The right choice matters!

SMT solving substantially improves model-based debugging of spreadsheets.

Simon Außerlechner, Sandra Fruhmann,
Wolfgang Wieser, Birgit Hofer, Raphael Spörk,
Clemens Mühlbacher, and Franz Wotawa

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Fault Localization in Spreadsheets

- What is Spreadsheet fault localization?
- Why important?
  - Spreadsheet users outnumber programmers
  - Basis for decisions, but error prone
  - Hard to debug spreadsheets
- Attempts to use model-based debugging
  Limitations
  → No support for real numbers
  → Solving time

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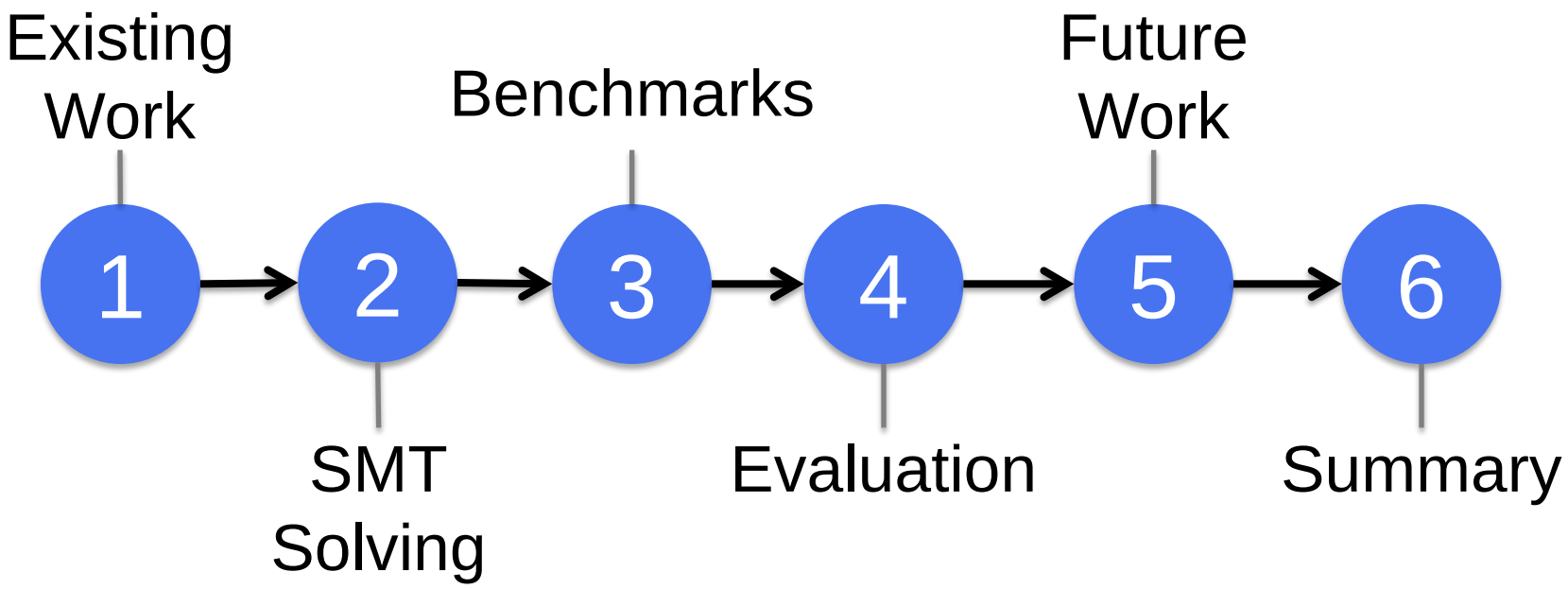
Outline



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Existing work

- Abreu et al.:“Constraint-based Debugging of Spreadsheets” [ARW12]
  Minion constraint solver
- Jannach and Engler: “Toward model-based debugging of spreadsheet programs” [JE10]
  Choco constraint solver

Limitations
No Support for Real Numbers
Solving Time

[ARW12] Rui Abreu, André Riboira, and Franz Wotawa. “Constraint-based Debugging of Spreadsheets.” 15th Iberoamerican Conference on Software Engineering, 2012, pp. 1–14.

[JE10] Dietmar Jannach and Ulrich Engler. “Toward model-based debugging of spreadsheet programs.” 9th Joint Conference on Knowledge-Based Software Engineering 2010, pp. 252–264.

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Running Example

Faulty Spreadsheet

	A	B	C	D	E	F
1		**week 1**	**week 2**	**Total**	**$/h**	**Gross Pay**
2	Green	23	31	23	15	$345,00
3	Jones	35	34	69	17	$1.173,00
4	**Total**	58	65	92		

Formula View

	A	B	C	D	E	F
1		**week 1**	**week 2**	**Total**	**$/h**	**Gross Pay**
2	Green	23	31	=SUM(B2)	15	=D2*E2
3	Jones	35	34	=SUM(B3:C3)	17	=D3*E3
4	**Total**	=SUM(B2:B3)	=SUM(C2:C3)	=SUM(D2:D3)		

Source: EUSES Spreadsheet Corpus

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Test Cases for Spreadsheets

- **Input cells:** cells that do not reference other cells

  I = {B2=23, C2=31, E2=15, B3=35, C3=34, E3=17}

- **Output cells:** any formula cell, determined by user

  O = {B4=58, C4=65, D4=123, F2=810, F3=1173}

	A	B	C	D	E	F
1		**week 1**	**week 2**	**Total**	**$/h**	**Gross Pay**
2	Green	23	31	23	15	$345,00
3	Jones	35	34	69	17	$1.173,00
4	**Total**	58	65	92		

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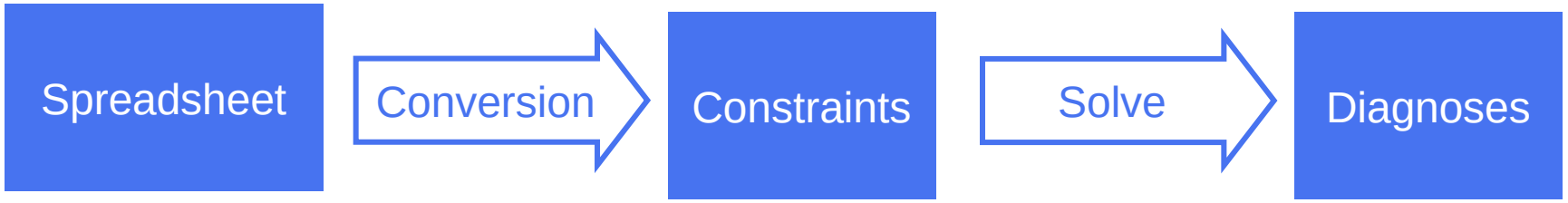
Constraint-based Debugging (ConBug)



	D
1	**Total**
2	=SUM(B2)
3	=SUM(B3:C3)
4	=SUM(D2:D3)

AB(f_D2) ∨ (D2 == B2)
AB(f_D3) ∨ (D3 == B3+C3)
AB(f_D4) ∨ (D4 == D2+D3)
…

Test case:
D4 == 123
…

For single faults:
SUM(f_D2, f_D3, f_D4)==1

For complete example:

{D2}, {D4,F2}, …

[ARW12] Rui Abreu, André Riboira, and Franz Wotawa. “Constraint-based Debugging of Spreadsheets.” 15th Iberoamerican Conference on Software Engineering, 2012, pp. 1–14.

Satisfiability modulo theories (SMT) solver

- Based on Boolean satisfiability
- Enhanced by different theories (e.g. Integer, Real)
- Solves decision problem
  - Determine diagnoses via MCSes and MCSes-U algorithms [LS08, LS09]
- Z3 solver
  - Speedup in computation time
  - Handling of real numbers

[LS08] M. H. Liffiton and K. A. Sakallah. “Algorithms for computing minimal unsatisfiable subsets of constraints,” J. Autom. Reason., vol. 40, no. 1, pp. 1–33, Jan. 2008.

[LS09] M. H. Liffiton and K. A. Sakallah.“Generalizing core-guided max-sat,” 12th Int. Conference on Theory and Applications of Satisfiability Testing (SAT ’09). Springer-Verlag, 2009, pp. 481–494.

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Spreadsheet Corpora (1)

- Limitations of EUSES spreadsheet corpus [FR05]
  - Many small spreadsheets
  - Missing input values
  - Obsolete file formats
  - No faulty versions

[FR05] Marc II Fisher and Gregg Rothermel. “The EUSES Spreadsheet Corpus: A Shared Resource for Supporting Experimentation with Spreadsheet Dependability Mechanisms.” 1st Workshop on End-User Software Engineering. 2005, pp. 47–51.

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Spreadsheet Corpora (2)

	Mod. EUSES corpus	Integer corpus
Source	Filtering from EUSES	Artificially created + existing spreadsheets
Domain	Reals	Integer
Mutants	622 mutants	220 mutants
	created with spreadsheet mutation operators [AE09]	
Complexity	6 to 4,000 formulas AVG: 225 formulas	7 to 233 formulas AVG: 39 formulas

Original spreadsheets + mutants publicly available

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Empirical Evaluation

- Runtime comparison
  - Minion vs. Choco vs. Z3 (MCSes and MCSes-U)
    Integer corpus
  - Integers vs. Real numbers
    Integer corpus + Real number version
- Reduction quality
  - Modified EUSES corpus

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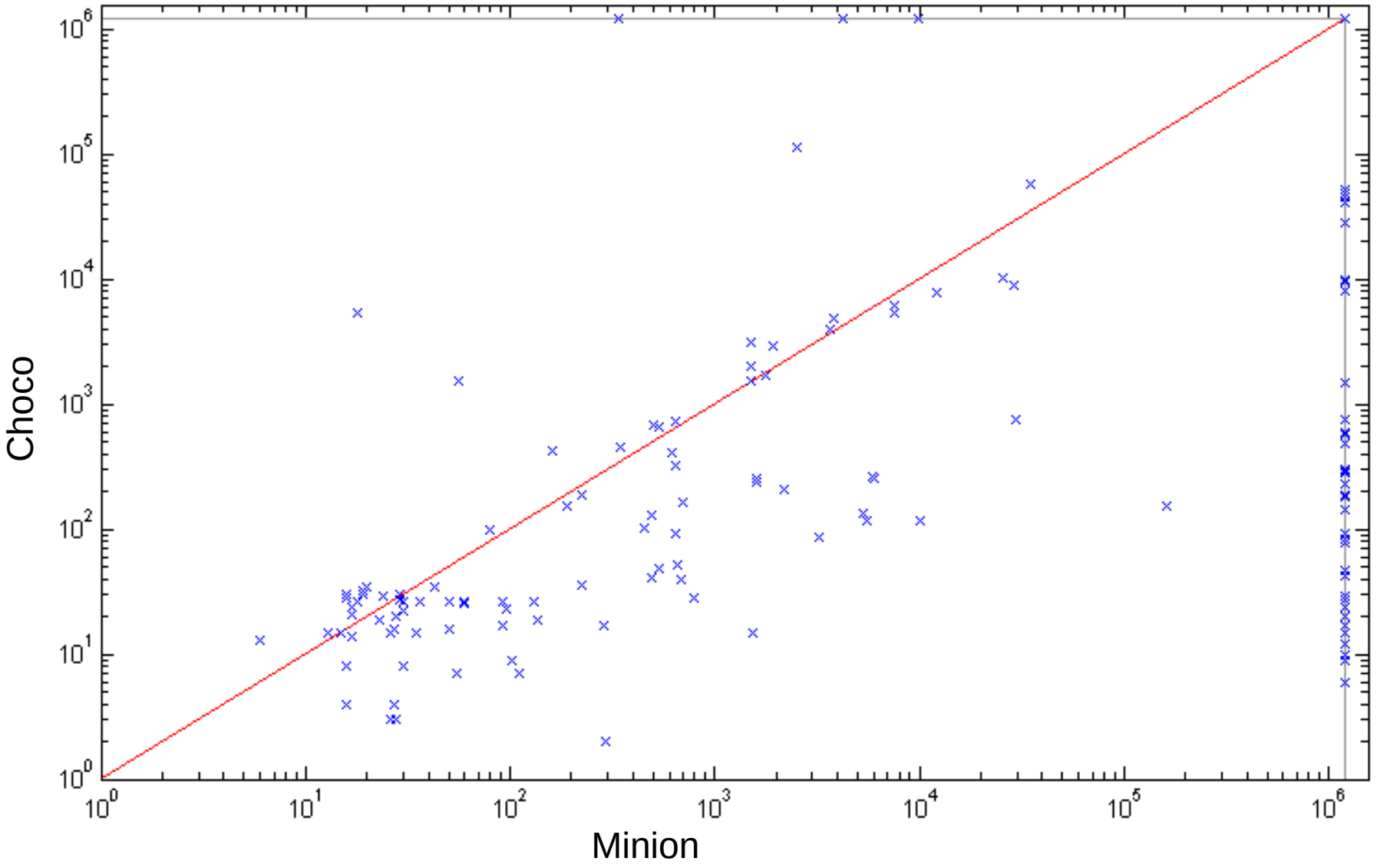
Runtime comparison [in ms]: Choco vs. Minion



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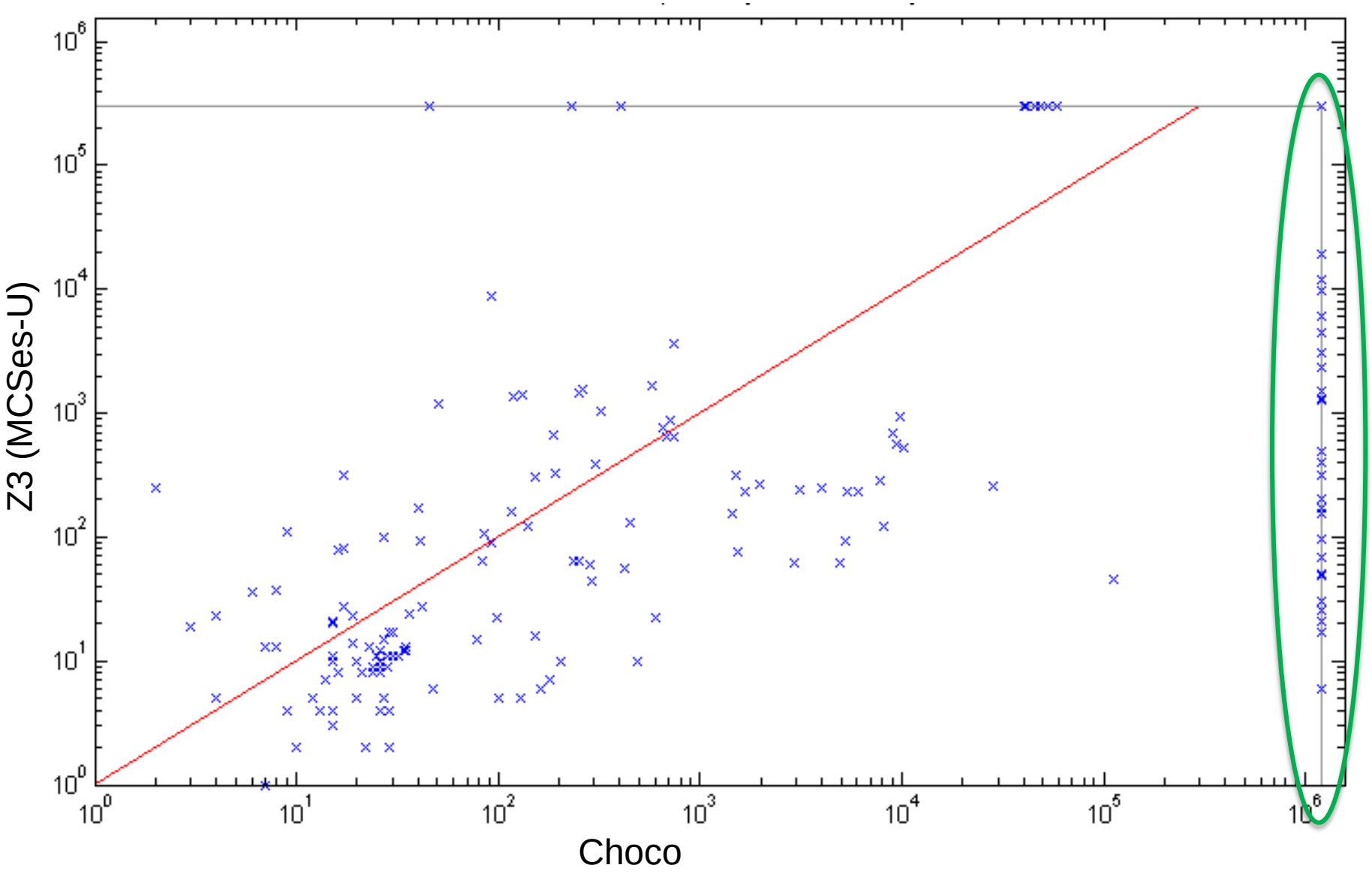
Runtime comparison [in ms]: Z3 vs. Choco



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Detailed runtime comparison

- Choco slightly faster than Minion
- Z3 faster than Minion and Choco
  - Approx. 6 times faster for Integer corpus
- Integer vs. Real domain
  - Integer spreadsheets approx. 2.6 times faster than Reals

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Reduction quality

- $\text{Reduction} = 1 - \frac{\text{Cells in diagnoses}}{\text{Formula cells}} \times 100\%$
- Evaluation basis
  - Subset of mod. EUSES corpus
  - 183 of 622 spreadsheets
- Results
  - 12 spreadsheets: timeout 5 minutes
  - ~ 80 % reduction
  - ~ 500 ms avg. solving time (Z3)

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Future Work and Open Challenges

- Scalability problem (Hypertree complexity)
- User interface and user acceptance study
- Explanations for the user (traceability)
- Dealing with vague user input

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Using Z3 as solver …

… makes it possible to use model-based debugging for spreadsheets

- In practice (Real numbers) and
- For interactive debugging (Solving time)

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