Multi-Objective Optimisation with Multiple Preferred Regions

Md. Shahriar Mahbub[1,3], **Markus Wagner**[2], Luigi Crema[1]

[1]Fondazione Bruno Kessler, Trento, Italy

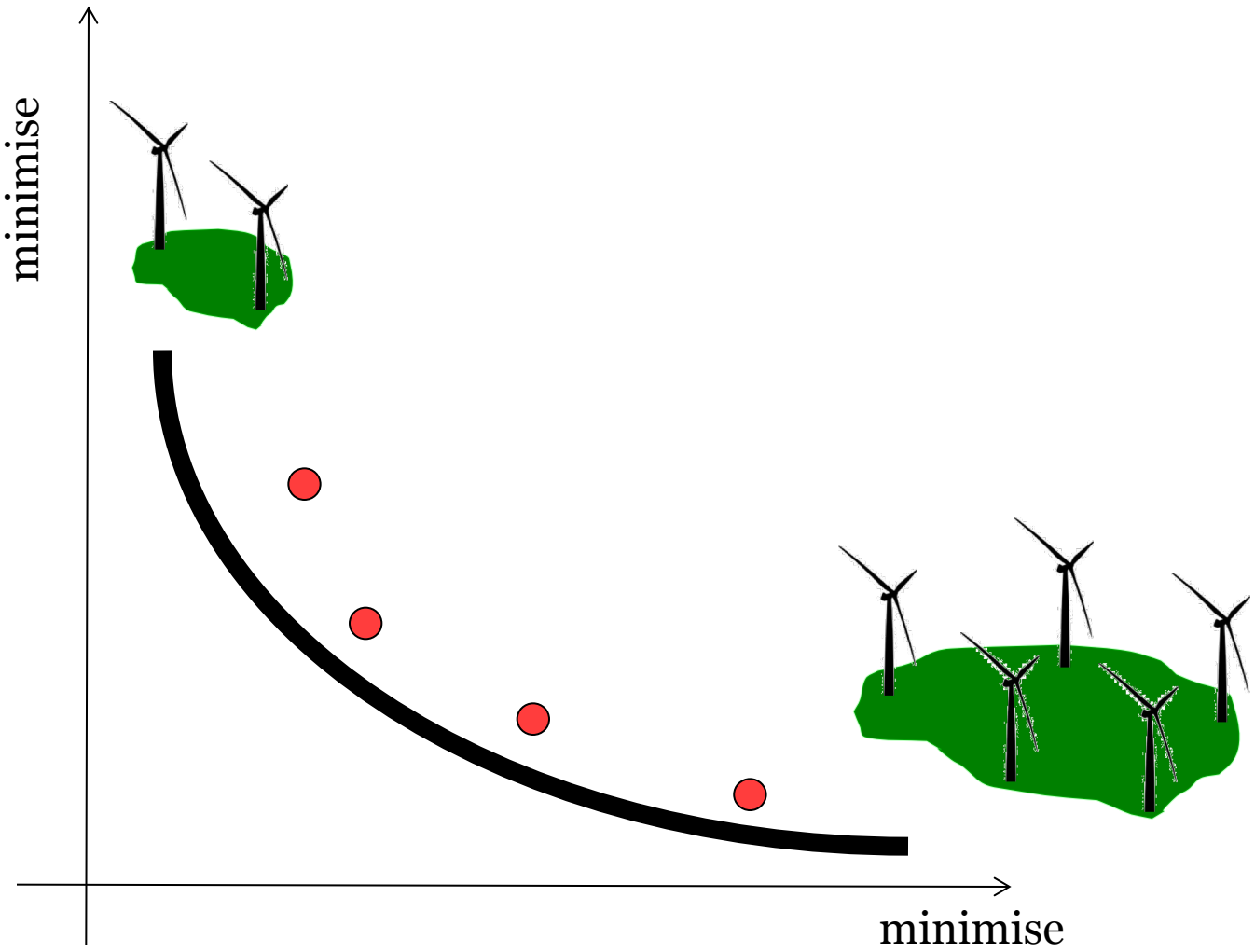
[2] University of Adelaide, Adelaide, Australia

[3] University of Trento, Trento, Italy

Introduction

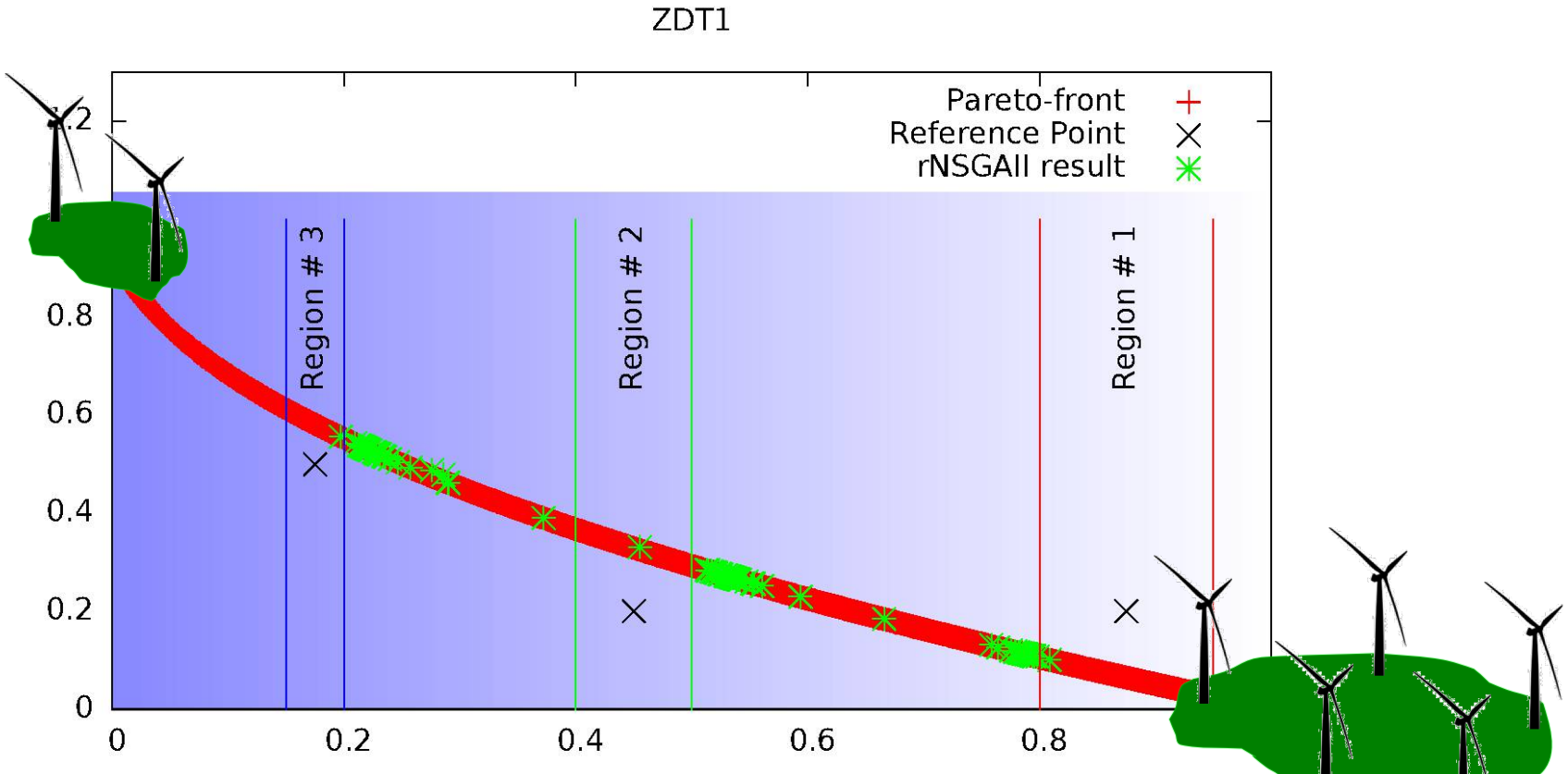
- Multiple user-preferred regions can be explored
- Propose an easy way to specify and consider user preferences
- A practical Example:
  - Energy system optimization problem (balance coal, geothermal, wind, import/export, …): minimize emission and annual cost
  - A reference system: *x* emissions
  - Identify optimized scenarios with 20-30% less emissions with respect to *x*
- Proposed modifications of two algorithms
  - NSGAII (pNSGAII)
  - AGE (pAGE)

Multi-Objective Optimisation



Difference between our approach and existing approaches for integrating user preferences

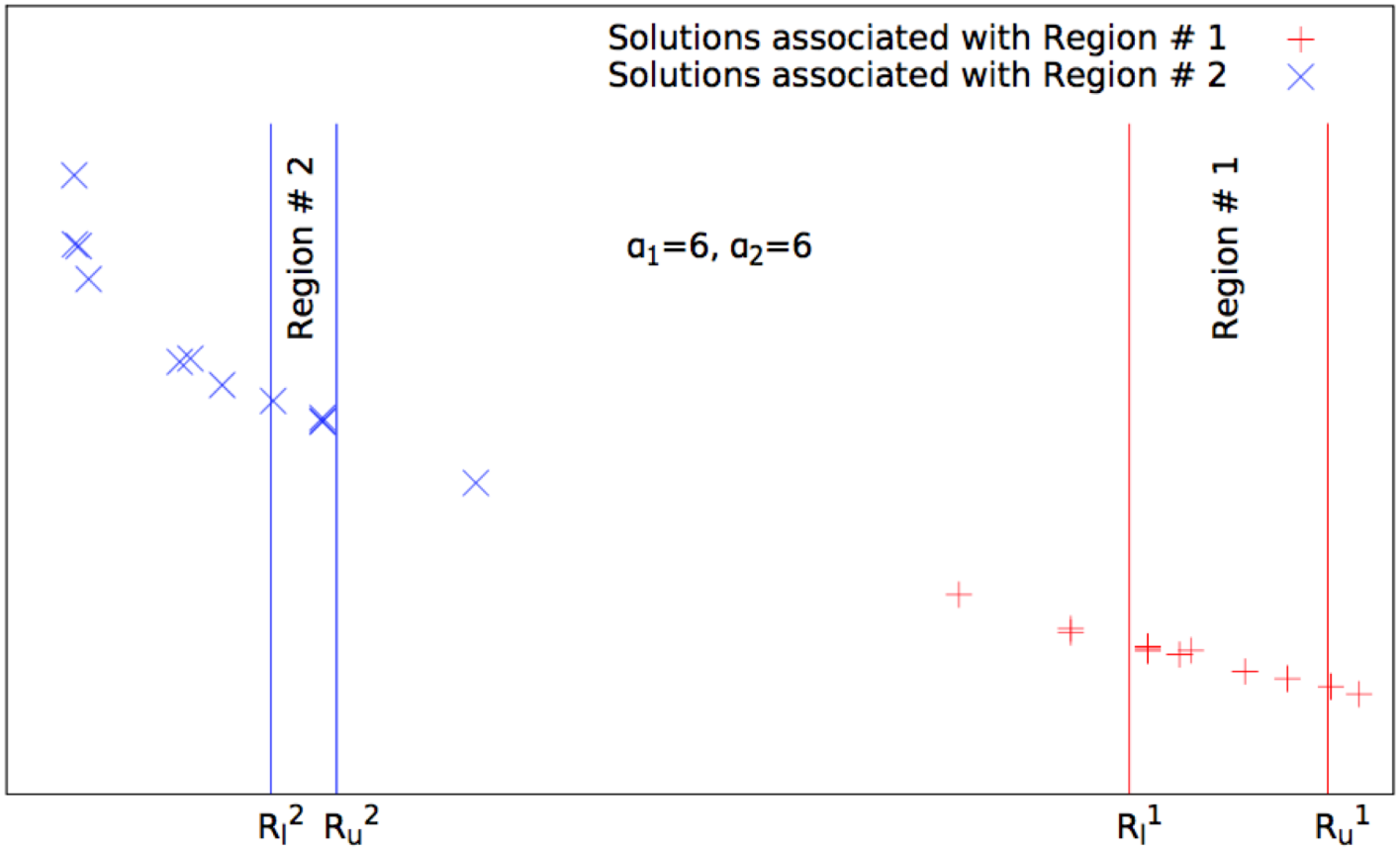
- Defining reference points: Difficult to set properly without knowing the space of the front



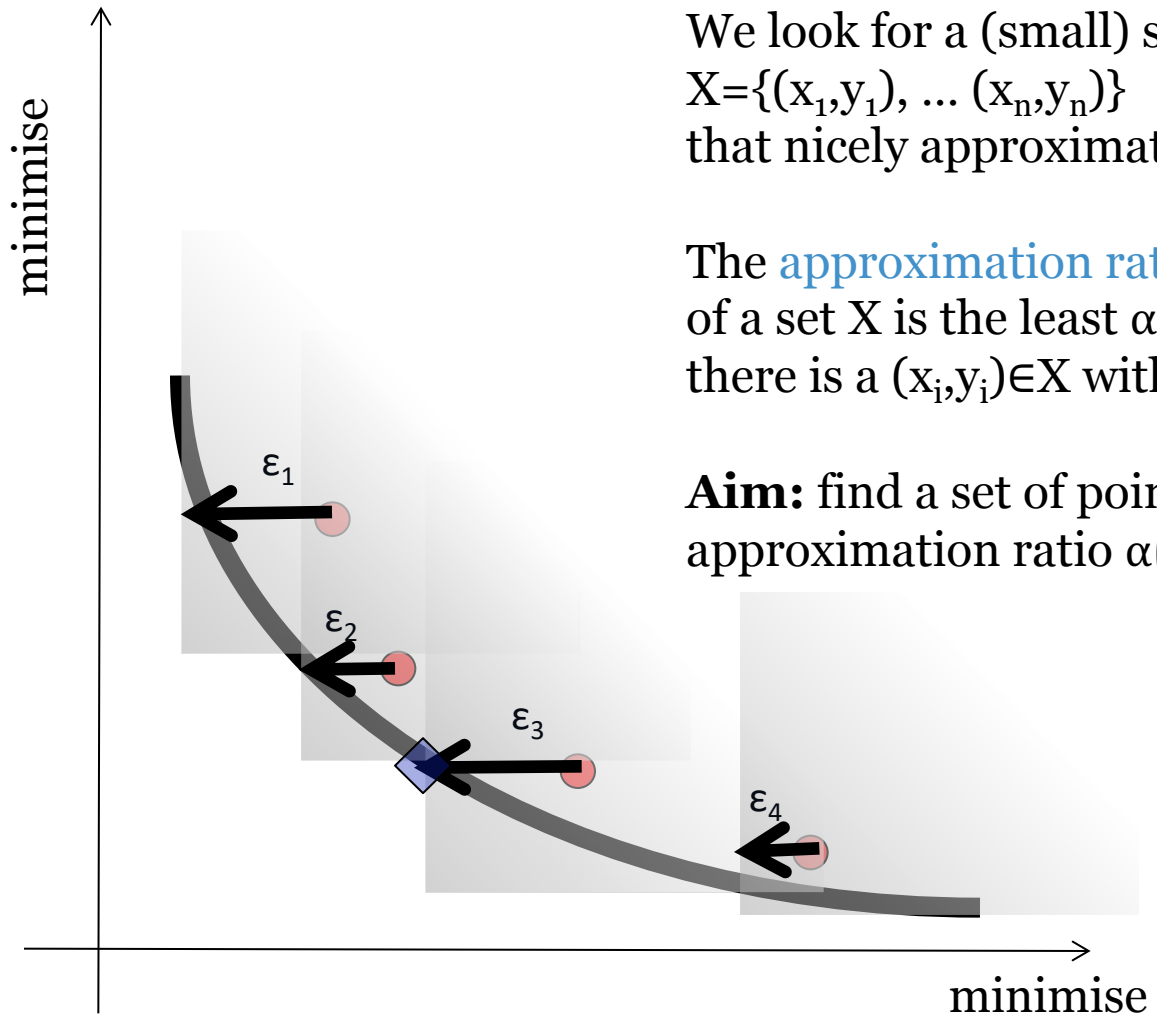
Blue: indication of “weight”, if a weight-based technology is used

Proposed Ideas (pNSGAII)

- Associate solutions with regions
  - Based on distance from a solution to a region
- Modified parent selection procedure
  - Selected from same region
  - Selected from different regions
- Population sub-division
  - Based on regions
- Modified ranking procedure
  - Closeness of an individual to the preferred regions
  - Based on dominance relations



Approximation-Guided Optimisation



We look for a (small) set of points
$X=\{(x_1,y_1), \ldots (x_n,y_n)\}$
that nicely approximates the front F.

The approximation ratio (theory-motivated) of a set X is the least α such that for each $d \in F$ there is a $(x_i,y_i) \in X$ with $f_x \leq \alpha x_i$ and $f_y \leq \alpha y_i$.

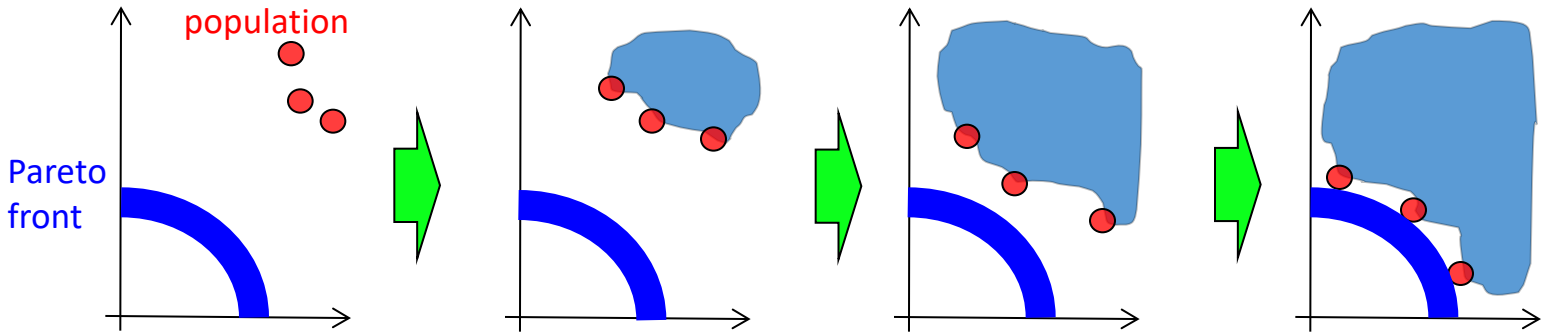
Aim: find a set of points with a large approximation ratio $\alpha(f,X)$ of the Pareto front.

$\alpha($●, P$)=\varepsilon_3$

Approximation-Guided Optimisation

Problem: we do not know the Pareto front f

Solution: use the union of all non-dominated points as an approximation of the Pareto front f

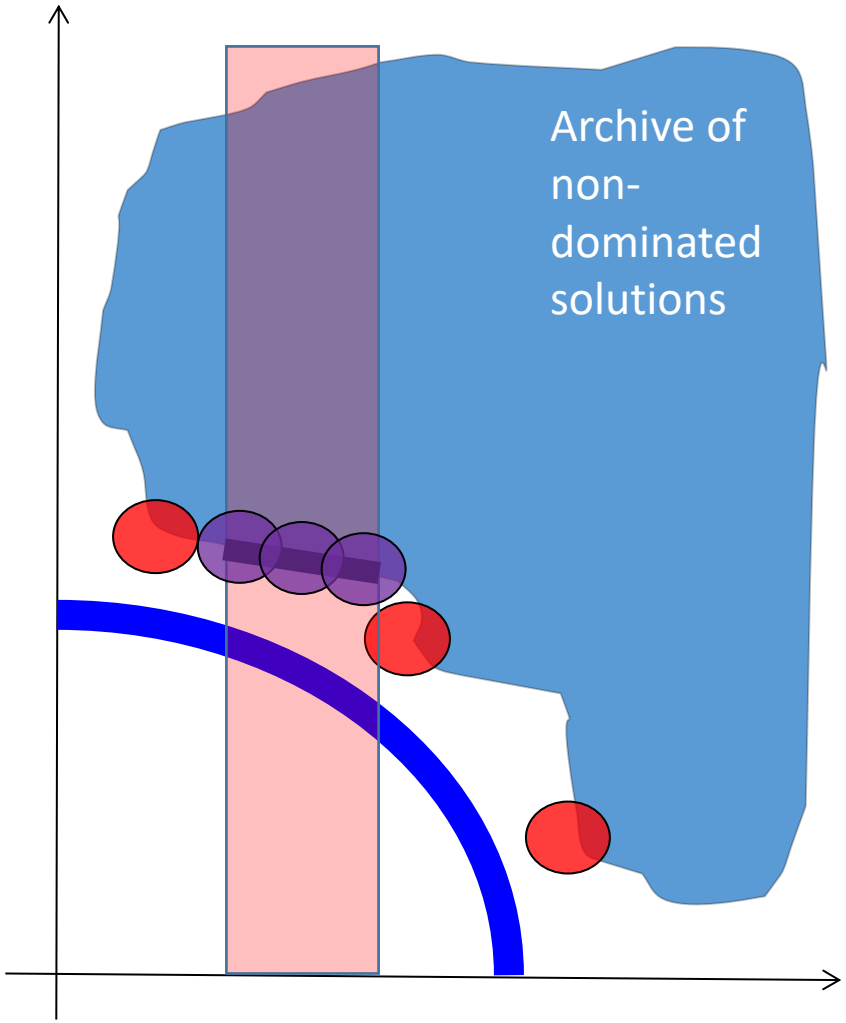


Runtime: linear with the number of objectives

$$O\,(\,d\,(\mu+\lambda)\,|A|\,)$$

IJCAI 2011: we were the first to ”solve” problems with 6+ objectives

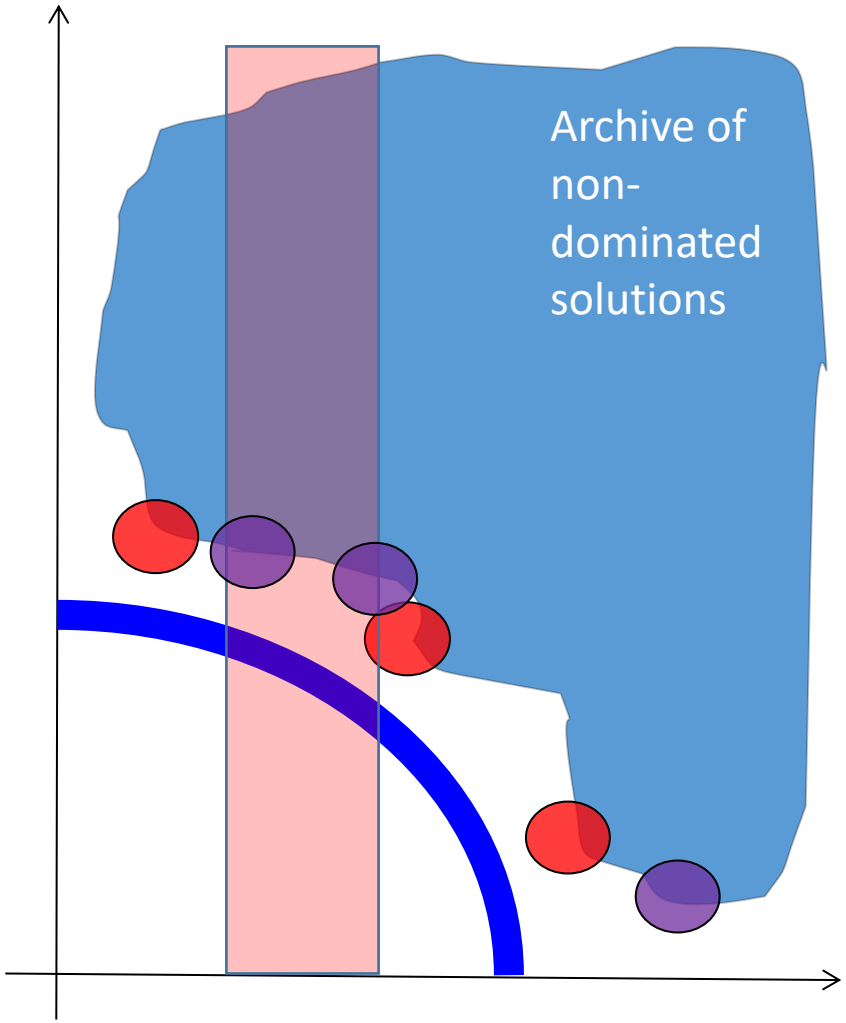
Approximation-Guided Optimisation with Preferred Region 1/2



pAGE-offline:

1. Post-processing of the archive.
2. Uses AGE's own subset selection mechanism.

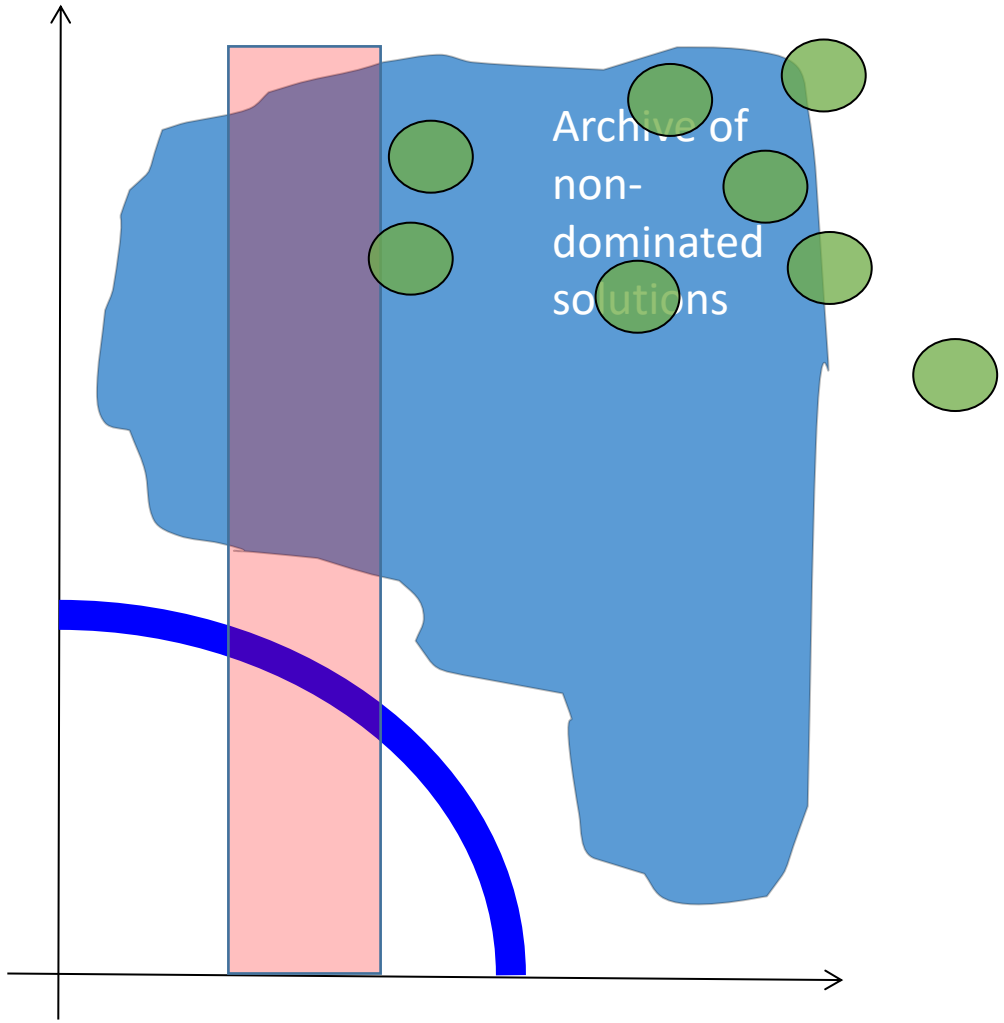
Approximation-Guided Optimisation with Preferred Region 2/2



pAGE-online:

1. When AGE does its subset selection of PARENTS u OFFSPRING: kick out points with some increasing probability (as optimisation progresses)

Approximation-Guided Optimisation with Preferred Region 2/2



pAGE-online:

1. When AGE does its subset selection of PARENTS u OFFSPRING: kick out points with some increasing probability (as optimisation progresses)

Careful: don’t kick out right from the start of evolution!

Experimental setup

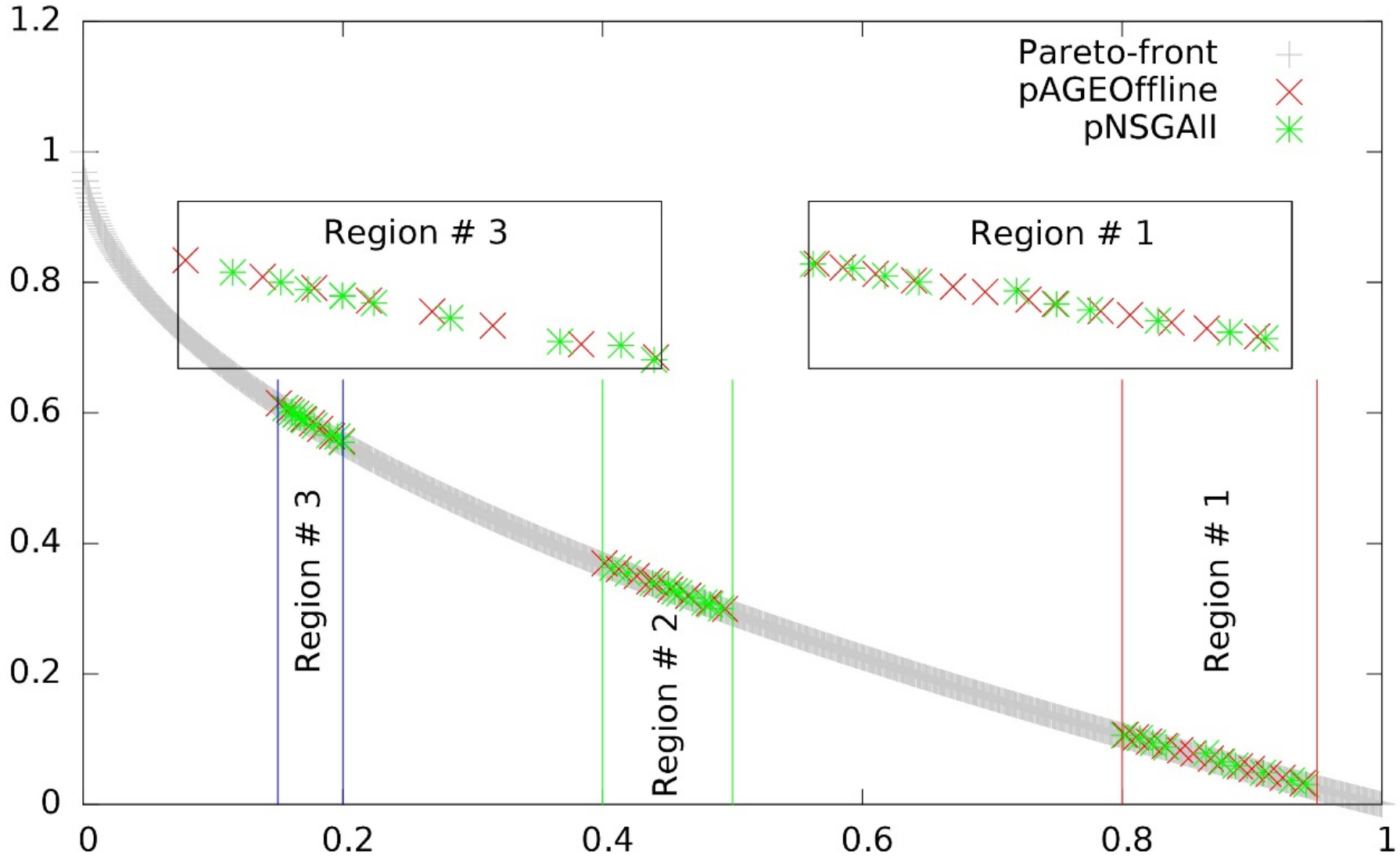
- Five two dimensional problems:
  - ZDT1, ZDT2, ZDT3, ZDT4, ZDT6
- Two three dimensional problems:
  - DTLZ2, DTLZ3

Problem	Algorithm	μ	FE
ZDT	pMOEA	30	12000
	MOEA	30	12000
		100	12000
		100	24000
DTLZ	pMOEA	30	50000
	MOEA	150	49950

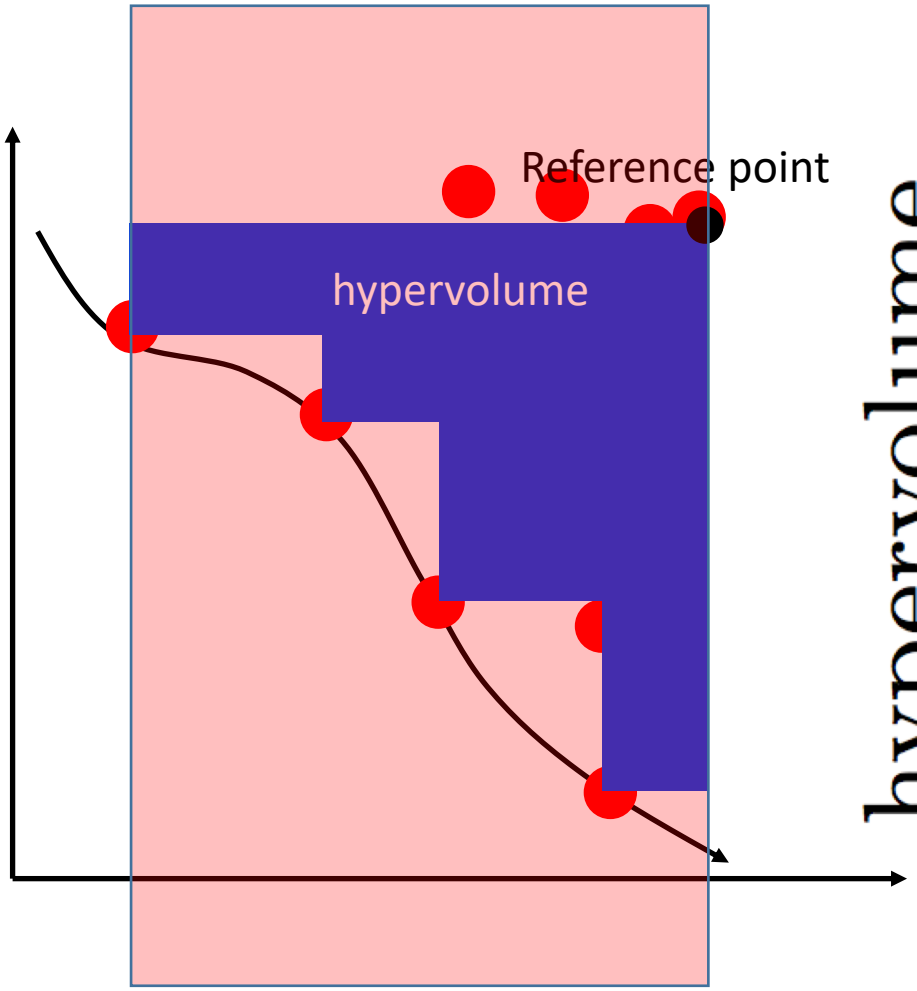
Parameters	Value	Used on
$[R_l, R_u]$	[0.80, 0.95]	All algorithms
	[0.40, 0.50]	
	[0.15, 0.20]	
α	[10, 10, 10]	pNSGAII
Crossover	SBX	All algorithms
Mutation	Polynomial mutation	All algorithms
Mutation probability	1/ndv	All algorithms
Distribution index	20	All algorithms
Parent selection	Binary tournament	NSGAII
ε_{grid}	0.01	pAGE online, offline

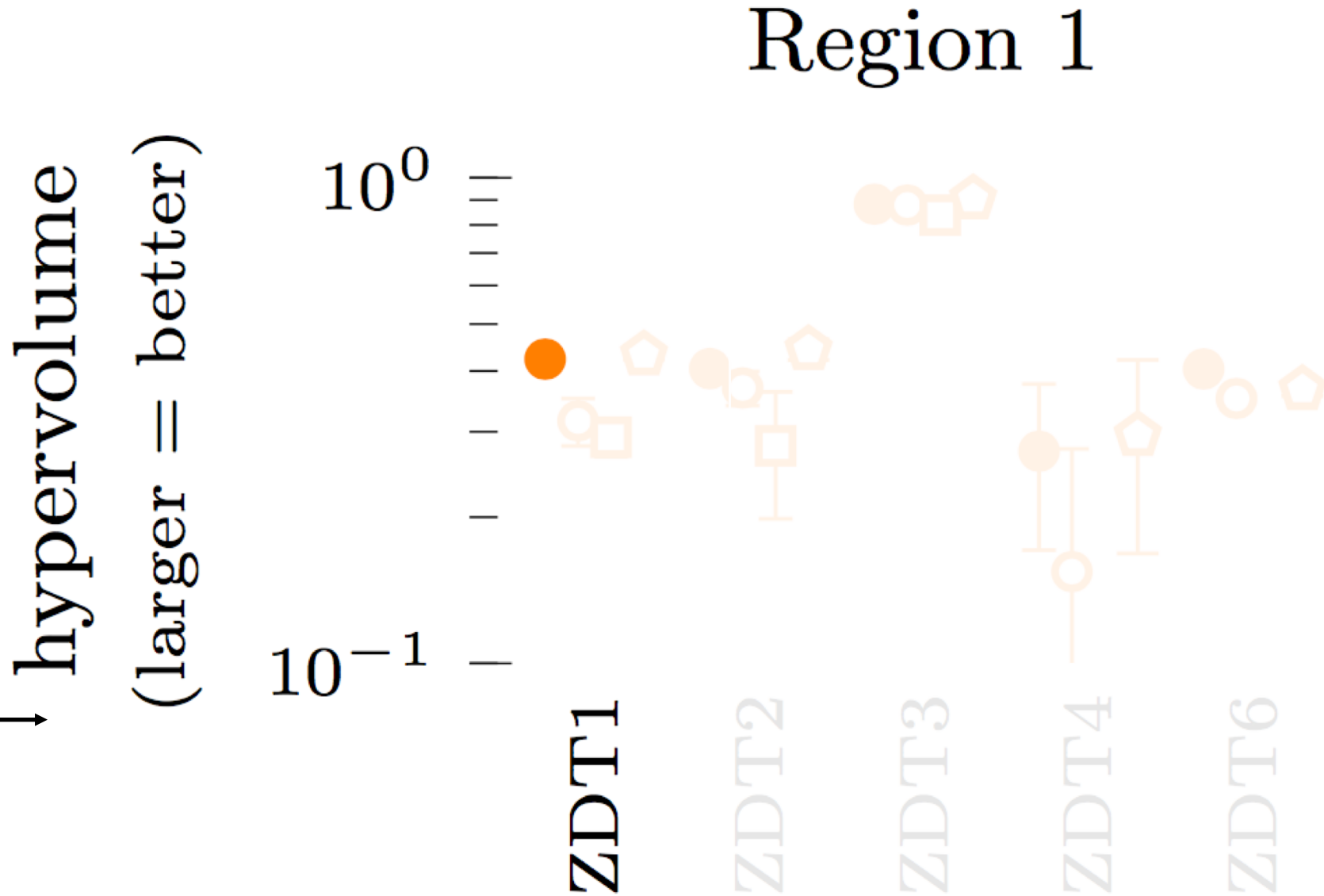
Budget chosen such that the regular approach has not yet converged

Results: Pareto-front, ZDT1

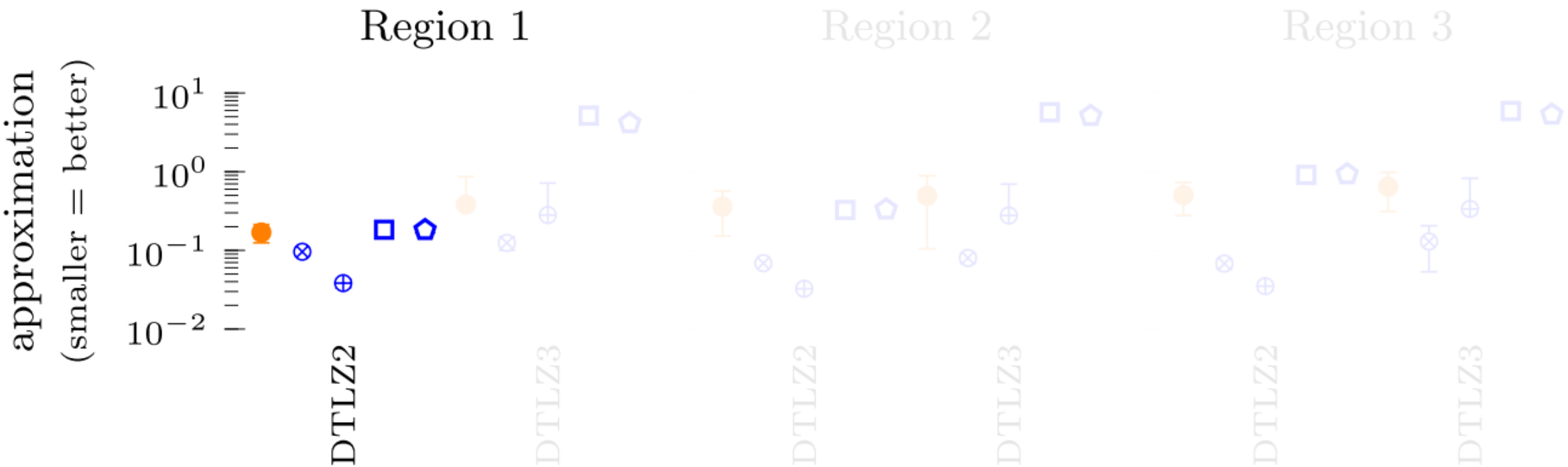


ZDT results, NSGA-II





DTLZ results, 3d

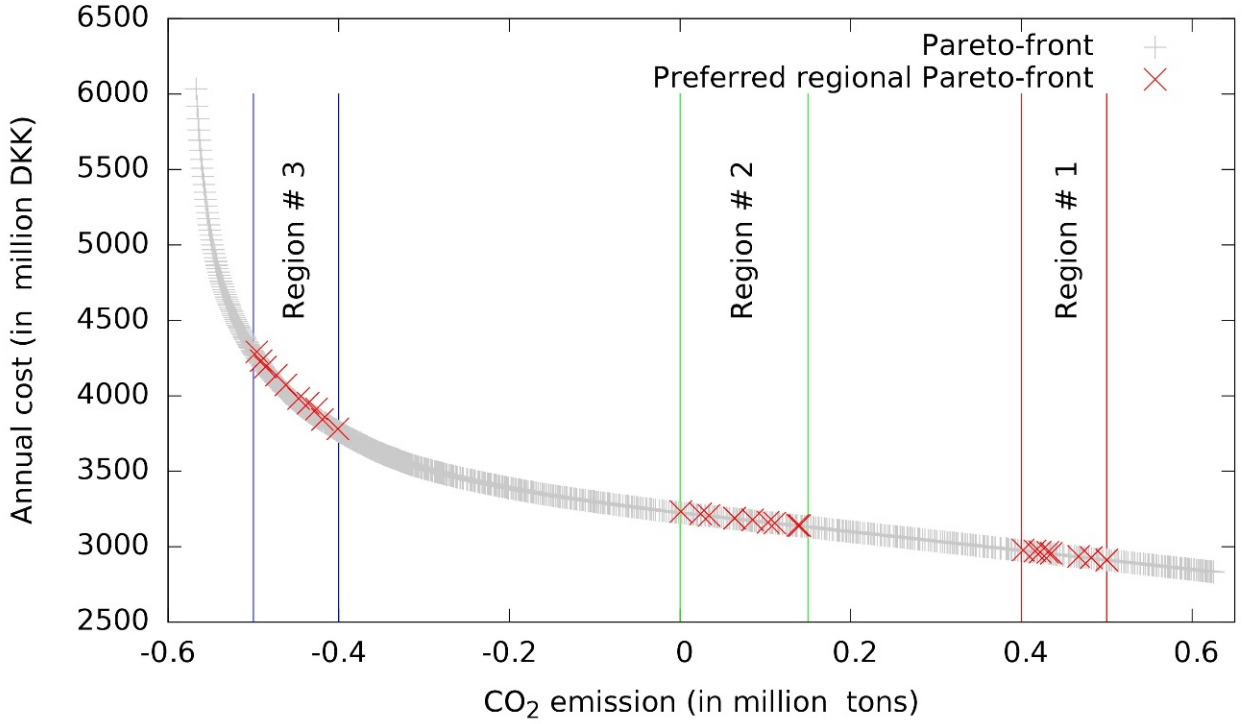


More results are in the paper…

A practical Example: pNSGAII on Energy system optimization problem

- Identify optimized scenario by minimizing:
  - CO2 emission
  - Annual cost
- Requirements:
  - Electric and thermal demand of approx 200,000 inhabitants in an area in Denmark
- Preferred regions for CO2 reductions: [0.40, 0.50], [0.0, 0.15] and [-0.50, -0.40]
- 10 solutions per region

Energy System Optimization Problem



Conclusion

- “preferred region” as an alternative for decision makers to “preference point”
- really simple to implement when starting with AGE
- PhD training exercise
- jMetal/Java code available, https://g