A Comparative Study of the Effect of Parameter Scalability in Multi-Objective Metaheuristics

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Outline of the talk

Motivation

Parameter scalability in MO metaheuristics

- MO community is paying much attention to many-objective optimization
- Few works devoted to dimensionality (number of decision variables)
- Real-world engineering problems $\longrightarrow$ thousands of variables
- Performance assessment of MO algorithms
  - Standard benchmarks: usually, 30 decision variables
  - Only 10 decision variables for the hardest problems (e.g., ZDT4)

Convergence speed of MO metaheuristics

1. A predefined maximum number of function evaluations is normally used
2. Goal: study computational effort to reach the true Pareto front
3. Practical interest when solving time-consuming MOPs

Contributions of this work

1. Scalability and convergence speed in-depth analysis of MO metaheuristics
2. Six state-of-the-art algorithms
   1. Three GAs: NSGA-II, SPEA2, and PESA-II
   2. An evolution strategy: PAES
   3. A particle swarm optimization: OMOPSO
   4. A cellular GA: MOCell
3. The ZDT problem family
   1. Keep the same Pareto front with different number of decision variables
   2. Experiments that range from 8 up to 2048 decision variables

Parameterization and methodology

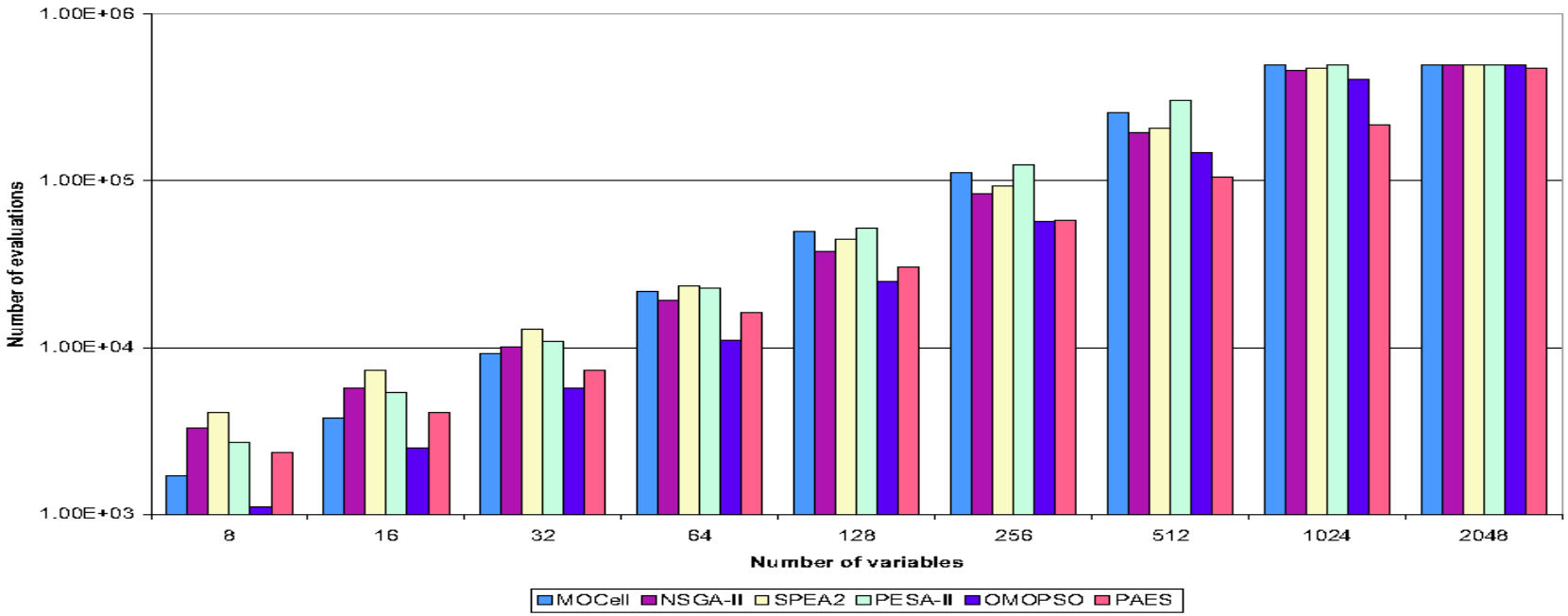
Parameterization

1. Aimed at fairly comparing the algorithms (e.g. using the same population size)
2. They all are implemented using jMetal (`http://neo.lcc.uma.es/metal`)

Methodology

1. The stopping condition is either
   1. 500,000 function evaluation, or
   2. Convergence criterium reached $\longrightarrow$ the Hypervolume indicator
2. The convergence criterium in-depth
   1. Reach 95% of the HV value of the true Pareto front of the problem
   2. Every 100 function evaluations
      1. Nondominated solutions at each generation of NSGA-II and SPEA2
      2. The external archive of PESA-II, PAES, and MOCell
      3. The leaders archive of OMOPSO

Analysis of the ZDT1 problem



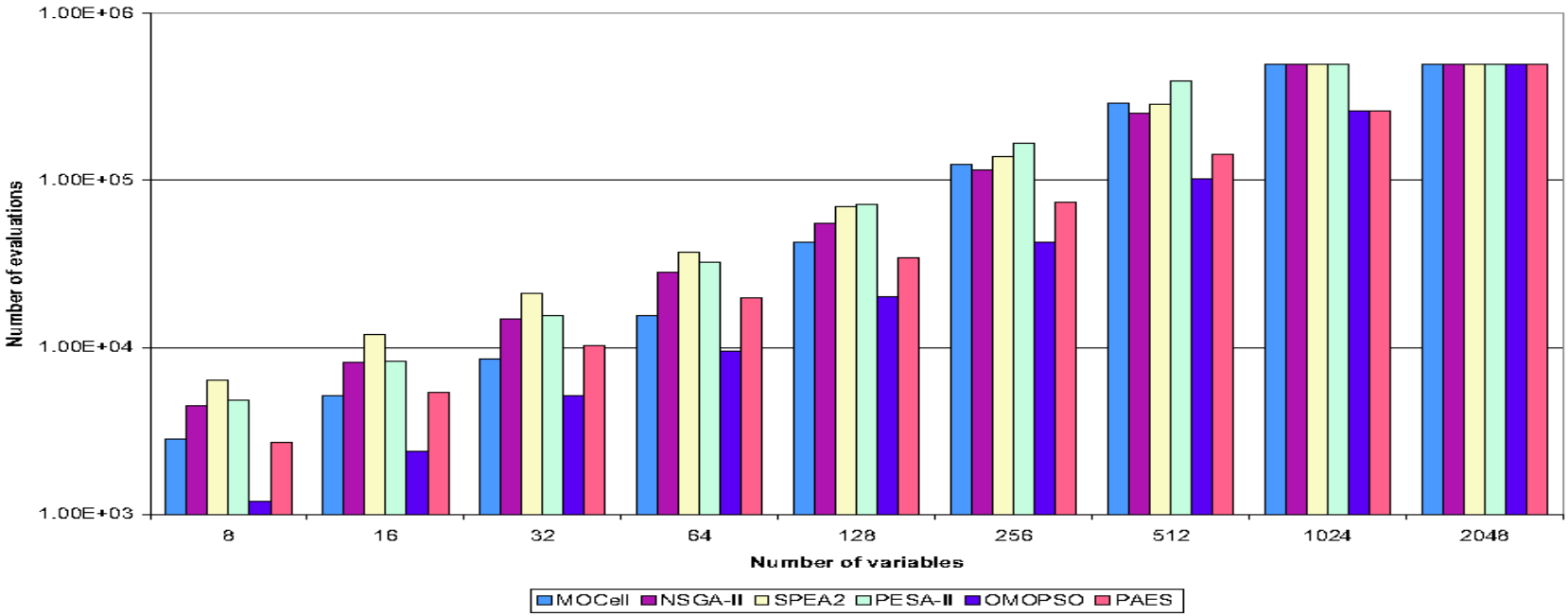
Scalability

1. Up to 512 variables: all the algorithms reached 95% HV of true Pareto front
2. 1024 variables: MOCell and PESA-II failed
3. 2048 variables: only PAES

Speed

1. Up to 256 variables: OMOPSO
2. More than 512 variables: PAES

Analysis of the ZDT2 problem



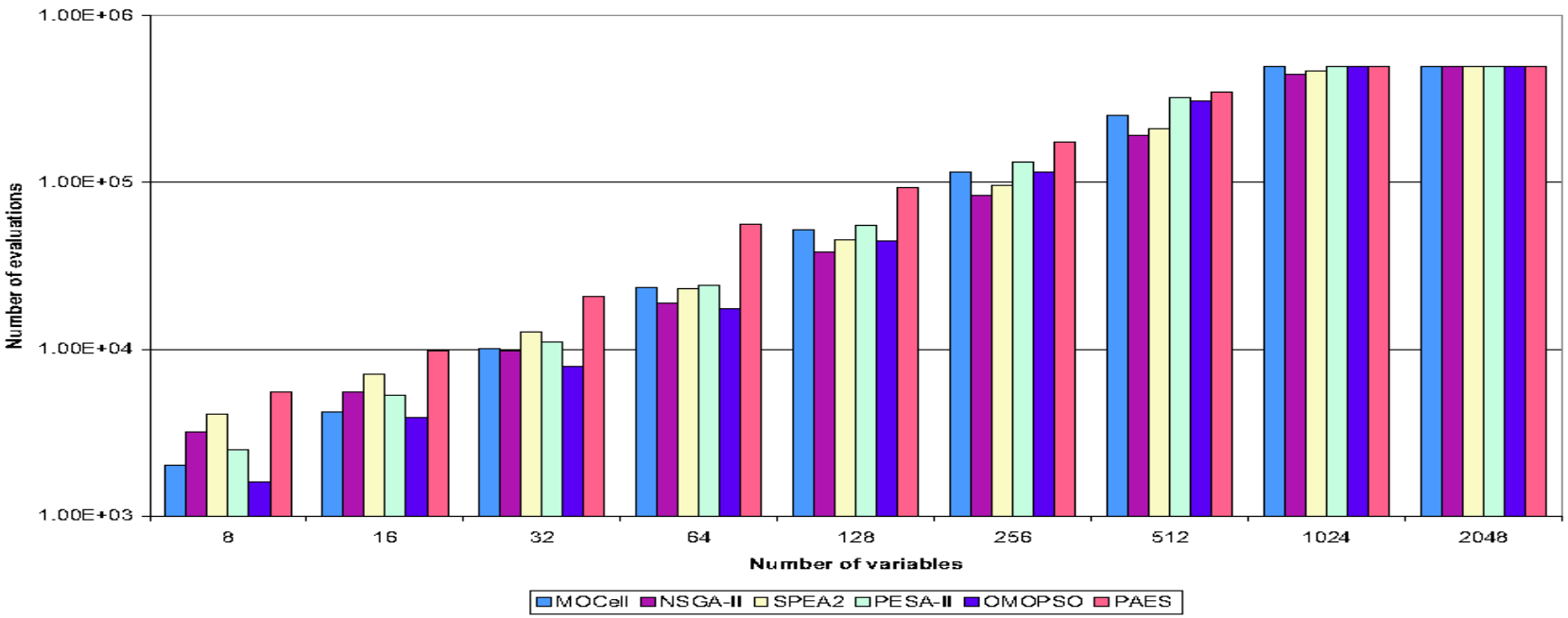
Scalability

1. Up to 512 variables: the same as ZDT1
2. 1024 variables: just OMOPSO and PAES successfully solved this MOP
3. 2048 variables: again, only PAES

Speed

1. Up to 512 variables: OMOPSO
2. More than 512 variables: PAES

Analysis of the ZDT3 problem



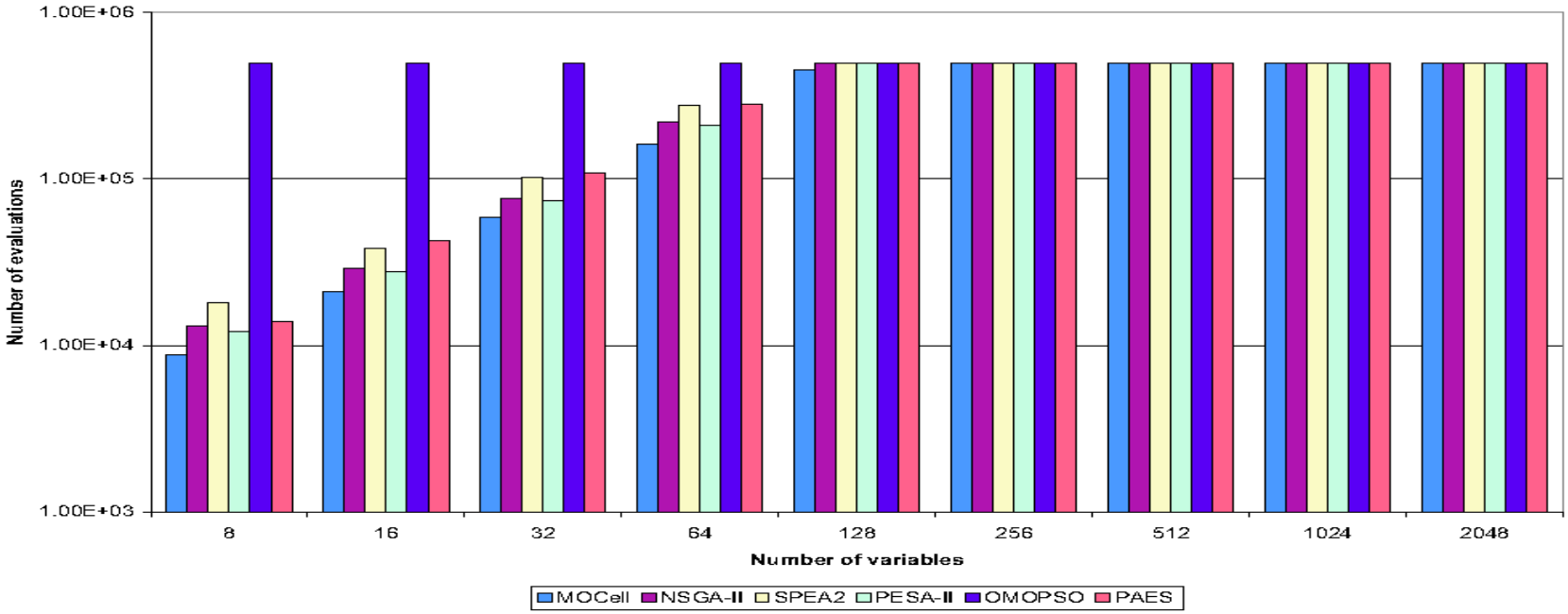
Scalability

1. Up to 512 variables: all the algorithms
2. 1024 variables: MOCell, PESA-II, and OMOPSO failed
3. 2048 variables: again, only PAES

Speed

1. Up to 64 variables: OMOPSO
2. 128 to 1024 variables: NSGA-II

Analysis of the ZDT4 problem



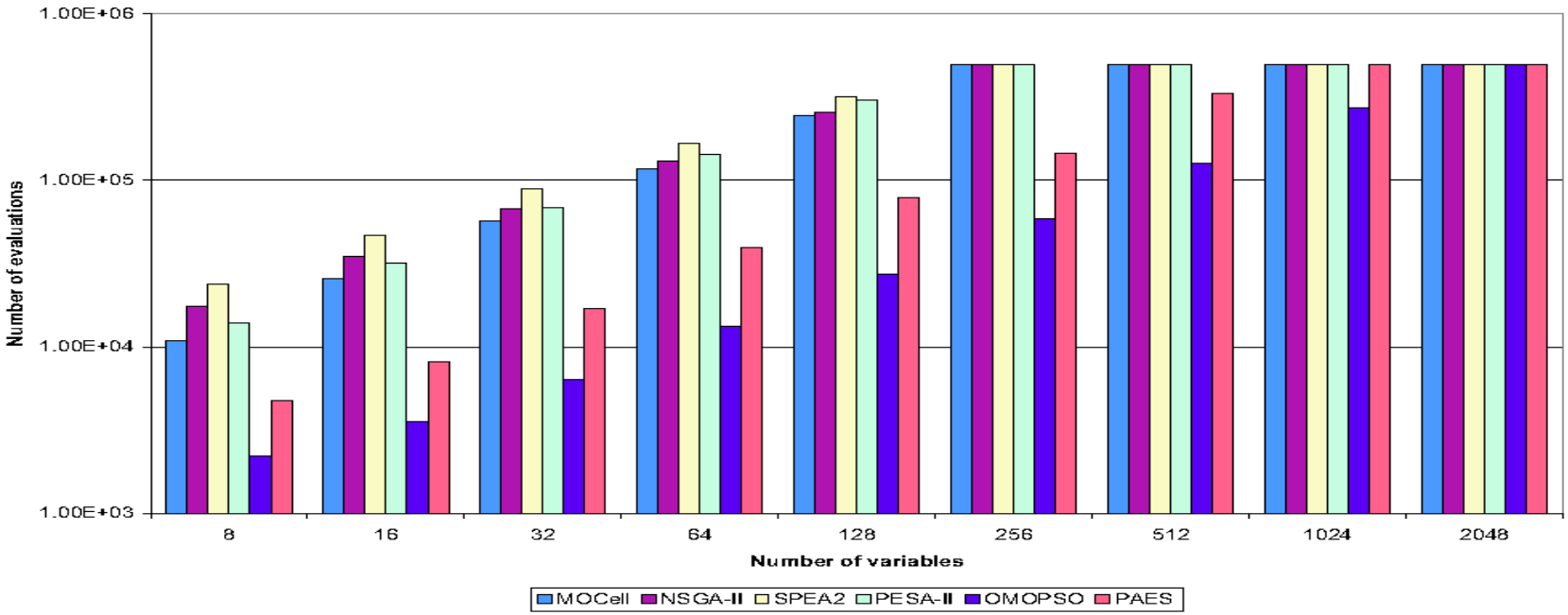
Scalability

1. OMOPSO has never converged
2. MOCell reached the best results up to 128 variables
3. More than 128 variables: no solver converged

Speed

1. MOCell is the fastest
2. PESA-II is the second best

Analysis of the ZDT6 problem



Scalability

1. Up to 128 variables: all the algorithms converged
2. OMOPSO and PAES succesfully solved the MOP up to 1024 variables
3. 2048 variables: no algorithm converged

Speed

1. OMOPSO is the fastest
2. PAES is the second best

Global results

Scalability: address the problems with the higher number of decision variables

Ranking	ZDT1	ZDT2	ZDT3	ZDT4	ZDT6
1	PAES	PAES	NSGA-II	MOCell	OMOPSO
2	OMOPSO	OMOPSO	SPEA2	PESA-II	PAES
3	NSGA-II	MOCell	PAES	NSGA-II	MOCell

Speed: lowest number of function evaluation to reach 95% HV of the true PF

Ranking	ZDT1	ZDT2	ZDT3	ZDT4	ZDT6
1	OMOPSO	OMOPSO	NSGA-II	MOCell	OMOPSO
2	PAES	PAES	OMOPSO	PESA-II	PAES
3	NSGA-II	MOCell	MOCell	NSGA-II	MOCell

When an algorithm scales well, it usually requires a low number of function evaluation to converge towards high quality Pareto fronts

Conclusions and future work

Conclusions

1. Study of 6 MO metaheuristics over the parameter-wise, scalable ZDT family
   1. Scalability analysis
   2. Convergence speed
2. Results
   1. PAES scales the best and it converges the second best
   2. OMOPSO converges the fastest, but it fails with multifrontal MOPs
   3. MOCell fits specially well on ZDT4 (the most difficult MOP)

Future Work

1. Include a wide study with more scalable MOPs
2. Design new MO metaheuristics to overcome the limitations of those in current use

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Questions?