Automated Configuration of MIP solvers

Frank Hutter, Holger Hoos, and Kevin Leyton-Brown

Department of Computer Science
University of British Columbia
Vancouver, Canada
{hutter,hoos,kevinlb}@cs.ubc.ca

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Parameters in Algorithms

Most algorithms have parameters

- Decisions that are left open during algorithm design
  - numerical parameters (*e.g.*, real-valued thresholds)
  - categorical parameters (*e.g.*, which heuristic to use)
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Prominent parameters in MIP solvers

- Preprocessing
- Which type of cuts to apply
- MIP strategy parameters
- Details of underlying linear (or quadratic) programming solver

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- Cplex automated tuning tool (since version 11)
  - Saves valuable human time
  - Improves performance

Our work: automated algorithm configuration

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  - Runnable algorithm A, its parameters and their domains
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  - 10^{47} possible configurations $\rightsquigarrow$ **algorithm configuration**

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This paper: application study for MIP solvers

- Use existing algorithm configuration tool (PARAMILS)
- Use different MIP solvers (CPLEX, GUROBI, LPSOLVE)
- Use six different MIP benchmark sets
- Optimize different objectives (runtime to optimality/MIP gap)

Outline

1. Related work
2. Details about this study
3. Results
4. Conclusions

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- COMPOSER [Gratch & Dejong, '92; Gratch and Chien, '96]
  - Spacecraft communication scheduling
- CALIBRA [Diaz and Laguna, '06]
  - Optimized various metaheuristics
- F-RACE [Birattari et al., '04-present]
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  - Main problem: only optimized performance for single instances
  - Only used small subset of 10 CPLEX parameters

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ParamILS [Hutter et al., AAAI'07 & '09]:
Iterated local search: biased random walk over local optima

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  - typically outperforms BasicILS
  - used in this study

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- Results
  - Provably never hurts
  - Sometimes substantial speedups

    [Hutter et al., JAIR'09]

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- Concise bug reports $\rightsquigarrow$ helped to fix 2 bugs in GUROBI (!)

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Benchmark sets used

Domain	Type	#instances	Citation
Comp. sustainability (SUST)	MILP	2 000	[Gomes et al, '08]
Combinatorial auctions (WDP)	MILP	2 000	[Leyton-Brown et al., '00]
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Split benchmarks 50:50 into training and test sets

- Optimized parameters on the training set
- Reported performance on the test set
- Necessary to check for *over-tuning*

Setup of configuration experiments

Perform 10 independent runs of ParamILS

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Compare test performance of:

- ParamILS's configuration $\hat{\boldsymbol{\theta}}^*$
- Default algorithm settings
- Cplex tuning tool
  - Gurobi and lpsolve: no tuning tool available

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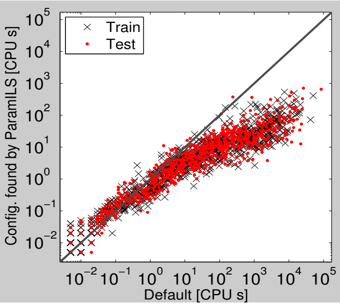

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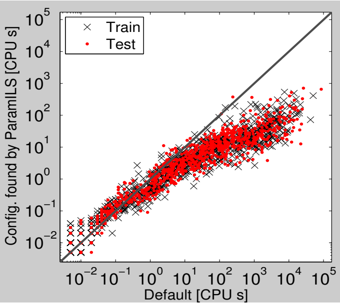

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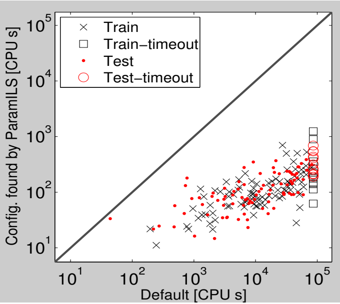

LPSOLVE on WDP instances (150x)

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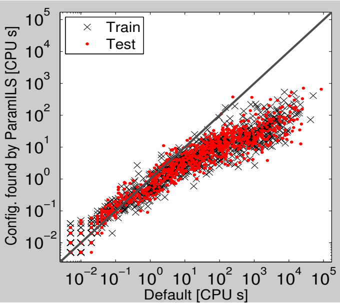

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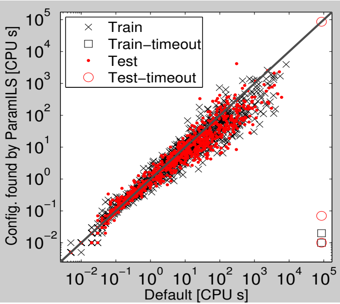

GUROBI on SUST instances (2.3x)

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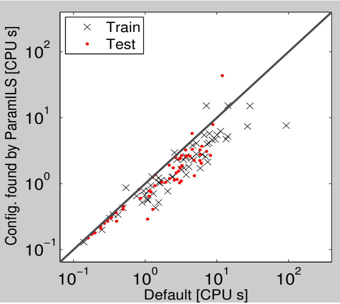
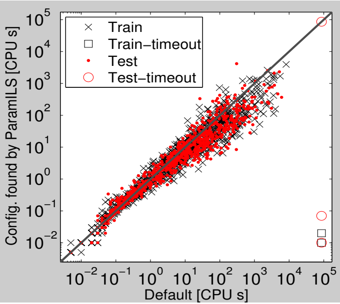


GUROBI on MIK instances (1.2x)



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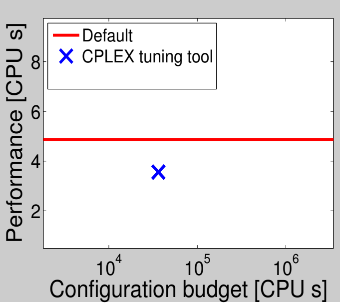

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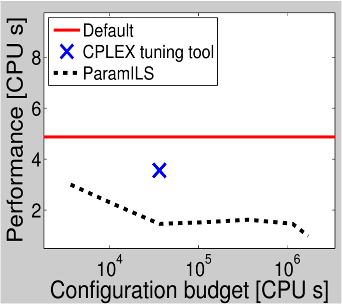

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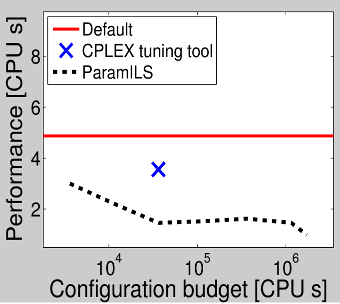

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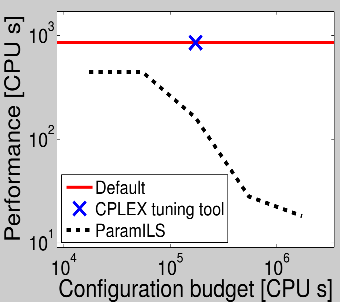

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- Representative instance set
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- Per-instance approaches for heterogeneous benchmarks
  - Given a new unseen instance:
    - Compute instance characteristics (fast)
    - Use parameter config. predicted to be best for the instance

Thanks to:

- Providers of instance benchmark sets
  - Louis-Martin Rousseau
  - Bistra Dilkina
  - Berkeley Computational Optimization Lab
- Commercial MIP solvers for free full academic license
  - IBM (CPLEX)
  - GUROBI
- LPSOLVE developers for their solver
- Compute clusters
  - Westgrid
  - CFI-funded arrow cluster
- Funding agencies
  - Postdoc fellowship from CBIE
  - MITACS
  - NSERC

Backup slides

Differences to STOP [Baz et al, '09]

Baz et al optimized for single instances

"In practice, users would typically be tuning for a family of related instances rather than for an individual instance"

- Generalization to *sets* of instances is nontrivial
  - Cannot afford to run all instances for each configuration
  - $\rightsquigarrow$ FocusedILS adapts # runs per configuration

Further differences

- Baz et al used older Cplex version (9.0)
  - defaults improved in newer Cplex versions
- Baz et al considered (only) 10 Cplex parameters
  - and also not all possible values for each parameter
  - in order to improve Stop's performance
  - $\rightsquigarrow$ requires domain knowledge

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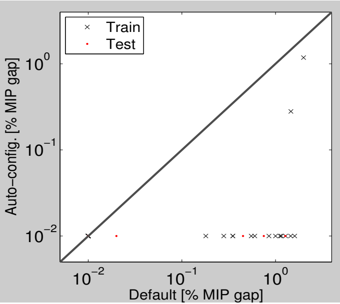

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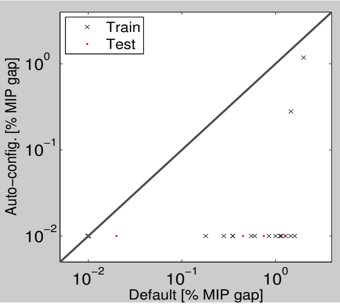

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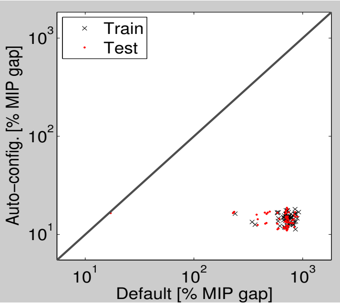

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