Why does my spreadsheet compute wrong values?

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Why spreadsheets?

- Used in nearly every company
- Basis for decisions
- Error prone
  - 3-5 % chance to make a fault in a formula
  - 88 % of spreadsheets contain faults
- Hard to debug
  - Size of spreadsheets
  - Structure hidden

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Outline

1. Related work
2. Running Example
3. Models
   a. value-based
   b. dependency-based
   c. improved dependency-based
4. Evaluation
5. Conclusion

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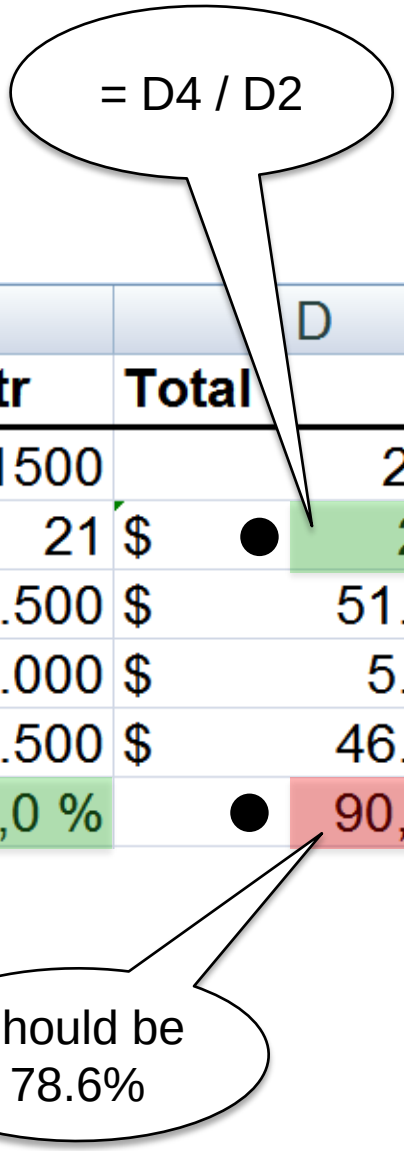
Spreadsheet Fault Localization

- Spectrum-based Fault Localization
- Model-based Software Debugging
  - o Abreu et al. [AHP14]
  - o Jannach and Schmitz [JS14]
- Localization by repair

[AHP14] R. Abreu, B. Hofer, A. Perez, and F. Wotawa: “Using constraints to diagnose faulty spreadsheets.” *Software Quality Journal, pp. 1–26,* 2014.

[JS14] Dietmar Jannach and Thomas Schmitz, “Model-based diagnosis of spreadsheet programs - A constraint-based debugging approach,” *Automated Software Engineering, Springer, pp. 1-40, 2014.*

Running Example



	A	B	C	D
1	**Item**	**1st Qtr**	**2nd Qtr**	**Total**
2	**Units Sold**	1000	1500	2500
3	**ASP/Unit**	$ 20	$ 21	$ 20,6
4	**Sales Revenue**	$ 20.000	$ 31.500	$ 51.500
5	**Expenses**	$ 5.000	$ 6.000	$ 5.000
6	**Operating Income**	$ 15.000	$ 25.500	$ 46.500
7	**Op Income in %**	75,0 %	81,0 %	90,3 %

This is a simplified version of the homework/Budgetone spreadsheet from the EUSES Spreadsheet Corpus

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Running Example – Formula View

	A	B	C	D
1	**Item**	**1st Qtr**	**2nd Qtr**	**Total**
2	**Units Sold**	1000	1500	=SUM(B2:C2)
3	**ASP/Unit**	20	21	=D4/D2
4	**Sales Revenue**	=B3*B2	=C3*C2	=SUM(B4:C4)
5	**Expenses**	5000	6000	=SUM(B5:B5)
6	**Operating Income**	=B4-B5	=C4-C5	=D4-D5
7	**Op Income in %**	=B6/B4	=C6/C4	=D6/D4

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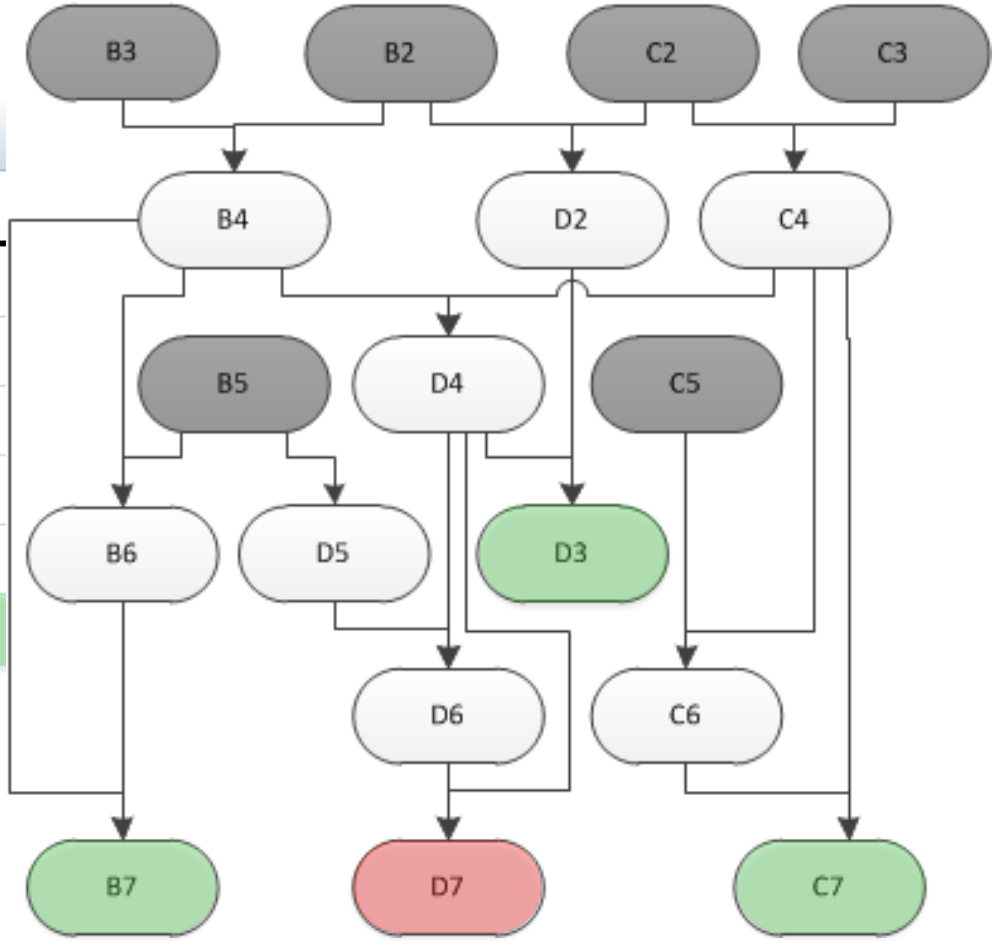
Running Example – Dependency Graph

	A	B
1	**Item**	**1st Qtr**
2	**Units Sold**	1000
3	**ASP/Unit**	20
4	**Sales Revenue**	=B3*B2
5	**Expenses**	5000
6	**Operating Income**	=B4-B5
7	**Op Income in %**	=B6/B4



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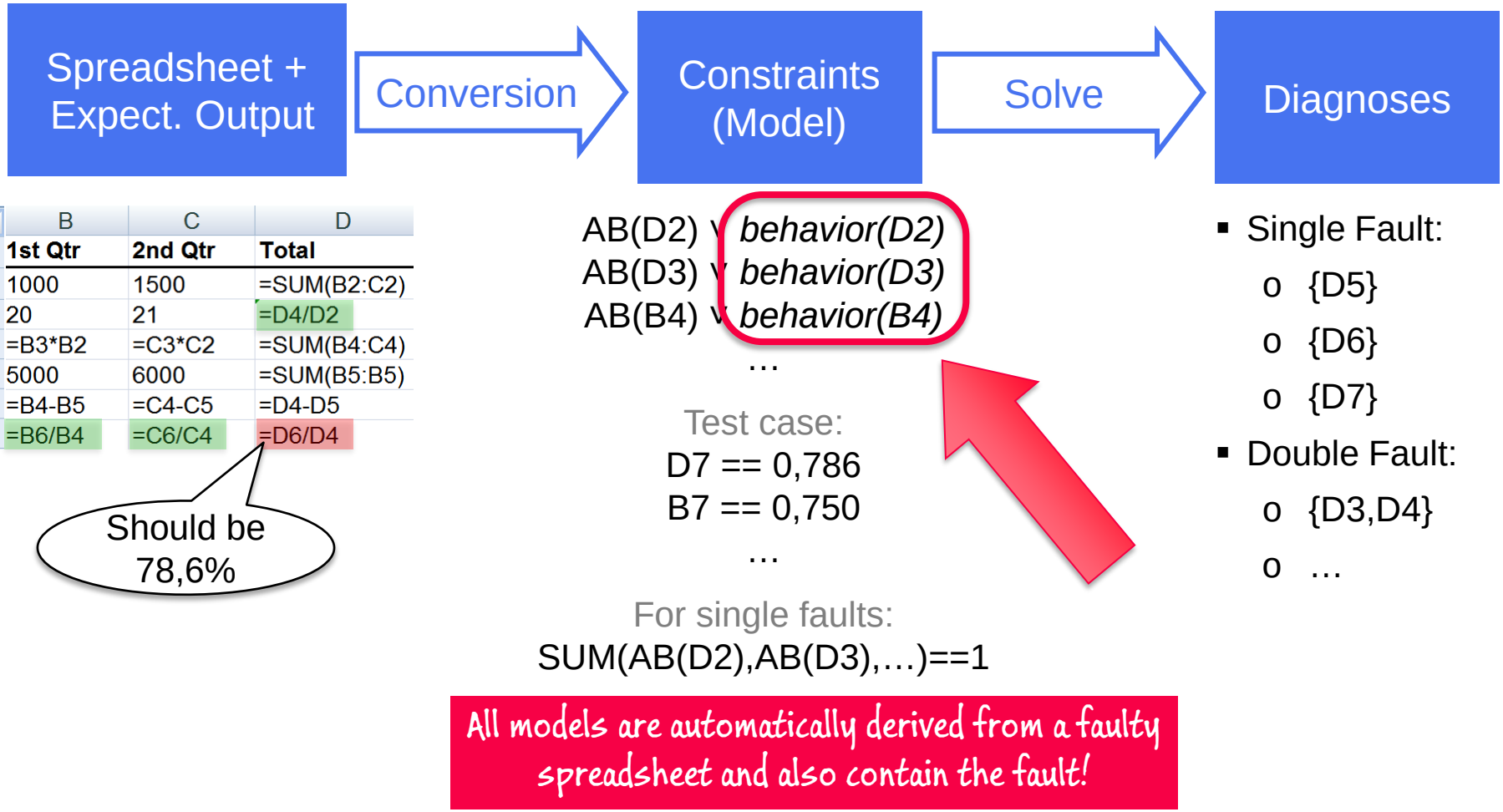
Model-Based (Software) Debugging



[AHP14] Abreu, Hofer, Perez, Wotawa: "Using constraints to diagnose faulty spreadsheets." *Software Quality Journal, pp. 1–26,* 2014.

Models for a Spreadsheet's Behavior

Value-based

- D2 = B2 + C2
- D3 = D4 / D2
- B4 = B3 * B2

Dependency-based

- ok(B2) ∧ ok(C2) → ok(D2)
- ok(D4) ∧ ok(D2) → ok(D3)
- ok(B3) ∧ ok(B2) → ok(B4)

	A	B	C	D
1	**Item**	**1st Qtr**	**2nd Qtr**	**Total**
2	**Units Sold**	1000	1500	=SUM(B2:C2)
3	**ASP/Unit**	20	21	=D4/D2
4	**Sales Revenue**	=B3*B2	=C3*C2	=SUM(B4:C4)
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6	**Operating Income**	=B4-B5	=C4-C5	=D4-D5
7	**Op Income in %**	=B6/B4	=C6/C4	=D6/D4

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Models for a Spreadsheet's Behavior

Value-based

- D2 == B2 + C2
- D3 == D4 / D2
- B4 == B3 * B2

\+ exact, few diagnoses

– computation time

– Reals: lacking support

Dependency-based

- ok(B2) $\wedge$ ok(C2) → ok(D2)
- ok(D4) $\wedge$ ok(D2) → ok(D3)
- ok(B3) $\wedge$ ok(B2) → ok(B4)

\+ fast

\+ only Boolean

– many diagnoses

Focus of this work

[AFW13] S. Ausserlechner et al.: "The Right Choice Matters! SMT Solving Substantially Improves Model-Based Debugging of Spreadsheets." QSIC 2013: 139-148

Improving the Dependency-based Model

- Use ↔ instead of →
  - ok(B2) ∧ ok(C2) ↔ ok(D2)
  - ok(D4) ∧ ok(D2) ↔ ok(D3)
  - ok(B3) ∧ ok(B2) ↔ ok(B4)

	A	B	C	D
1	**Item**	**1st Qtr**	**2nd Qtr**	**Total**
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- Coincidental correctness
  - Conditional like IF-function
  - Abstraction function like MIN, MAX, COUNT
  - Boolean
  - Multiplication by zero
  - Power with 0 or 1 as base number or 0 as exponent

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Empirical Evaluation

- Java implementation using
  - Apache POI
  - Minion Constraint solver
- Spreadsheets from Integer corpus
  - Single fault only

94 spreadsheets

63 spreadsheets **31 spreadsheets**

→ Timeout (20 minutes) for 31 spreadsheets for Value-based model

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Empirical Evaluation

Model	63 spreadsheets	31 spreadsheets
Number of single fault diagnoses		
Value-based	4.0	-
Dependency-based	13.2	45.0
Improved Dep.-based	11.0 **(-16.6%)**	38.6 **(-14.2%)**
Runtime in ms		
Value-based	56,818.8	> 20 minutes
Dependency-based	32.0	187.4
Improved Dep.-based	31.6	164.8

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Implications

– Still **more diagnoses** than value-based model

\+ **Real time** applicable

\+ **Arbitrary solver** (only Boolean needed)

\+ Debugging of spreadsheets containing **Real numbers**

\+ **Correct/wrong** instead of concrete values for cells

\+ Approach can be used in **other domains** as well

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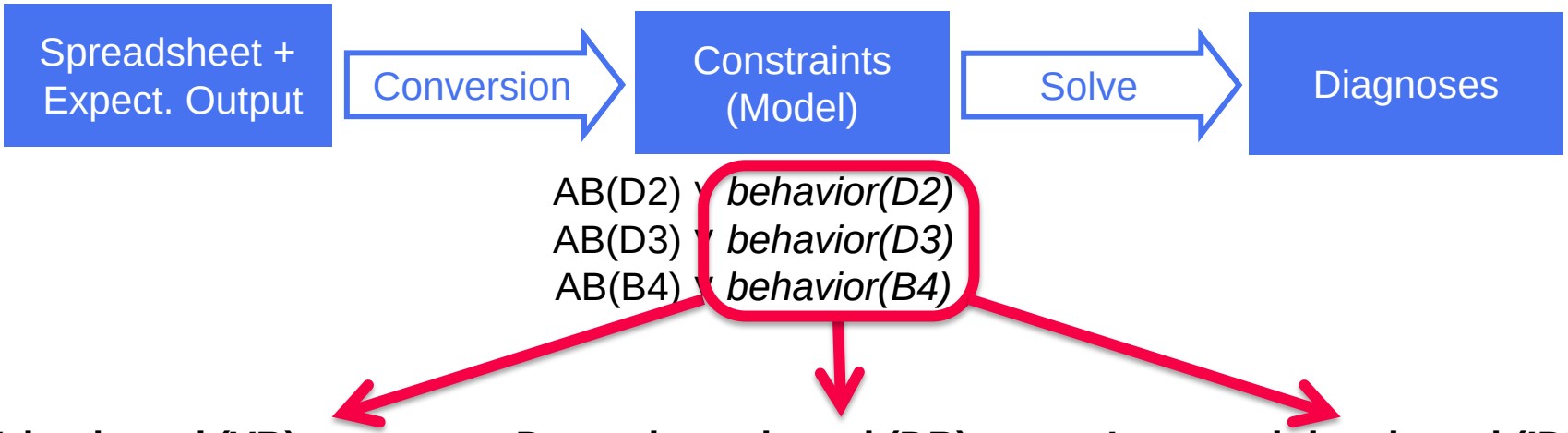
Summary



Value-based (VB)

D2 = B2 + C2

\+ less diagnoses

− high computation time
1/3: 20 min timeout
2/3: 1 minute

Dependency-based (DB)

ok(B2) ∧ ok(C2) → ok(D2)

− many diagnoses
3.3 times more than VB

\+ low computation time
less than 1 second

Improved dep.-based (IDB)

ok(B2) ∧ ok(C2) ↔ ok(D2)

~ reduced number of diagnoses
15% less diagnoses than DB

\+ low computation time
less than 1 second

Thank you! Questions?

Coincidental correctness
- Conditional like IF-function
- Abstraction functions
- Boolean
- Multiplication and Power

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