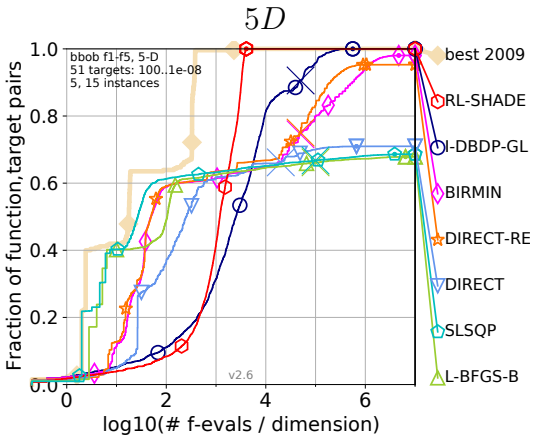
- The first selected method was DIRECT-REV, which is a DIRECT algorithm with enhancements for the reduction of the global drag.
- The other two methods were both modifications of the BIRECT method, which uses bisection of hyper-rectangles
  - the first one of the two was BIRMIN, which is globally-biased hybridized version of the BIRECT method
  - the second one was I-DBDP-GL, which uses hyper-rectangular partitioning based on 1-dimensional bisection and objective function evaluations at two diagonal points with global and local search enhancements

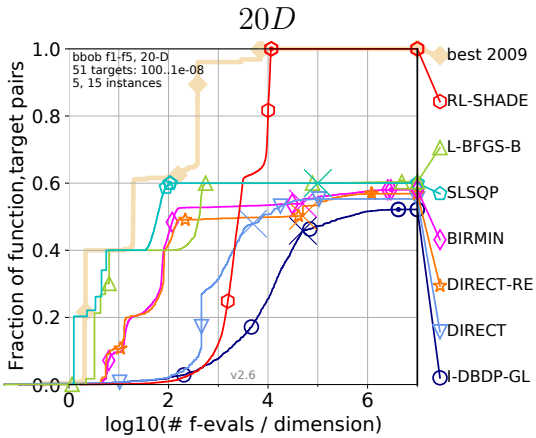
Experiments

- The code for all three methods was obtained from the DIRECTGO toolbox[4] and the methods were run on the BBOB benchmark functions in their default settings for a maximum budget of $5 \cdot 10^4 \times D$ function evaluations.
- The choice of the relatively low number of function evaluations stems from the way the DIRECT-type algorithms function.
- The time required to sample new points becomes more time-consuming in later phases of optimization, as these methods do not "forget" anything (before selecting the next rectangles to divide, they must get through all the rectangles they created previously).

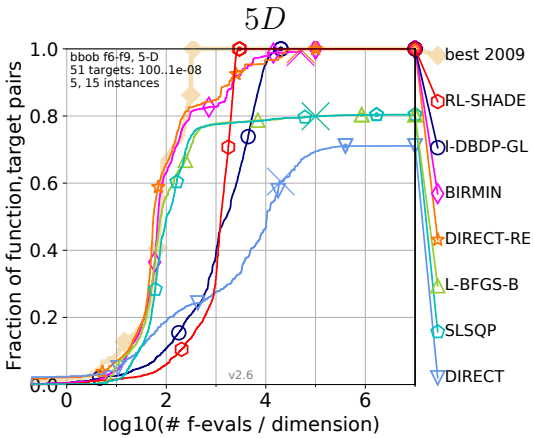
[4] `https://github.com/blockchain-group/DIRECTGO`

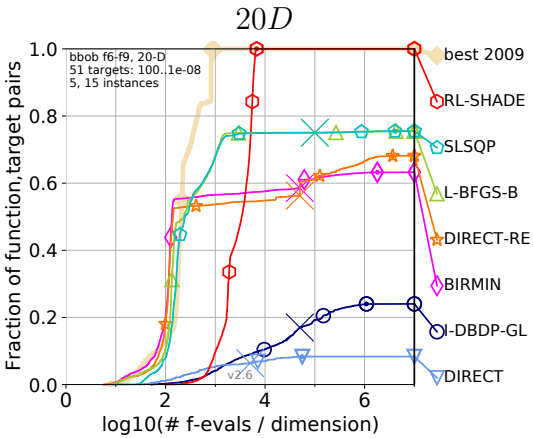
Separable Functions



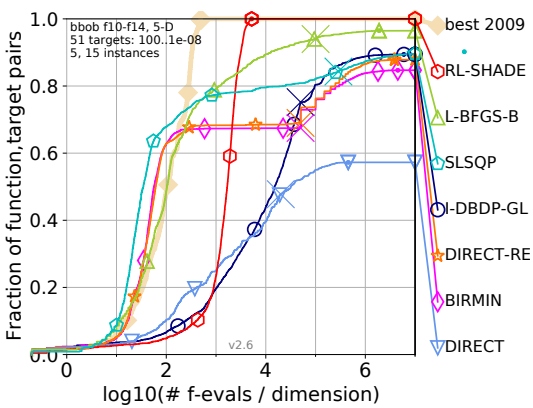


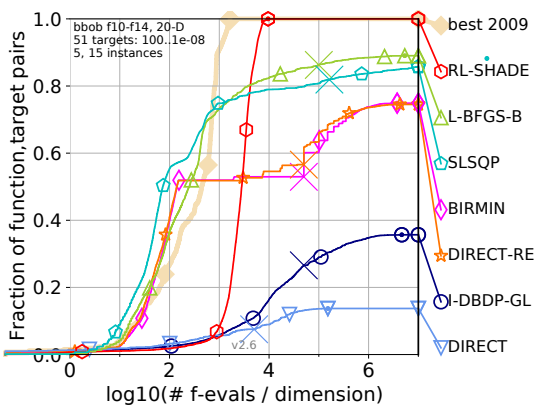
Moderate Functions



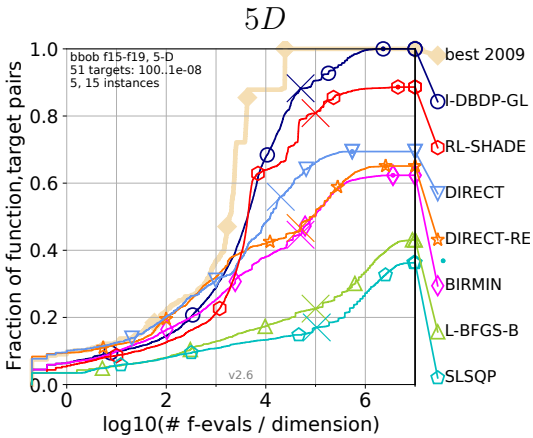


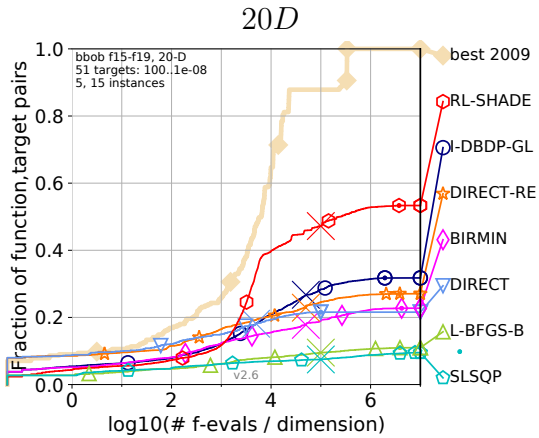
Ill-conditioned Functions



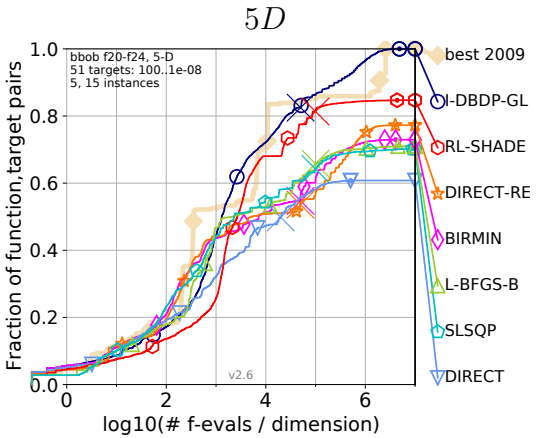


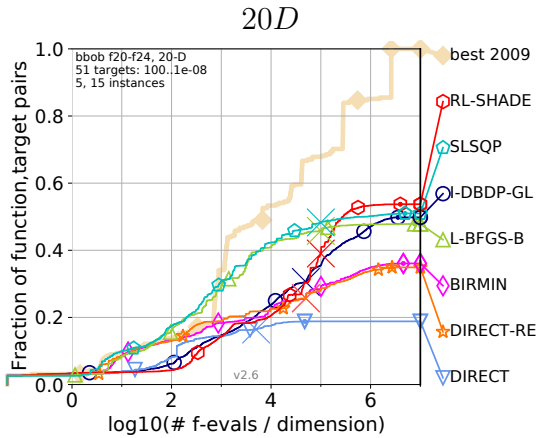
Multi-modal Functions



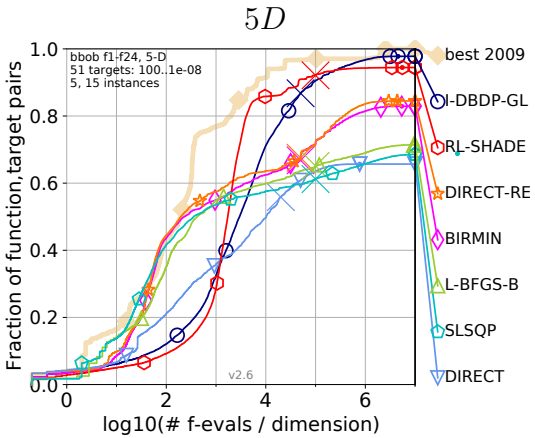


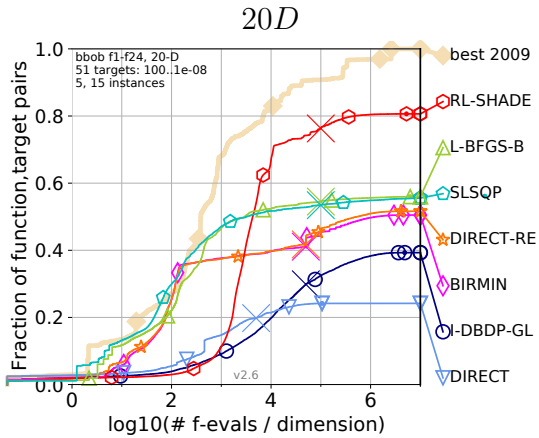
Weakly Structured Multi-modal Functions





All Functions





Conclusion

- We saw that the DIRECT-type methods are well-performing for lower dimensions (up to 5), but their performance on the BBOB testbed degrades substantially (especially in the separable and ill-conditioned problem classes) with increasing dimensions, much more other methods.
- On the other hand, the DIRECT-type methods performed quite well on multimodal classes, even in higher dimensions (again, especially I-DBDP-GL).
- It should be noted that the selected DIRECT-type methods are space decomposition techniques, for which it is difficult to devise suitable restart strategies (which is in stark contrast to the other considered methods).
- Overall, we can conclude that the advancements in the DIRECT-type algorithms over the last few years brought substantial improvements over the original DIRECT method.

Thank you for your attention!

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