Improving Strong Branching by Domain Propagation

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Zuse Institute Berlin · Berlin Mathematical School

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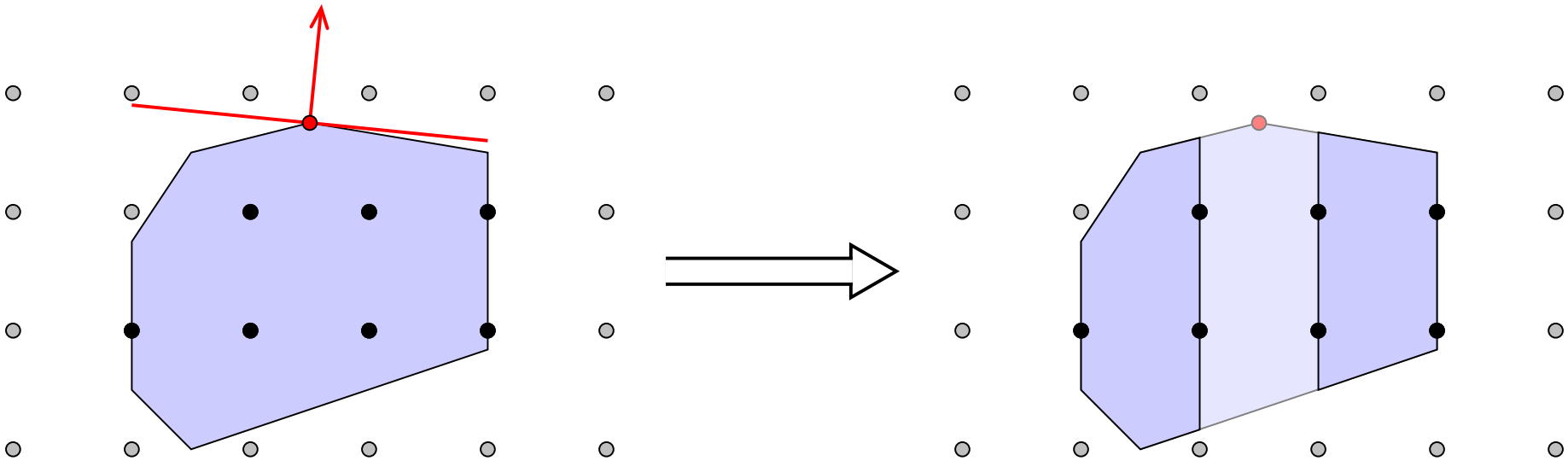
Branching on Variables for MIPs



Goals

- increase child nodes' dual bounds
- prove optimality fast

Tools

- LP solution value
- history information
- strong branching

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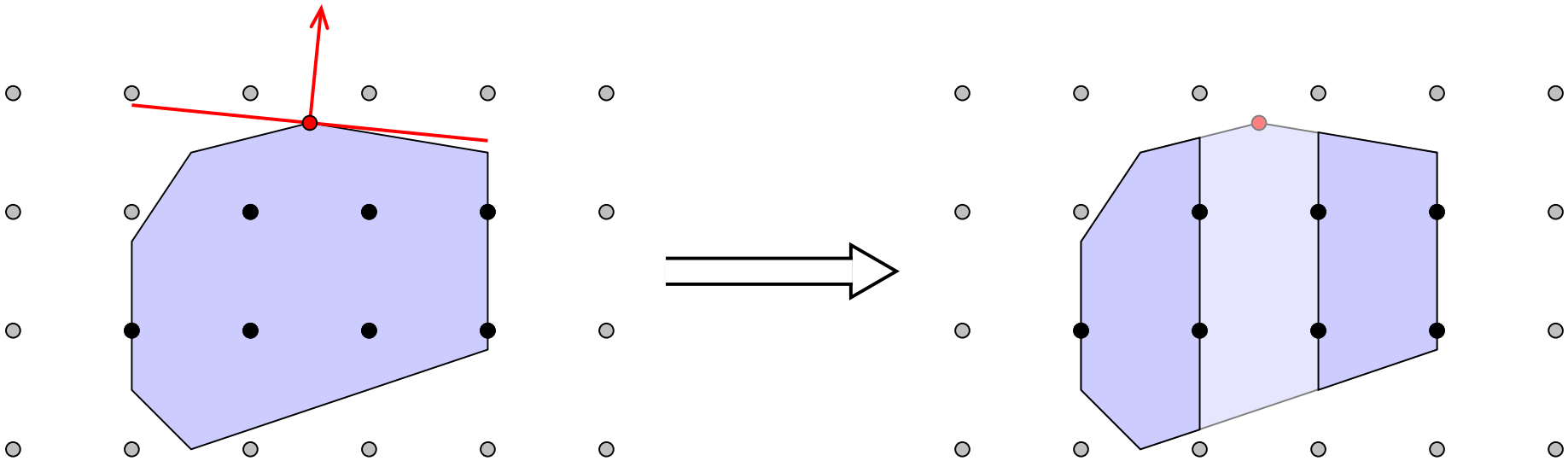

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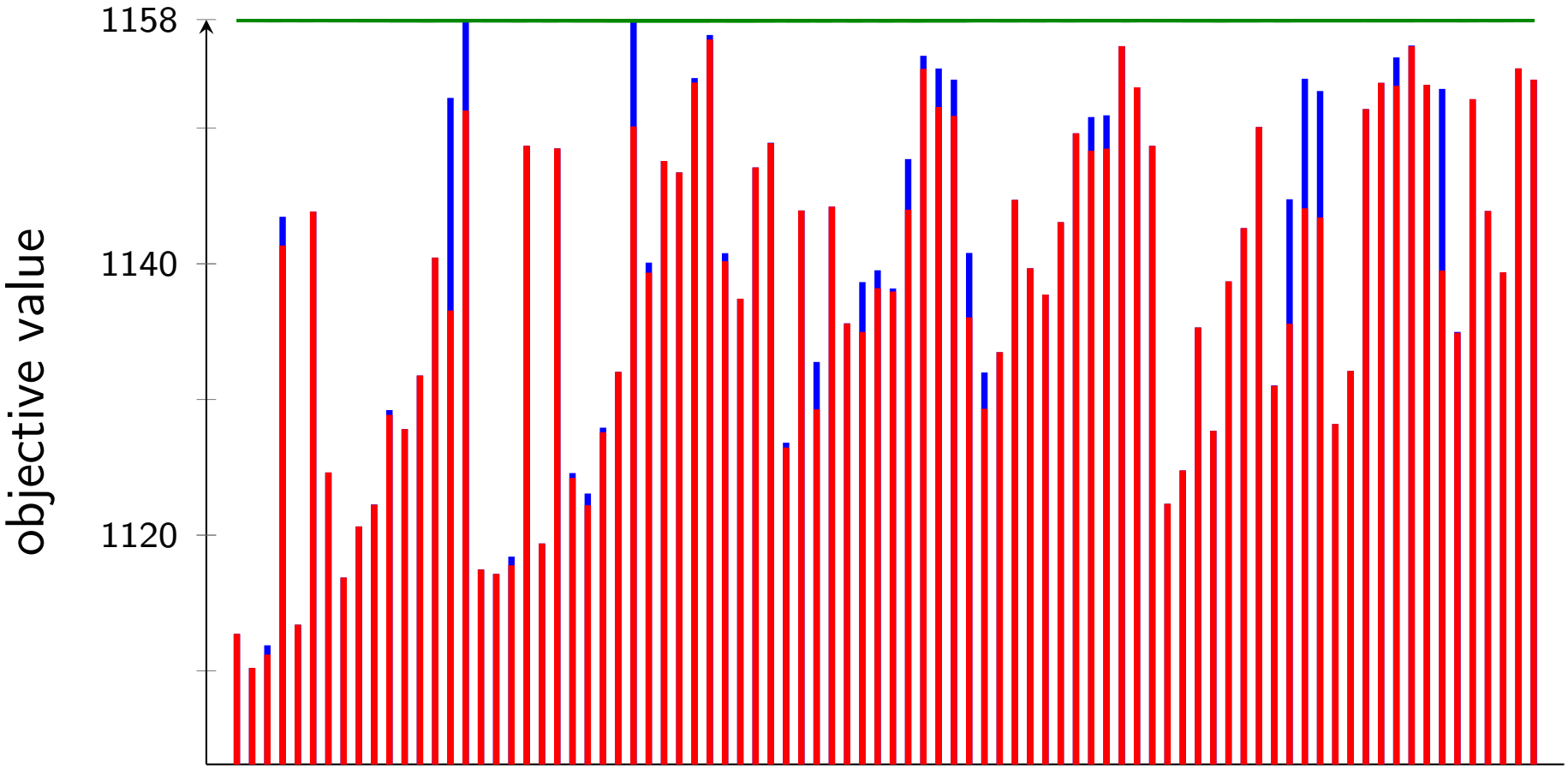
Quality of Strong Branching Results

strong branching dual bounds vs. LP value during node processing

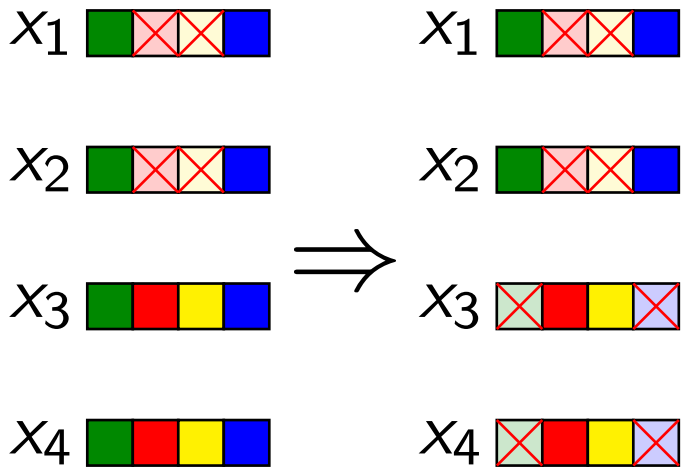


instance: aflow30a (MIPLIB 2003), full strong branching,
optimum value provided, solved after 87 nodes

Domain Propagation (Node Preprocessing)

Idea:

- analyze local constraints and domains
- tighten local variable domains
- first step in node processing
- better dual bounds



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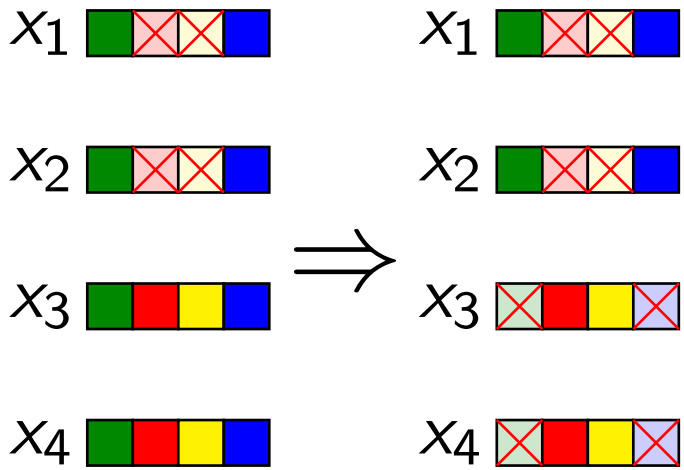


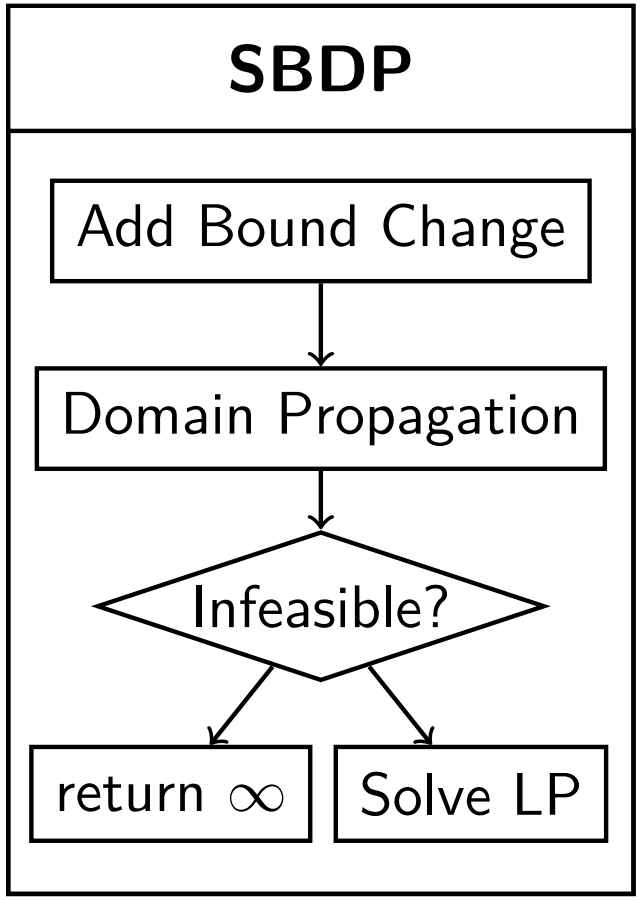
Idea of this talk

Strong branching should consider the effects of domain propagation!

Strong Branching with Domain Propagation

Strong Branching with Domain Propagation (SBDP):

- add branching bound
- perform "default" domain propagation
- solve LP



Strong Branching with Domain Propagation

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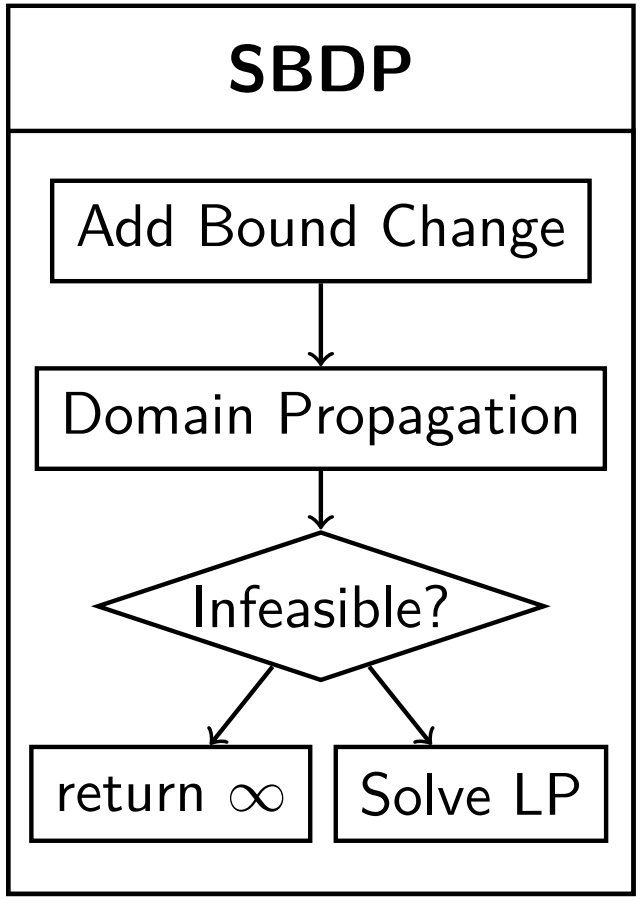
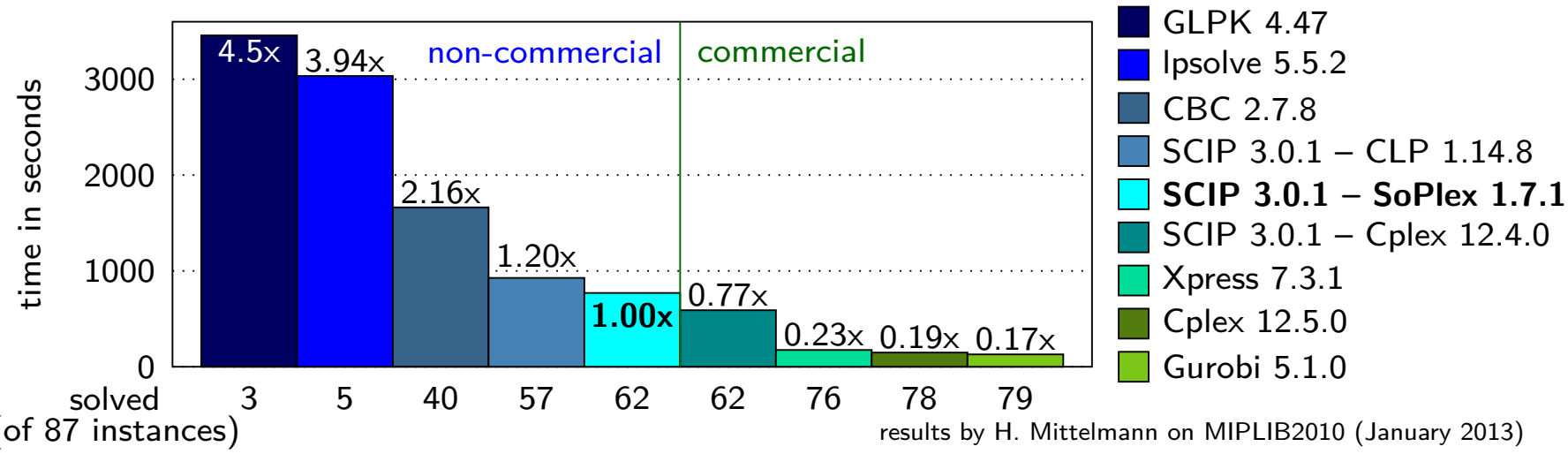
Open Questions:

- better predictions?
- change in strong branching effort?
- overall impact?



SCIP: Solving Constraint Integer Programs

- standalone solver / branch-cut-and-price-framework
- modular structure via plugins
- free for academic use: `http://scip.zib.de`
- available in source code
- very fast non-commercial MIP solver



Computational Experiment: Single Calls

- 168 instances (MIPLIB 3, 2003, 2010 benchmark)
- excluded infeasible instances + instances without branching
- 147 instances left
- time limit: 2 hours

- full strong branching
- optimal solution value provided
- heuristics, separation turned off

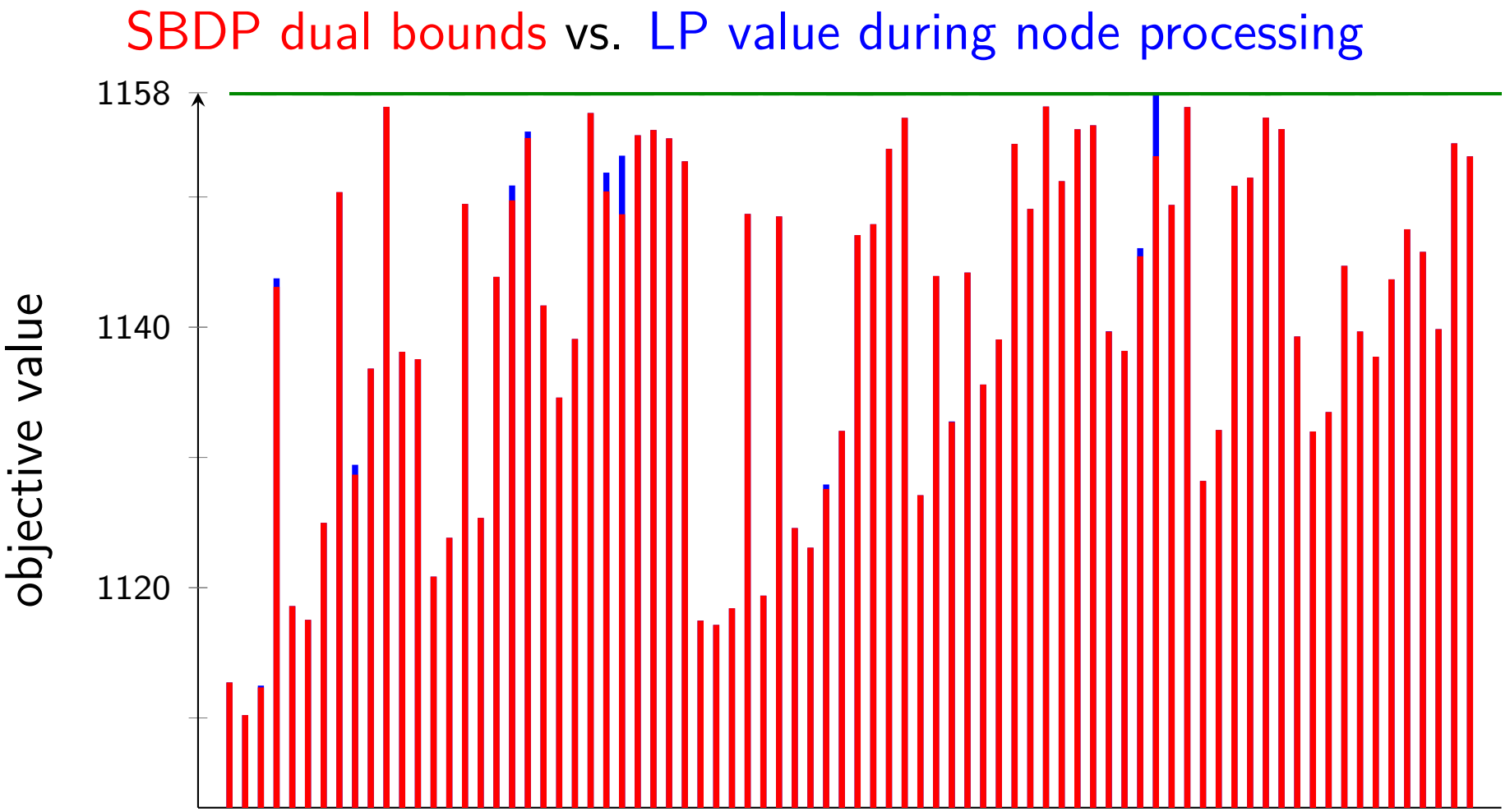
- SBDP in addition to "standard" strong branching
- only "standard" strong branching results used for branching

First Computational Insights

Compare single strong branching (SB) calls

- SB children detected infeasible: 14% → 17%
  - 15% during propagation
- SB children with better dual bound: 5.6%
  - gap closed by 20% on average
- LP iterations:
  - infeasible children: – 18%
  - better dual bounds: + 30%
  - all other SB children: – 4%
- Domain propagation time: about 5%
- SB time increased by about 1%

Update: Quality of Strong Branching Results



instance: aflow30a (MIPLIB 2003), full strong branching,
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Further Improvements

Let's add some more things:

- additional statistics:
  - implications, cutoffs, conflicts

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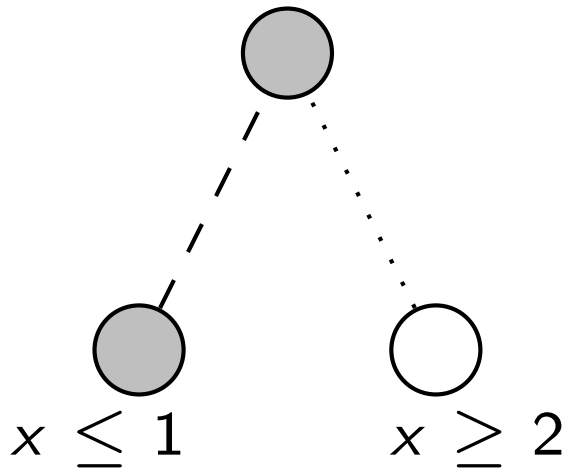
- stop when infeasible
  - up-child first
  - use locking numbers



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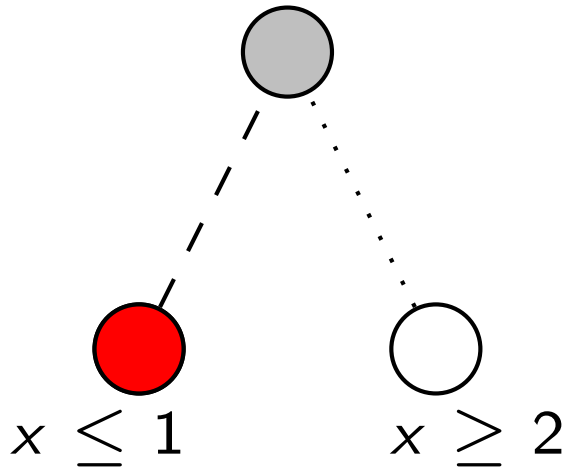

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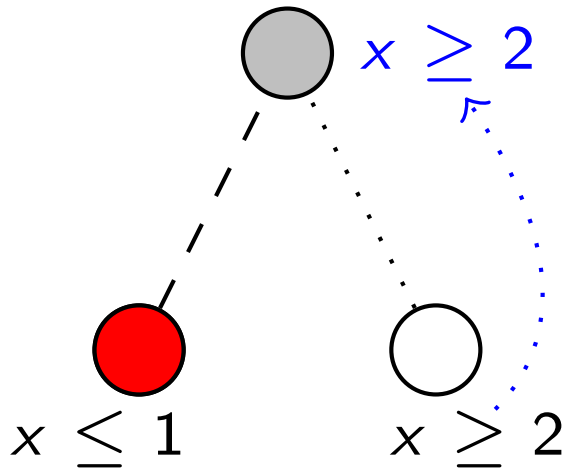

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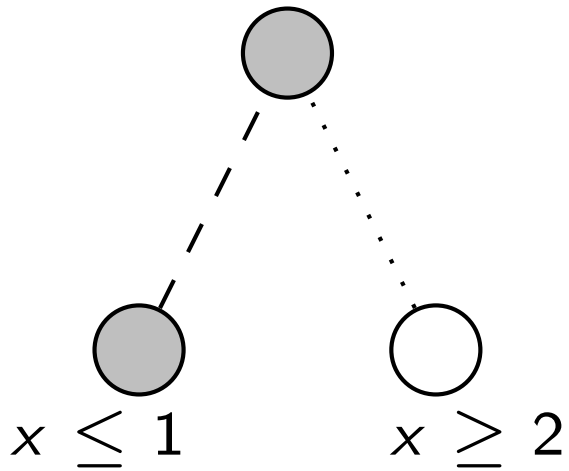
  - simple rounding heuristic



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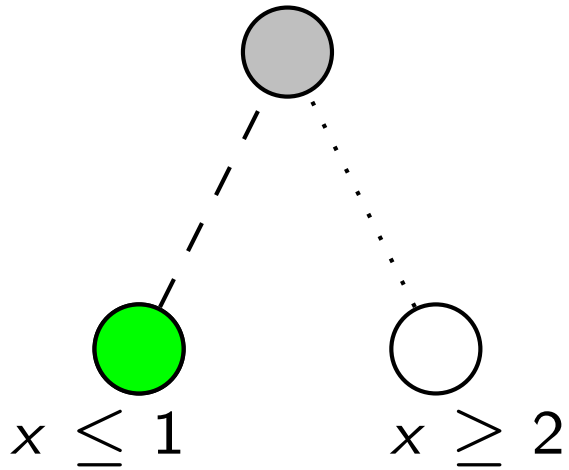

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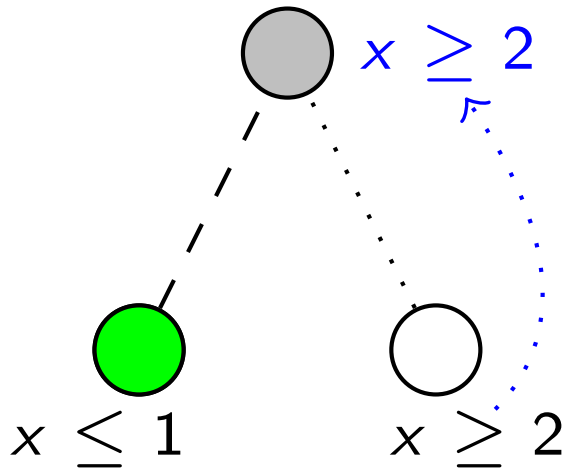

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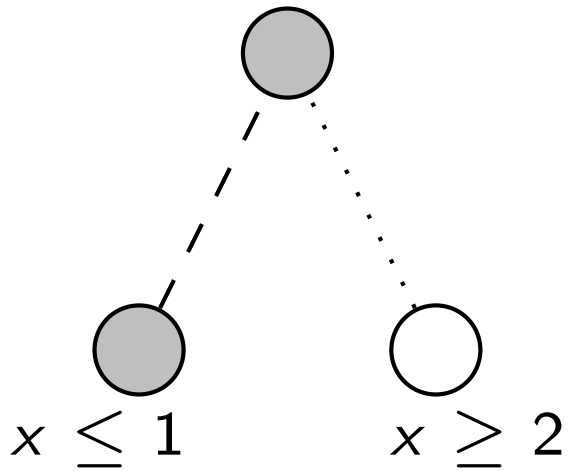
- probing-like bound tightening



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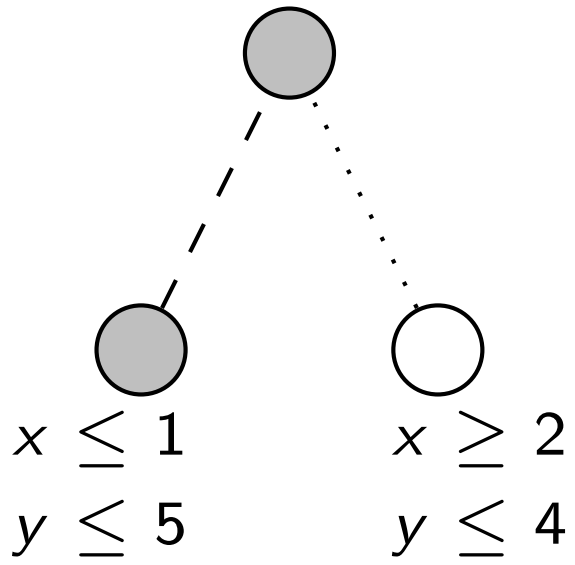

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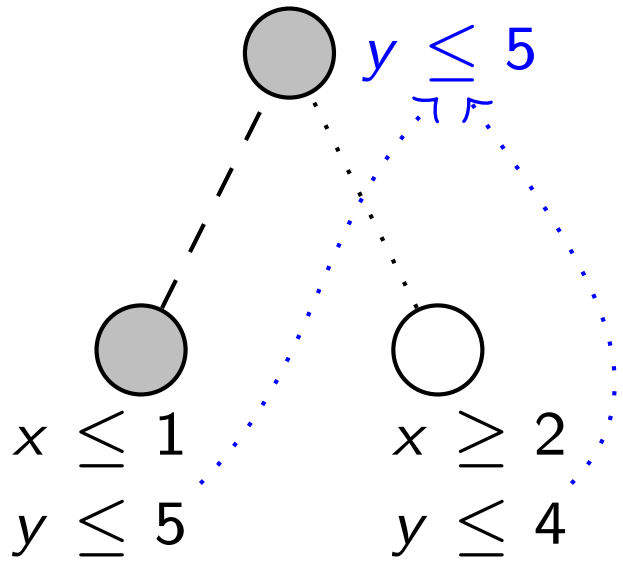


Computational Experiment: Proving Optimality

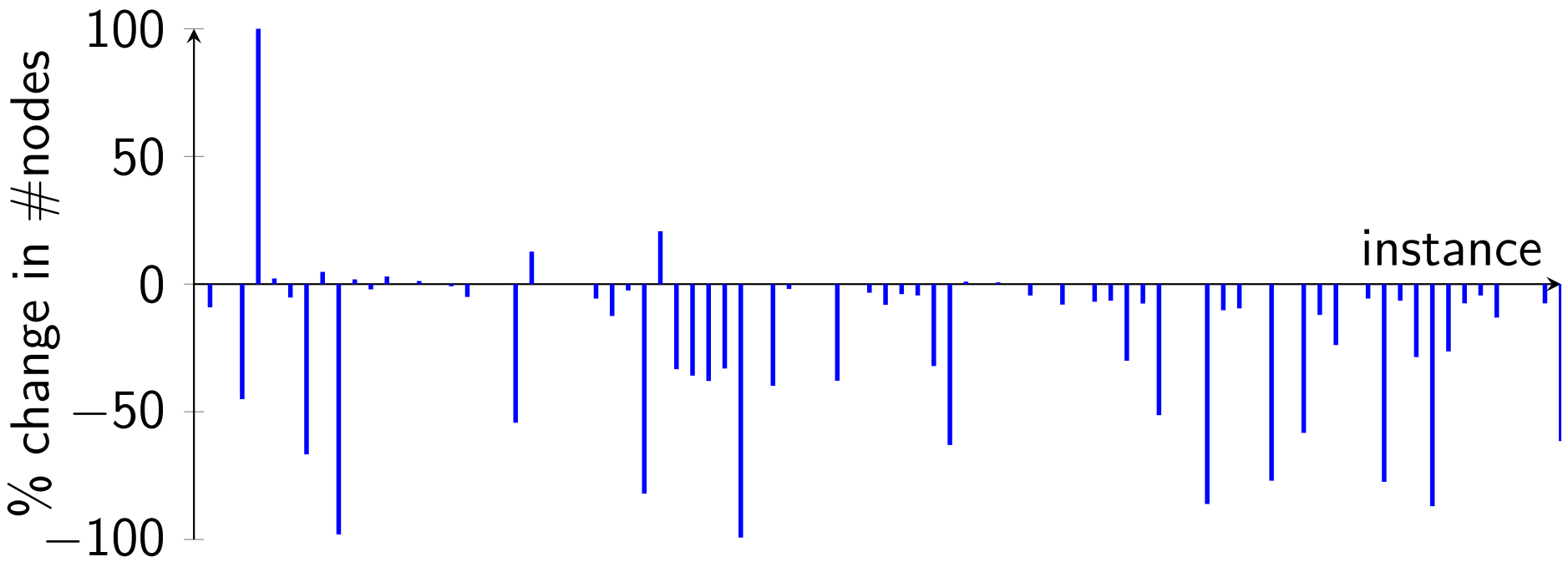
- all 168 instances (MIPLIB 3, 2003, 2010 benchmark)
- time limit: 2 hours
- original + 3 random permutations to reduce performance variability
- arithmetic mean of solving time and node number per instance
- instances solved iff all four permutations were solved

- full strong branching
- optimal solution value provided
- heuristics, separation turned off

- two individual runs
- compare B&B tree and solving time

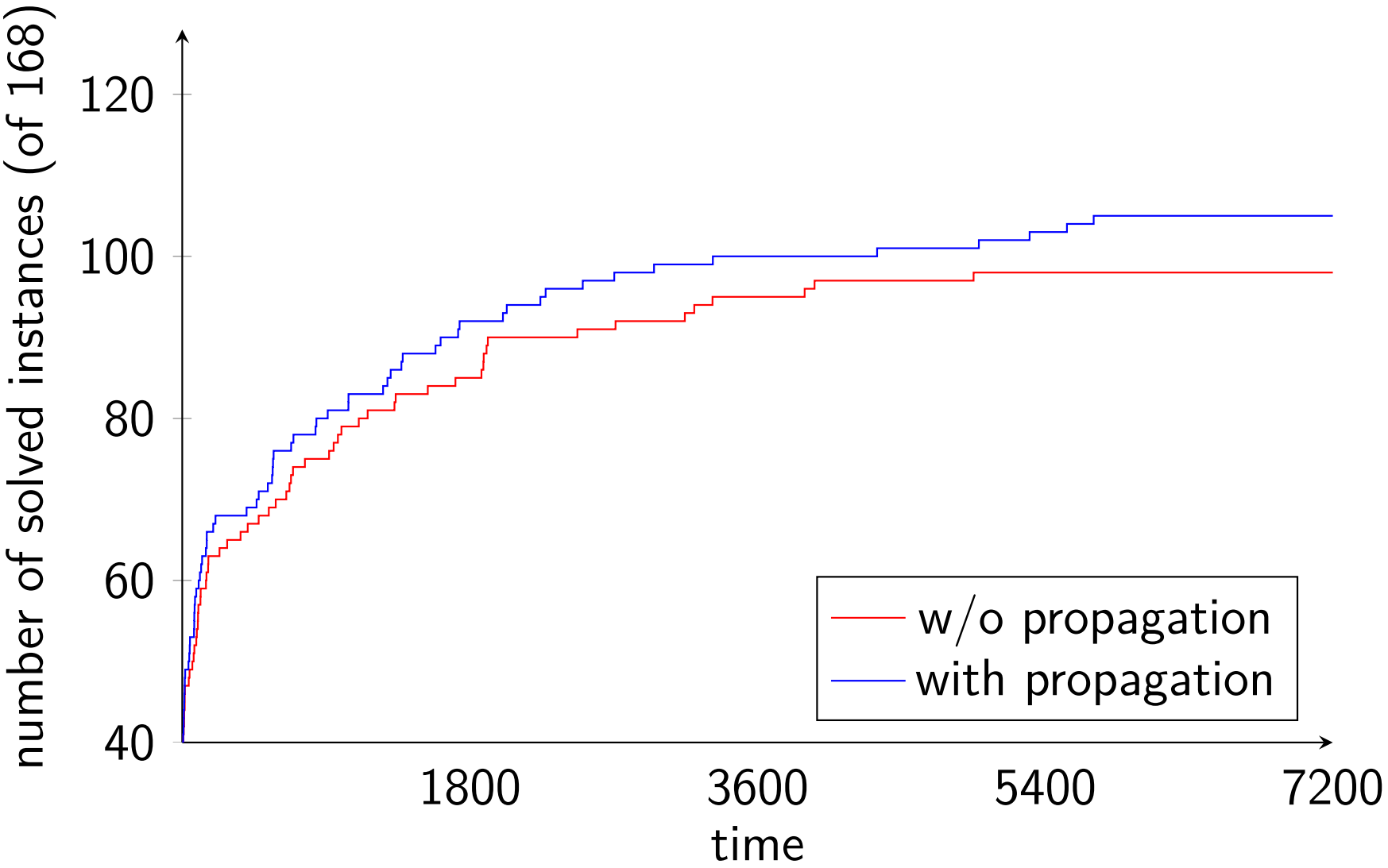
Number of Nodes: Proving Optimality

- relative change of number of nodes when using SBDP
- only instances solved to optimality by both variants



- shifted geometric mean reduced by 25%

Performance Diagram: Proving Optimality



- result: 7 more instances solved, shifted geom. time reduced by 13%

Hybrid Branching

- extension of reliability pseudo-cost branching
- + other history information
  - inferences, conflicts, cutoffs
- strong branching LP iteration limit
- "lookahead" strategy

What does this mean for SDBP?

- smaller strong branching impact
- but: first branchings most important
- initializes other history information as well
- SBDP reaches LP iteration limit twice as often: 10% instead of 5%
- less "stable"

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- instances solved iff all four permutations were solved

- hybrid branching
- SCIP default settings

- two individual runs
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Number of Nodes: Hybrid Branching

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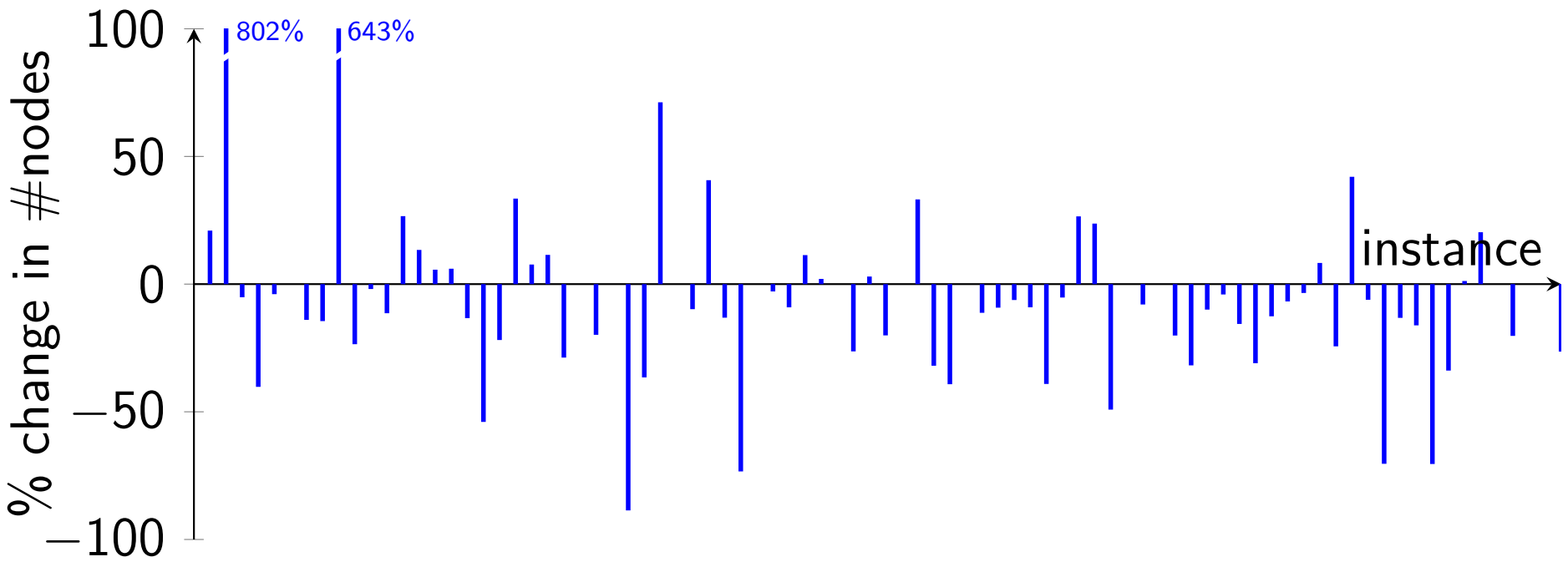
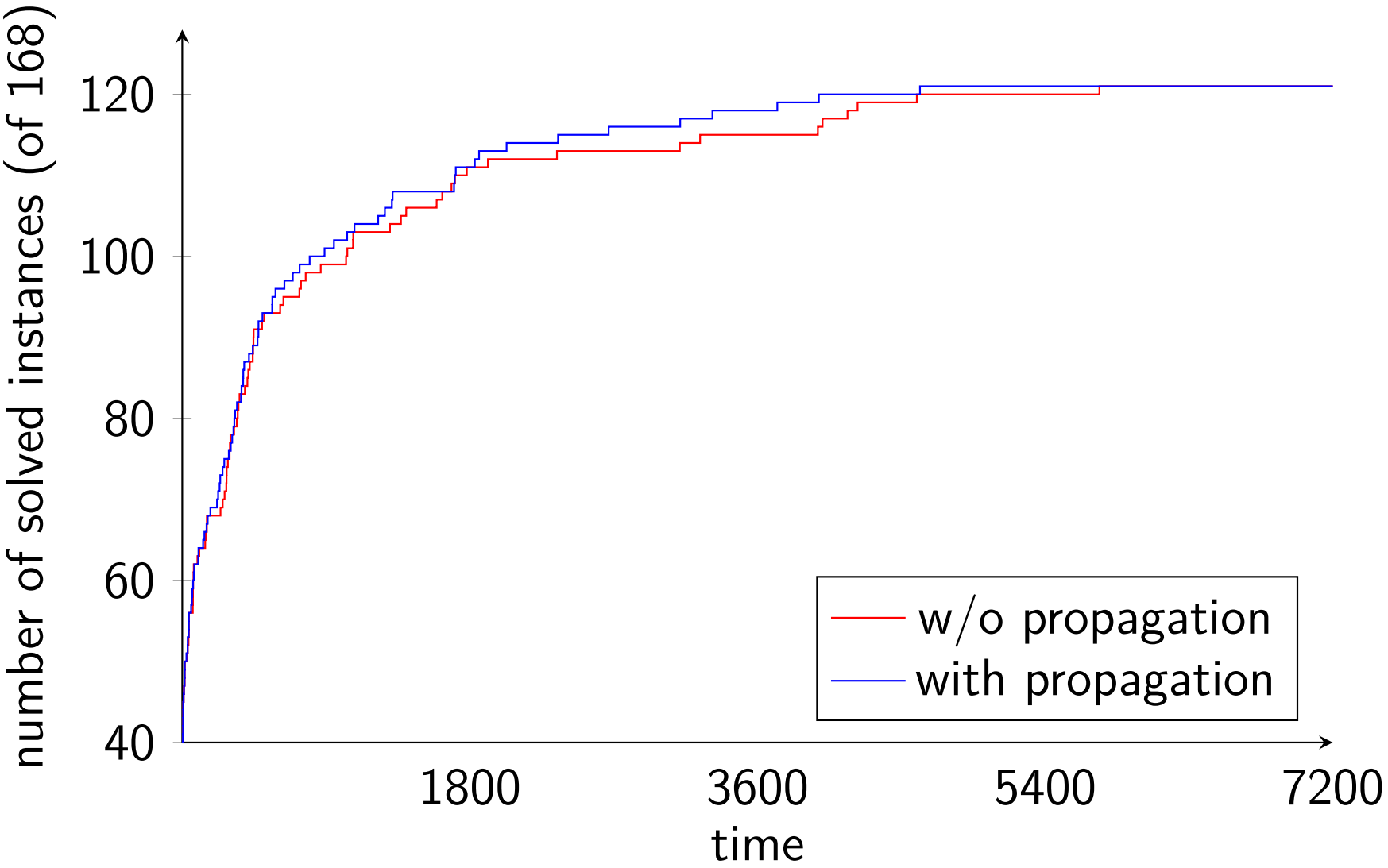


- shifted geometric mean reduced by 7%

Performance Diagram: Hybrid Branching



- result: shifted geom. time reduced by 4%

Conclusions

Domain propagation in strong branching...

- increases strong branching time marginally
- improves dual bound predictions
- decreases tree size significantly
- improves performance of two common branching rules
- default in SCIP 3.1

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Next Steps

- test on other problem types
- dynamic (de)activation of domain propagation
- nonchimerical + cloud + propagation = ?

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