Markus Wagner and Tobias Friedrich

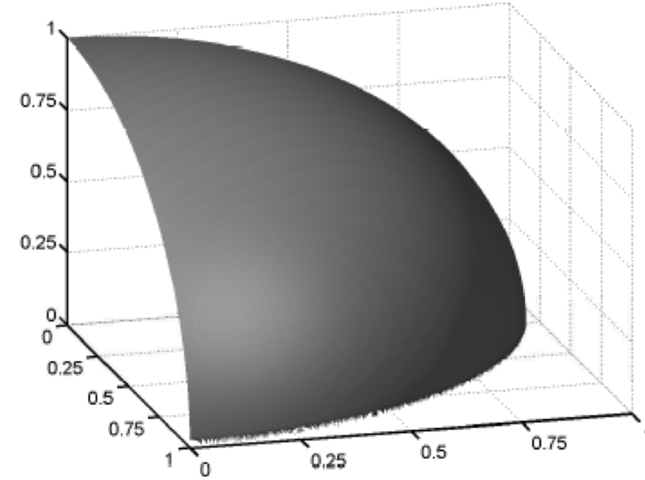
Efficient Parent Selection for Approximation-Guided Evolutionary Multi-Objective Optimization

THE UNIVERSITY of ADELAIDE

Friedrich Schiller University of Jena

since 1558

Introduction



- Pareto front: set of all the (many) different trade-offs
- EMOAs restrict themselves to a smaller set that should be a good approximation of the Pareto front
- Different EMOAs (e.g., NSGA-II, SPEA2, IBEA, SMS-EMOA, MOEA/D, …) try to achieve approximations by preferring diverse sets of non-dominated solutions.
- The typical lack of a formal notion of approximation makes it hard to evaluate and compare algorithms for MOO problems.

Approximation-Guided Evolution (AGE)

- Motivated by studies in theoretical computer science
  [initially: formal notion
  then: comparison with the hypervolume indicator
  now: an efficient framework]

  [Cheng, Janiak, Kovalyov 1998]
  [Papadimitriou, Yannikakis 2000, 2001]
  [Vasilvitskii, Yannakakis 2005]
  [Diakonikolas, Yannakakis 2009]
  [Daskalakis, Diakonikolas, Yannakakis 2010]
  [Bringmann, Friedrich 2010]

- The AGE framework
  - allows to incorporate a formal notion of approximation
  - improves the approximation quality iteratively
  - uses the best knowledge obtained so far ("archive")

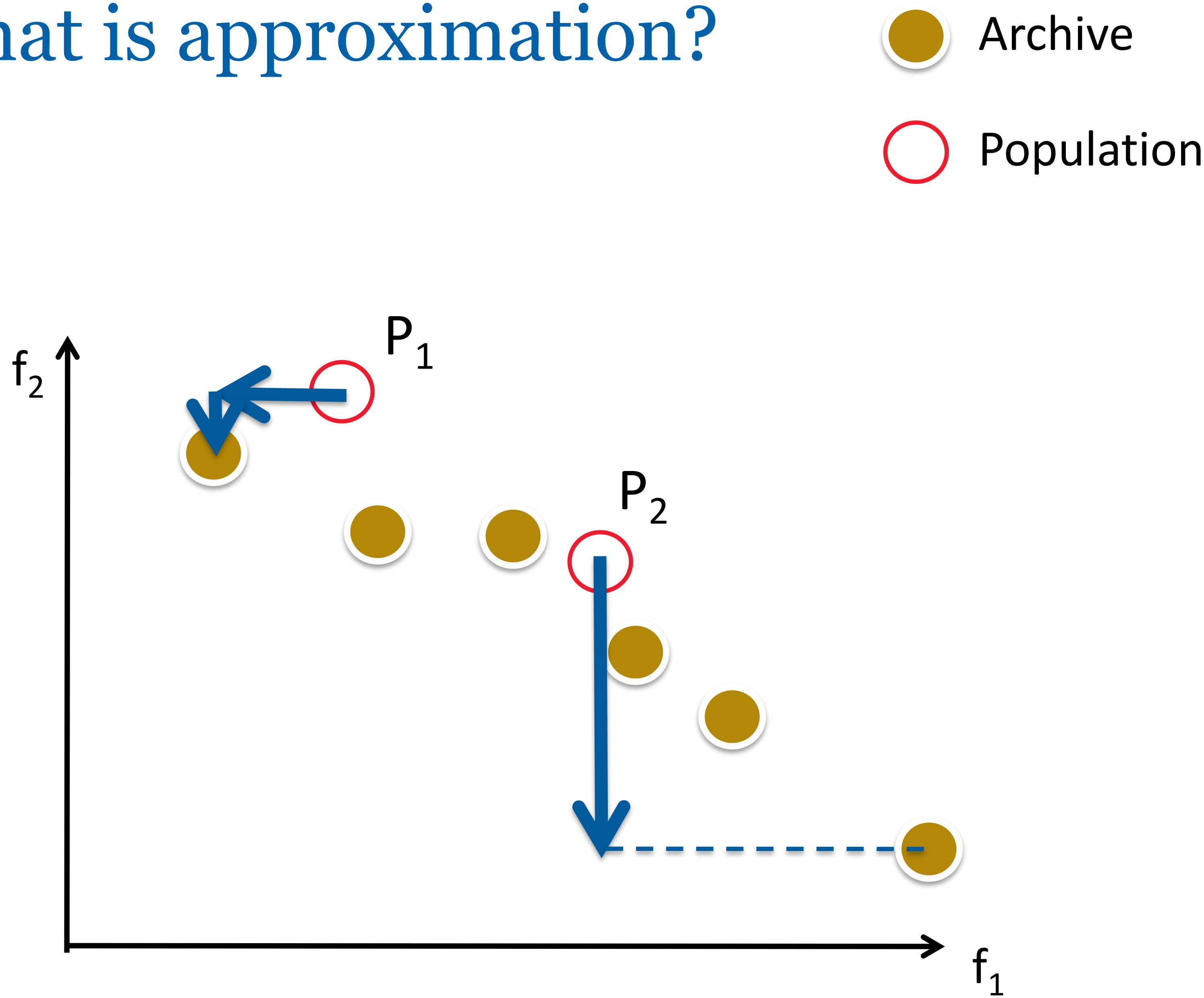
- Given a fixed time+evaluations budget, AGE outperforms other EMOAs in terms of the desired additive approximation, as well as the covered hypervolume (see our IJCAI '11 article)

Contribution

- Approximation-Guided Evolution (AGE) [IJCAI ’11]
    1. Its runtime of AGE can suffer in high-dimensional spaces
    2. It has a mediocre performance on “easy” problems

- Parent Selection for AGE **today**
    1. Non-random
    2. Computationally efficient
    3. Not detrimental in high-dimensional spaces

What is approximation?

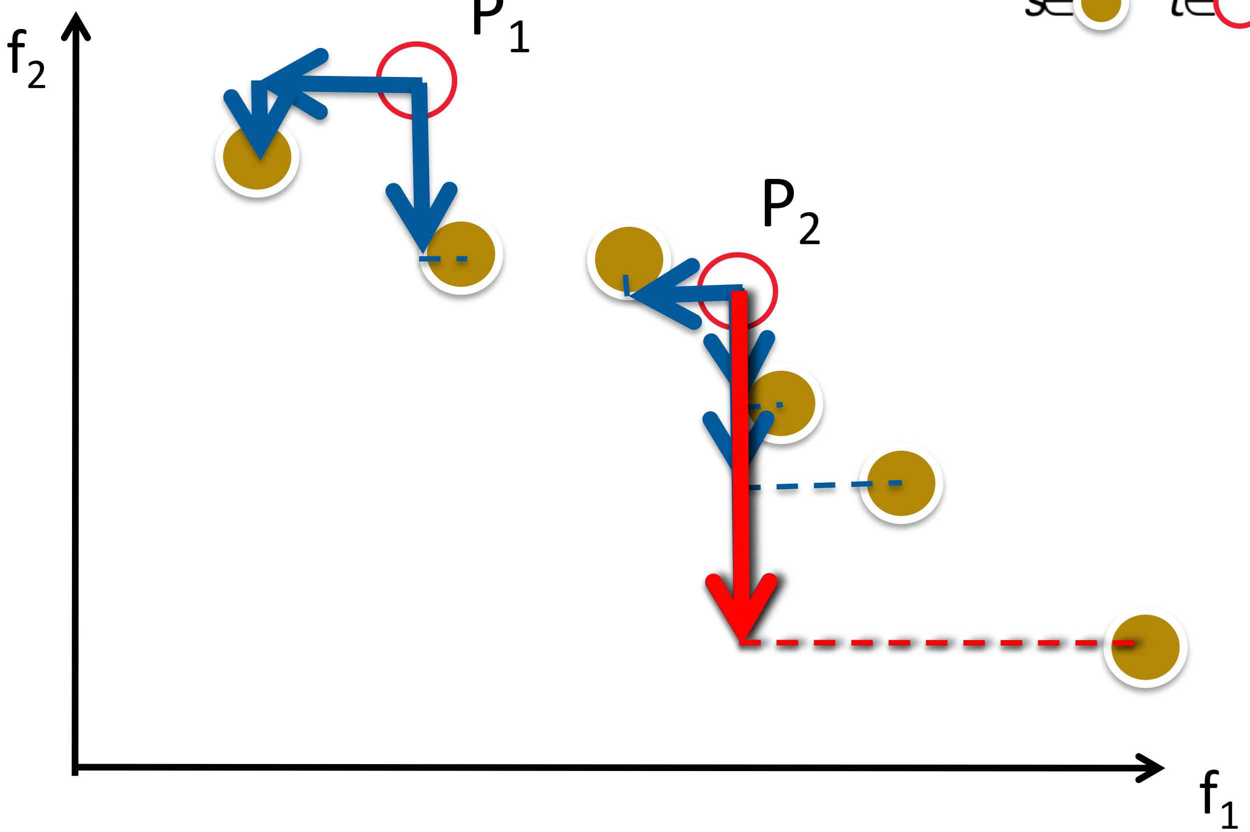


What is approximation?

Archive

Population

$$\alpha(S,T) := \max_{s \in S} \min_{t \in T} \max_{1 \le i \le d} (s_i - t_i)$$



On Problems with Many Objectives (see Section IIb)

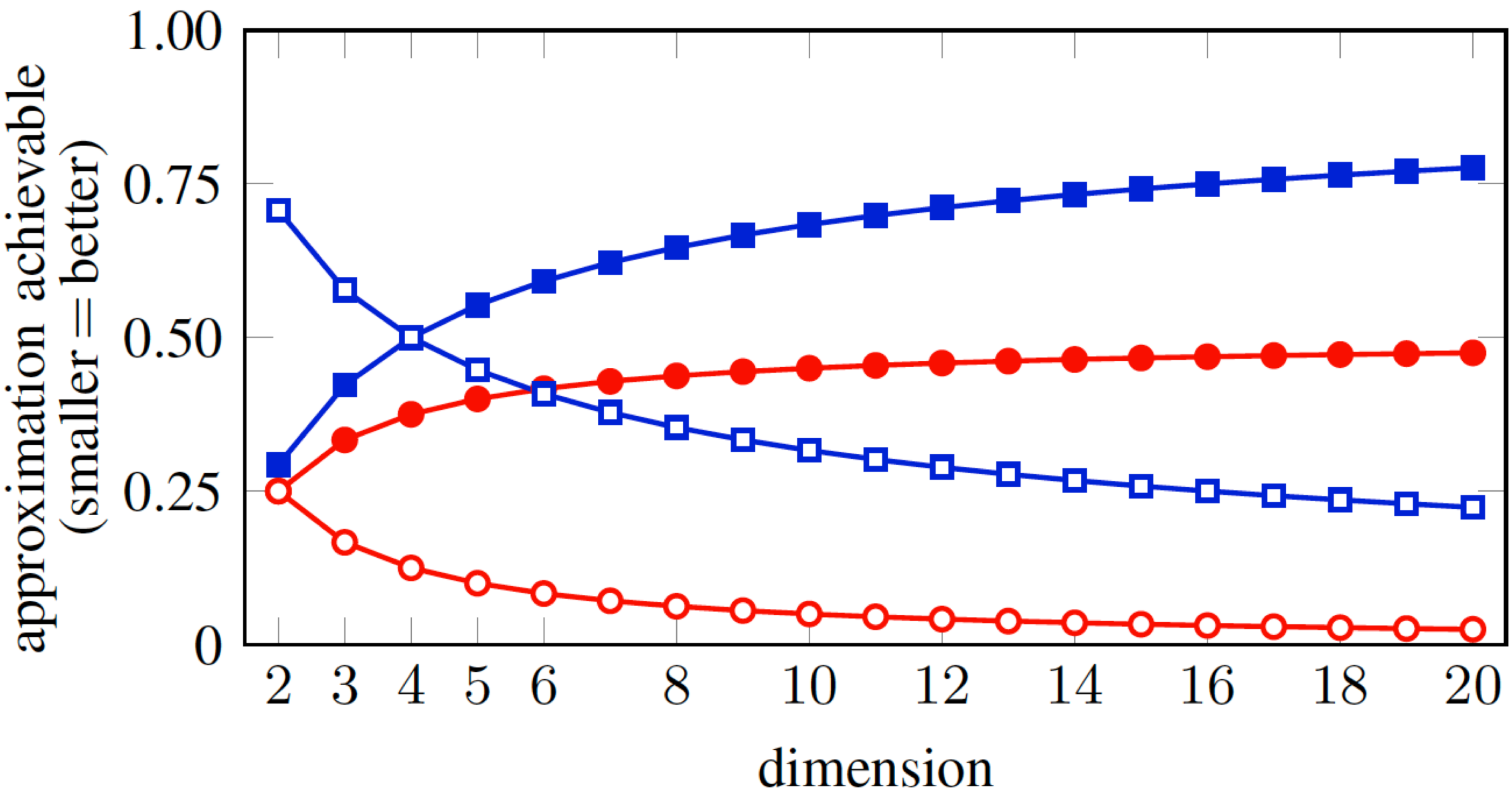
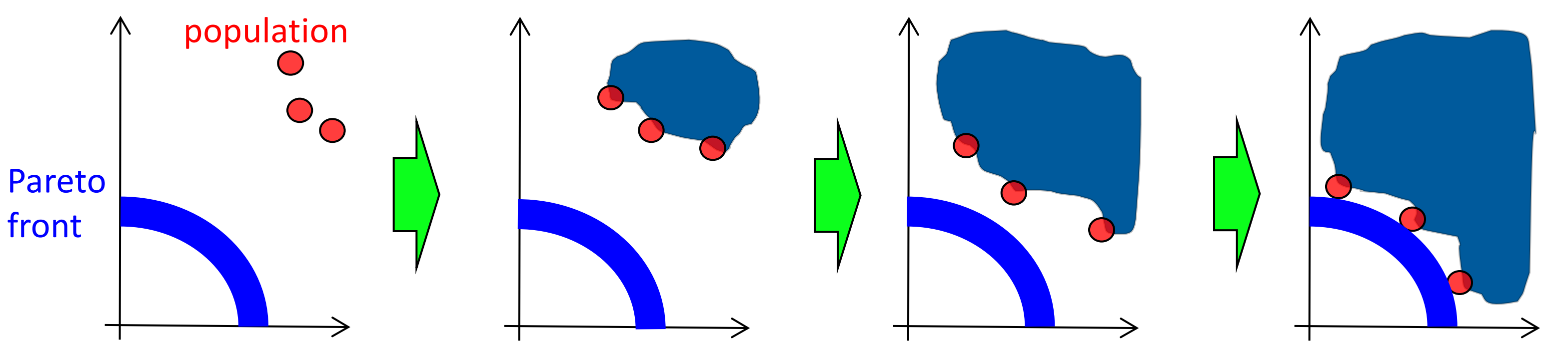


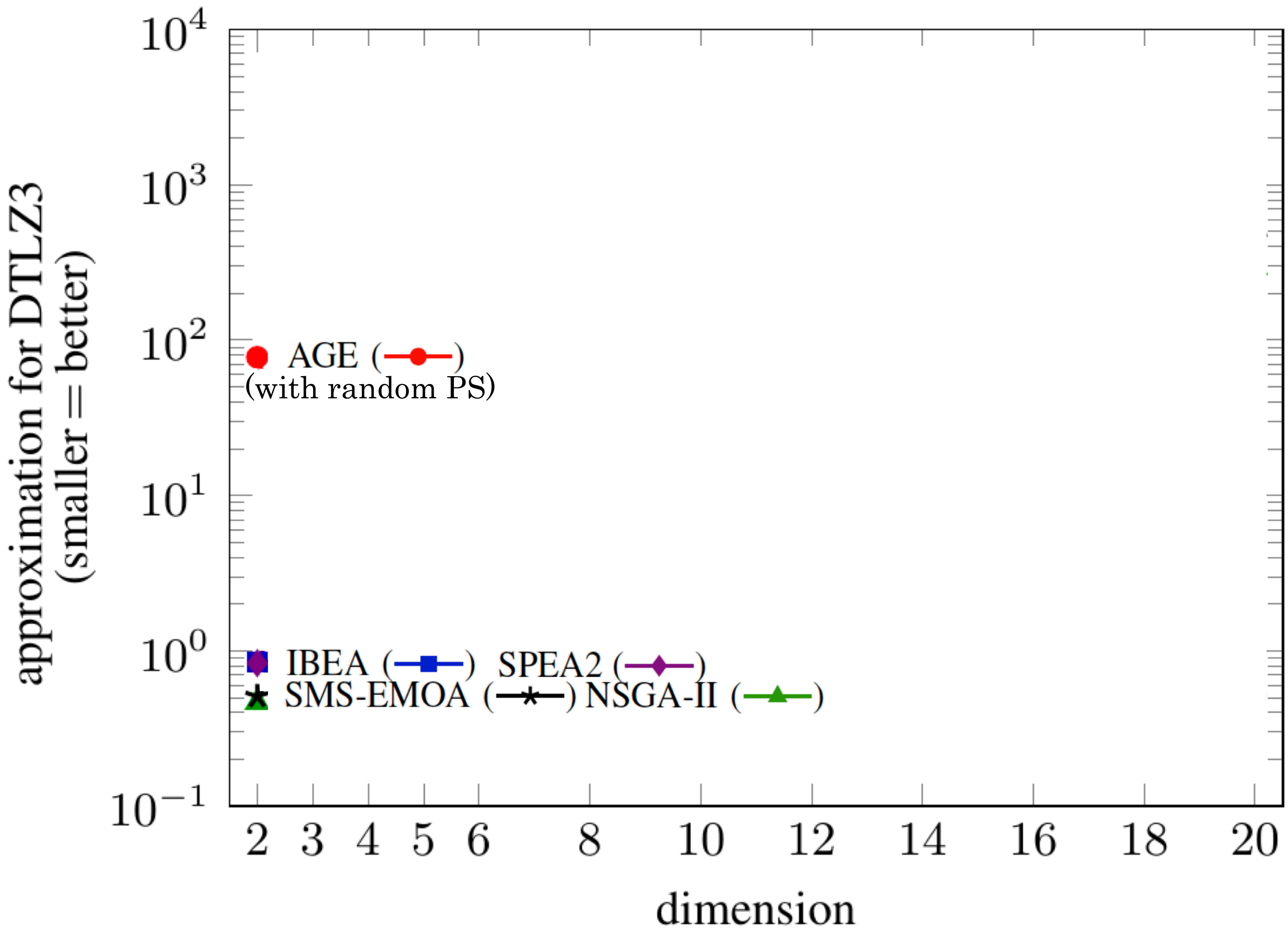
Fig. 1. Achievable additive approximations of the Pareto fronts, when only all corner points are found for DTLZ 1 (—●—) and for DTLZ 2/3/4 (—■—), and when only the centre of the Pareto front is found for DTLZ 1 (—○—) and for DTLZ 2/3/4 (—□—)

Approximation-Guided EA

- α(f,X) is the approximation ratio achieved by the set X with respect to the Pareto front f
- Aim: find X such that α(f,X) is minimised
- Problem: we do not know the Pareto front f
- Solution: use the union of all non-dominated points seen so far ("archive") as an approximation of the Pareto front f



Parent Selection



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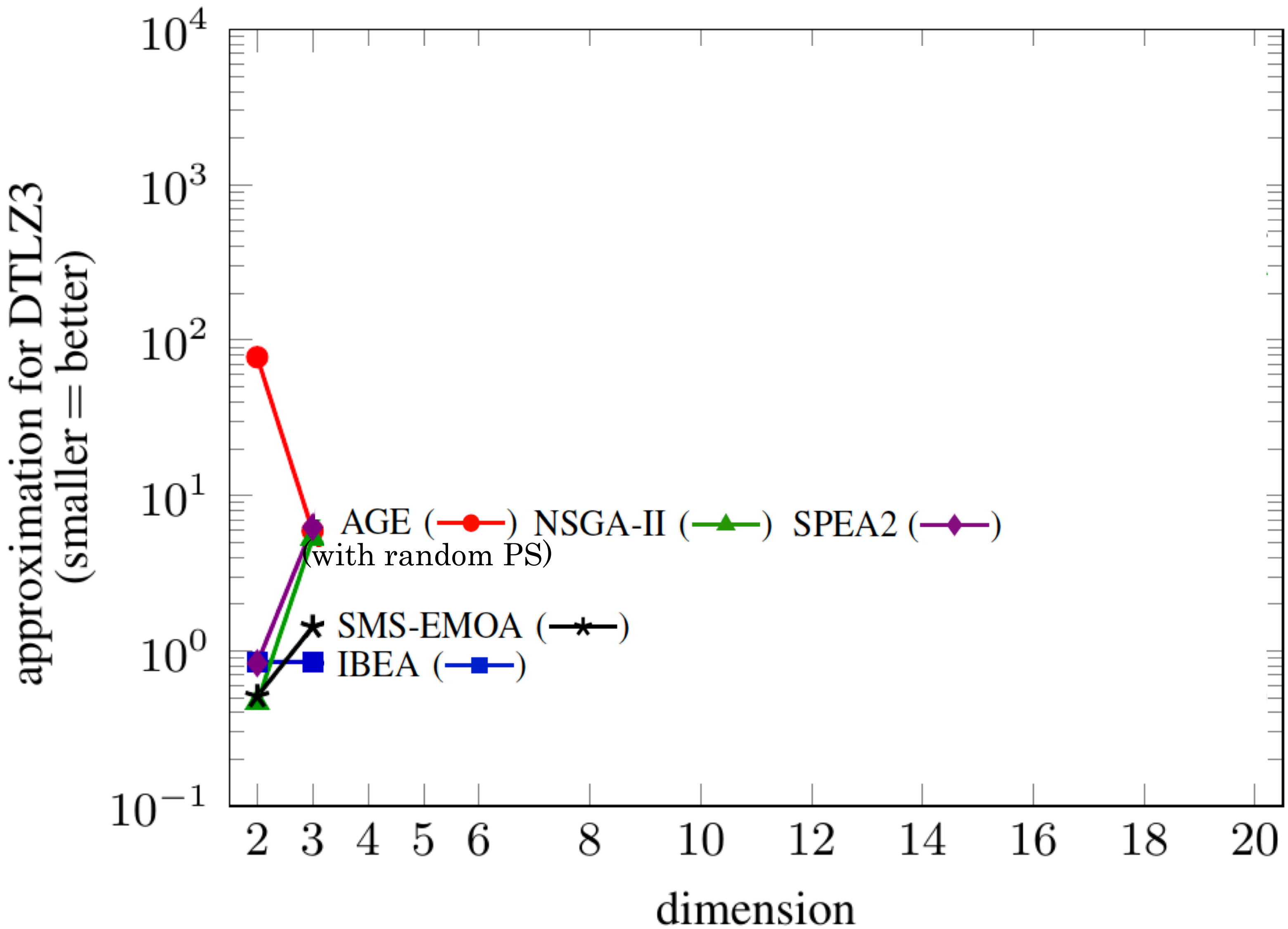

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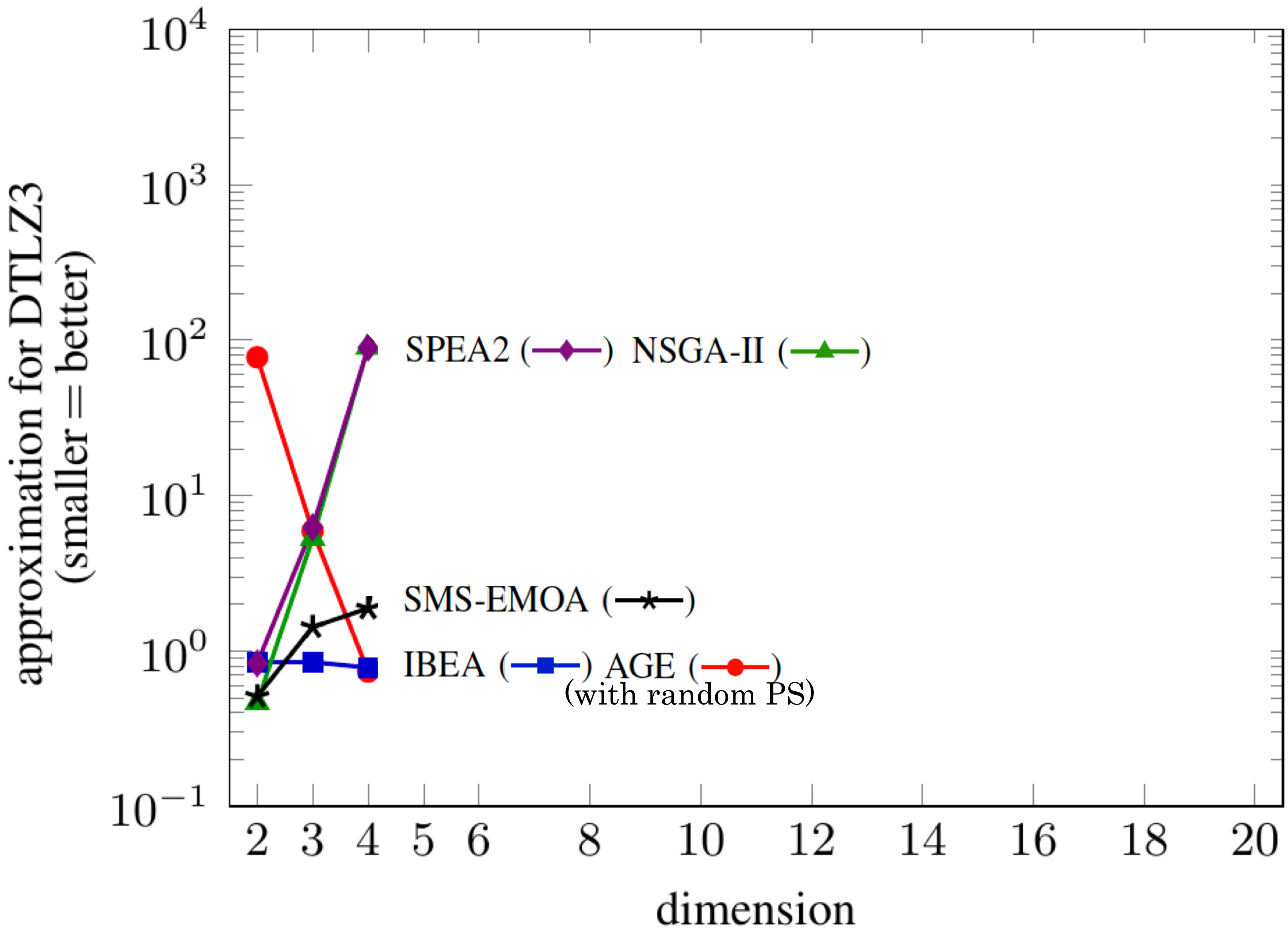

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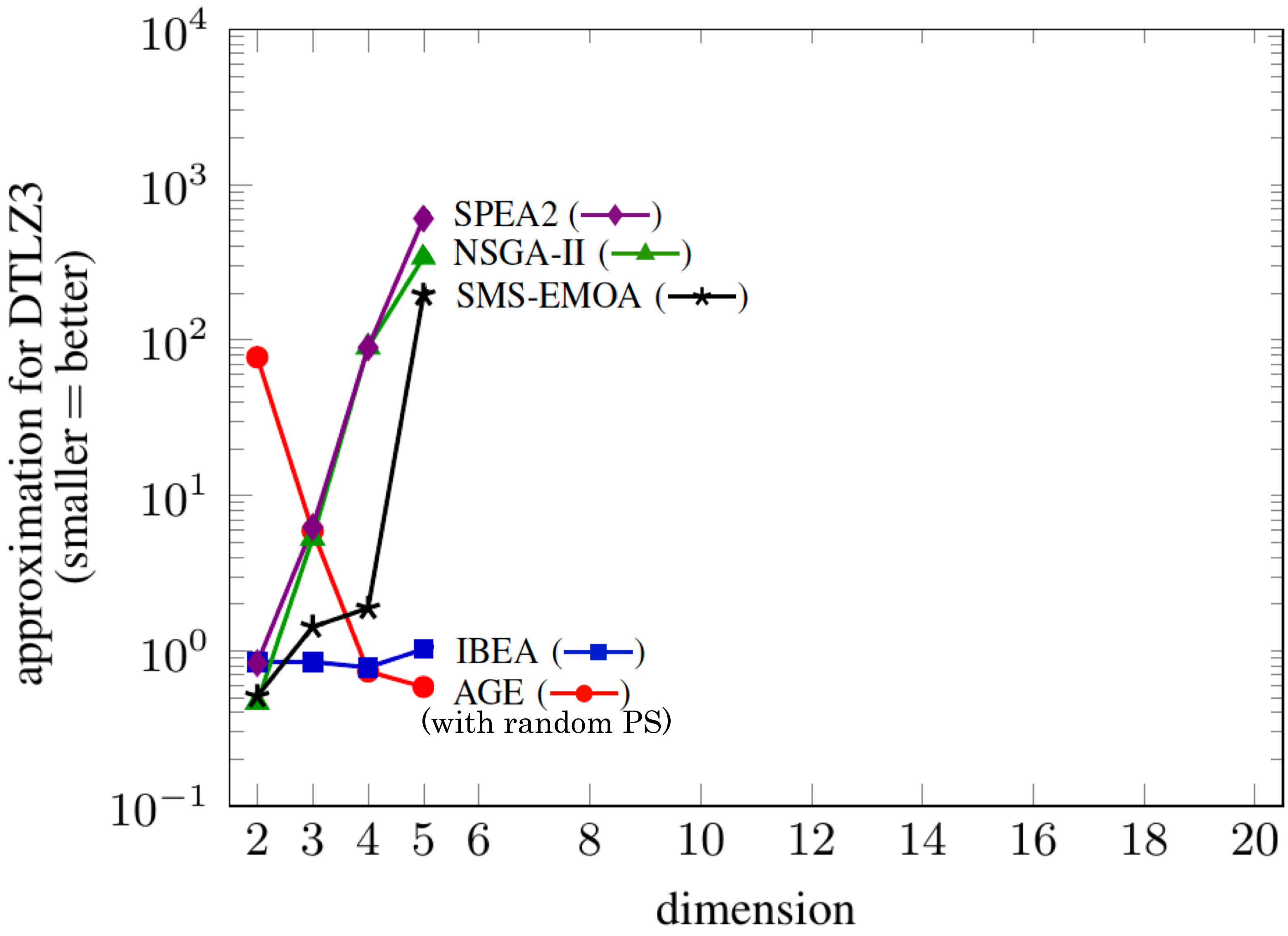

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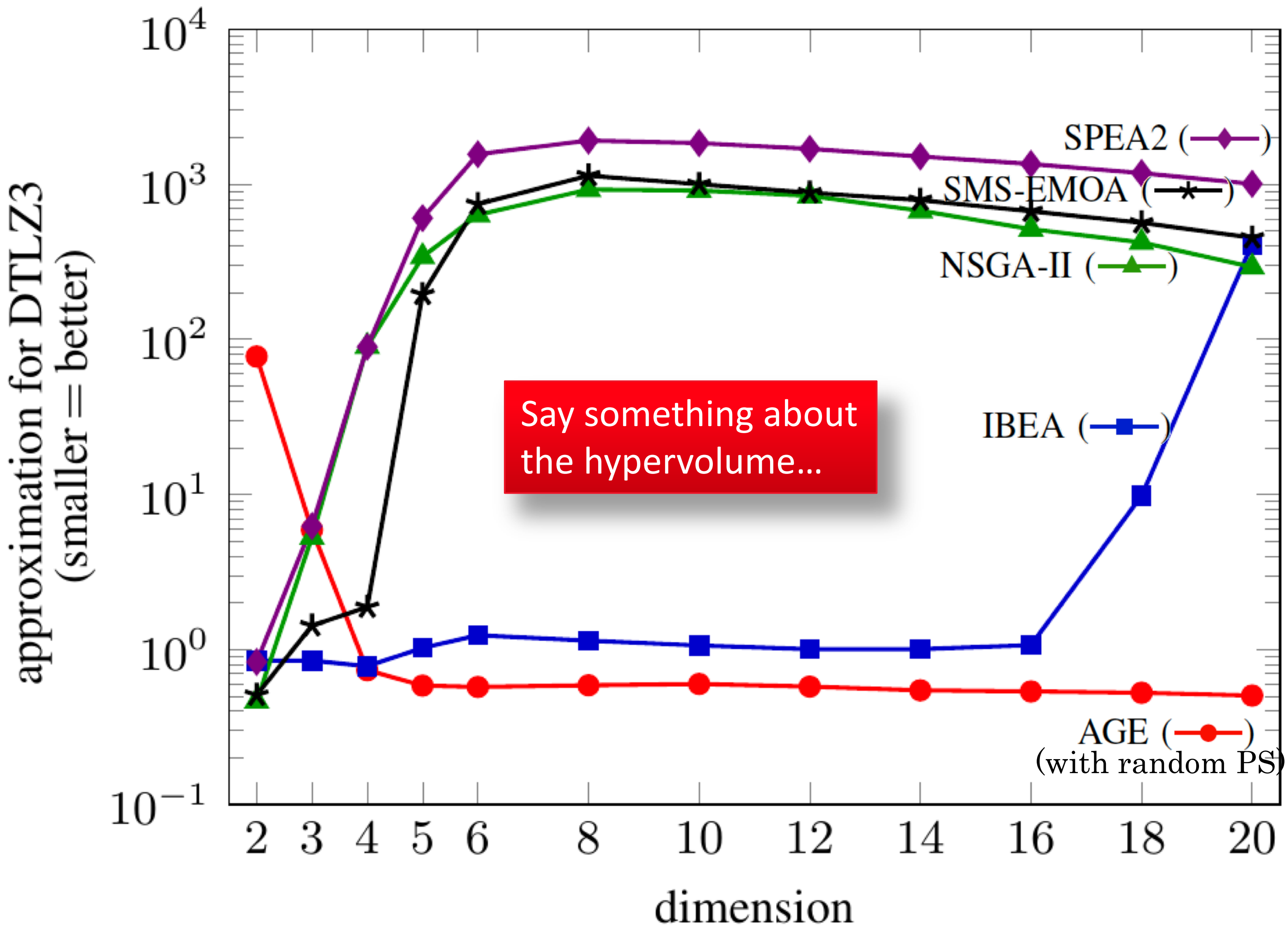


Say something about the hypervolume…

Parent Selection

All eight investigated approaches are

- computationally inexpensive
- increase the selection pressure

Approaches

1. Random selection
2. Focus on the first fronts of the population
   - Variant 1: exclusive focus on the first front
   - Variant 2: bias towards the first front
3. Use of crowding distance
4. Random omission of solutions

… and several combinations of these

Experiments

- NSGA-II, IBEA, SPEA2, SMS-EMOA

  AGE with eight parent selection strategies

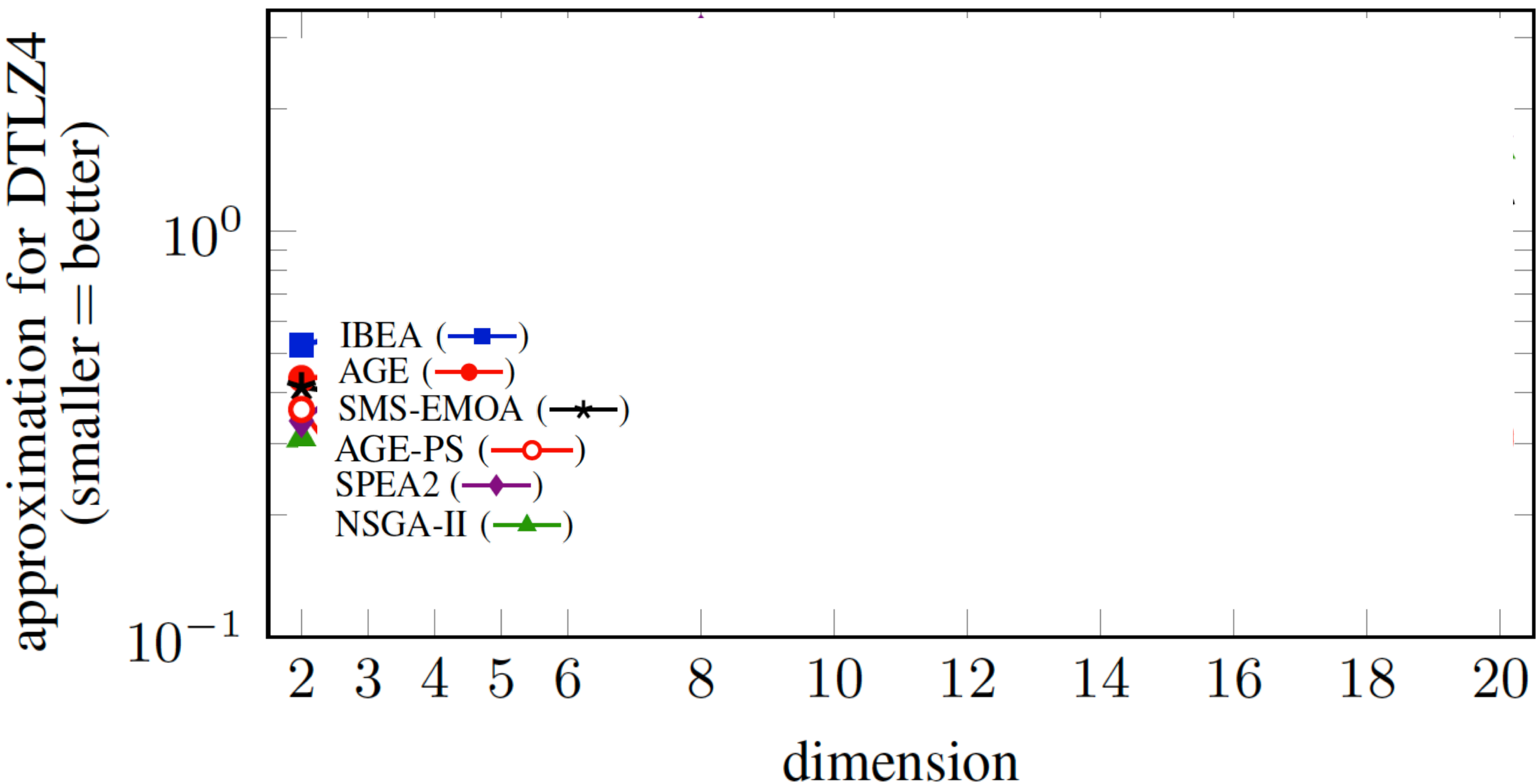
- DTLZ family can be scaled in the number of objectives:
  DTLZ 1/2/3/4 (each with d=2,…,20)
  → 48 functions, plenty of plots

- Limits: 100.000 evaluations, 4h

- μ=100, SBX, PM, implemented in jMetal

(Psst… code is available online…
http://tinyurl.com/age2013)

Results



approximation for DTLZ4
(smaller = better)
10^0
10^{-1}
IBEA
AGE
SMS-EMOA
AGE-PS
SPEA2
NSGA-II
2
3
4
5
6
8
10
12
14
16
18
20
dimension

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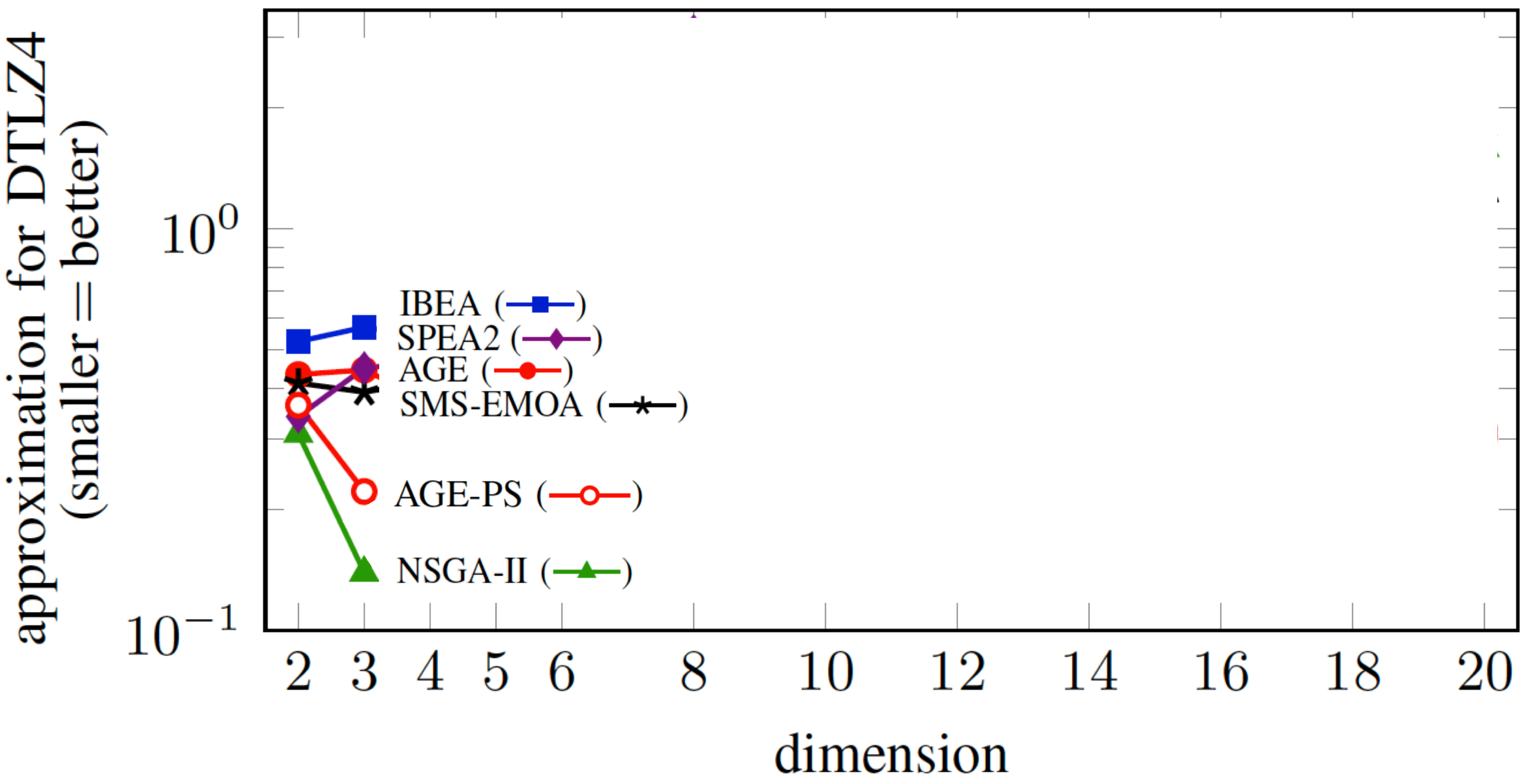
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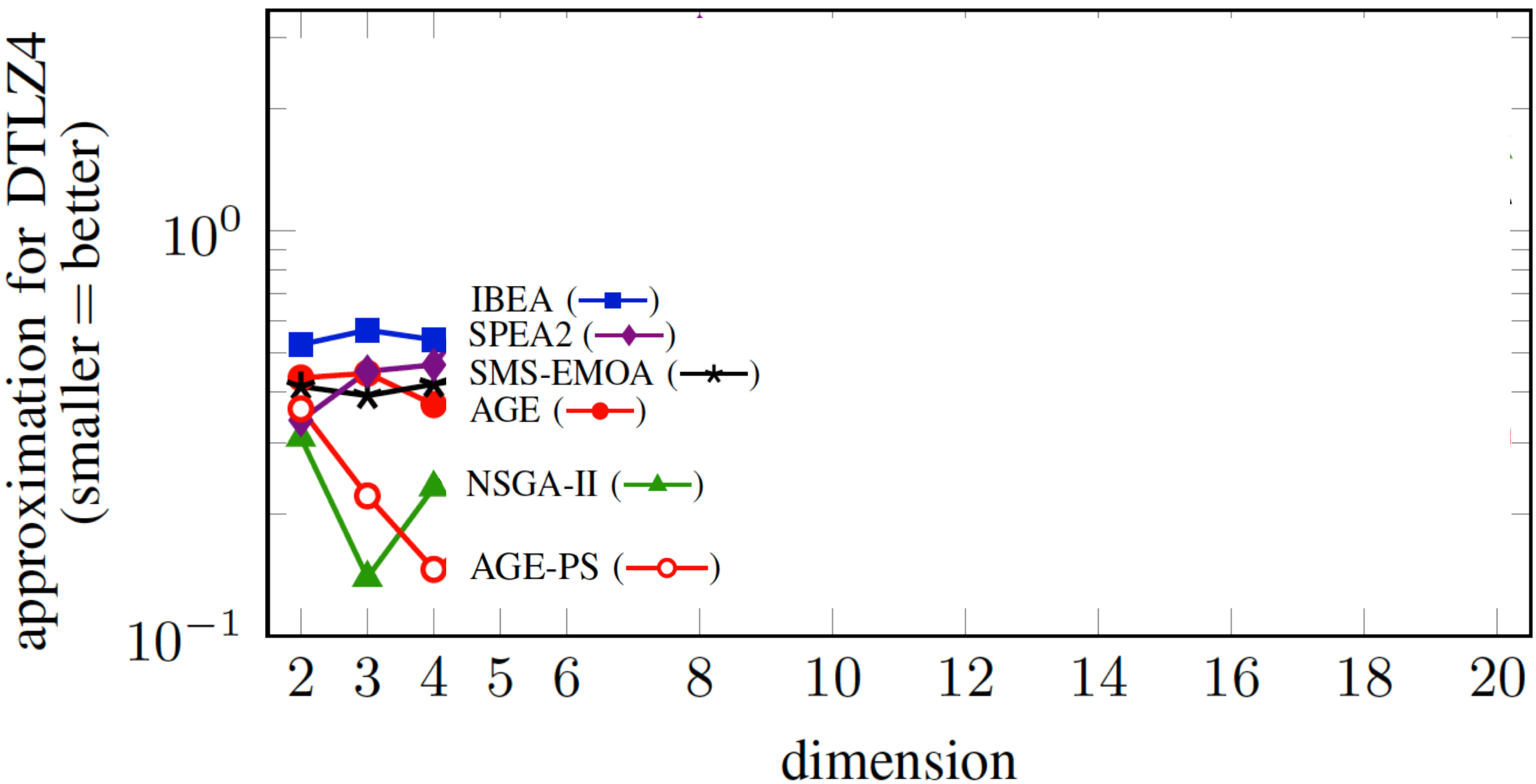
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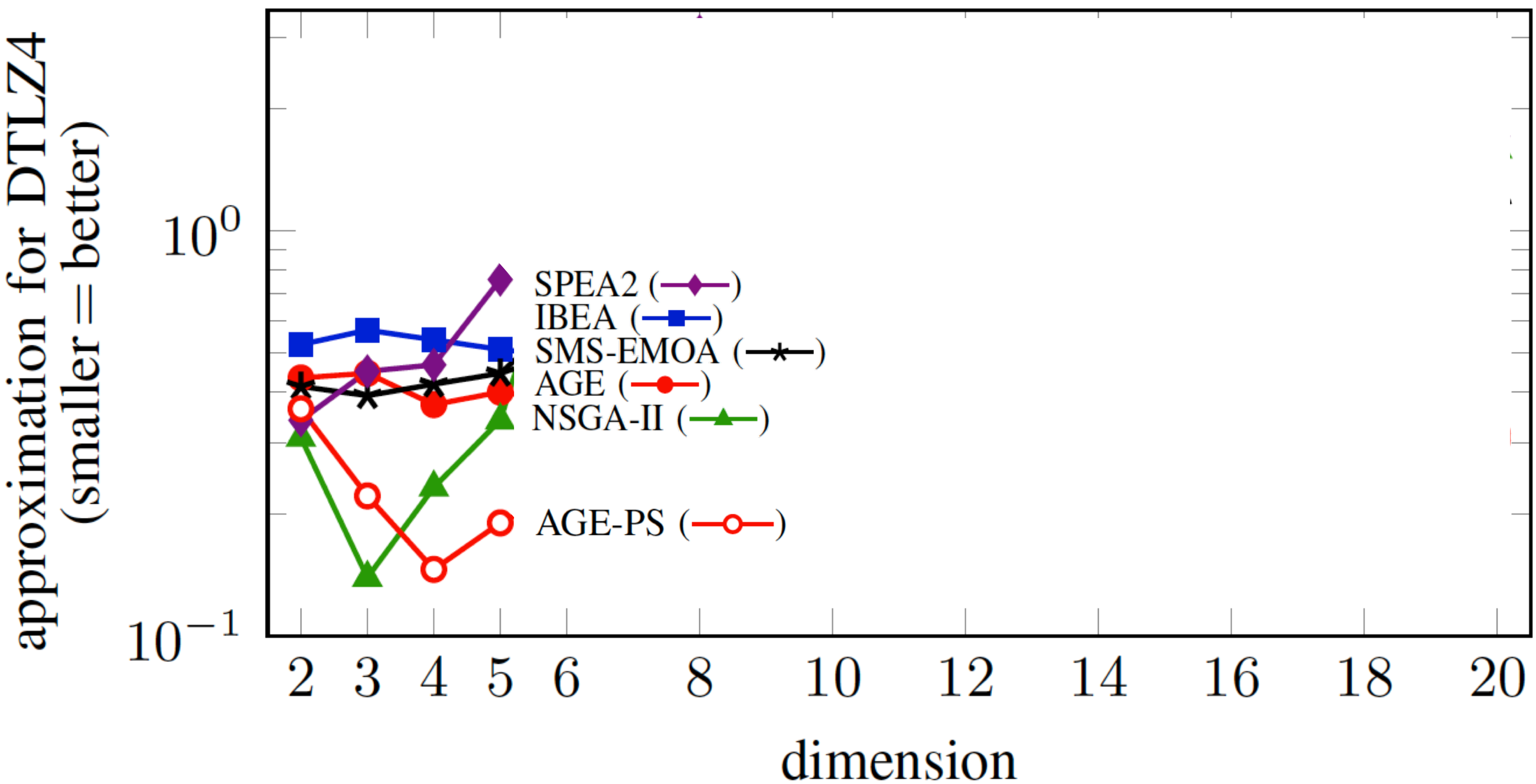

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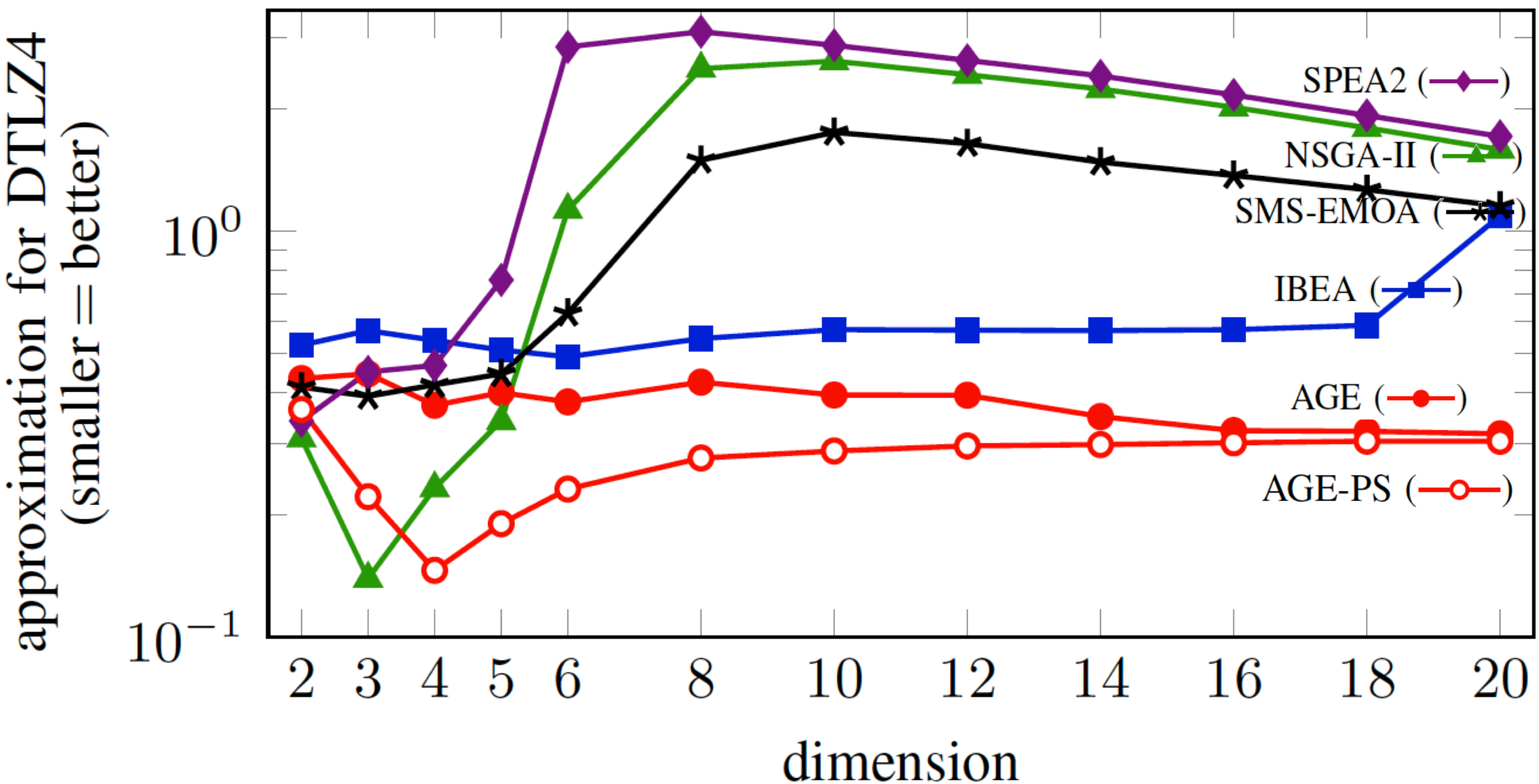

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SPEA2 ( )
NSGA-II ( )
SMS-EMOA ( )
IBEA ( )
AGE ( )
AGE-PS ( )

Conclusions

Approximation-Guided Evolution with non-random Parent-Selection

- an efficient approach to solve multi-objective optimisation problems with few and many objectives
- no parameters
- enables practitioners
  1. to **add objectives** with only minor consequences
  2. to **explore** problems for even higher dimensions

Future work

- Use it!
- Code is available online… **http://tinyurl.com/age2013**
  Java + C (soon)
- Bonus: AGE will be in the next jMetal version! ☺