SCIENCE ▪ PASSION ▪ TECHNOLOGY

SFL for Spreadsheets: Influence of Correct Output Cells on the Fault Localization Quality

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5th IEEE Int. Workshop on Program Debugging (IWPD), November 2014, Naples, Italy

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

Spectrum-based Fault Localization (SFL) can help to narrow down the search space.

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Outline

1. SFL for Spreadsheets
2. Initial Situation
3. Research questions
   - **RQ1** Do spreadsheets contain correct output cells that positively or negatively influence the ranking of the faulty cells?
   - **RQ2** If yes, is it possible to a-priori determine which correct output cells would positively influence the ranking?
   - **RQ3** Is it possible to avoid a decreasing fault localization quality when adding more correct output cells?
4. Future work

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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SFL for Spreadsheets (1)

Program debugging: execution traces, slices
Spreadsheets: cones (borrowed from hardware debugging)

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

The function *ρ(c)* returns all cells referenced in *c*.

	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)		

CONE(F2) = {B2, D2, E2, F2}

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SFL for Spreadsheets (2)

Spectra: Cones of erroneous and correct output cells

	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)		

CONE(F2) = {B2,D2,E2,F2}

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

CONE(B4) = {B2,B3,B4}

CONE(C4) = {C2,C3,C4}

CONE(F3) = {B3,C3,D3,E3,F3}

SFL for Spreadsheets (3)

CONE(F2) = {B2,D2,E2,F2}
CONE(D4) = {B2,D2,B3,C3,D3,D4}
CONE(B4) = {B2,B3,B4}
CONE(C4) = {C2,C3,C4}
CONE(F3) = {B3,C3,D3,E3,F3}

$$a_{11}(c) = |\{c' | c \in CONE(c') \wedge c' is\ erroneous\}|$$
$$a_{10}(c) = |\{c' | c \in CONE(c') \wedge c' is\ correct\}|$$
$$a_{01}(c) = |\{c' | c \notin CONE(c') \wedge c' is\ erroneous\}|$$

$$Ochiai(c) = \frac{a_{11}(c)}{\sqrt{(a_{11}(c)+a_{01}(c)) \times (a_{11}(c)+a_{10}(c))}}$$

	F2	D4	B4	C4	F3	SC	Rank.
B2	●	●	●			0.82	2
B3		●	●		●	0.41	7
B4			●			-	
C2				●		-	
C3		●		●	●	0.41	7
C4				●		-	
D2	●	●				1.00	1
D3		●			●	0.50	6
D4		●				0.71	3
E2	●					0.71	3
E3					●	-	
F2	●					0.71	3
F3					●	-	
Error	●	●					

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Evaluation Methods

- Best Case

$$Rank_{Best} = |\{c \mid Ochiai(c) > f\}| + 1$$

- Average Case

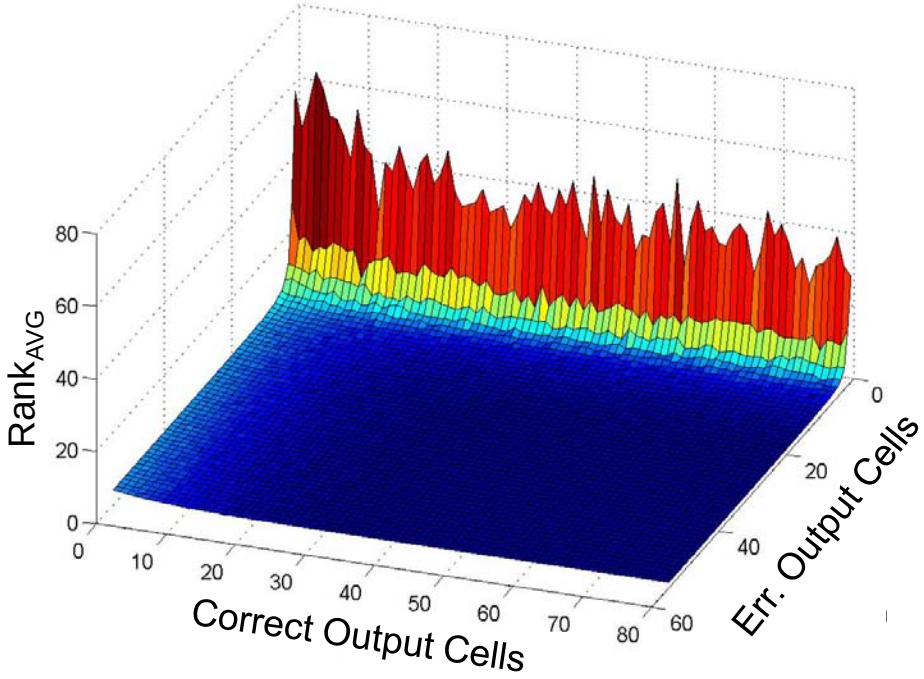
$$Rank_{AVG} = |\{c \mid Ochiai(c) > f\}| + \frac{|\{c \mid Ochiai(c) = f\}|}{2} + 0.5$$

- Worst Case

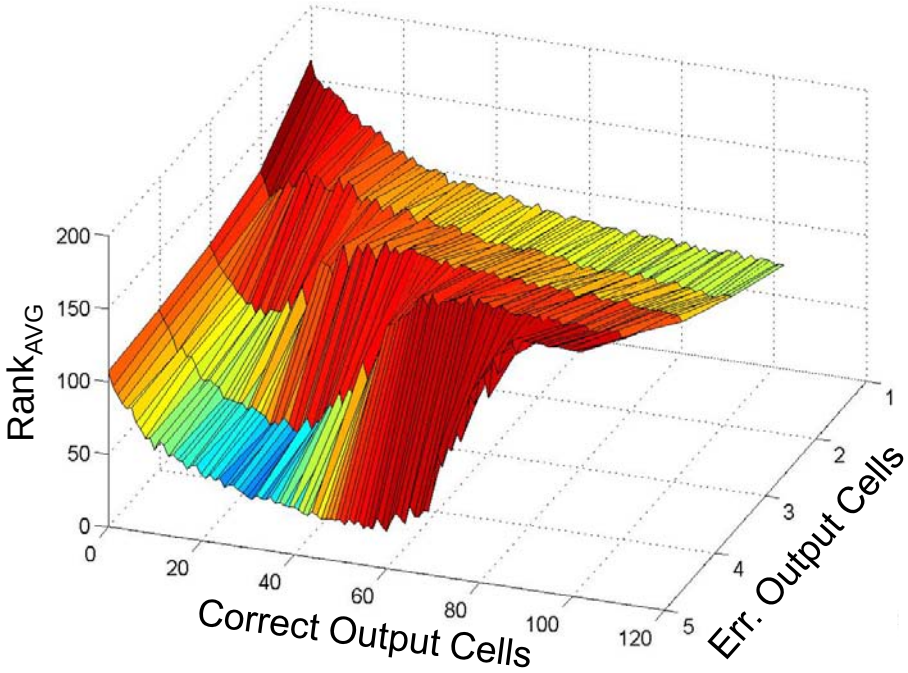
$$Rank_{WORST} = |\{c \mid Ochiai(c) \geq f\}|$$

Initial situation – Average SFL Ranking

EUSES
my_financial_model_1FAULTS_V5



ISCAS85
c7552_BOOL_tc1_96_1Fault



No user wants to indicate for so many output cells if they are correct.

Source: Hofer, Perez, Abreu, and Wotawa: "*On the empirical evaluation of similarity coefficients for spreadsheets fault localization*", Automated Software Engineering, 2014.

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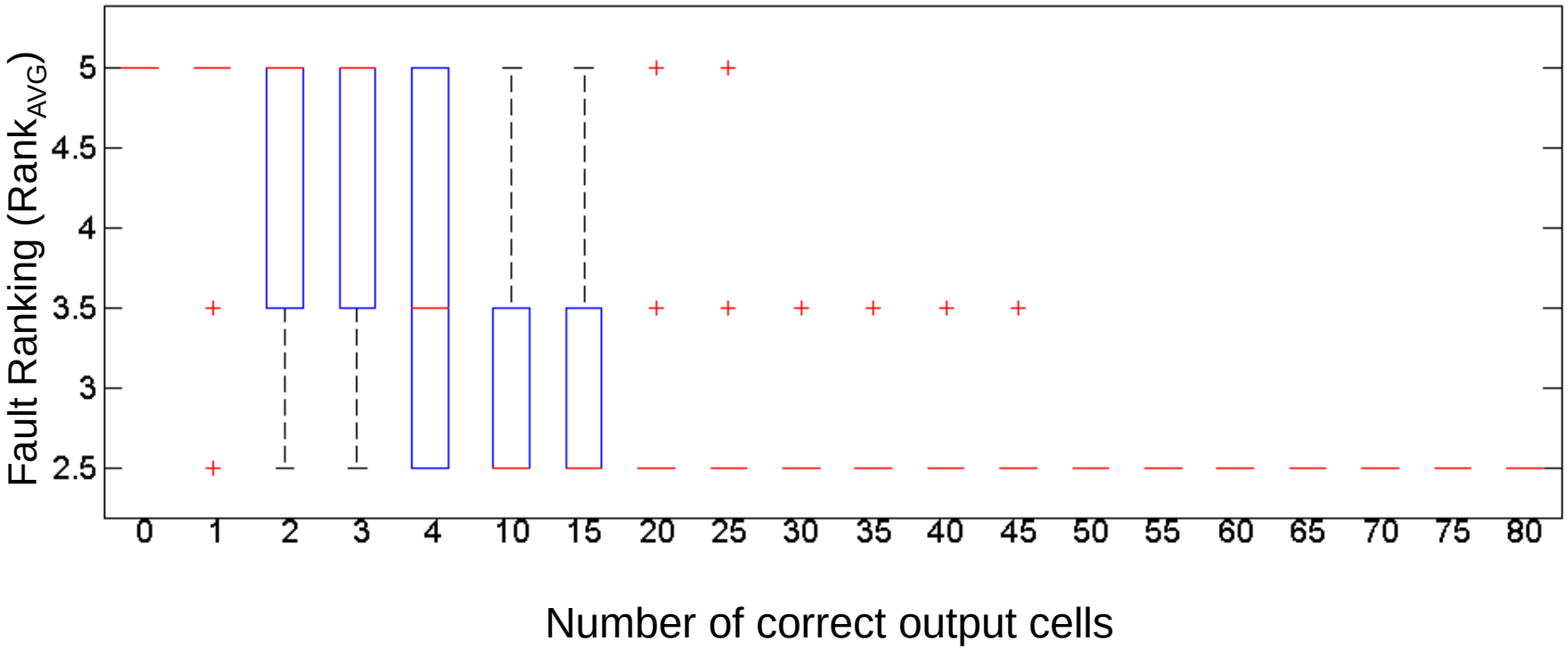
RQ1: Do spreadsheets contain correct output cells that positively or negatively influence the ranking of the faulty cells?

EUSES my_financial_model



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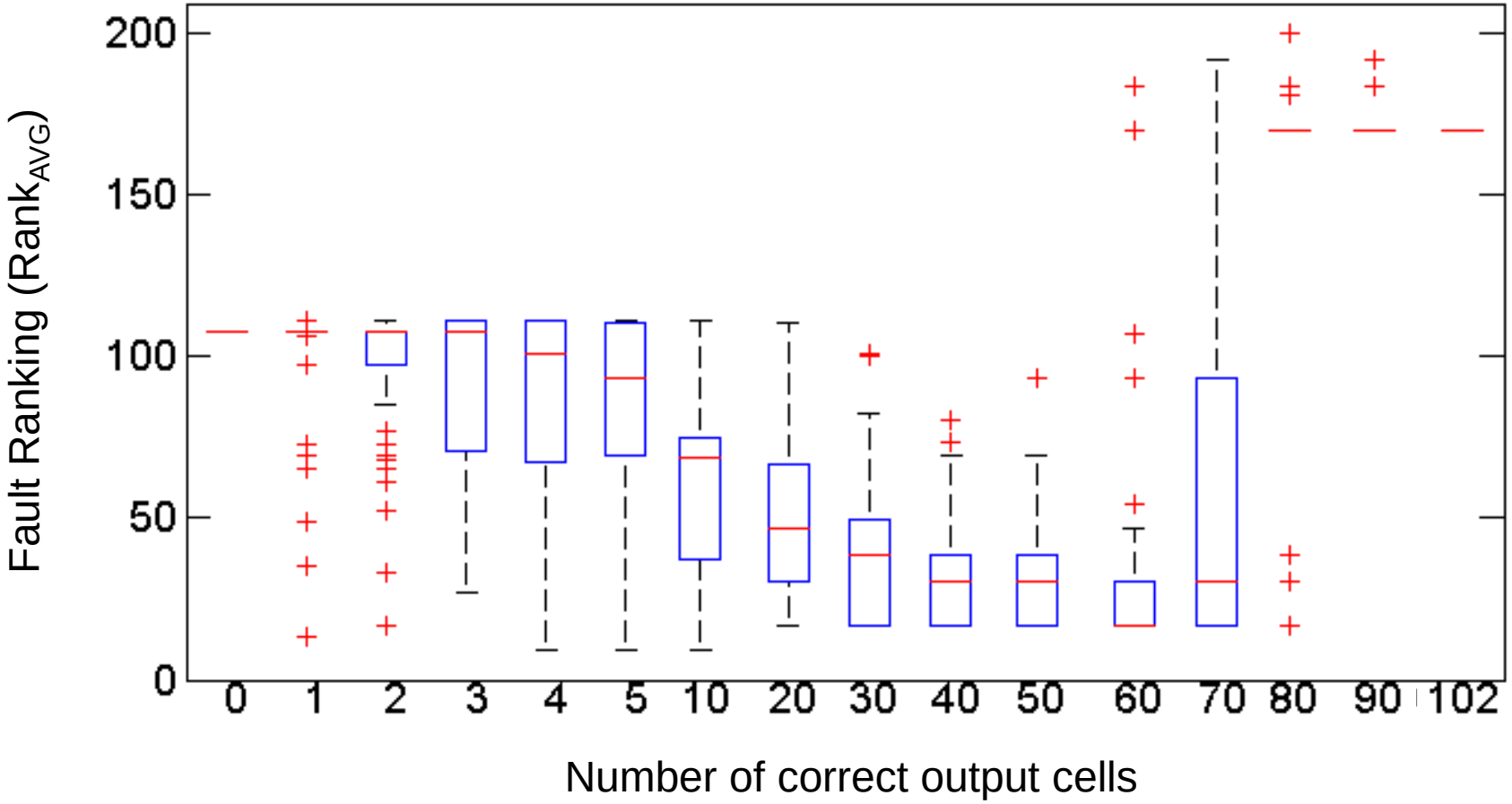
RQ1: Do spreadsheets contain correct output cells that positively or negatively influence the ranking of the faulty cells?

ISCAS85 c7552



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RQ2: If yes, is it possible to a-priori determine which correct output cells would positively influence the ranking?

- Avoid coincidental correct output cells
  - A-priori definition not possible
  - Too many potential coincidental correct output cells

- Take output cells with largest cones first

$Rank_{AVG}$ for one correct output cell	Random selection	Largest cone
EUSES my_financial	5.8	2.5
ISCAS85 c7552	100.6	69.5

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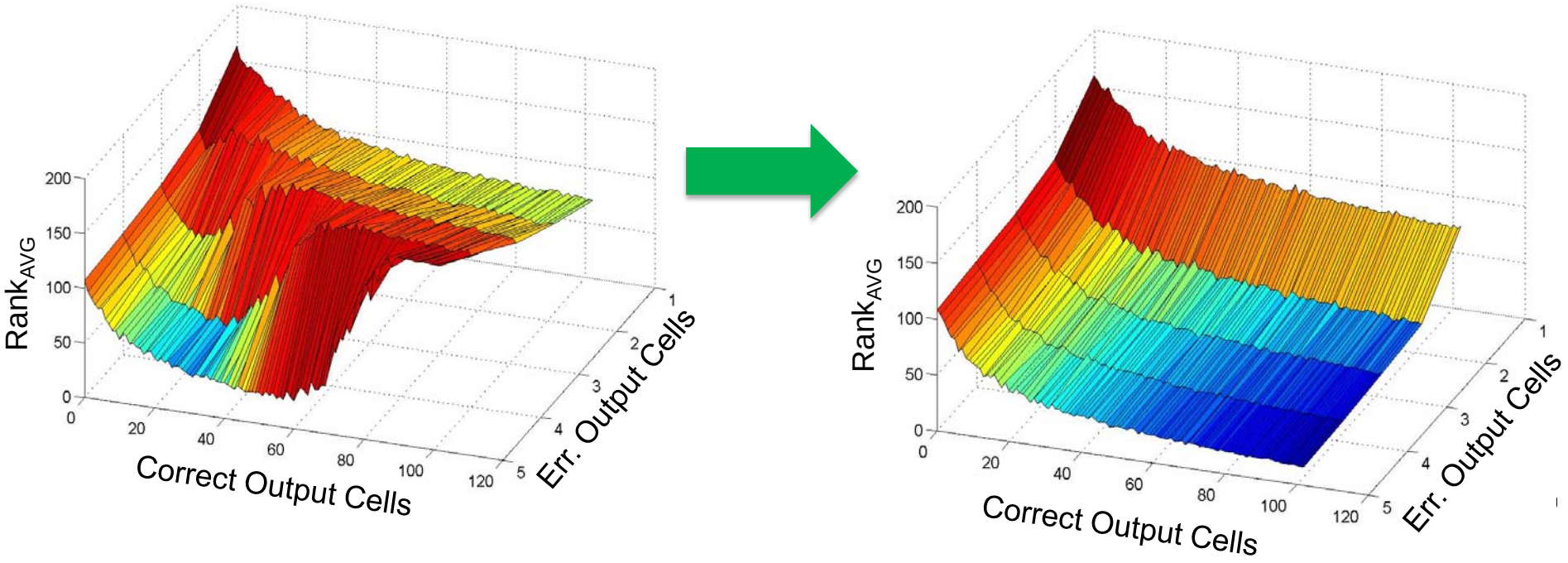
RQ3: Is it possible to avoid a decreasing fault localization quality when adding more correct output cells?

→Balance ratio of correct and erroneous output cells
→Duplicate cones of erroneous output cells

ISCAS85 c7552



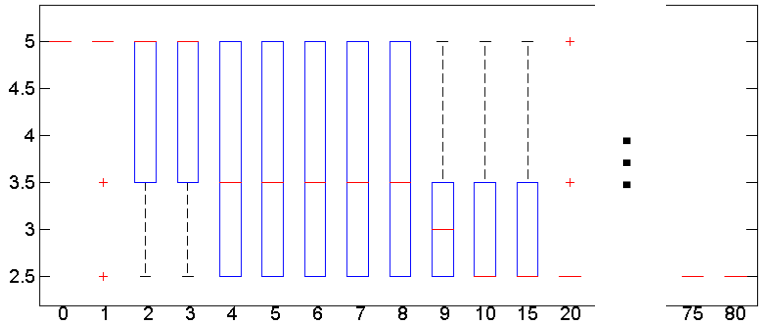
Future work

- Extend evaluation
  - All EUSES and ISCAS85 spreadsheets
- Weighting instead of duplication
  - Wong's Heuristic III
- Several faults
  - Influence on ranking
  - Clustering

Summary

RQ1 Do spreadsheets contain correct output cells that positively or negatively influence the ranking of the faulty cells?

YES



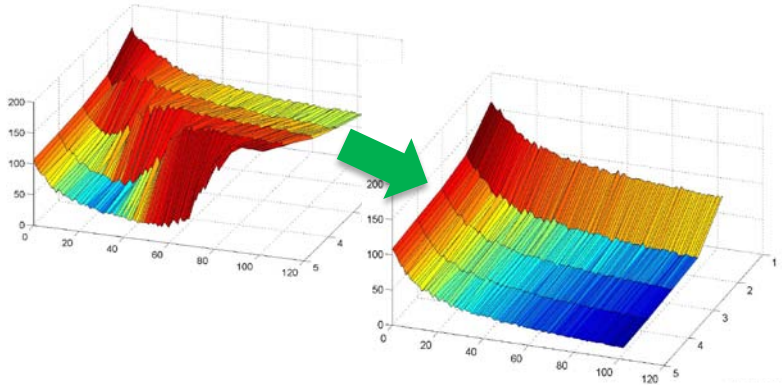
RQ2 If yes, is it possible to a-priori determine which correct output cells would positively influence the ranking?

YES (use largest cones first)

$Rank_{AVG}$ (1 correct output cell)	Random	Largest cone
EUSES my_financial	5.8	2.5
ISCAS85 c7552	100.6	69.5

RQ3 Is it possible to avoid a decreasing fault localization quality when adding more correct output cells?

YES (duplicate cones of erroneous output cells)



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