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SCIP: Past, Present, Future

SCIP 20 Workshop

Marc Pfetsch, TU Darmstadt

Discrete Optimization

Reminder of SCIP Facts

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SCIP (Solving Constraint Integer Programs) ...

- is a branch-and-cut-and-price framework,
- contains a fast MIP- and MINLP-solver,
- can solve Constraint Programs (CP),
- includes some SAT-solver techniques (conflict analysis, restarts),
- is open source (Apache 2.0),
- available at `http://scipopt.org`.
- SCIP Optimization Suite = SCIP + SoPlex + ZIMPL
- The SCIP core has 797 844 lines of code with 46 449 asserts.
- `swmath.org` lists $\geq$ 558 articles that are SCIP related (31 in 2022 so far).

Disclaimer

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- SCIP is not only a ZIB thing: It is also developed in Darmstadt, Eindhoven, Erlangen, Twente, ...
- There are many codes related to SCIP:
  - ZIMPL (modeling language)
  - SoPlex (LP-solver)
  - UG (ParaSCIP and FiberSCIP, parallelization)
  - Papilo (preprocessor)
  - GCG (generic decomposition solver for mixed-integer programs, RWTH Aachen)
  - SCIP-Jack (Steiner trees)
  - SCIP-SDP (mixed-integer semidefinite programming, TU Darmstadt)
  - ...
- Today we only celebrate the birthday of SCIP ...
  The others deserve their own celebration.

Overview

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SCIP History – The Early Years

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1998	SIP – Solving Integer Programs (Alexander Martin)
10/23/2002	first commit to SCIP repository (Tobias Achterberg)
02/2003	first version 0.1 that can solve MIPs
06/2003	initial commit of my first SCIP project (Maximum Feasible Subsystem Problem)
2003	Gomory cuts and conflict analysis
03/09/2004	knapsack cover separator (Kati Wolter (Yark))
04/2004	restarts, c-MIR cuts
01/31/2005	feasibility pump (Timo Berthold)
09/2005	first public version 0.80
07/12/2007	dissertation defense of Tobias Achterberg
2007	SOS1 and SOS2
09/2007	Version 1.00
09/2008	Version 1.1.0 (counting)
09/2009	Version 1.2.0 (hybrid relpscost branching)
09/2010	Version 2.0.0 (nonlinear problems, copying, indicator constraints)
10/2011	Version 2.1.0 (pseudo-Boolean constraints, LNS with copying)

SCIP History – Maturity Years

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10/2012	Version 3.0.0
02/2014	Version 3.1.0
07/2015	Version 3.2.0 (reoptimization, presolving rounds, orbitopes)
03/2017	Version 4.0.0 (components presolver)
12/2017	Version 5.0.0 (ALNS, symmetry handling)
06/2018	Version 6.0.0 (Benders)
09/2020	Version 7.0.0 (more conflict analysis, more presolvers)
01/2022	Version 8.0.0 (MINLP restructured)

Since Version 3.2 there are release reports for the major versions.

SCIP Releases Overview

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09/2005	Version 0.80
03/2006	Version 0.81
05/2006	Version 0.82
09/2006	Version 0.90
09/2007	Version 1.00
09/2008	Version 1.1.0
09/2009	Version 1.2.0
09/2010	Version 2.0.0
01/2011	Version 2.0.1
08/2011	Version 2.0.2
10/2011	Version 2.1.0
12/2011	Version 2.1.1
10/2012	Version 3.0.0
01/2013	Version 3.0.1
10/2013	Version 3.0.2
02/2014	Version 3.1.0
12/2014	Version 3.1.1
07/2015	Version 3.2.0
02/2016	Version 3.2.1
03/2017	Version 4.0.0
09/2017	Version 4.0.1
12/2017	Version 5.0.0
05/2018	Version 5.0.1
06/2018	Version 6.0.0
01/2019	Version 6.0.1
07/2019	Version 6.0.2
09/2020	Version 7.0.0
06/2020	Version 7.0.1
01/2021	Version 7.0.2
08/2021	Version 7.0.3
01/2022	Version 8.0.0
06/2022	Version 8.0.1
10/2022	Version 8.0.2

Major Releases in T-Shirts
Version 1.1 (2008)

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Major Releases in T-Shirts
Version 2.0 (2010)

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Major Releases in T-Shirts
Version 3.0 (2012)

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Major Releases in T-Shirts
Version 3.0 (2012)

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Major Releases in T-Shirts
Version 3.1 (2014)

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Major Releases in T-Shirts
Version 4.0 (2017)

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Major Releases in T-Shirts
Version 5 (2017)

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Major Releases in Hoodie
Version 5.0 (2017)

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Major Releases in T-Shirts
Version 6.0 (2018)

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SCIP History – Software Engineering

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- SCIP includes scripts to regularly run tests from the beginning.
- We also use (pc)lint from the beginning.
- original versioning system: CVS
- switch to git in 2011; also use GitLab
- Continuous integration then came soon after.
- We have checks that have to pass before merging as well as nightly and weekly runs.
- Automatic collection and visualization of results (IPET by Gregor Hendel).
- Add cmake as build system in 2017 (long discussion).
- Unit tests started in 2013; extended later and automized (Criterion).

- Each step significantly increased the quality of the code.
- Most steps were essential to “control” a project with many developers.

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Best SCIP Line of Code/Commit Message

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- I started a contest for the best SCIP line of code/commit message.
- The rules allow lines of C/C++ code or comments that fit into a single line and the code is present in the main part of SCIP in the current bugfix or master branch.
- Submissions: 68 commit messages, 34 lines of code. Thanks to all submitters, in particular, Franziska Schlösser!
- There was a jury consisting of Domenico Salvagnin – thanks!.

Winner – Best SCIP Commit Message

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```
409901453e - add temporary hack (4 years, 7 months ago) <Felipe Serrano>

a6da520395 - temporary hack was not a hack (4 years, 7 months ago)
             <Felipe Serrano>

2180424711 - make alns great again (5 years ago) <Gregor Hendel>
```

Winner – Best SCIP Line of Code

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```
src/scip/reopt.c: && SCIPsetIsGT(set, bestsim, 0.985) )
     /* 0.985 is a magic number determined in some experiments */

src/scip/heur_subnlp.c:1582
SCIPdebugMsg(scip, "LP is unbounded in root node, so we are quite
     desperate; run NLP heuristic and pray\n");
```

Honorable Mentions – Best SCIP Commit Message

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```
3d955ccb|dropped sentence that caused a heavy debate |
5ae0518a|merge-accident
3ea98235|use SCIP_ROWPREP in cons_abspower | - bringing the magic of
        cut beautification into the abspower conshdlr
e4dff10b|be less polite |
f7750cac|dos compiler does not believe that a const variable is a constant
d0167c91|handle the impossible | - bestcand should never be -1, but it
        seem to happen in seldom cases when run in ug[scip]
db97c3f0|add space for beauty |
839409c9|fix bug commited by Stefan (not me) in last-last commit
780e3dce|change warning message to debug message | - seems to confuse
        people and one wouldn't know what to do about it, too
57068522|don't export symbols for SCIP's binary | I hate Windows...
```

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Contributors

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Many people have contributed to SCIP, see https://www.scipopt.org/index.php#developers for more details:

Tobias Achterberg, Mathieu Besançon, Ksenia Bestuzheva, Timo Berthold, Suresh Bolusani, Antonia Chmiela, Leon Eifler Tobias Fischer, Tristan Gally, Gerald Gamrath, Ambros Gleixner, Leona Gottwald, Christoph Graczyk, Katrin Halbig, Stefan Heinz, Gregor Hendel, Alexander Hoen, Christopher Hojny, Thorsten Koch, Kati Jarck, Stephen J. Maher, Gioni Mexi, Matthias Miltenberger, Benjamin Müller, Marc Pfetsch, Franziska Schlösser, Felipe Serrano, Yuji Shinano, Boro Sofranac, Stefan Vigerske, Fabian Wegscheider, Dieter Weninger, Michael Winkler, Jakob Witzig

Additional Contributors

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DARMSTADT

Daniel Anderson, Martin Ballerstein, Chris Beck, Livio Bertacco, Andreas Bley, Pierre Le Bodic, Tobias Buchwald, Weikun Chen, Frederic Didier, Daniel Espinoza, John Forrest, Maxime Gasse, Thorsten Gellermann, Patrick Gemander, Naga Venkata Chaitanya Gudapati, Bo Jensen, Renke Kuhlmann, Manuel Kutschka, Anna Melchiori, Dennis Michaels, Giacomo Nannicini, Michael Perregaard, Frédéric Pythoud, Christian Raack, Jörg Rambau, Daniel Rehfeldt, Domenico Salvagnin, Sebastian Schenker, Jens Schulz, Cornelius Schwarz, Robert Schwarz, Felix Hennings, Yuji Shinano, Dan Steffy, Timo Strunk, Andreas Tuchscherer, Ingmar Vierhaus, Stefan Weltge

Some SCIP Contributors Sorted by First Commit

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2002-10-23: Tobias Achterberg
2004-01-15: Marc Pfetsch
2004-03-09: Kati Wolter
2005-01-31: Timo Berthold
2005-09-13: Annegret Dix
2006-05-10: Benjamin Hiller
2006-05-22: Stefan Heinz
2006-09-03: Sebastion Orlowski
2007-01-15: Marika Neumann
2007-09-21: Lingfeng Niu
2007-09-24: Thorsten Koch
2008-02-14: Michael Winkler
2008-02-26: Robert Waniek
2008-06-05: Gerald Gamrath
2008-07-09: Christian Raack
2008-07-24: Stefan Vigerske
2008-09-26: Ambros Gleixner
2009-05-15: Yuji Shinano
2009-07-06: Pietro Belotti
2009-08-07: Daniel Steffy
2009-12-04: Gregor Hendel
2010-03-31: Thomas Lehmann
2010-05-27: Andre Augusto Cire
2010-09-15: Robert Schwarz
2011-03-07: Matthias Miltenberger
2010-11-26: Jesco Humpola
2011-07-15: Dan Steffy
2011-11-02: Stefan Weltge
2012-02-01: Dieter Weninger
2012-04-10: Frederic Pythoud
2012-06-20: Domenico Salvagnin
2012-07-31: Felipe Serrano
2013-03-22: Alexandra Kraft
2013-08-02: Ingmar Vierhaus
2013-08-08: Jakob Witzig
2013-09-26: Daniel Rehfeldt
2013-10-21: Tobias Buchwald
2013-11-11: Benjamin Müller
2013-12-04: Felix Simon
2014-01-27: Leif Naundorf
2014-02-12: Timo Strunk
2014-02-21: Stephen J Maher

Total Number of Commits per Person

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6310	Stefan Vigerske
4371	Marc Pfetsch
2451	Gerald Gamrath
2372	Benjamin Mueller
2353	Gregor Hendel
2033	Daniel Rehfeldt
1891	Stefan Heinz
1760	Jakob Witzig
1406	Michael Winkler
1303	Tobias Achterberg
1108	Felipe Serrano
1061	Ambros Gleixner
1024	Leona Gottwald
1022	Franziska Schloesser
978	Christopher Hojny
907	Stephen J. Maher
643	Timo Berthold
633	Ksenia Bestuzheva
621	Matthias Miltenberger
470	Fabian Wegscheider
363	Kati Wolter (Jarck)
260	Tobias Fischer
252	Christoph Schubert
242	Katrin Halbig
199	Tristan Gally
173	Leon Eifler
157	Antonia Chmiela
140	Stephen J Maher
128	Dieter Weninger
119	Merlin Viernickel
98	Franziska Schlösser
	...

Beware – list is (strongly) biased on age in project.

Some Dissertations Closely Connected to SCIP

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- Tobias Achterberg (2007)
- Christian Raack (2012)
- Timo Berthold (2014)
- Ambros Gleixner (2015)
- Tobias Fischer (2017)
- Tristan Gally (2018)
- Christopher Hojny (2018)
- Stefan Heinz (2018)
- Kati Jarck (2019)
- Benjamin Müller (2020)
- Jakob Witzig (2021)
- Daniel Rehfeldt (2021)
- Gredor Hendel (2022)

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SCIP Around the World
Locations of Downloads

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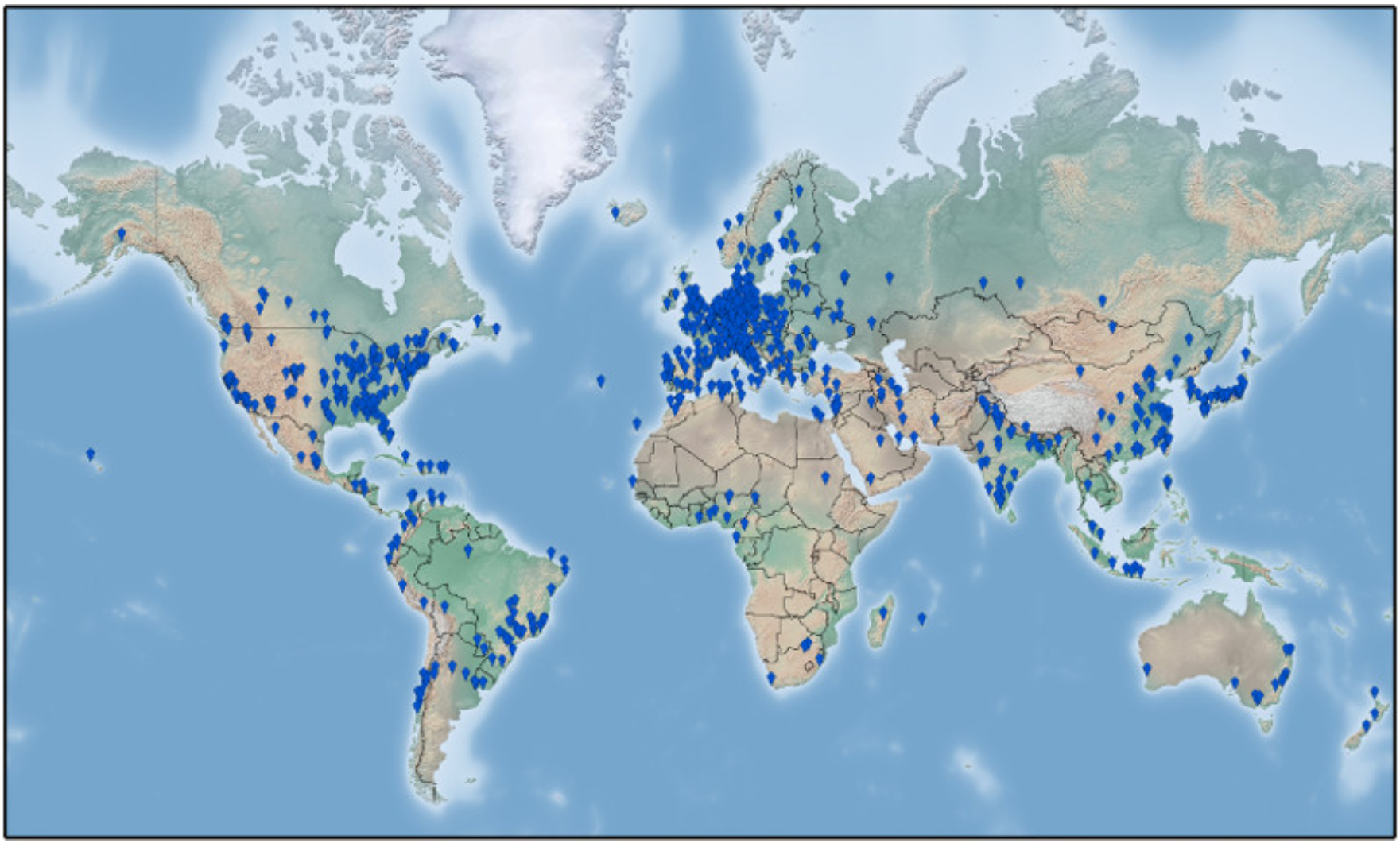

SCIP Around the World
Vienna around 1895

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SCIP Around the World
New York 2013, London 2014

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SCIP Around the World
Kleinwalsertal 2015

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SCIP Around the World
Pittsburgh ISMP 2015

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SCIP Around the World
Auckland 2016

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SCIP Around the World
Banff 2016

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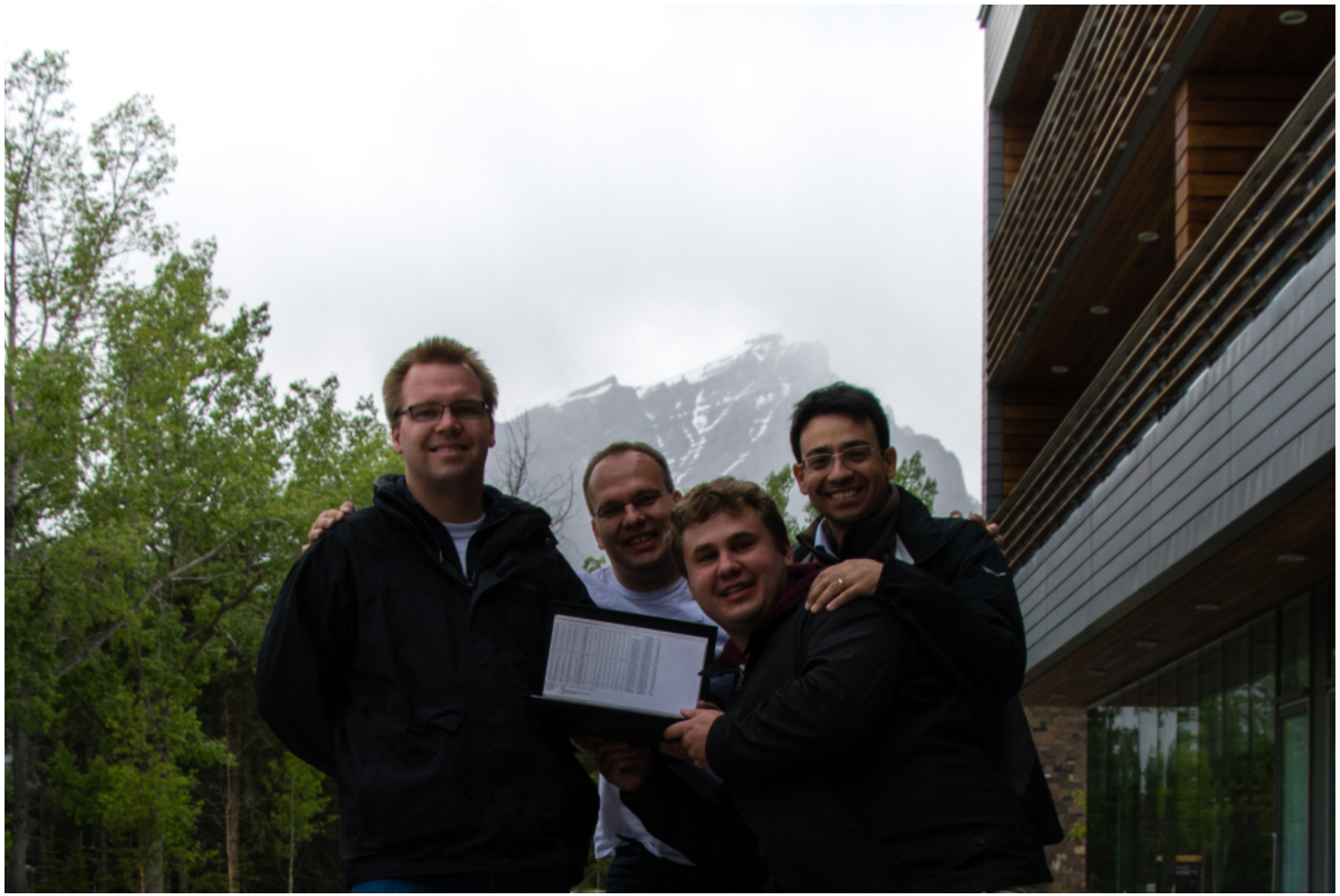

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Unique Points

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General:

- SCIP is very powerful and embedded into an ecosystem of software. (But is also quite complex and not easy to learn.)
- It is quite mature and well tested (but still actively developed).

Some unique properties:

- reoptimization
- extensive symmetry framework
- many formats/interfaces (C, Julia, Python, Matlab, . . .)
- supports branch-and-cut-and-price
- state-of-the-art MINLP solver
- . . .

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Some Experiments for MIP-Solving

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- Idea: Compare different SCIP versions over time.
- Use same LP-solver – in this case CPLEX (12.10.0.0), because its interface only slightly changed over the years.
- Use bliss version 0.73; bliss 0.77 for SCIP 8.0.1 (now shipped with SCIP)
- There are 32 different SCIP versions; restrict presentation to one version per major version $\rightarrow$ 17 versions.

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- Compiling was no problem itself (use relatively old gcc 5.4.0).
- Minor changes were necessary for the older releases: libz interface, some parameters/error codes of CPLEX (fastmip, ranged rows).
- This is remarkable and one of the original reasons why SCIP was written in C and not C++!

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- Time limit: 1 hour.
- Intel Xeon CPU E5-1620 v4 @ 3.50GHz
- Use MIPLIB 2017 benchmark test set.

SCIP X/CPX12.10: Time for MIPLIB 2017

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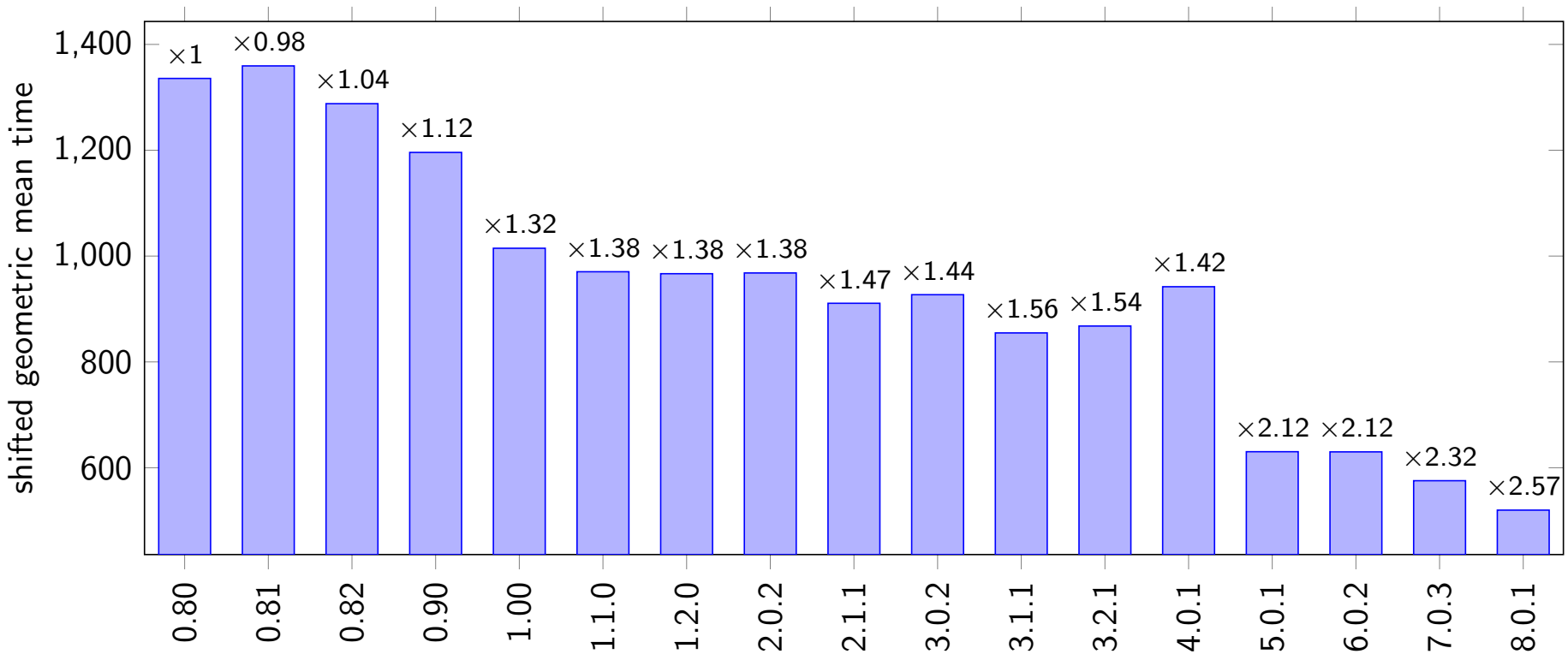

SCIP X/CPX12.10: # Solved Instances for MIPLIB 2017

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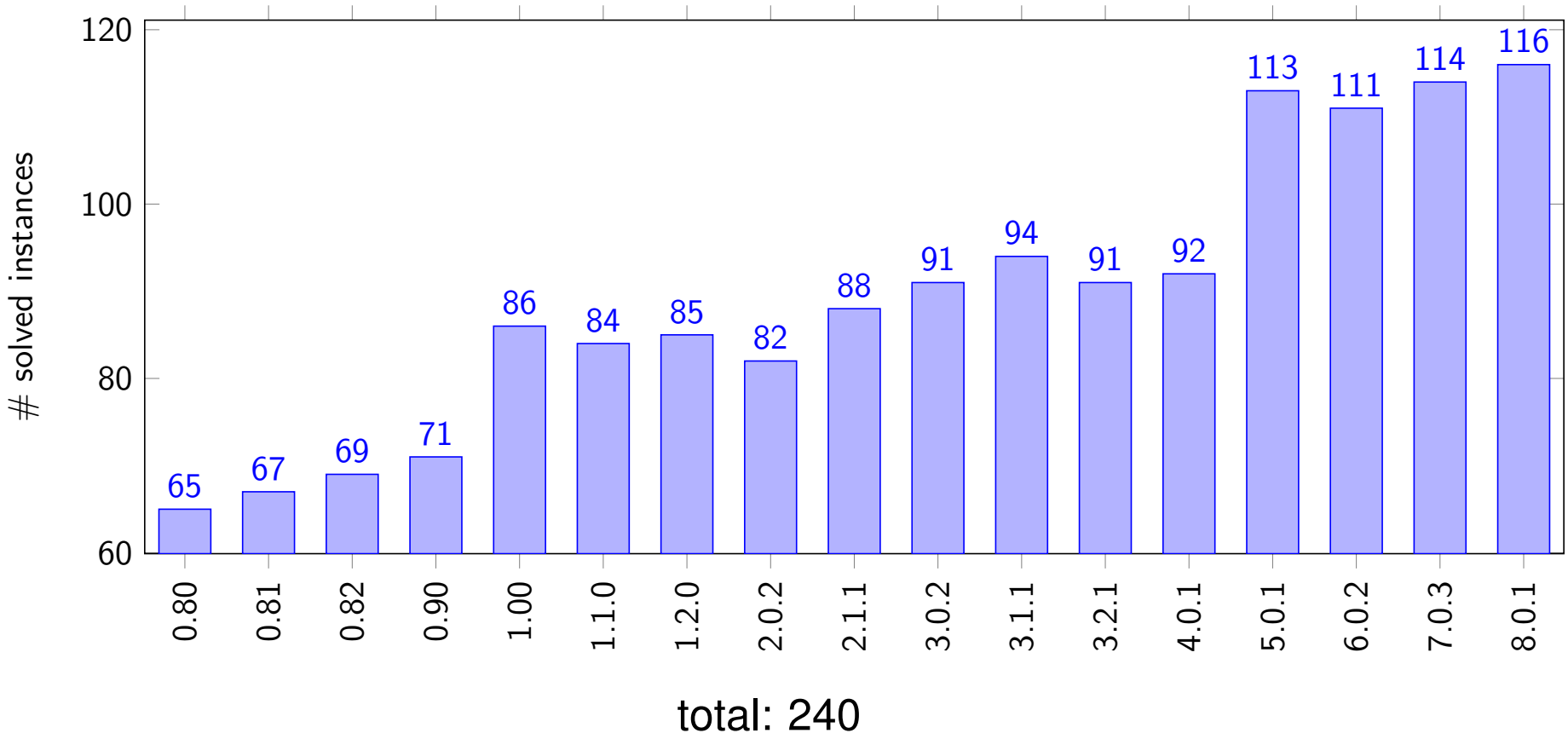

Experiments with SoPlex

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- Idea: Same setup, but see how SCIP with SoPlex has developed.
- Use SCIPOptSuite versions starting with version 1.00 (originally called ZIBOptSuite).
- Thus, the matching SoPlex versions are used.

SCIP X/SoPlex Y: Time for MIPLIB 2017

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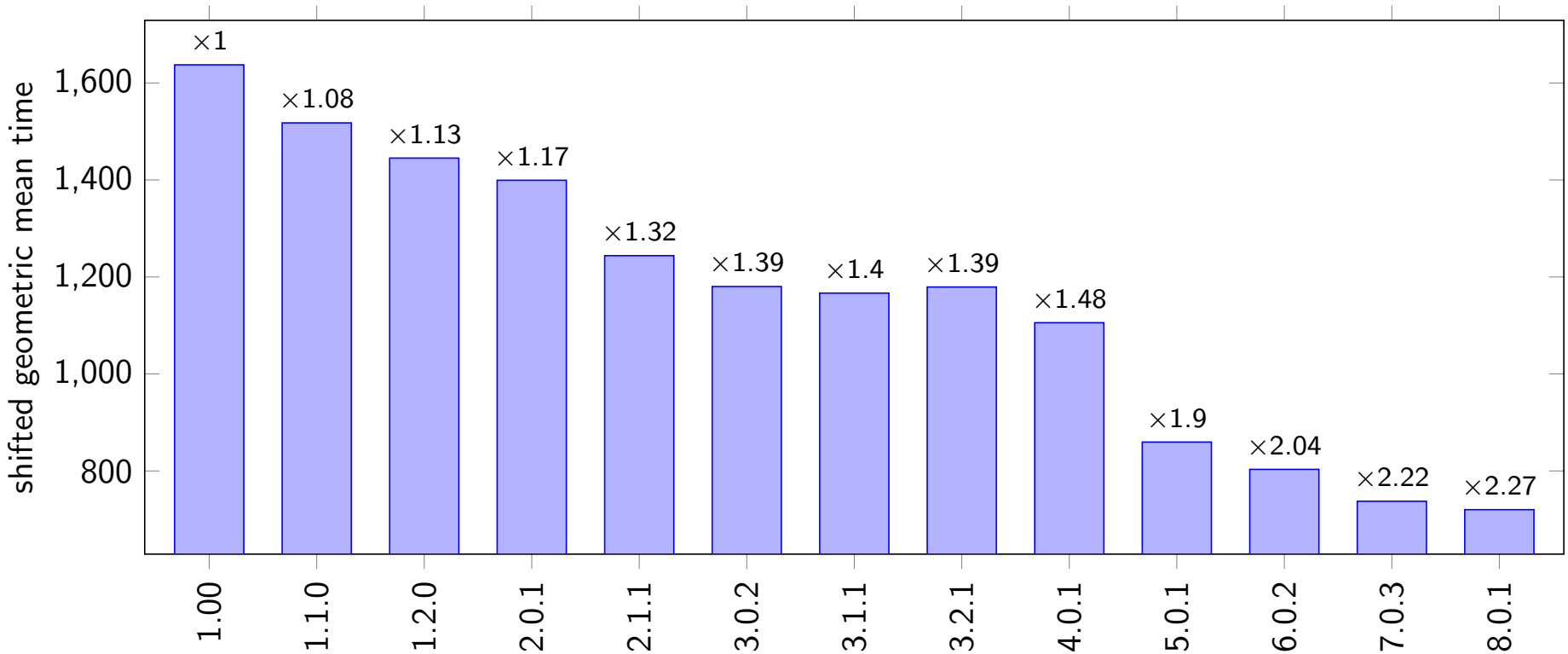

SCIP X/SoPlex Y: # Solved Instances Results for MIPLIB 2017

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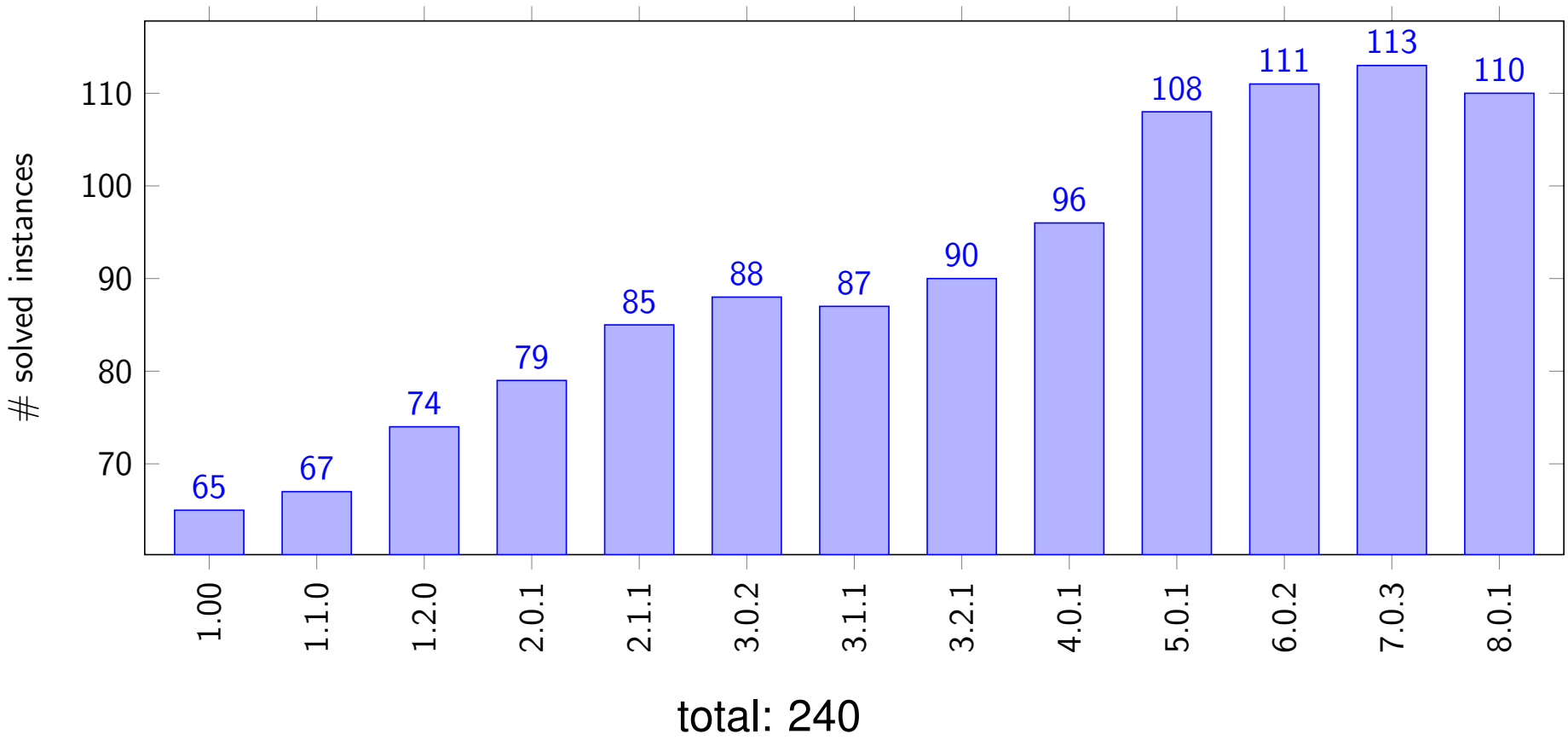

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Some Experiments for MINLP-Solving

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Test set:

- 183 “solvable” instances from MINLPLib (defined by Stefan Vigerske)

Settings:

- relative gap tolerance 10^{-4}
- feasibility tolerance 10^{-6}
- 1 hour time limit
- CPLEX (12.10.0.0) and IPOPT 3.12
- Intel Xeon CPU E5-1620 v4 @ 3.50GHz

SCIP X/CPX12.10: Time for MINLP

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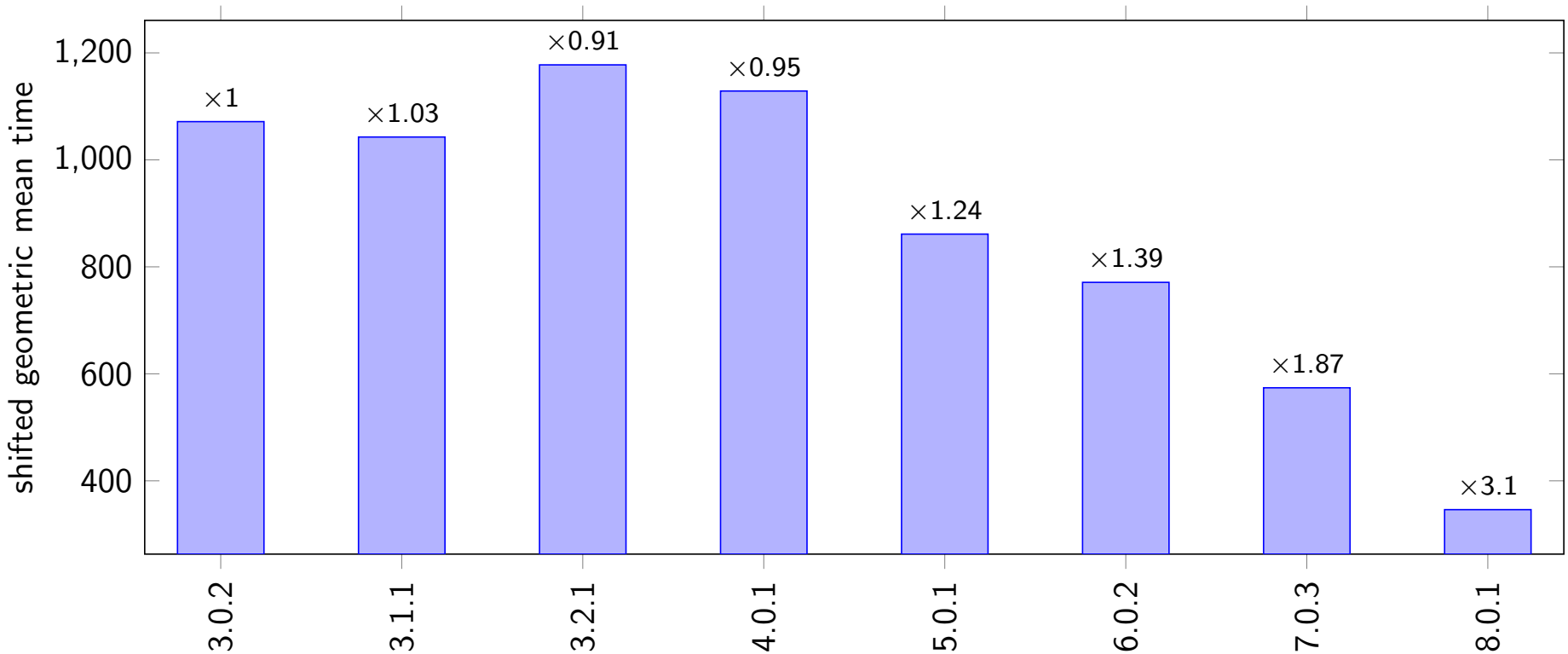

SCIP X/CPX12.10: # Solved Instances for MINLP

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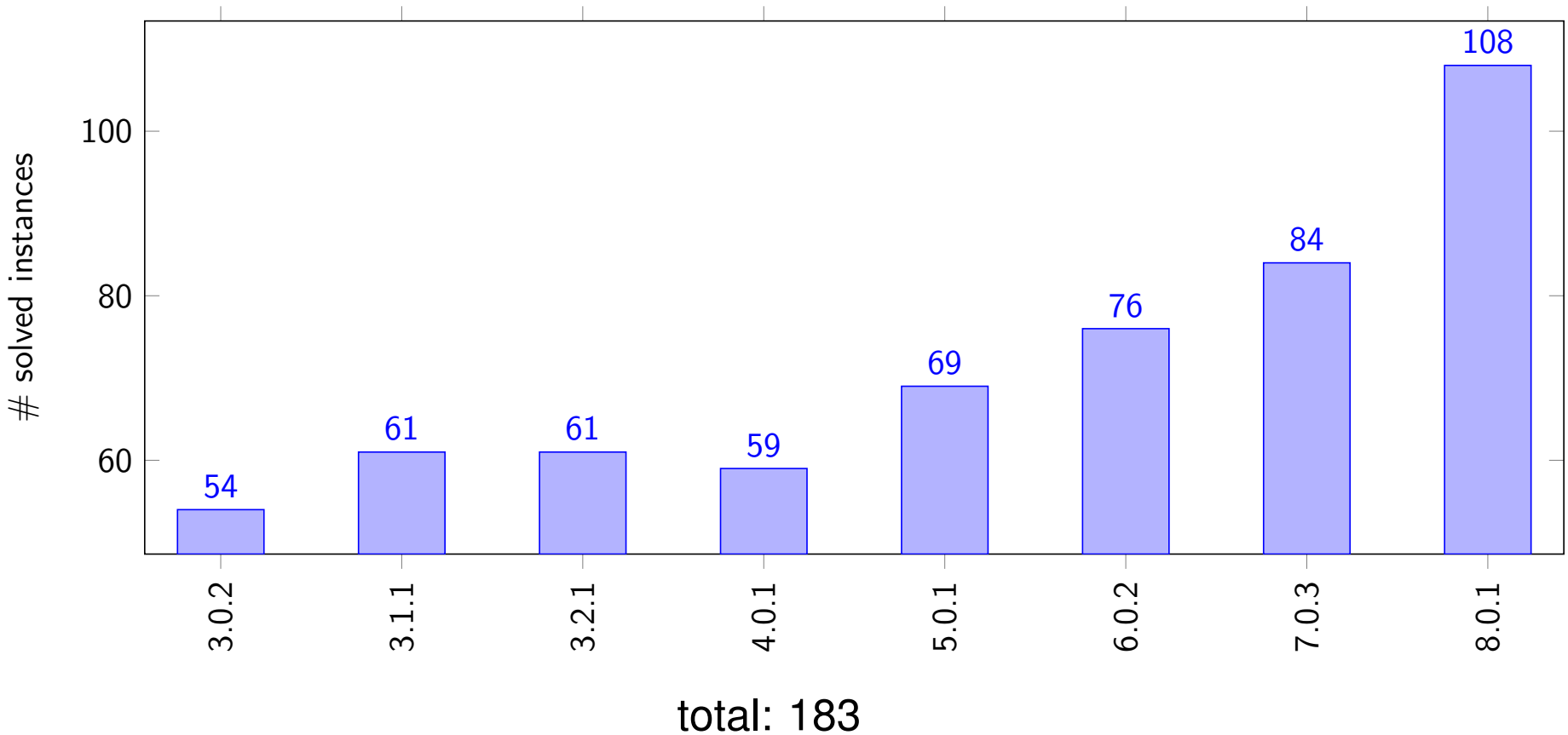

Comparison to Other MINLP-Solvers

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- Results from Stefan Vigerske.
- Same test set and settings as before.
- bound unbounded variables by 10^{12}
- 2 hours time limit
- 1 thread
- 50 GB RAM
- Intel Xeon CPU E5-2670 v2 @ 2.50GHz

MINLP Comparison

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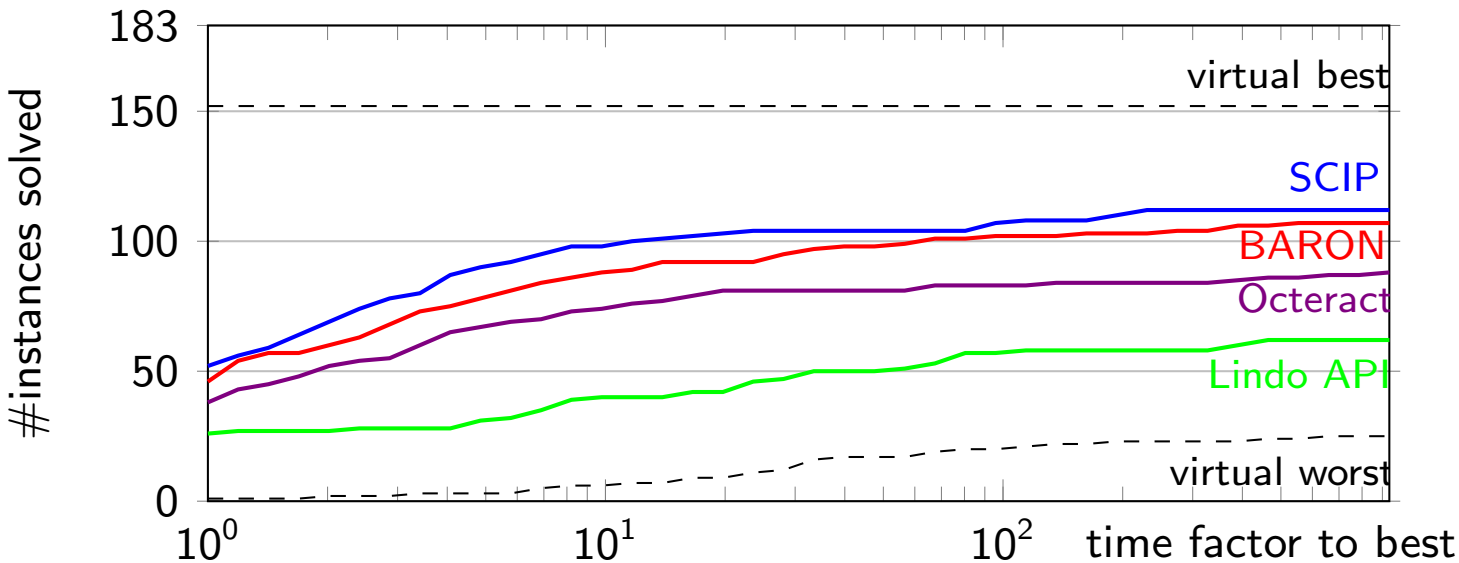
	solved	timeout	mean time*
BARON 22.9.1	107	72	616s
Lindo API 13.0.340	62	80	1116s
Octeract 4.4.1	88	85	849s
SCIP 8.0 (f0a1490e3b)	112	66	497s
virtual best	152	–	109s

* w.r.t. 135 instances on which no solver returned wrong results



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Future Plans

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- SCIP is still actively developed.
- This is mainly driven by dissertation theses.
- We plan to continue along this path . . .
- . . . However, acquiring funding for software development together with scientific research is hard. For instance, almost all EU projects are tied to an application. If you have ideas, please tell me . . .
- Contributors/ions are welcome!

SCIP vs. Other Solvers

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- Gap between SCIP as MIP-solver and commercial MIP-Solvers is increasing: Achterberg & Wunderling [2013] observed a speed-up of ≈ 90 of CPLEX between 1998 and 2012 (10000s time limit, 1753 instances).

SCIP vs. Other Solvers

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- Gap between SCIP as MIP-solver and commercial MIP-Solvers is increasing: Achterberg & Wunderling [2013] observed a speed-up of ≈ 90 of CPLEX between 1998 and 2012 (10000s time limit, 1753 instances).
- License fees of commercial solvers are increasing.
- Some academic alternatives exist (CBC, HiGHS) – maybe more to come.
- Commercial solvers are increasingly covering nonlinear aspects.
- So far, SCIP is one of the best general MINLP solvers available.

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- License fees of commercial solvers are increasing.
- Some academic alternatives exist (CBC, HiGHS) – maybe more to come.
- Commercial solvers are increasingly covering nonlinear aspects.
- So far, SCIP is one of the best general MINLP solvers available.
- The SCIP project has “produced” many developers of commercial solvers (across the board). [I know at least 6.]
- Will academic licenses of commercial solvers still be available in the future? Probably yes, because it is a very good advertisement and recruitment possibility. But who knows?
- Thus, keeping a good relation seems to be a good idea.
- But to keep research alive in this area is a much more complicated task.

Future Needs

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Does the world need an academic solver like SCIP?

Future Needs

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Does the world need an academic solver like SCIP?

Maybe no:

- Researchers are increasingly using Gurobi (no other solver) for experiments.
- The gap is increasing (see last slide).
- One reason: careful engineering, which is hard to do in a research project (e.g., tuning parallelization).

Future Needs

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Does the world need an academic solver like SCIP?

Maybe no:

- Researchers are increasingly using Gurobi (no other solver) for experiments.
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- One reason: careful engineering, which is hard to do in a research project (e.g., tuning parallelization).

Well, yes:

- We need a framework, e.g., for branch-and-cut-and-price.
- It is essential to have the source code for developing MIP- or MINLP- solvers.
- It is scientificly sound to at least be able to understand what an underlying solver is doing instead of treating it as a black-box.

Outlook

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- SCIP is an excellent and very powerful tool for research as well for applications.
- It should be developed and improved further!
- At least I will use it as the basis of projects.
- New contributions are always welcome!

Outlook

TECHNISCHE UNIVERSITÄT DARMSTADT

- SCIP is an excellent and very powerful tool for research as well for applications.
- It should be developed and improved further!
- At least I will use it as the basis of projects.
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Happy birthday to you SCIP

and live long and prosper!