

# Performance of modular CMA-ES on strict box constrained problems in the SBOX-COST benchmarking suite

Diederick Vermetten  
LIACS, Leiden University  
Leiden, The Netherlands  
d.l.vermetten@liacs.leidenuniv.nl

Olaf Mersmann  
TH Köln  
Köln, Germany  
olaf.mersmann@th-koeln.de

Anna V. Kononova  
LIACS, Leiden University  
Leiden, The Netherlands  
a.kononova@liacs.leidenuniv.nl

Manuel López-Ibáñez  
University of Manchester  
Manchester, UK  
manuel.lopez-ibanez@manchester.ac.uk

Youngmin Kim  
University of Manchester  
Manchester, UK  
youngmin.kim@manchester.ac.uk

Richard Allmendinger  
University of Manchester  
Manchester, UK  
richard.allmendinger@manchester.ac.uk

## ABSTRACT

todo: write abstract, edit title, all authors?, author order, keywords, CCS concepts, finish various items marked within the paper, upload to the website and link to CfP. The paper should be up to 4 pages. Please feel free to edit whatever you like.

## CCS CONCEPTS

• Theory of computation → Theory of randomized search heuristics; Algorithm design techniques; Discrete optimization; • Mathematics of computing → Evolutionary algorithms.

## KEYWORDS

keyword, keyword

### ACM Reference Format:

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## 1 INTRODUCTION

to extend in the context of SBOX-COST The Covariance Matrix Adaptation Evolution Strategy (CMA-ES) is a very popular heuristic optimisation algorithm for continuous optimisation problems [?]. CMA-ES is considered state-of-the-art in evolutionary computation and has been adopted as one of the standard tools for continuous optimisation in many research labs. There are many flavours and variants of CMA-ES developed through the years and different implementations of sub-components such as the sampling strategy and the boundary correction method. In recent works, the different modules and configurations of CMA-ES are explored and analysed based on their performance [?]. In that research a modular CMA-ES framework is presented, representing a plethora of different CMA-ES configurations. In this paper, the modular CMA-ES framework is used to analyse the effect of introducing boundaries to standard BBOB problems, as done in the new SBOX-COST benchmark.

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This paper serves as an *example* of a short paper for the ACM Workshop on Strict Box-Constrained Optimization <sup>1</sup> (SBOX-COST) within GECCO 2023.

## 2 METHODOLOGY

### 2.1 SBOX-COST benchmarking suite

to extend

COCO/BBOB [?] ...

Newly proposed Strict Box-Constraint Optimization Studies benchmark <sup>2</sup> (SBOX-COST) [?]:

- is BBOB with *hard box-constraints*: points evaluated outside of the domain  $[-5, 5]^d$  are considered infeasible and evaluated to  $\infty$ ,
- has optima across instances located uniformly within the full domain – except for, as in BBOB, F4, F8, F9, F19, F20, F24 which have optima uniform in  $[-4, 4]^d$  and F5 - in the corners of  $[-5, 5]^d$ .

### 2.2 Algorithm

to re-write Explain basic CMA-ES

To investigate several commonly and less commonly used configurations and variants of the CMA-ES algorithm, we use the Modular CMA-ES framework [?]. The framework is open-source and available as part of the IOHprofiler [?] environment<sup>3</sup>.

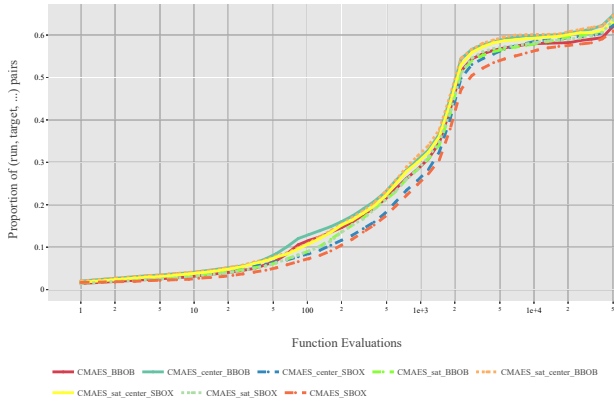
Modular CMA-ES framework is currently made up of 11 modules, each having a number of implemented options: Active update (2), Elitism (2), Orthogonal Sampling (2), Sequential Selection (2), Threshold Convergence (2), Step-Size adaptation (7), Mirrored Sampling (3), Quasi-Gaussian Sampling (3), Recombination Weights (2), Restart Strategy (3) and Boundary Correction (6). The framework allows a total of 72.576 possible configurations. A detailed description of each module and their settings can be found in [?].

In this paper, to investigate the effect of the introduction of strict boundaries on BBOB problems in SBOX-COST, we compare the behaviour of 4 different variants of CMA-ES by considering two *initialization* methods for the centre of mass (set to the origin of the space, centre, or set uniformly at random in the domain) and

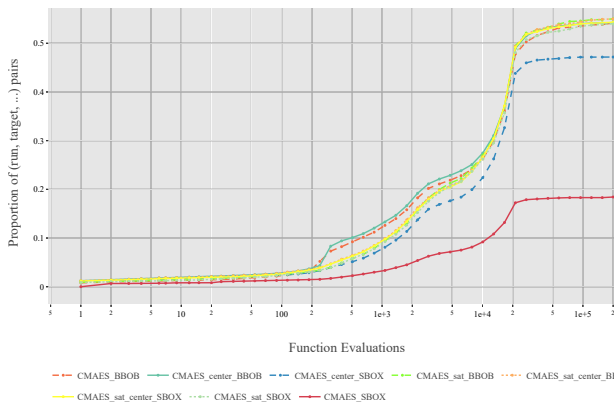
<sup>1</sup><https://sbox-cost.github.io/>

<sup>2</sup><https://github.com/sbox-cost>

<sup>3</sup><https://github.com/IOHprofiler/ModularCMAES>



**Figure 1: Empirical Cumulative Distribution Function for all considered variants of CMA-ES, aggregated over the 24 functions of BBOB and SBOX-COST in 5D. Targets are 51 log-spaces values between  $10^2$  and  $10^{-8}$  ('bbob' default in IOHalyzer).**



**Figure 2: Empirical Cumulative Distribution Function for all considered variants of CMA-ES, aggregated over the 24 functions of BBOB and SBOX-COST in 20D. Targets are 51 log-spaces values between  $10^2$  and  $10^{-8}$  ('bbob' default in IOHalyzer).**

enabling or disabling the method for dealing with *box-constraints* (saturate, which places the infeasible coordinates to the closest corresponding bound or none which allows infeasible points). All *other modules* are set to their default settings specified in [?].

### 3 EXPERIMENTAL SETUP

**to extend** 24 functions of SBOX-COST vs 24 functions of BBOB

Identical setup: 15 instances per function, 1 run per instance, dimensionality  $d \in \{5, 20, 40\}$ , budget  $10000 \times d$

Experiments reported in this study are carried out in the IO-Hexperimenter environment [?] which implements both sets of functions.

## 4 RESULTS

**to discuss** impact of changing from BBOB [?] to SBOX-COST, why higher dimensions are more difficult, why centre initialization sees less impact than random (more infeasible points at the start of the run in the latter case), what else?

## 5 CONCLUSIONS

**todo**

## REPRODUCIBILITY

To ensure the reproducibility of results presented in this paper, the complete code used for experiments and runs data in the IOH format have been uploaded to a Zenodo repository <https://doi.org/10.5281/zenodo.7649077>.

## ACKNOWLEDGMENTS

**anything?**

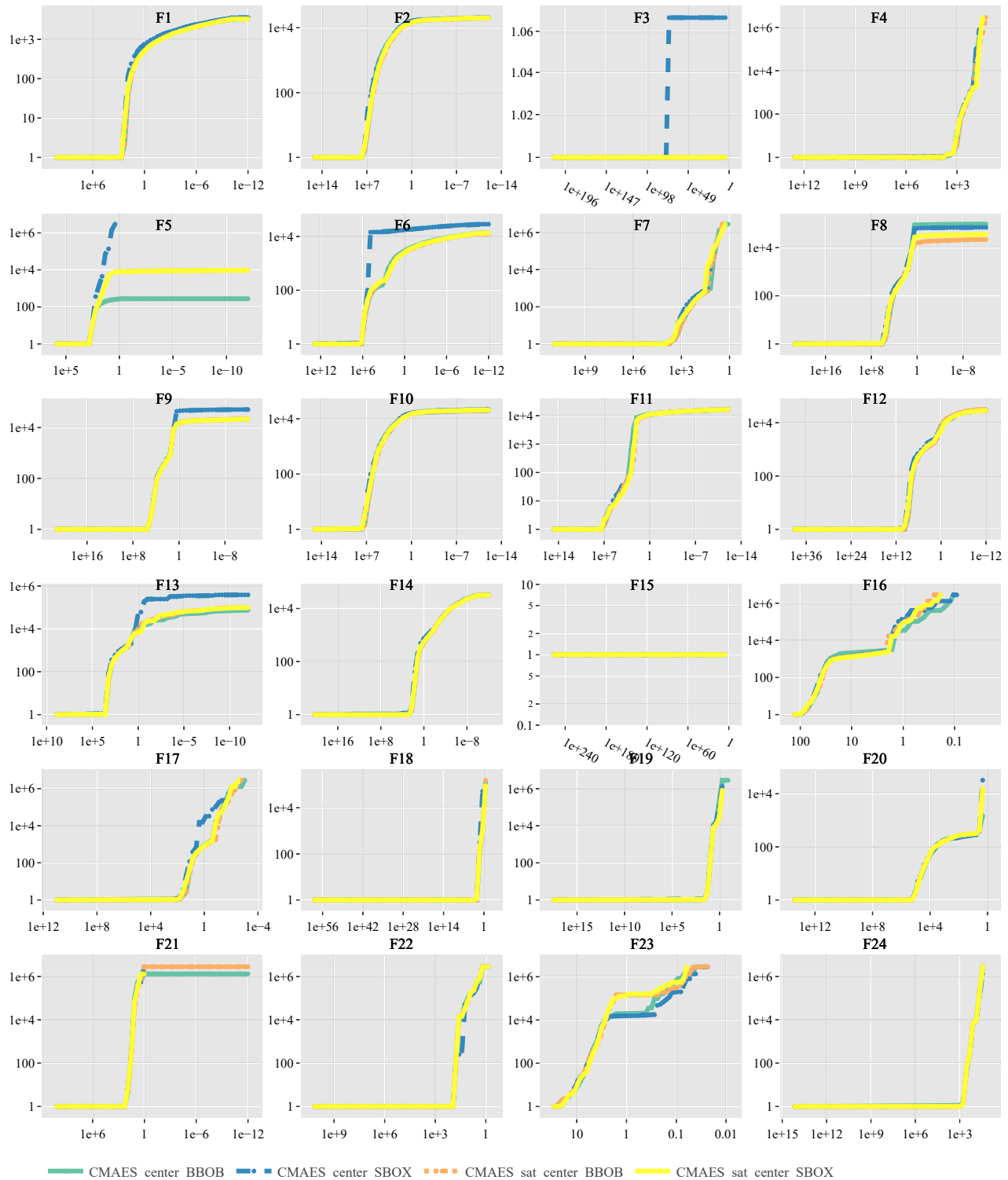


Figure 3: Expected Running time for the CMA-ES methods with centre initialization, for 24 SBOX-COST functions of BBOB and SBOX-COST in 20D.