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Multi-objective Cooperative Coevolutionary Algorithms for Robust Scheduling

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Outline

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- Introduction
- Coevolutionary Genetic Algorithms
- Multi-Objective Coevolutionary Framework
- Application on the RSMP
- Conclusion & Perspectives

Introduction

- Deal with large scale complex multi-objective problems
- Where classical EAs tend to perform poorly
- Use of cooperative coevolutionary techniques to simultaneously optimize several subproblems
- Not popular in multi-objective optimization domain

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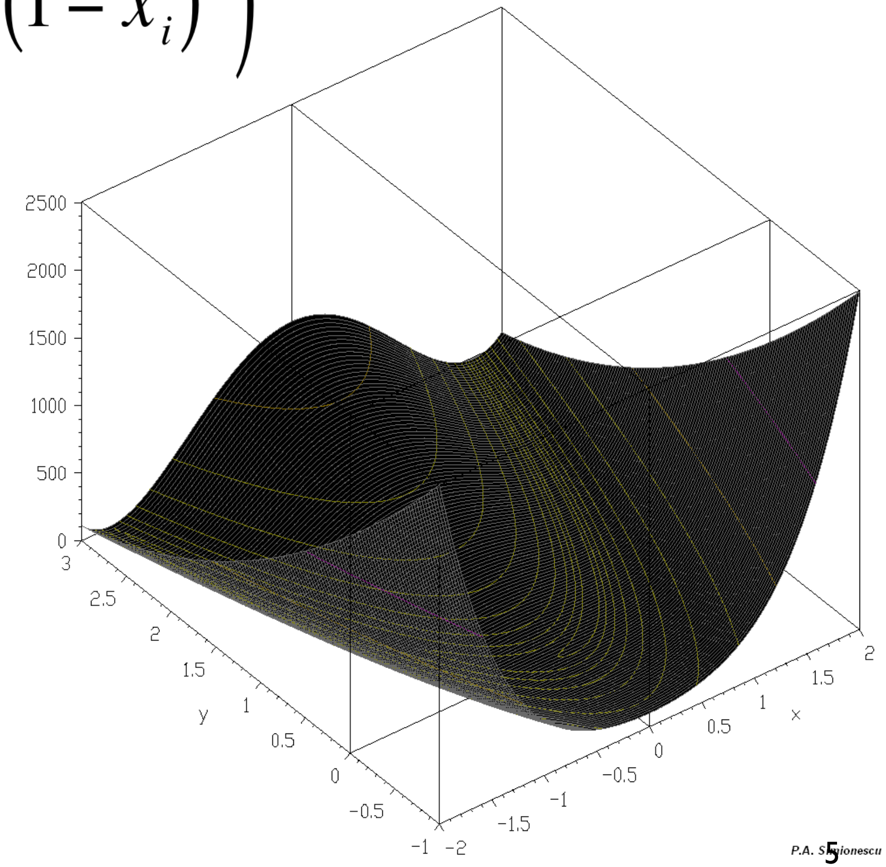
Rosenbrock Function

- Part of De Jong's five function test suite
- Continuous and unimodal

$$f(x) = \sum_{i=1}^{n}\left(100\left(x_i^2 - x_{i+1}\right)^2 + \left(1 - x_i\right)^2\right)$$

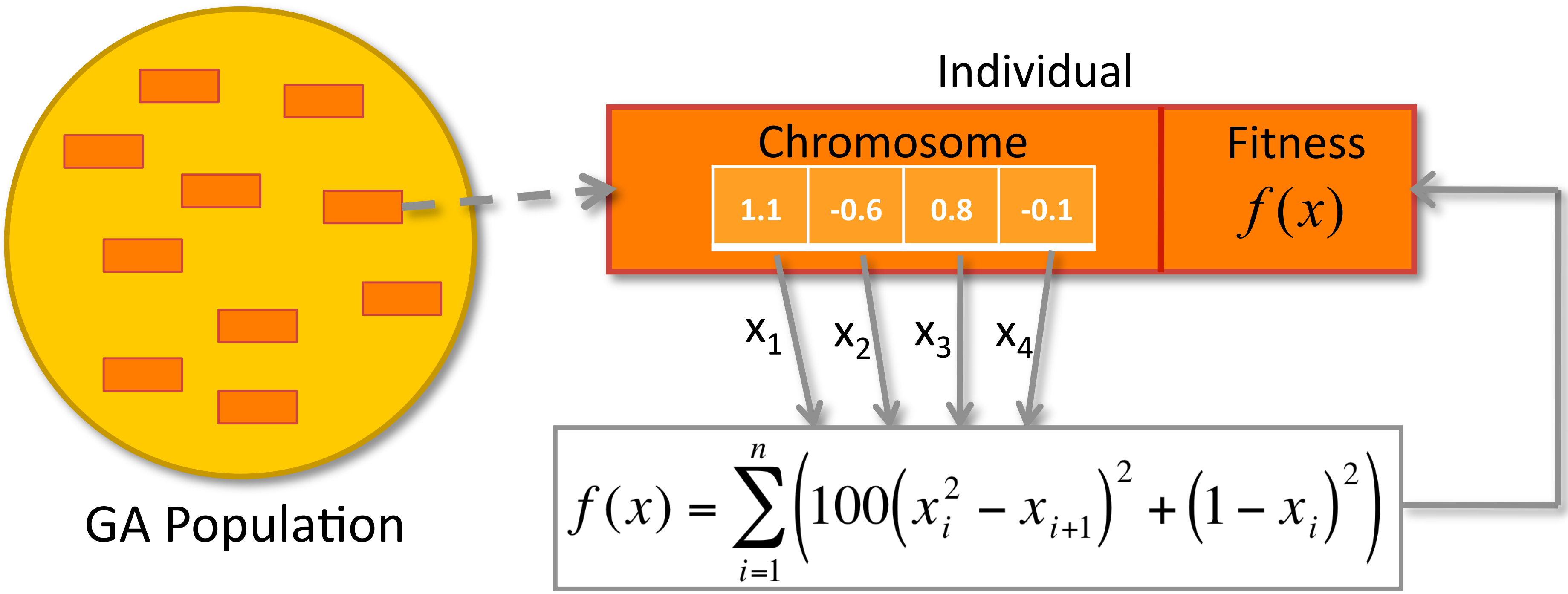
with $-2.12 \leq x_i \leq 2.12$

- Global minimum $f(x^*) = 0$
with $x^* = (1,1,\ldots 1)$



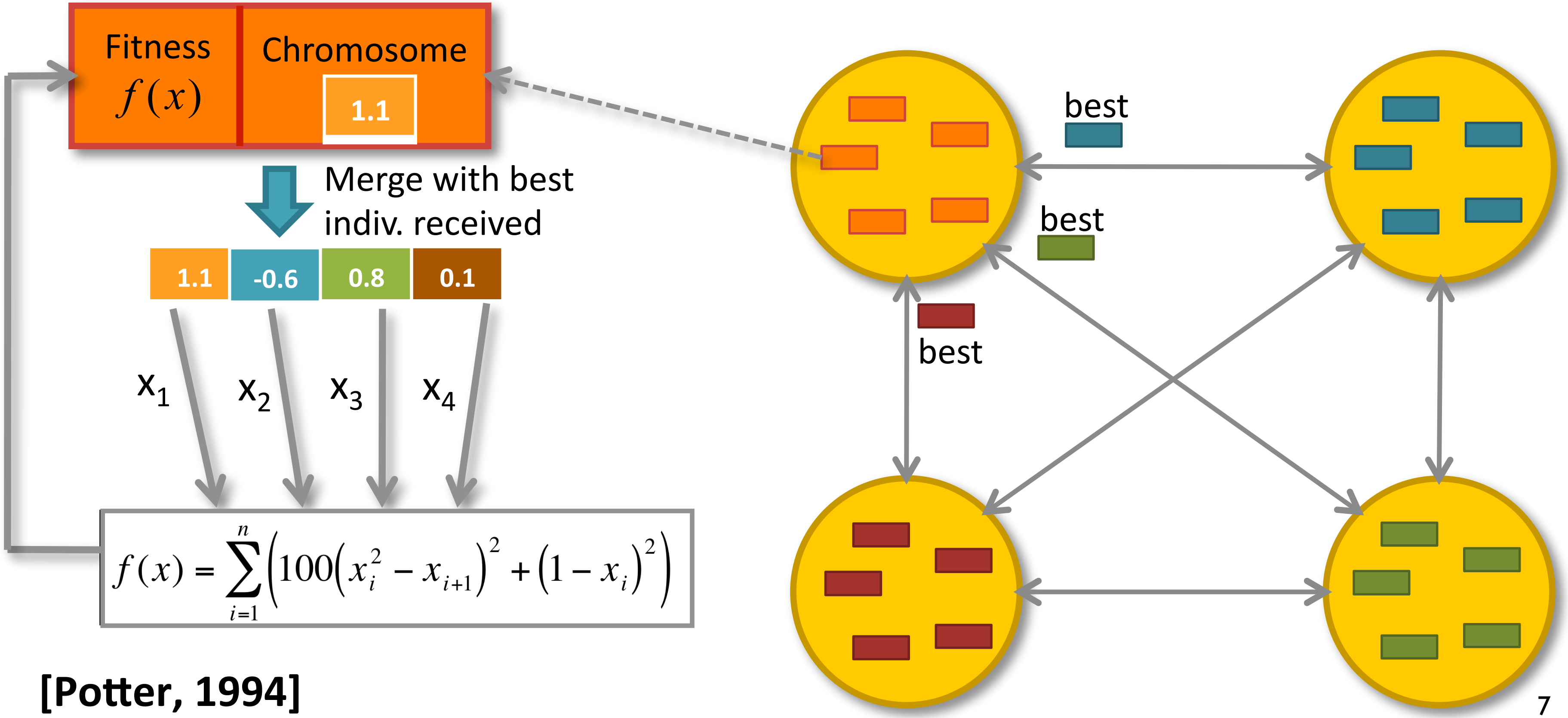
GA on Rosenbrock (4 variables)

- A chromosome encodes a complete solution
- Solution evaluated on the global problem



Cooperative Coevolutionary GA (CCGA)

- Each node runs a subpopulation for a subset of the N variables
- Each population evaluates each of its individuals on the global fitness function using the best individual received from each other subpopulation



[Potter, 1994]

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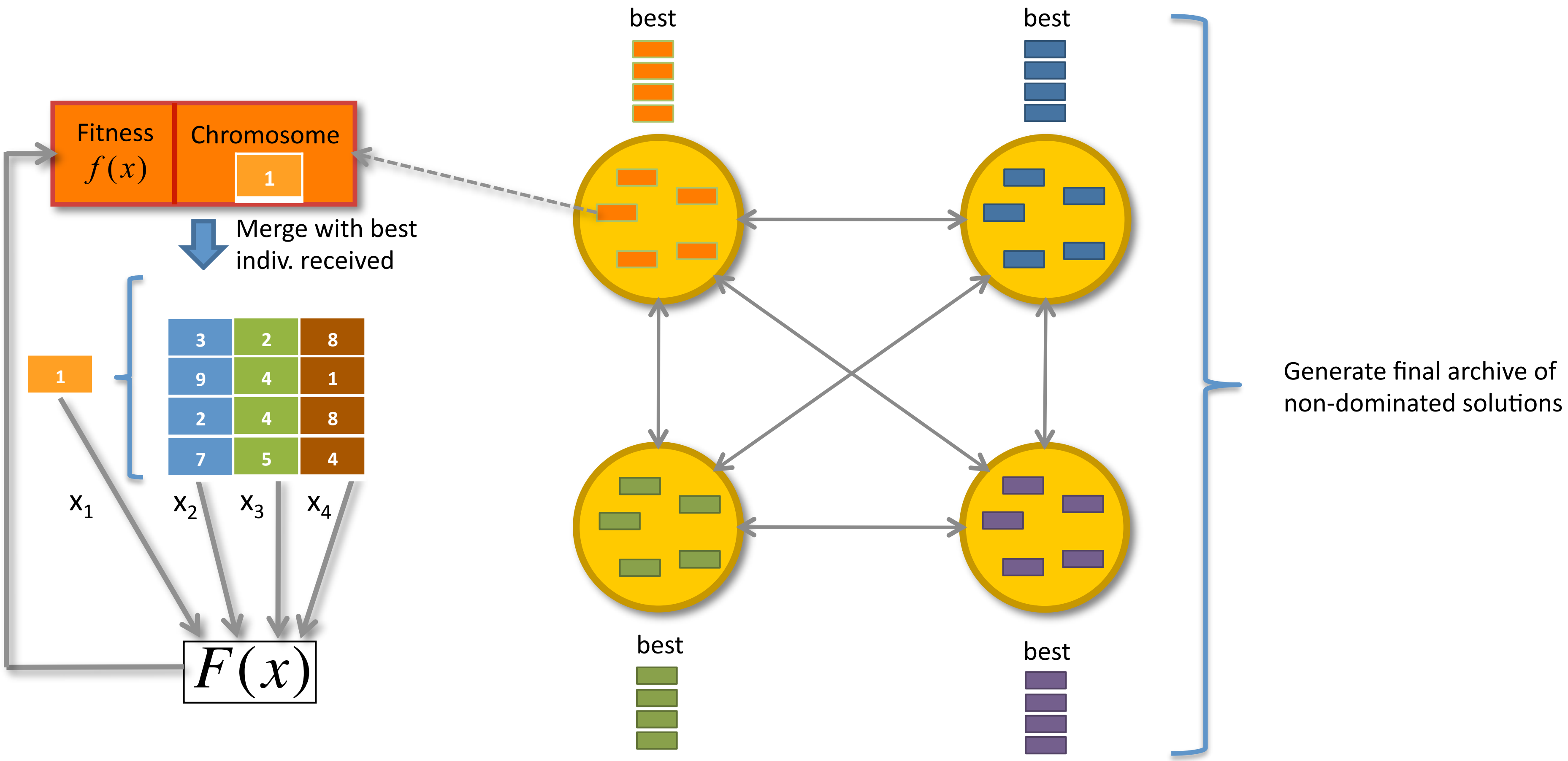
Multi-Objective CCGA



Three New Algorithms

- Three CCMOEAs designed
  - Based on NSGA-II: CCNSGAII
  - Based on SPEA2: CCSPEA2
  - Based on MOCell: CCMOCell

NSGA-II

- Reference algorithm
- Panmictic population
- Selection of solutions
  - Ranking
  - Crowding

SPEA2

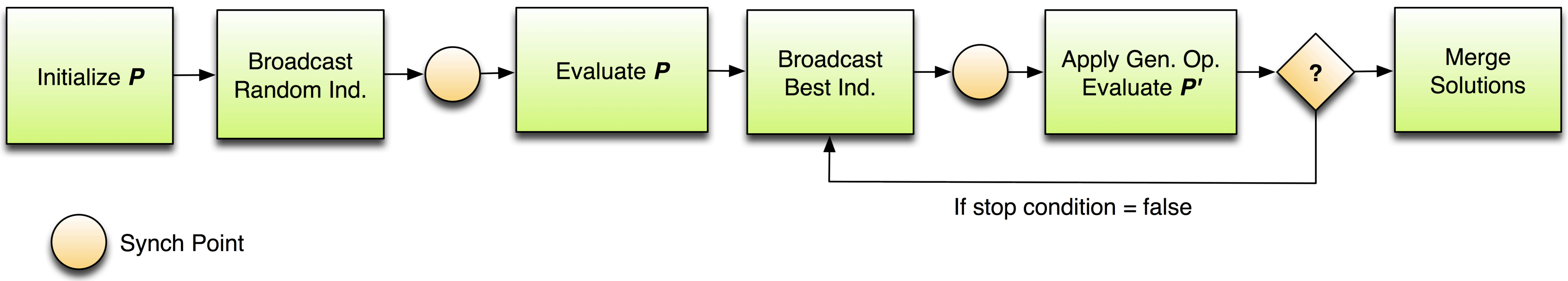
- Panmictic population
- External archive
  - Strength raw fitness
  - k-nearest neighbors

MOCell

- Cellular population
  - Only next individuals can interact
- External archive
  - Feedback to population

Parallelization

- Adaptation for parallelization
  - No sequential processing of the sub-populations
  - Remaining synchronization points



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Batch Tasks Mapping on Grids

- Based on the Estimated Time to Compute (ETC) simulation model by Braun et al.*

ETC

Machine \ Task	0	1	2	3	4	5	6
0	2	5	7	3	9	4	3
1	6	9	8	7	4	3	1
2	7	8	9	5	3	2	5

Time needed by machine 1 to compute task 6

- An instance of the problem:
  - A number of independent tasks to be scheduled
  - A number of heterogeneous machines candidates for scheduling
  - Ready time $ready_m$: when machine *m* will finish the previously assigned tasks
  - The ETC matrix (nb_tasks x nb_machines).
    ETC[j][m] is the expected execution time of task j in machine m

*T.D. Braun, H.J. Siegel, N. Beck, L. Bölöni, M. Maheswaran, A. Reuther, J. Robertson, M. Theys, B. Yao, D. Hensgen, and R. Freund. A comparison of eleven static heuristics for mapping a class of independent tasks onto heterogeneous distributed computing systems, Journal of Parallel and Distributed Computing 61(6):810-837, 2001

Multi-objective Robust Mapping on Grids*

- Objectives:
  - Minimize makespan $f_M(\vec{x}) = \{\max\{F_j(C)\}$
  - Maximize robustness $f_R(\vec{x}) = \{\min\{r_{\vec{x}}(F_j, C)\}$
- Finishing time of machine *j*: $F_j(C) = ready_j + \sum_{t \in S(j)} C_{t,j}$
- Robustness radius◆ of machine *j*:

$$r_{\vec{x}}(F_j, C) = \frac{\tau \cdot M^{orig} - F_j(\,ETC\,)}{\sqrt{\text{number of applications allocated to } m_j}}$$

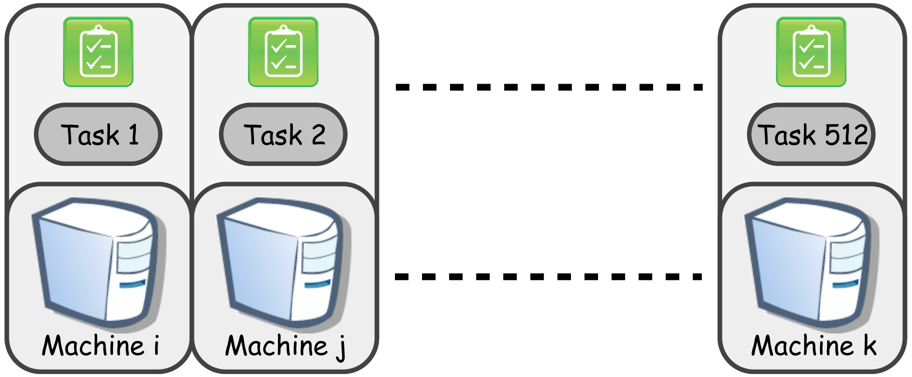
- Toleration variation: $\tau = 30\%$

  $\vec{x}$: An allocation
  C: matrix with the actual times to compute the tasks on every machine
  M^{orig}: Makespan of $\vec{x}$ according to ETC
  $S(j)$: Set of tasks assigned to machine j

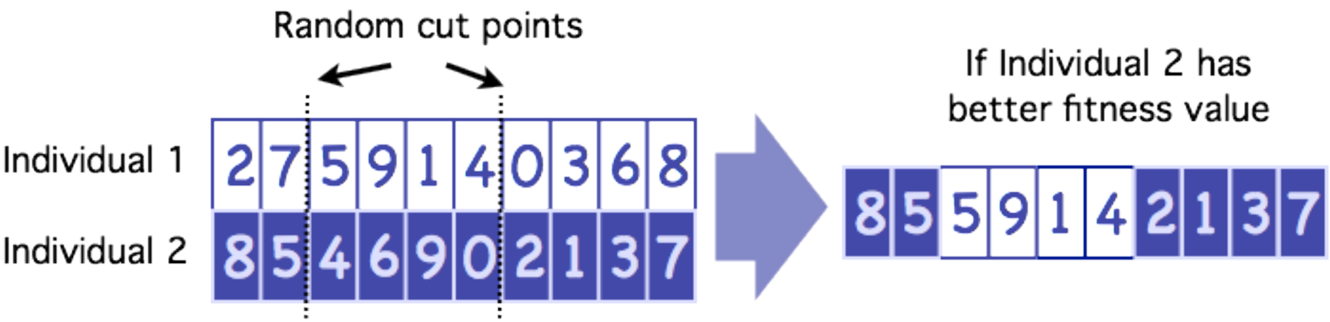
*B. Dorronsoro, P. Bouvry, J.A. Cañero, A.A. Maciejewski, H.J. Siegel, Multi-objective Robust Static Mapping of Independent Tasks on Grids, IEEE Congress on Evolutionary Computation (CEC), pp. 3389-3396, 2010.
◆S. Ali, A.A. Maciejewski, H.J. Siegel, and J.-K. Kim, Measuring the Robustness of a Resource Allocation, IEEE Trans. on Parallel and Distributed Systems 15(7), 2004.

Parameters Configuration

- Individual representation



- Two points recombination ($p_R = 0.9$)



- Rebalance mutation ($p_M = 0.2$)
  - Move one task from one of the 25% machines with longest completion time to one of the 25% machines with shortest completion time

Problem Instances

- Two sizes:

Small	Large
★ Tasks: 512	★ Tasks: 2048
★ Processors: 16	★ Processors: 64

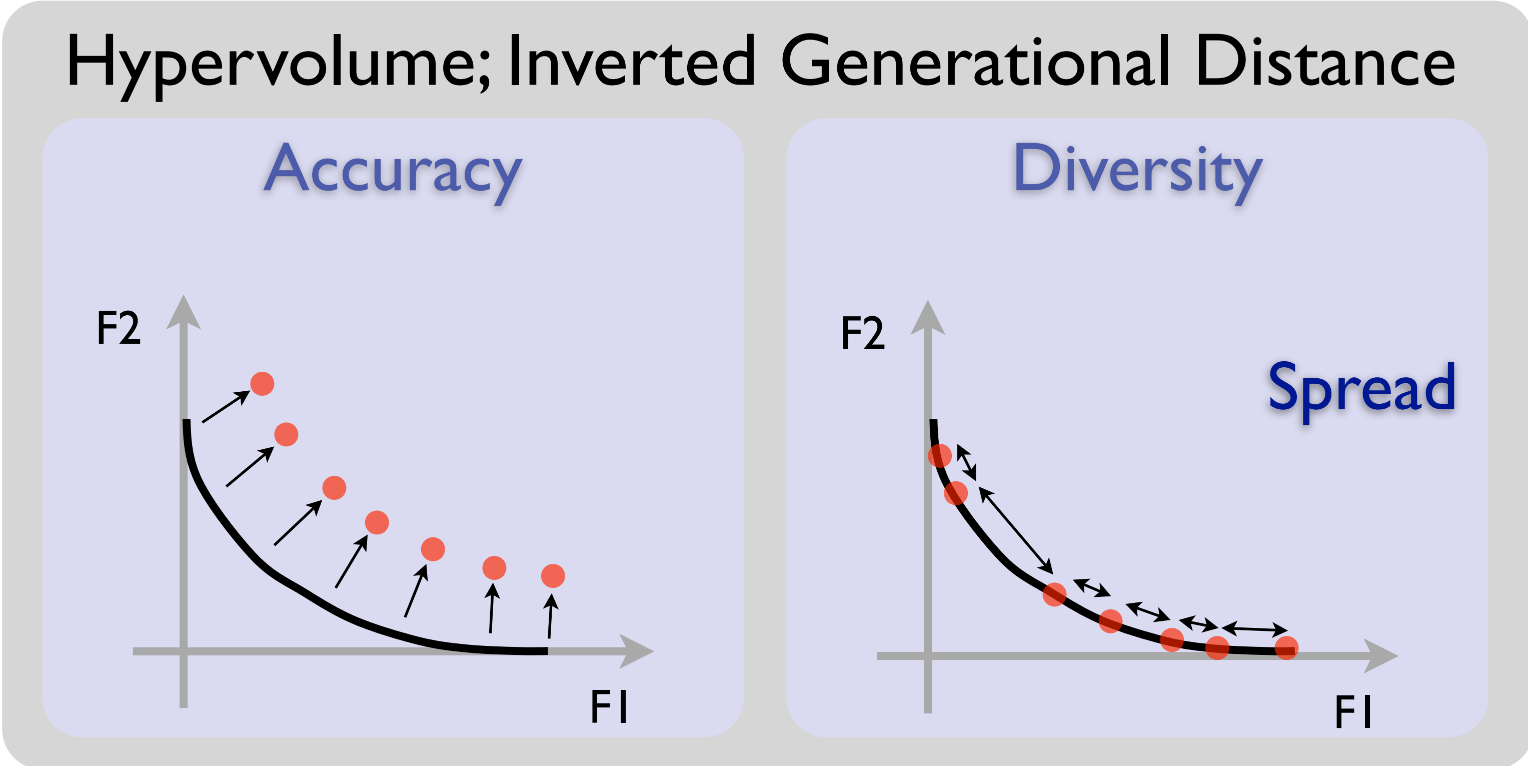
- Inconsistent:
  - The fact that machine *j* is faster than *k* for task *t* does not imply that *j* is faster than *k* for any task

- Two problem classes studied
  - High task and resource heterogeneity
  - Low task and resource heterogeneity

- We study 10 different instances per problem class
  - Each instance has a different ETC

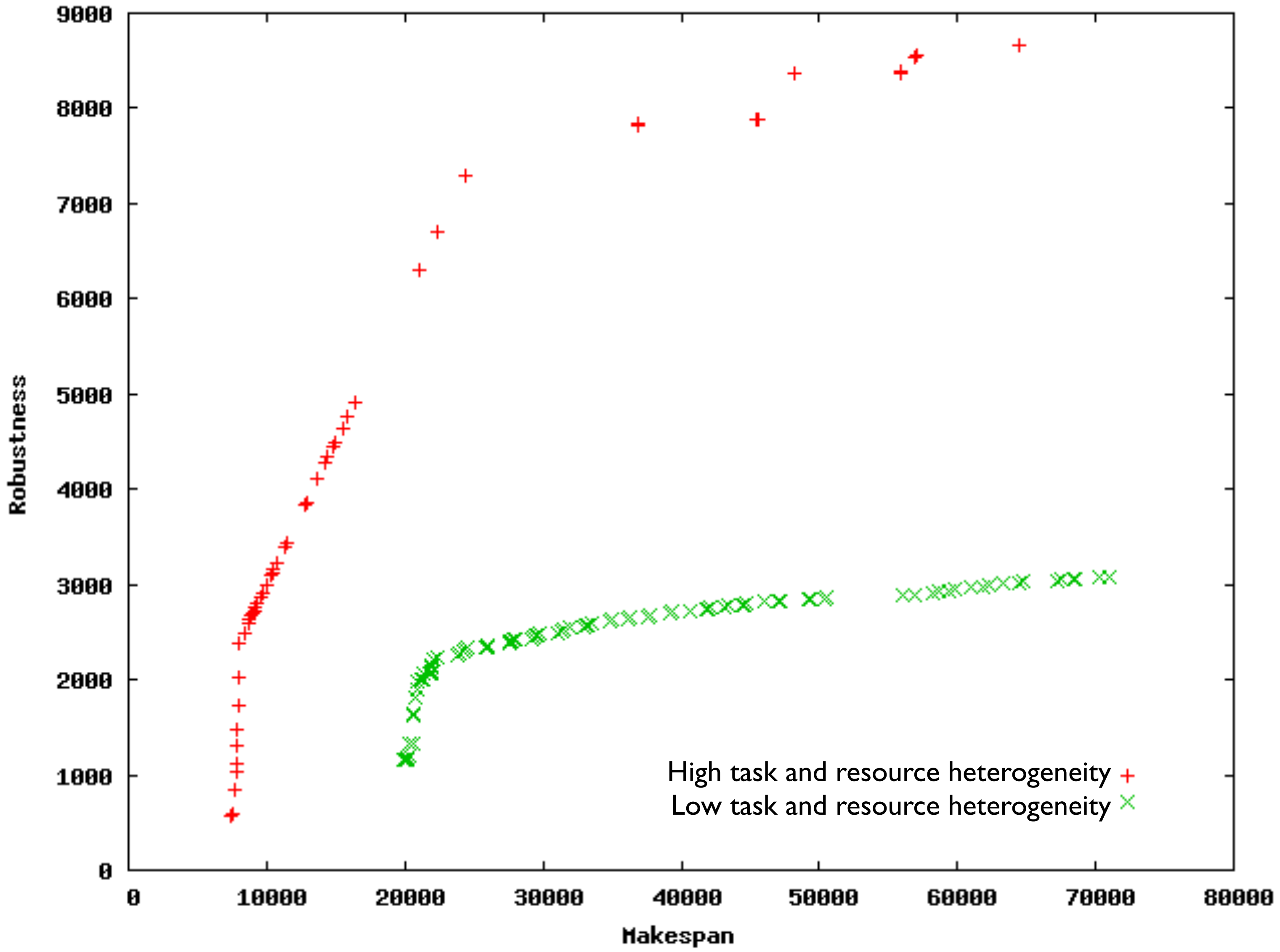
Performance Evaluation

- Three performance metrics

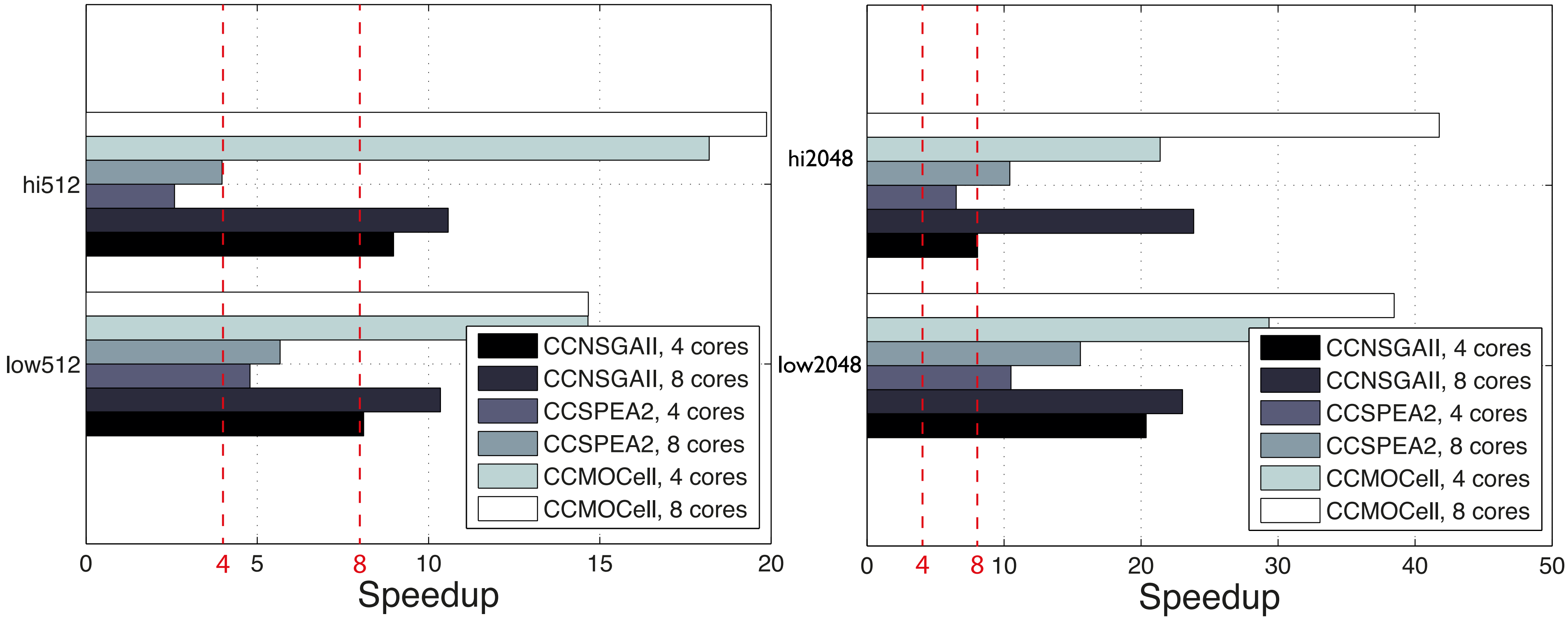


- The optimal Pareto front is not known
  - Reference Pareto front built by merging all the Pareto fronts obtained

Example of Reference Pareto Front

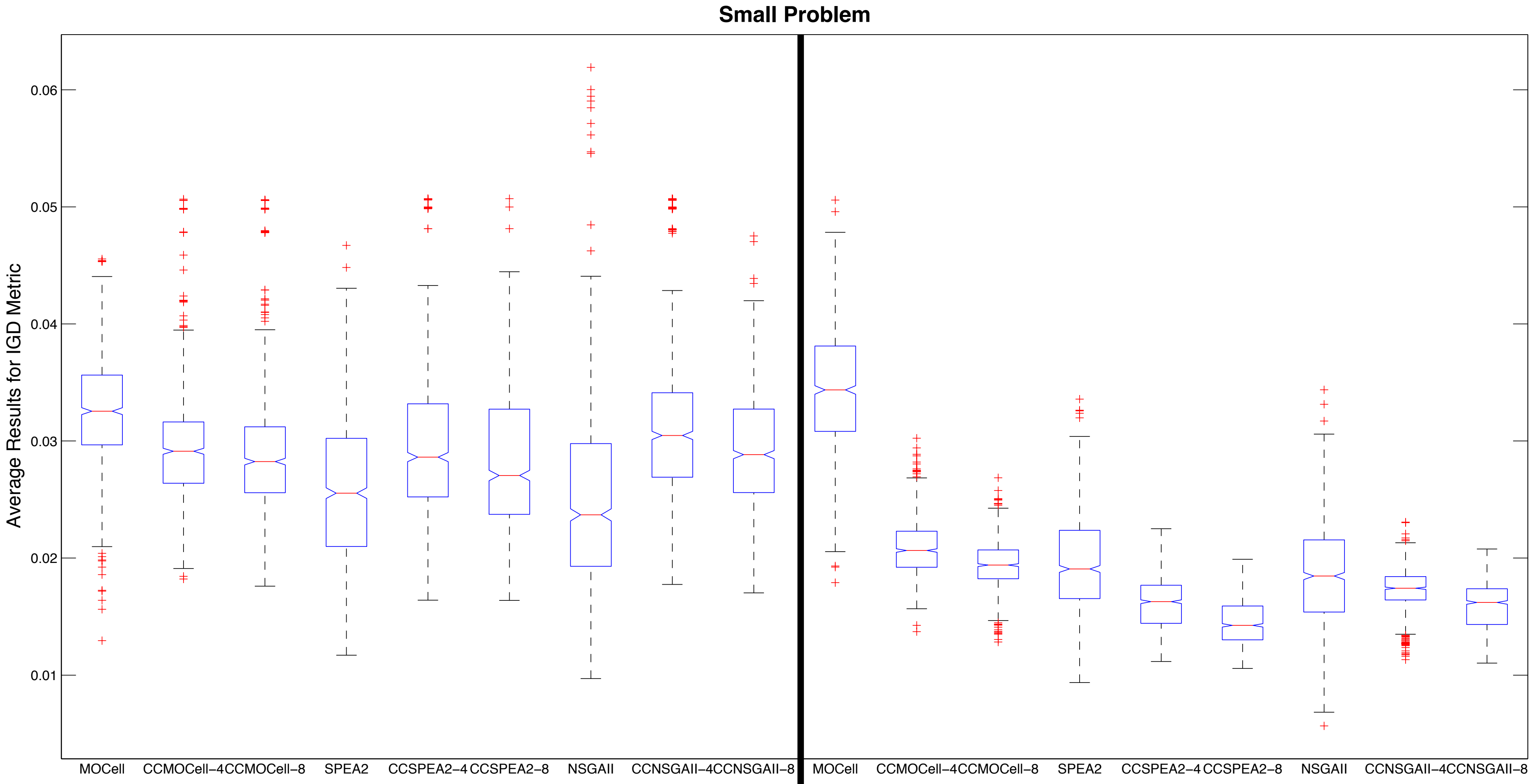


Speedup Results



$$Speedup = \frac{Time_{MOEA}}{Time_{CCMOEA}}$$

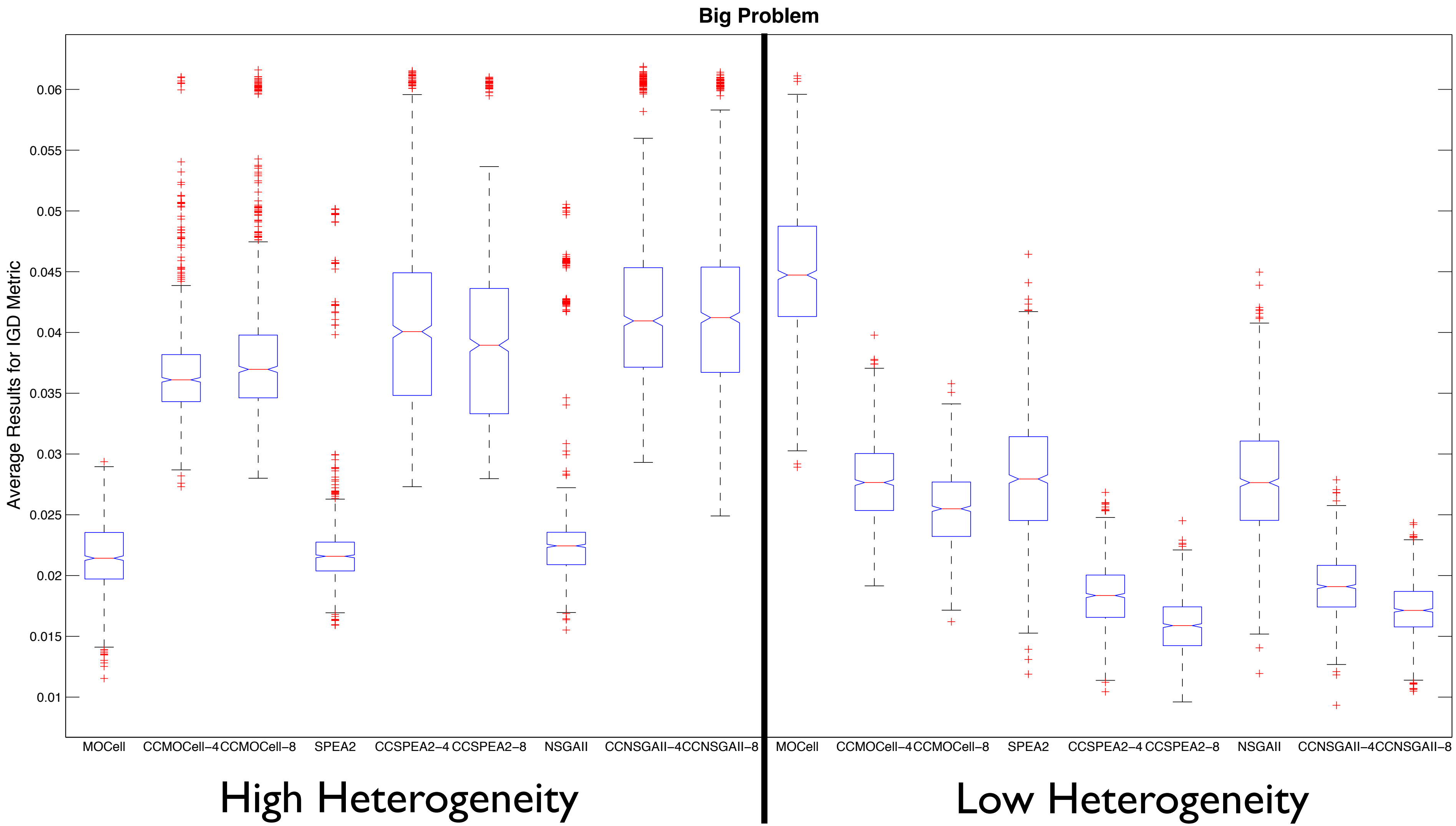
Algorithms Comparison: IGD



High Heterogeneity

Low Heterogeneity

Algorithms Comparison: IGD



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Conclusion & Perspectives

- Conclusion
  - Design of generic framework for Cooperative Coevolutionary Multi-objective Evolutionary Algorithms (CCMOEAs)
    - Accurate
    - Efficient
  - Implementation of three new CCMOEAs
    - Based on NSGA-II, SPEA2, and MOCell
  - Validate on a real-world problem
    - Robust Static Mapping of Independent Tasks on Grids (RSMP)

- Perspectives
  - Asynchronous communications between the subpopulations.
  - Tackle bigger instances of the RSMP problem

Thank you for your attention