ICCAD-2015 CAD Contest in Large-scale Equivalence Checking and Function Correction and Benchmark Suite

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ICCAD 2015/ CAD contest session

Agenda

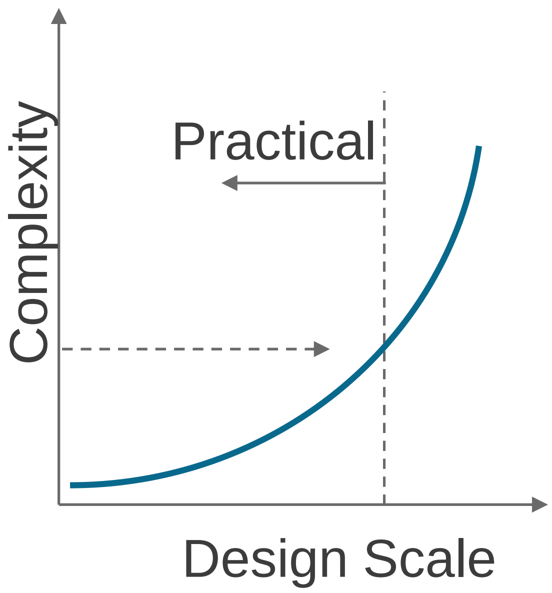
- Problem Description
- Benchmark Suites
- Contest Results

Introduction

- Two-design analysis builds the bridge, and shorten the implementation gap for advanced technologies.
- Two well-know two-design problems: Equivalence Checking(EC) and Functional Correction, a.k.a Engineering Change Order (ECO):
  - EC can assure functional correctness from the original design to the final implementation, such that we can adopt aggressive optimization.
  - ECO can correct the last-minute changes with minimal cost.
- Find the invariant on the implementation processes:
  - *Combinational optimization:* word-level transformation, architecture selection, and Boolean optimization
  - Sequential optimization: retiming, clock-gating.

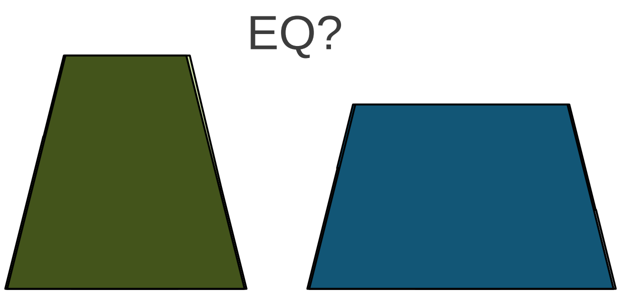
Challenge on Two-designs analysis

- Well-known problems but still a challenge.
- Basic framework:
  - EC: A. Kuehlmann. "Equivalence checking using cuts and heaps" DAC'97
  - ECO: C.-C. Lin and et. al. "Logic synthesis for engineering change" DAC'95
- Industry Issues:
  - Design scale
  - Arithmetic components
  - Optimization by high-level information
- Complexity grows exponentially
  if we directly rely on the core engine.



Two-designs Partitioning with functional consideration

- Finding the corresponding constraints/relations to partition the large-scale EC and ECO into small EC and ECO problems.
  – Use multiple-map with phase as “corresponding relation” in this contest.

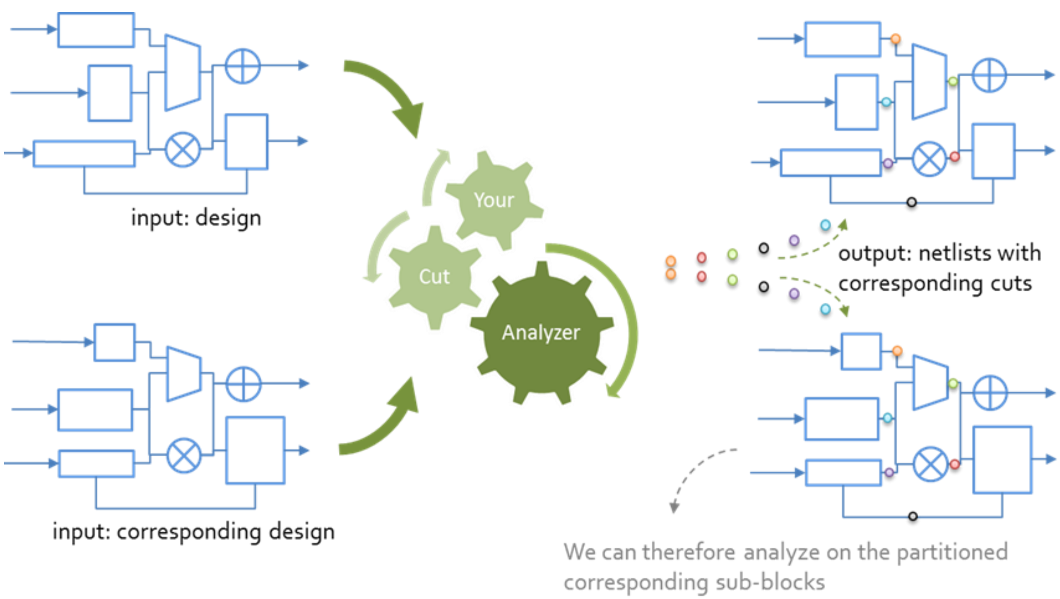


EQ? EQ? EQ? EQ?

- Paradox in EC partition
  – If we can assure the equivalence partition, we already prove they are equivalence.
- ECO partition:
  – Hard to map cuts after non-eq root-cause.

Problem Description

- Given 2 combinational gate-level netlists, find the corresponding cuts to partition the EC/ECO problem into smaller EC/ECO problem.
- We could treat the added corresponding cuts as the new PI and PO.
- Cuts can have phase, and group together.



Evaluation Criteria

- Result EQ is better than non-EQ
  - Notice that, if you insert the wrong cuts for EC problem, you may get the worse result than who do nothing.
- EQ is compared by the maximal cone, which is the most difficult part if the complexity of EC is exponential to its cone size.
- Non-EQ is compared by the summation of non-EQ cone size, which can be used to estimate the final patch size.

- We rank the team for each case, and rank 1 to 7 would get 10, 7, 5, 4, 3, 2, 1 point.
- The team get the highest points win the contest.

Benchmark Suites

- We use Genus Synthesizer to synthesize the cases for EC and ECO.
- Datapath problem is the arithmetic expression, ex: filter or high order expression.
- Simple ECO is to evaluate the capability for the implementation defect.
- Spec change is to evaluate the capability for common industrial ECO issues.

	EC	ECO	
		Simple error	Spec change
ITC 99	ut1, ut3, ut5	ut2, ut4, ut9	
OpenCore	ut7	ut8	
Datapath	ut10, ut12, ut14, ut16, (ut18), (ut20), (ut22)		ut11, ut13, ut15, ut17, (ut19), (ut21), (ut23)

Who can win the problem

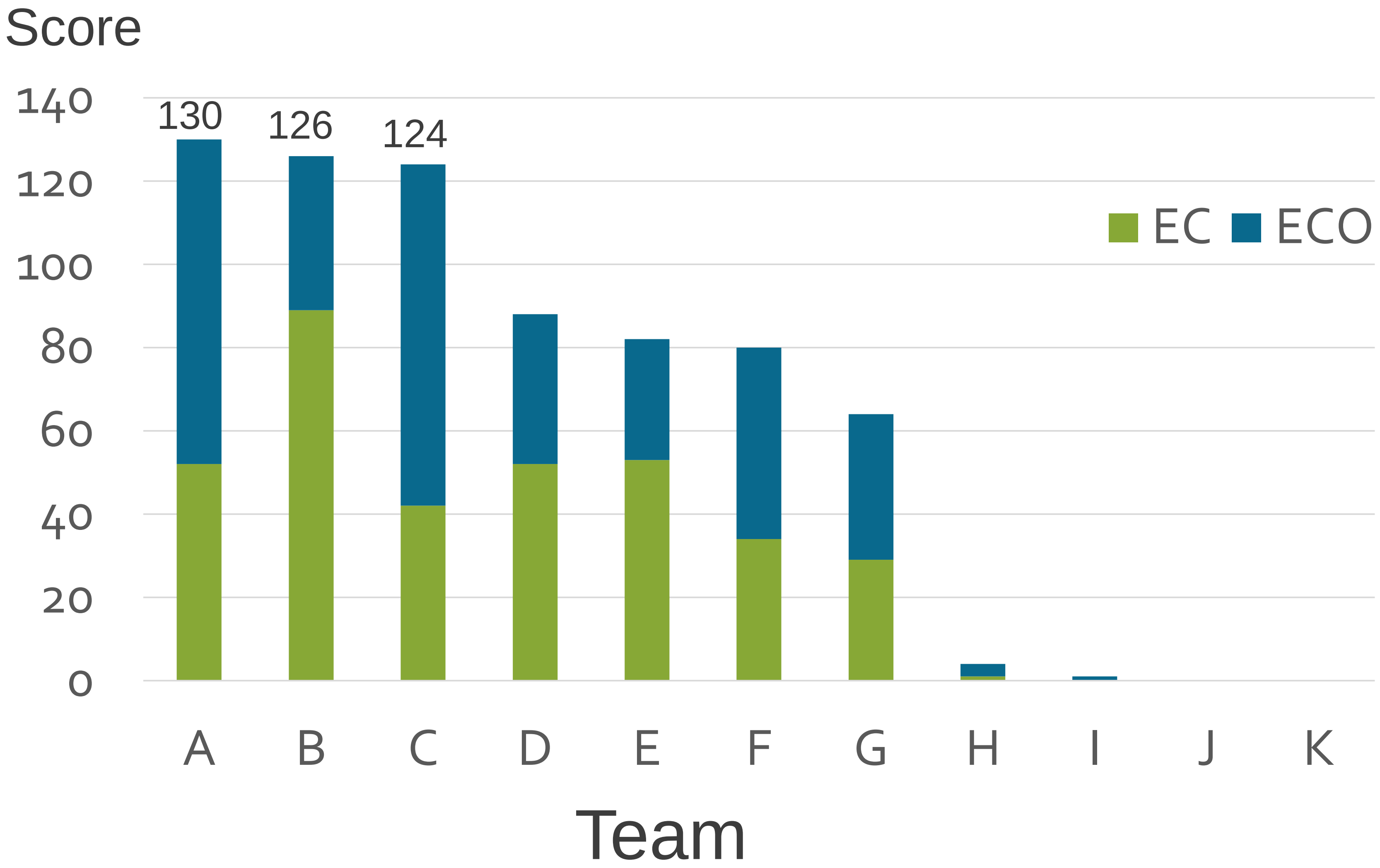
- For avoiding partitioning the EC problem into non-EQ, you must have accurate solver to evaluate the non-EQ.
- For avoiding EC-partitioning paradox, you must have quick approach and accurate engine to speculate equivalence.
- Equivalent cut selection, or global optimization would be possible approaches.

Participation Statistics

Phase	No. of Teams	No. of OK* result
Registration	36	-
Alpha Submission	10	2
Beta Submission	15	7
**Extra Submission	16	9
Final Submission	19	12

*OK means there is no segmentation fault and program generates correct result

Final Score



Score
140
120
100
80
60
40
20
0
130
126
124
EC
ECO
A
B
C
D
E
F
G
H
I
J
K
Team

Distribution on EC cases

	#1	#3	#5	#7	#10	#12	#14	#16	#18	#20	#22	SUM
A	3	5	5	3	10	4	3	4	5	5	5	52
B	7	10	10	10	7	10	7	10	1	7	10	89
C	10	7	7	5	3	3	2	1	2	1	1	42
D	4	4	3	4	5	5	4	5	7	4	7	52
E	1	1	2	0	1	7	10	7	10	10	4	53
F	5	2	1	7	2	2	5	2	3	2	3	34
G	2	3	4	2	4	1	1	3	4	3	2	29
H	0	0	0	1	0	0	0	0	0	0	0	1
I	0	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0

Distribution on ECO cases

	#2	#4	#8	#9	#11	#13	#15	#17	#19	#21	#23	SUM
A	7	7	7	7	7	7	7	7	2	10	10	78
B	4	5	3	5	3	3	2	3	4	5	0	37
C	10	10	10	10	10	10	10	10	0	2	0	82
D	2	2	2	3	2	0	1	5	10	4	5	36
E	0	1	0	1	5	4	4	1	3	7	3	29
F	5	3	5	4	0	5	5	2	7	3	7	46
G	3	4	4	2	4	2	3	4	5	0	4	35
H	0	0	1	0	1	1	0	0	0	0	0	3
I	1	0	0	0	0	0	0	0	0	0	0	1
J	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0

Detail Result on EC cases

	#1	#3	#5	#7	#10	#12	#14	#16	#18	#20	#22
MAX CONE SIZE											
A	4675	2247	7494	8134	13607	27748	15794	76931	108158	208487	90673
B	4124	1996	7043	8020	13610	27053	15793	76910	5214482	208486	90672
C	3240	2004	7361	8134	13611	27748	15794	76931	108158	208488	90673
SCORE											
A	3	5	5	3	10	4	3	4	5	5	5
B	7	10	10	10	7	10	7	10	1	7	10
C	10	7	7	5	3	3	2	1	2	1	1

Detail Result on ECO cases

	#2	#4	#8	#9	#11	#13	#15	#17	#19	#21	#23
SUM OF NONEQ CONE											
A	318661	832430	3557143	400296	86813	271694	1246862	3021783	60868791	3051084	476021
B	470050	988829	14577666	1174440	1513138	2483103	1516188	8856532	24821951	48463162	NA
C	41550	230280	267054	188662	57660	113618	49356	256658	NA	48463859	NA
SCORE											
A	7	7	7	7	7	7	7	7	2	10	10
B	4	5	3	5	3	3	2	3	4	5	0
C	10	10	10	10	10	10	10	10	0	2	0

Conclusion

- Contestants did very good jobs
- Results are better than our expectations
- Drive for new research topics

THIRD PLACE

cada072: frEEdom

Yi-Tin Sun, Grace Wu, Wei Fang, Yi-Yao Huang,
Prof. Jie-Hong Roland Jiang

National Taiwan University

SECOND PLACE

cada064: c6288

Li-Wei Wang, Ming-Jen Yang,
Kuan-Yu Lin, Yi-Hong Lu,
Prof. Chung-Yang (Ric) Huang

National Taiwan University

FIRST PLACE

cada109: Lomonosov Moscow State University

Grigorii Antiufeev, Evgeny Zenin, Vladimir Zhukov,
Prof. Mikhail Shupletsov

Lomonosov Moscow State University