S C I E N C E ▪ P A S S I O N ▪ T E C H N O L O G Y

Removing Coincidental Correctness in Spectrum-Based Fault Localization for Circuit and Spreadsheet Debugging

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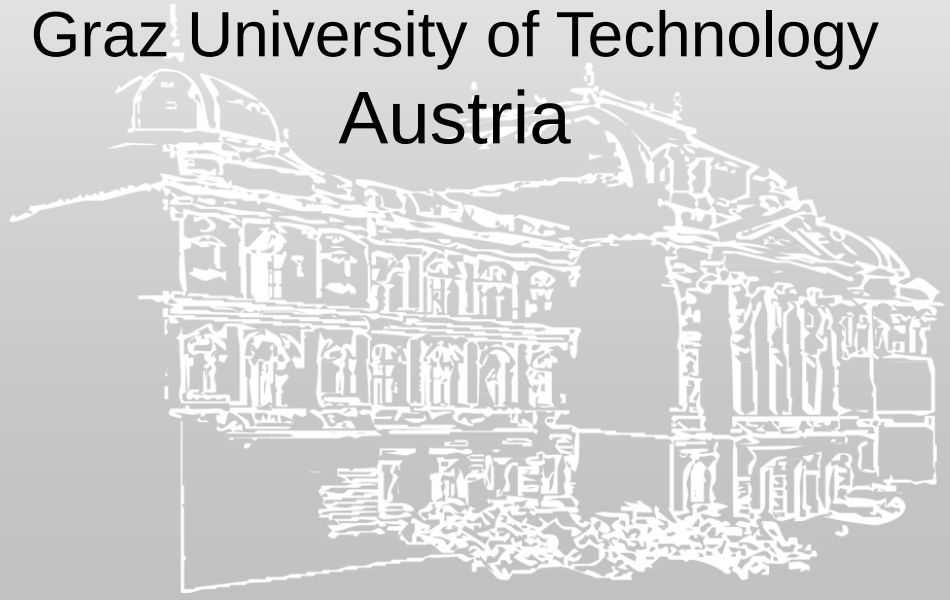

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Running example

	A	B	C	D	E	F
1	**Worker**	**Week 1**	**Week 2**	**Total**	**Bonus**	**Bonus**
2	**Smith**	45	40	85	100 €	YES
3	**Jones**	45	45	90	200 €	YES
4				**175**	**300 €**	
5						
6	**Weekly Bonus**	**100 €**				

	A	B	C	D	E	F
1	**Worker**	**Week 1**	**Week 2**	**Total**	**Bonus**	**Bonus**
2	**Smith**	45	40	=SUM(B2:C2)	=COUNTIF(B2:C2;">40")*B6	=IF(E2>0;"YES";"NO")
3	**Jones**	45	45	=SUM(B3:C3)	=COUNTIF(B3:C3;">40")*B6	=IF(E3>0;"YES";"NO")
4				**=SUM(D2:D3)**	**=SUM(E2:E3)**	
5						
6	**Weekly Bonus**	**100**				

$$\text{CONE}(c) = c \cup \bigcup_{c' \in \rho(c)} \text{CONE}(c')$$

CONE(E4) = {E4, E2, E3, B6, B2, C2, B3, C3}

CONE(D4) = {D4, D2, D3, B2, C2, B3, C3}

Observation Matrix

CONE(E4) = {E4, E2, E3, B6, B2, C2, B3, C3,}

CONE(D4) = {D4, D2, D3, B2, C2, B3, C3}

Cell	E4	D4	SC	Rank
B2	●	●	0.7	5
B3	●	●	0.7	5
B6	●		1.0	1
C2	●	●	0.7	5
C3	●	●	0.7	5
D2		●	-	-
D3		●	-	-
D4		●	-	-
E2	●		1.0	1
E3	●		1.0	1
E4	●		1.0	1
Test verdict	**false**	**true**		

Running example

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$$\text{CONE}(c) = c \cup \bigcup_{c' \in \rho(c)} \text{CONE}(c')$$

CONE(E4) = {E4, E2, E3, B6, B2, C2, B3, C3}

CONE(D4) = {D4, D2, D3, B2, C2, B3, C3}

CONE(F2) = {F2, E2, B2, C2, B6}

Observation Matrix

CONE(E4) = {E4, E2, E3, B6, B2, C2, B3, C3,}

CONE(D4) = {D4, D2, D3, B2, C2, B3, C3} CONE(F2) = {F2, E2, B2, C2, B6}

Cell	E4	D4	F2	SC	Rank
B2	●	●	●	0.6	7
B3	●	●		0.7	4
B6	●		●	1.0	1
C2	●	●	●	0.6	7
C3	●	●		0.7	4
D2		●		-	-
D3		●		-	-
D4		●		-	-
E2	●		●	0.7	4
E3	●			1.0	1
E4	●			1.0	1
Test verdict	**false**	**true**	**true**		

Running example

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6	**Weekly Bonus**	**100**				

$$\text{CONE}(c) = c \cup \bigcup_{c' \in \rho(c)} \text{CONE}(c')$$

CONE(E4) = {E4, E2, E3, B6, B2, C2, B3, C3}

CONE(D4) = {D4, D2, D3, B2, C2, B3, C3}

CONE(F2) = {F2, E2, B2, C2, B6}

Evaluation Basis

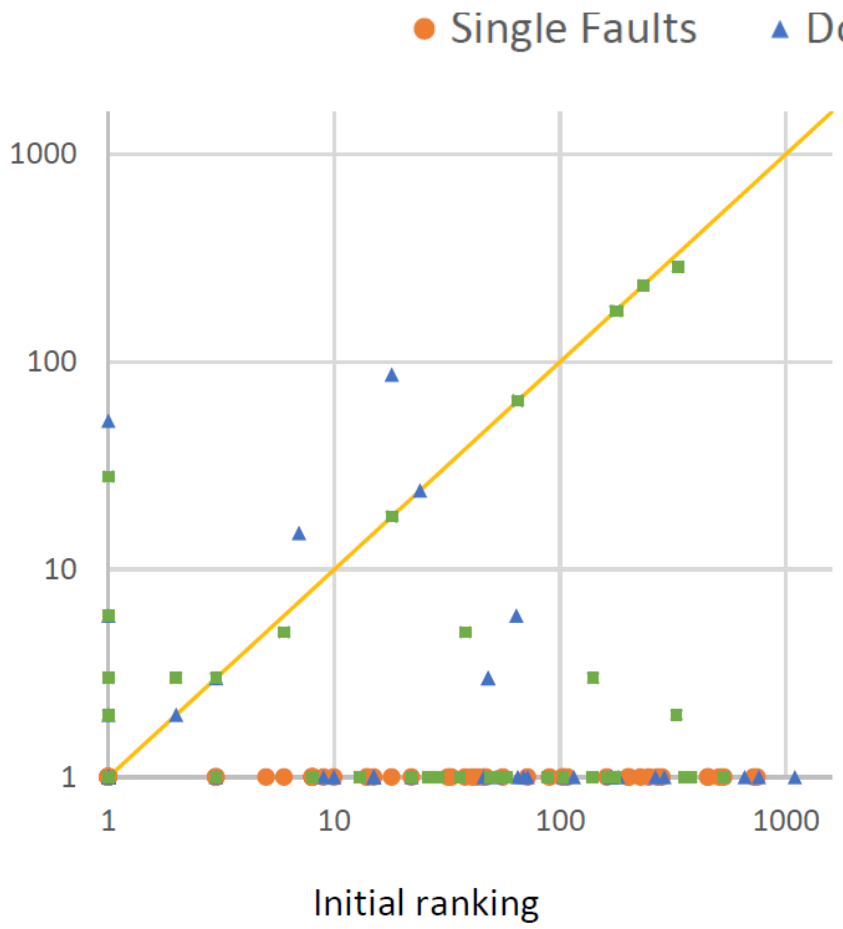
- ISCAS85 circuits
  - 300 faulty circuits
  - Single, double, and triple faults
- EUSES
  - Large, diverse, well-known
  - 184 base spreadsheets
  - 793 faulty versions
    - 576 single-fault
    - 122 double-fault
    - 95 triple-fault

RQ1: How many outcomes in circuits and spreadsheets are actually coincidentally correct?

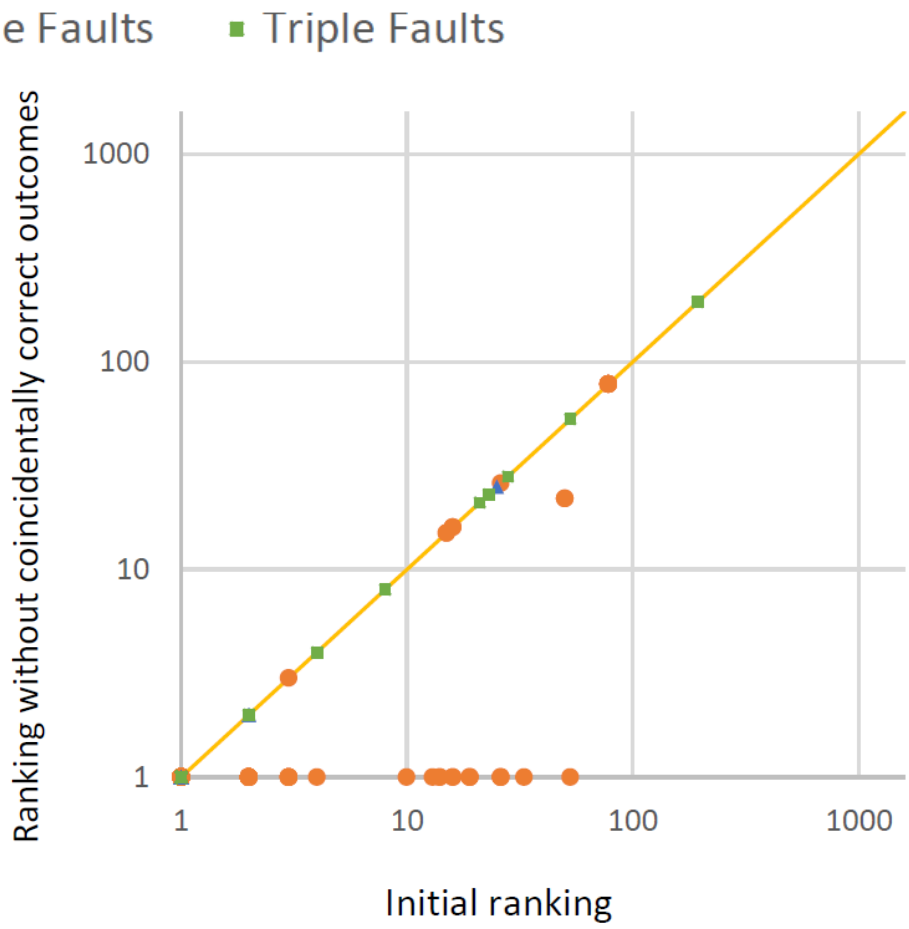
Domain	Total Correct Output	Coincidental Correct Output	Coincidental in % of Total
Circuits	13 217	2 286	17.3 %
Spreadsheets	53 016	605	1.1 %

RQ2: How strong is the impact of the coincidentally correct outcomes on the results of SBFL?

Circuits – Best case

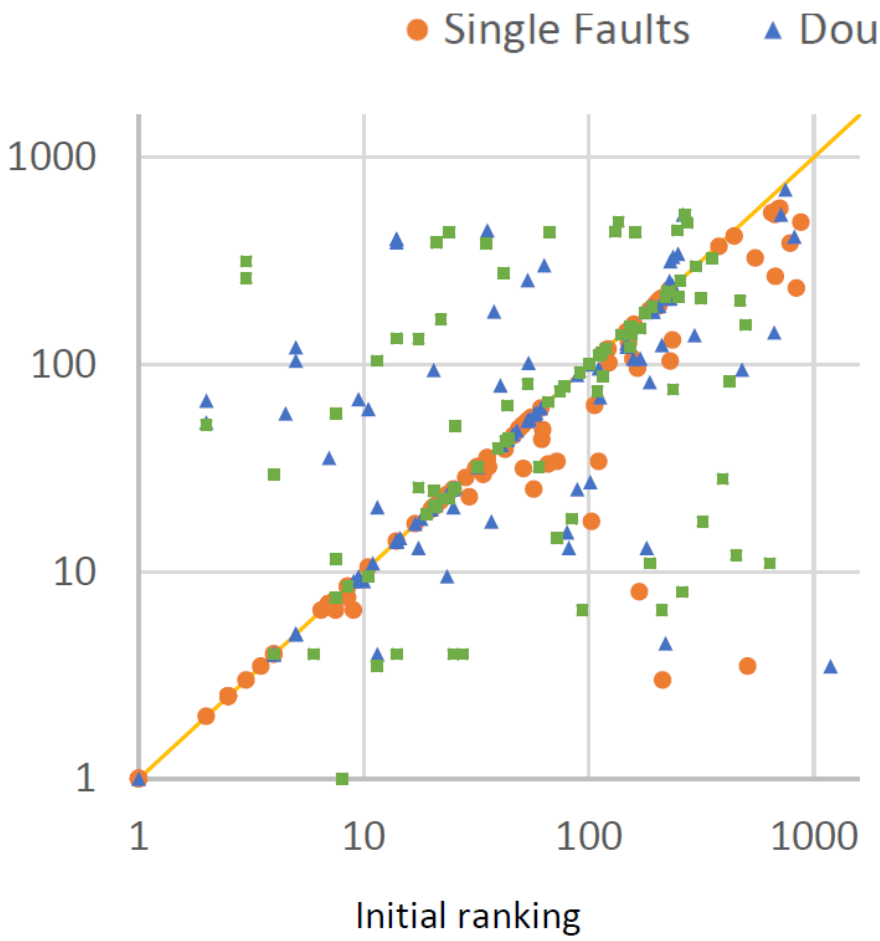


Spreadsheets – Best case

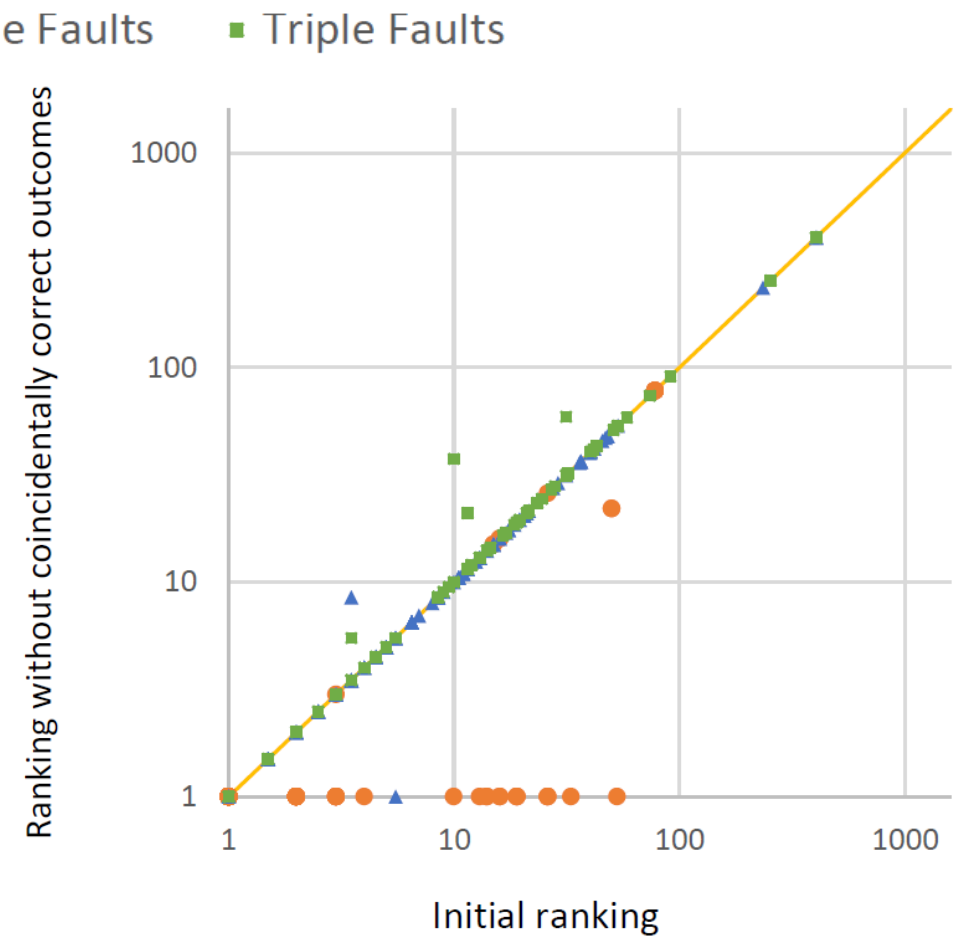


RQ2: How strong is the impact of the coincidentally correct outcomes on the results of SBFL?

Circuits – Avg. case



Spreadsheets – Avg. case



Can we determine
coincidentally correct output
a-priori
for circuits and spreadsheets?

Fault Masking in Circuits
(Single Fault Assumption)

in1	in2	AND	NAND	Masking
T	T	T	F	-
T	F	F	T	in1
F	T	F	T	in2
F	F	F	T	in1 or in2

in1	in2	OR	NOR	Masking
T	T	T	F	in1 or in2
T	F	T	F	in2
F	T	T	F	in1
F	F	F	T	-

Fault Masking in Spreadsheets
(Single Fault Assumption)

Operations	Masking
Addition and Subtraction	-
Multiplication and Division	When one of factors is 0
Power	When exponent is 0 or base is 0 or 1
Functions	• Conditional functions • Abstraction functions • Rounding functions • Irreversible functions
Boolean functions	Same as for circuits

RQ3: How many outcomes in circuits and spreadsheets are potential coincidentally correct?

	Average number of ... test outcomes / circuit or spreadsheet		
	correct	**coincidentally correct**	**potentially coincidentally correct**
Circuits	24.2	6.3 (26.0 %)	23.8 (98.3 %)
Spreadsheets	71.0	0.8 (1.1 %)	14.7 (20.7 %)

RQ4: Does the removal of potential coincidentally correct outcomes improve SBFL's results?

Fault	Change in ranking	Best	Avg.	Worst
Compared to the initial ranking				
Single	Improvement	17	14	9
	Worsening	1	15	15
	Same	79	68	73
Double	Improvement	0	0	0
	Worsening	0	0	0
	Same	15	15	15
Triple	Improvement	0	0	0
	Worsening	0	1	1
	Same	19	18	18
Compared to the ideal case				
Single	Improvement	5	1	1
	Worsening	25	44	28
	Same	67	52	68
Double	Improvement	0	1	1
	Worsening	0	1	1
	Same	15	13	13
Triple	Improvement	0	3	3
	Worsening	0	0	0
	Same	19	16	16

Summary

- Negative influence of coincidental correct outcomes on Spectrum-based ranking
- Possible to determine a-priori potential coincidental correct outcomes for spreadsheets, but not for circuits
- Results better then initial results, but not as good as for the perfect case

Questions?