Problem C:
Incremental Timing-driven Placement

http://cad-contest.el.cycu.edu.tw/problem_C/default.html

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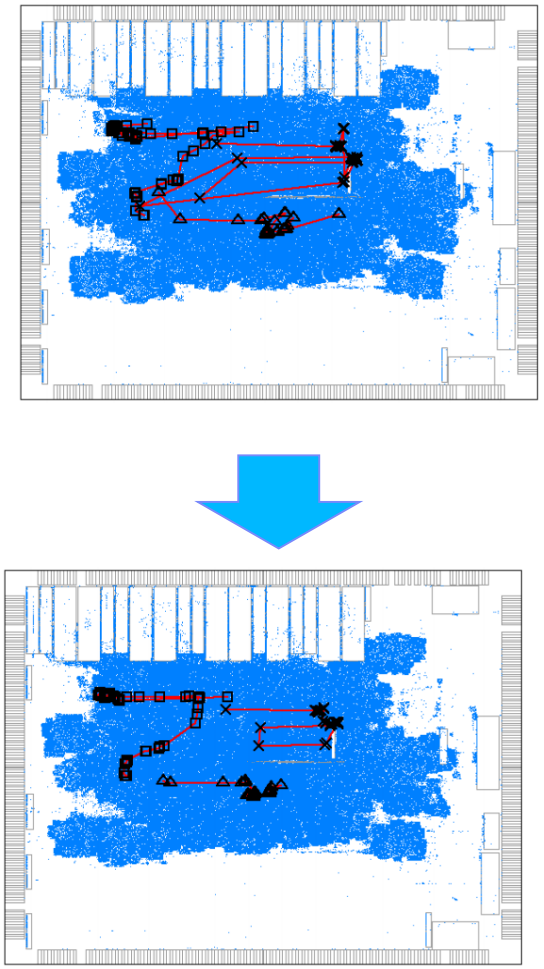
Outline

- **Motivation**
- **Contest Constraints**
- **New feature at ICCAD15 Contest – Clock virtualization**
- **Contest Benchmarks**
- **Contest Evaluation Methodology**
- **Contest Results**

Motivation and Challenges

- **Timing-driven placement (TDP) plays a key role in *timing closure***
  - Timing-unaware tools often overlook the requirements of specific nets, and cannot effortlessly close timing
  - TDP incorporates timing information within, and perform placement operations based on timer feedback
- **Challenges:**
  - Timing convergence
  - Do-no-harm on other chracteristics
  - Timing information accuracy & integration



Motivation for the ICCAD-2015 Contest in TDP

- **Encourage academic research and development in TDP**
  - Propose evaluation metrics for TDP techniques
  - Provide a timing-integrated placement framework
  - The use of an academic timer that works on industry standard liberty format w/ CPPR – OpenTimer @ TAU 2015 timer contest
- **Release large realistic industrial benchmarks**
  (1) enable fair comparisons of the techniques in academic environment
  (2) amenable to extension to other PD areas
  - Reversed-engineered from past contests' bookshelf format files by UCSD team
  - Millions of gates and numerous non-rectangular shaped macros with timing and hierarchy info
  - Provide comprehensive technology information for future PD research (info for gate sizing / CNS / buffering / routing..)

ICCAD 2015 Placement Contest Constraints

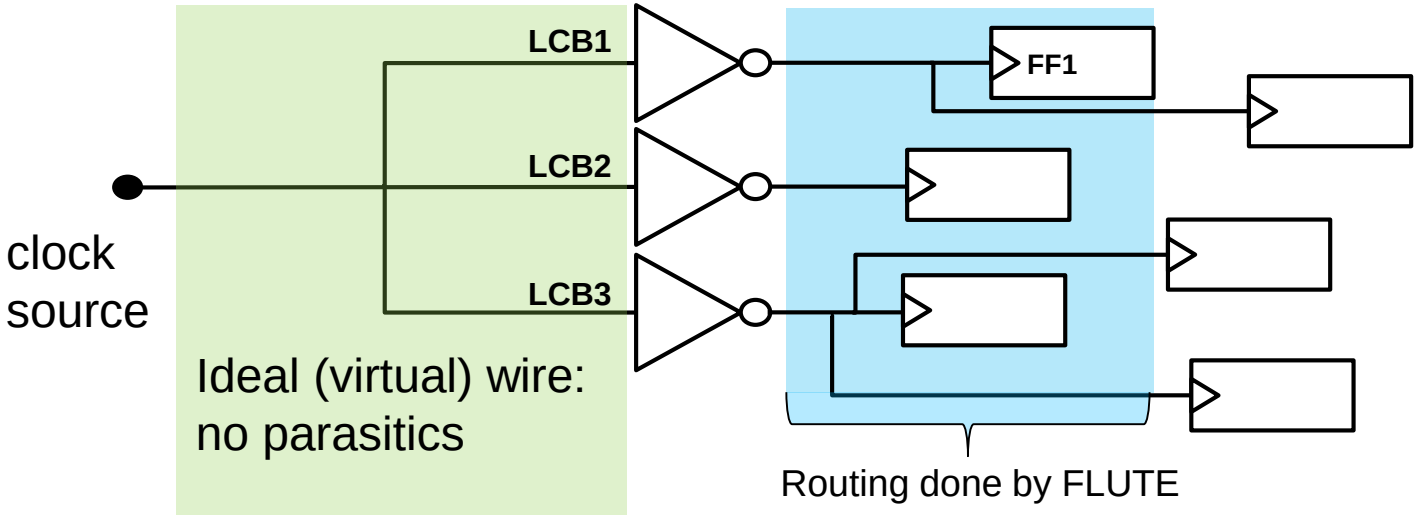
- **Hard constraints: Disqualify solutions when violated**
  A. Maximum cell displacements imposing incrementality
  B. Legality
  C. FF-to-LCB connection validity

- **Soft constraint:**
  Degradation in density profiles will be penalized

- **Maximum runtime of 12 hours**

ICCAD 2015 Contest – Clock Network Virtualization

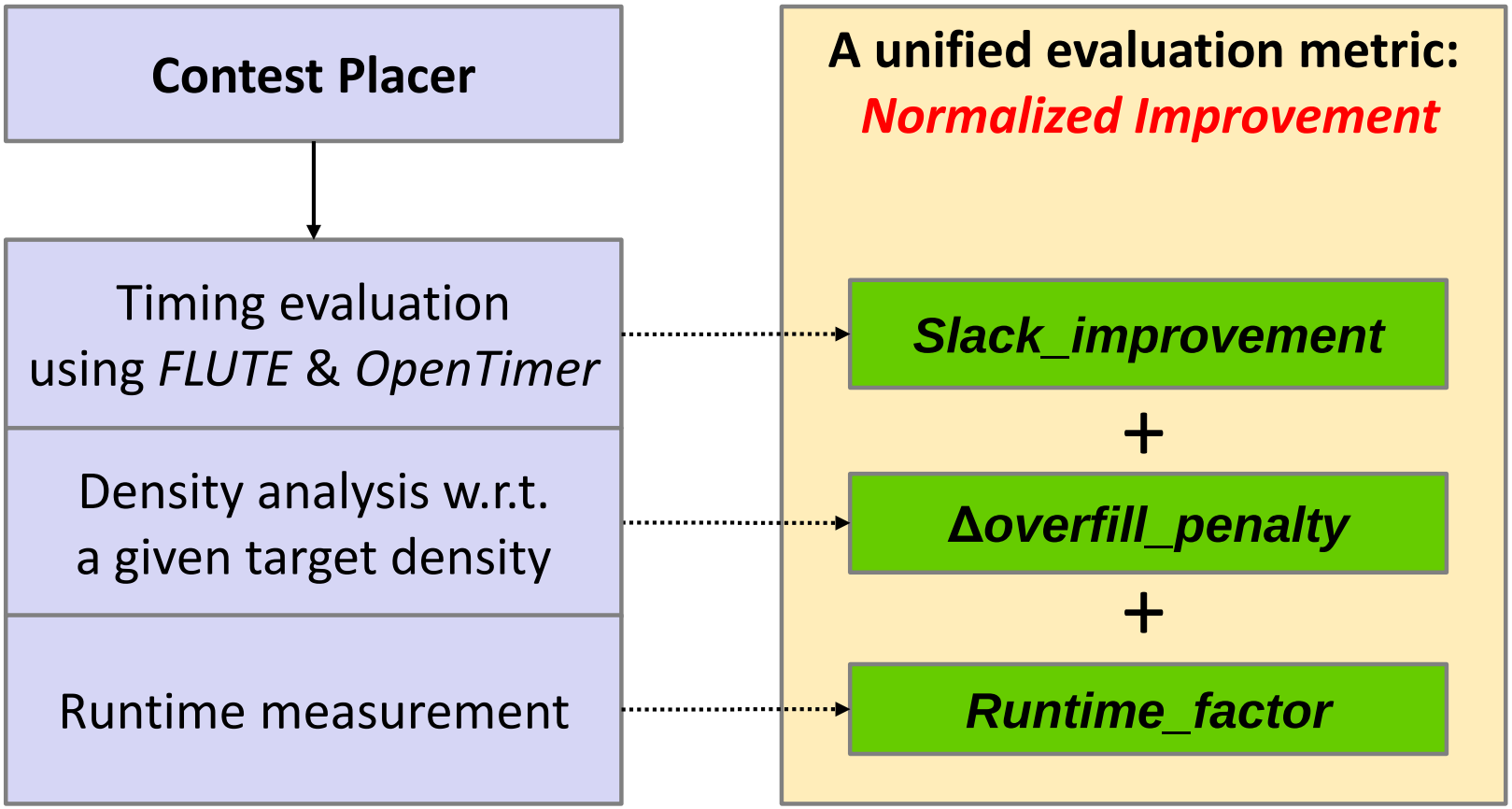
- **Lessons learned from the previous contest..**
  - Clock routing by FLUTE is very sensitive to placement change, so thus RC parasitic and overall timing
  - Even with smaller res/cap, very long clock routes can potentially dominate overall performance due to lack of buffering
- **Local Clock Buffers (LCBs) introduced for clock network**



FF-to-LCB connection validity

- **The contestants are allowed to change the given FF-to-LCB association**
  - The given association is based on k-mean clustering
  - The evaluation script takes a series of pin-level netlist modification operations (as in TAU 2015 format) and configure clock network
- **Nevertheless, the following properties must be honored**
  - Each FF’s clock signal must be driven by a single LCB.
  - Each LCB's # of fanouts must be less than a threshold

Contest Evaluation Flow and Metric



** Please see the ICCAD 2014 paper for details of parasitic extraction*

Evaluation Metric: *Slack_improvement*

- **With respect to the initial timing results of the original placement,**

$$\boldsymbol{Slack\_improvement}\ (\text{a unit of percentage}) =$$

$$\{w_{TNS} \times (w_{late} \times \boldsymbol{TNS\_improv.}^{late} + w_{early} \times \boldsymbol{TNS\_improv.}^{early})$$

$$+ w_{WNS} \times (w_{late} \times \boldsymbol{WNS\_improv.}^{late} + w_{early} \times \boldsymbol{WNS\_improv.}^{early})\}$$

where all TNS or WNS improvements are relative percentages

- **We set** $\{w_{TNS}, w_{WNS}, w_{late}, w_{early}\} = \{2.0, 1.0, 5.0, 1.0\}$
  - Emphasis on TNS > WNS, and late slack >> early slack improvements
  - With given weights, maximum achievable slack improvement = 1800 (%)

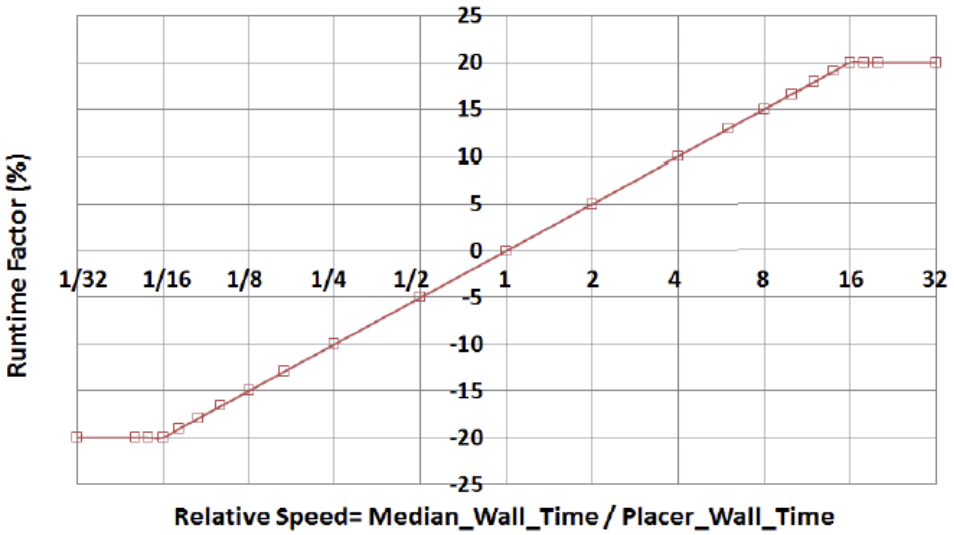
Evaluation Metric: Δ*overfill_penalty*

- ***Overfill_penalty is defined as a weighted sum of*** $\gamma\_over\_utilization$ **that tracks the average overflow of top Γ% densities bins.**
  - $Overfill\ penality = \frac{K_\gamma \times \gamma\_over\_utilization}{\Sigma K_\gamma}$ where $\gamma = \{2,5,10,20\}$
  - Higher weights on peak utilization: $K_2 = 10, K_5 = 4, K_{10} = 2, K_{20} = 1$
  - The best case : overfill_penalty = 0.0

- **We track Δoverfill_penalty between before and after each run**
  - $\boldsymbol{Quality\ Score = max(\ Slack\_improv. \times (\ 1 - \Delta\ overfill\_penalty), 0)}$
  - **Any degradation (overfill_penalty increase) diminishes quality score!**

Evaluation Metric: *Runtime_factor*

- **Allow parallel / multi-threaded implementations up to 8**
- **For each test case**
  - $Relative\_speed = \frac{Median\ Wall\ Time}{Placer\ Wall\ Time}$
  - $Runtime\_factor = 0.05 \times \log_2(Relative\_speed)$



i.e., 5% bonus to the quality score for 2X speed-up (capped at ±20%)

A Unified Evaluation Metric: Normalized Improv.

Normalized Improvement

$$= \underbrace{\begin{array}{l} \textit{Slack\_improv.} \\ \times\ (\ 1 - \Delta \textit{overfill\_penalty}) \end{array}}_{\text{Placement quality}} \times\ (\ 1 + \textit{Runtime\_factor}\ ) \quad \text{Placer runtime}$$

- **First round: Top 5 teams based on quality of placements**
  - Zero score is given to solutions that violate hard constraints or degrade
- **Second round: Top 3 teams based on normalized improv.**
  - The median runtimes were calculated for top 5 teams

Contest Finalists (10 teams)

Team	Affiliation	Team	Affiliation
NCTU-EDA	National Chiao Tung University	Leverage	National University of Defense Technology
UTDA	University of Texas at Austin	CUHK-ITP	The Chinese University of Hong Kong
IITMPlacer	IIT Madras	UFRGS-Brazil	Universidade Federal do Rio Grande do Sul
First Place	Federal University of Santa Catarina	NTUTDP	National Taiwan University
RAPID	(UNIST)Ulsan National Institute of Science and Technology, Korea	iPlace	Nation Chiao Tung University

ICCAD 2015 Benchmark Suite

- Derived from ICCAD-2012 routability-driven Placement contest and converted to industrial format (v,LEF/DEF,sdc,early/late lib)
- FreePDK45 library, OpenTimer placement APIs, input placements

Design	# nodes	# latches	# fixed	target clock periods	target density	max. displ. limits
superblue1	1209716	144266	56898	9 ns	0.80	40 / 500 um
superblue3	1213253	167923	58970	10 ns	0.87	40 / 400 um
superblue4	795645	176895	45289	6 ns	0.90	50 / 500 um
superblue5	1086888	114103	76676	9 ns	0.85	30 / 400 um
superblue7	1931639	270219	72256	5.5 ns	0.90	50 / 400 um
superblue10	1876103	241267	101837	10 ns	0.87	20 / 400 um
superblue16	981559	142543	4868	5.5ns	0.85	20 / 400 um
superblue18	768068	103544	27099	7 ns	0.85	30 /400 um

Notes

- **Detailed results are given for the top five teams in the contest**
- **All experiments run on:**
  - 16 x Quad Cores @ 2.3GHz with 64 GB Memory
  - OS: Linux 2.6.18-404.el5
  - Allowing 8 threads, 12 hour runtime limit
- **The following will become available on the contest website for future benchmarking and research**
  - Benchmark circuits and benchmark format description
  - All the scripts and source codes used for contest evaluation
  - Placement solutions of the top three teams

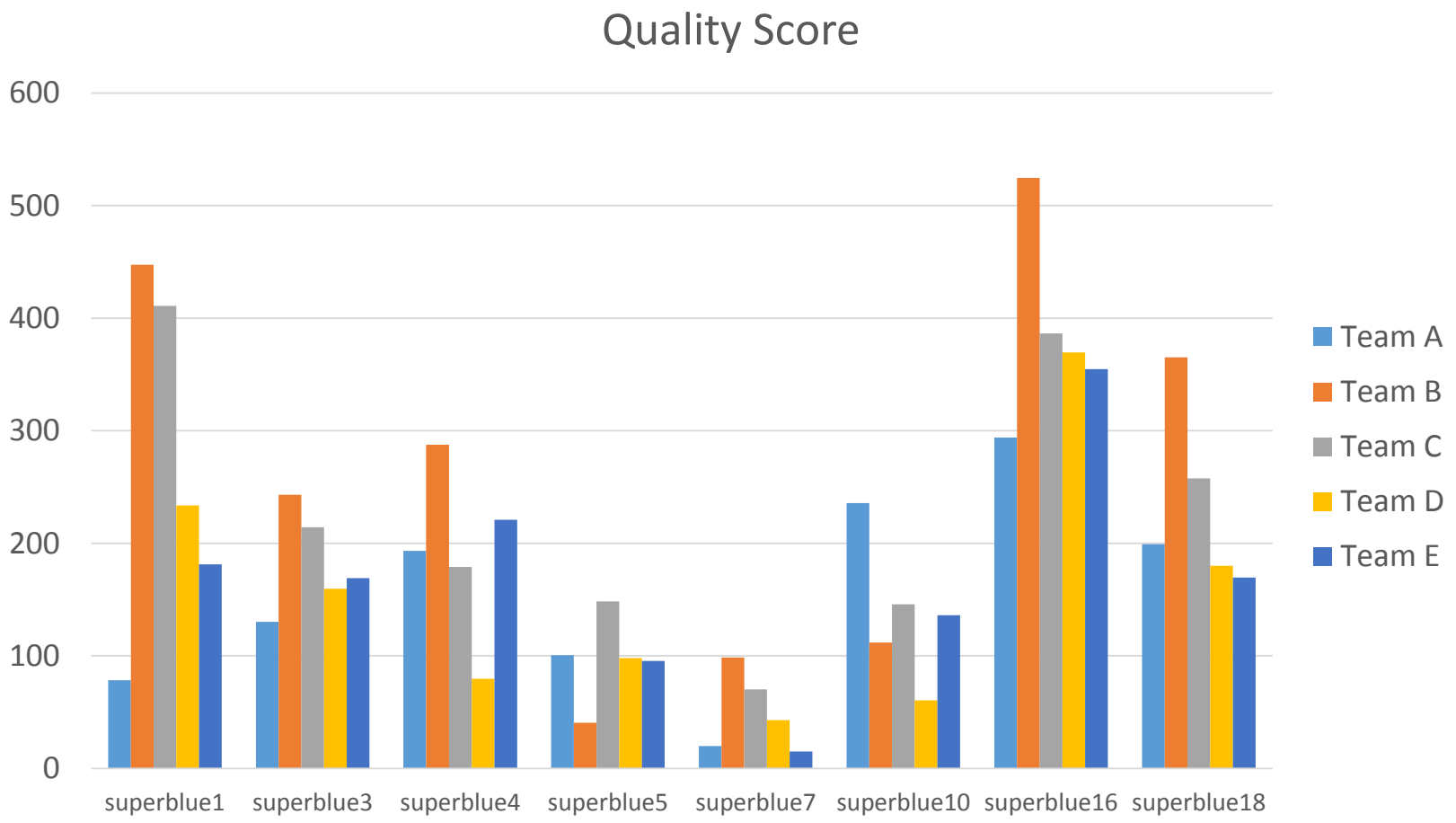
Contest Results for Top 5 Teams

Quality Improvements and Runtimes : short displ.

Design	Quality Improvement (%)					Runtimes (sec)				
	Team A	Team B	Team C	Team D	Team E	Team A	Team B	Team C	Team D	Team E
superblue1	78.38	447.59	410.89	233.61	181.25	1581.654	1365.664	43201.17	4808.363	15528.98
superblue3	130.3	243.18	214.24	159.67	169.11	1879.319	1368.334	43106.77	1813.86	37515.95
superblue4	193.23	287.55	178.95	79.6	220.97	1355.276	1002.649	43082.39	1818.43	16792.64
superblue5	100.53	40.67	148.23	97.98	95.44	1293.663	1352.448	43057.9	893.97	8393.717
superblue7	19.96	98.48	70.3	42.86	15.01	2209.872	2567.818	34759.85	2107.548	17155.84
superblue10	235.64	111.87	145.92	60.55	136.08	3193.136	2427.671	43185.34	4041.276	39695.87
superblue16	293.84	524.72	386.39	369.64	354.81	1202.504	1165.032	28342.53	937.403	25183.18
superblue18	199.1	365.26	257.68	179.95	169.52	879.817	883.234	11638.63	951.017	13090.38
Average	**156.37**	**264.92**	**226.58**	**152.98**	**167.77**	**1699.41**	**1516.61**	**36296.82**	**2171.483**	**21669.57**

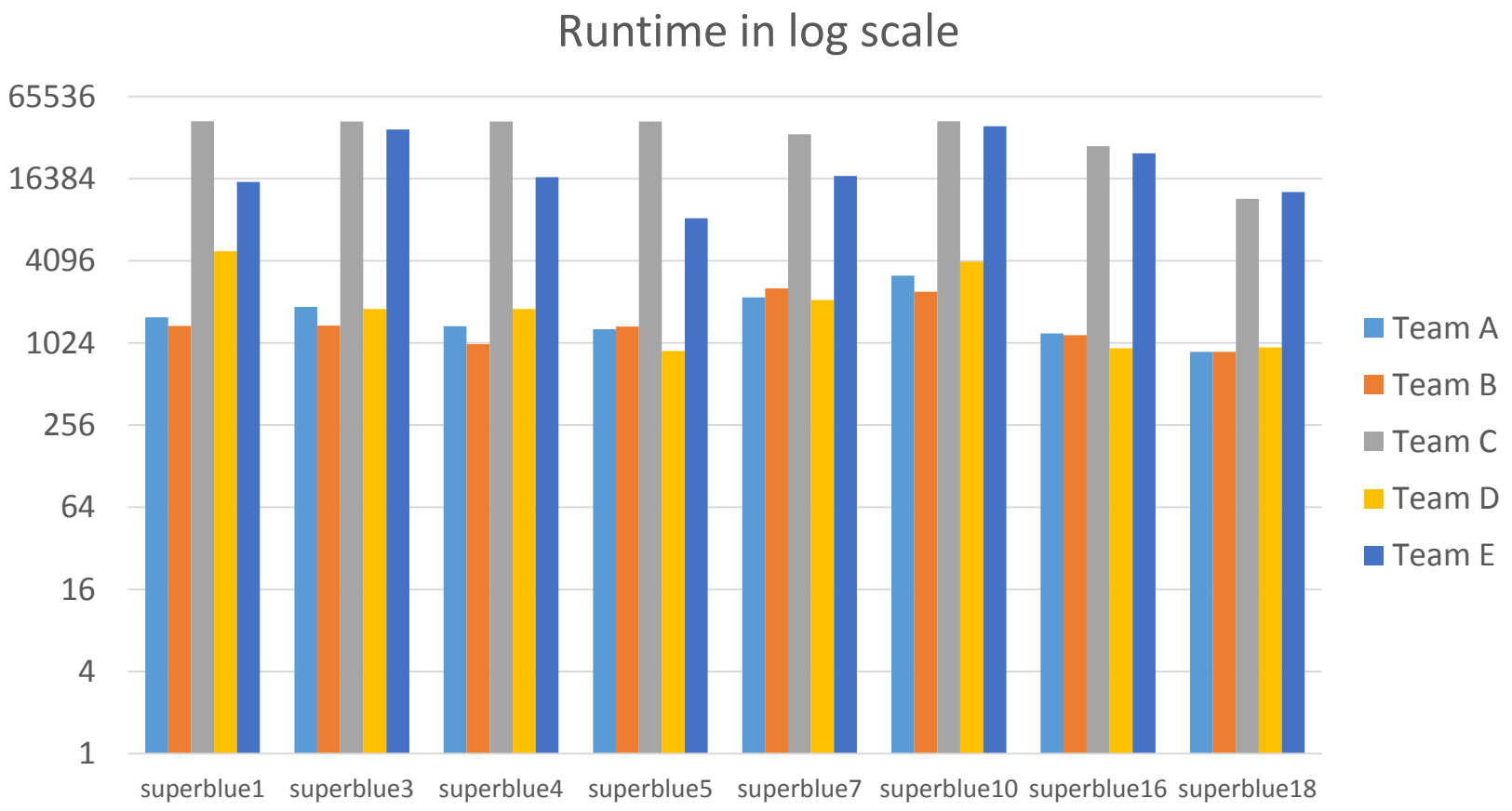
Results: Quality Improvements (short displ. limits)

	Team A	Team B	Team C	Team D	Team E
Avg. quality score (%)	156.37	264.92	226.58	152.98	167.77



Results: Runtimes (short displ. limits)

	Team A	Team B	Team C	Team D	Team E
Avg. runtime (sec)	1699.41	1516.61	36296.82	2171.483	21669.57

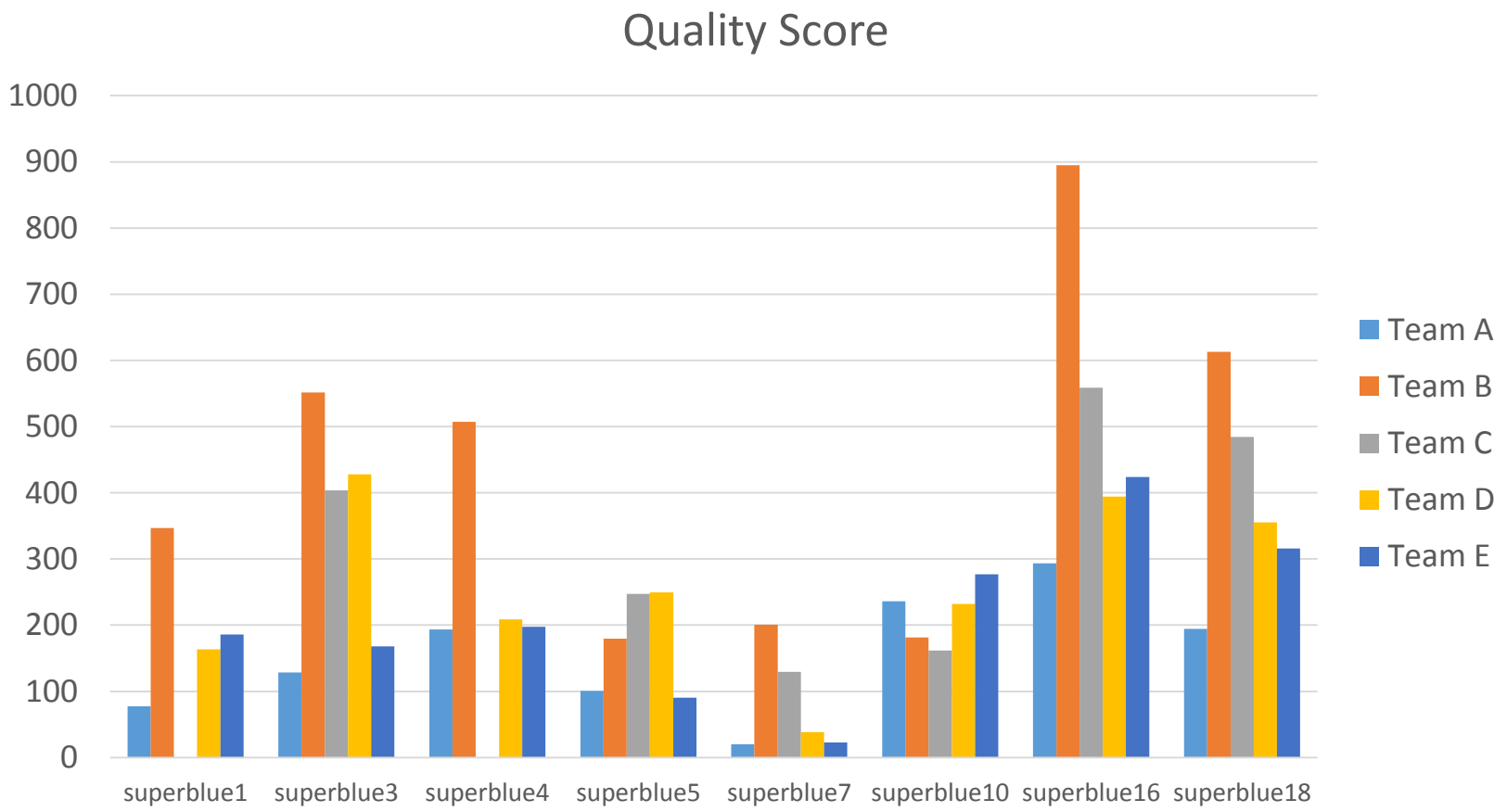


Quality Improvements and Runtimes (long)

Design	Quality Improvement (%)					Runtimes (sec)				
	Team A	Team B	Team C	Team D	Team E	Team A	Team B	Team C	Team D	Team E
superblue1	77.53	346.64	0	163.68	185.79	1490.98	1917.67	43201.97	2420.19	21199.88
superblue3	128.3	551.74	403.63	427.69	167.84	1387.44	1619.07	43201.36	2143.66	35083.48
superblue4	193.39	507.31	0	208.53	197.5	1463.37	1117.46	43201.83	1066.13	32645.49
superblue5	100.54	179.53	247.33	249.40	90.42	1310.47	1520.09	43100.64	1148.04	17571.28
superblue7	19.97	200.72	129.62	38.6	22.72	2715.72	3186.75	43201.92	2183.24	39277.98
superblue10	235.95	181.33	161.75	231.83	276.89	3330.59	2245.89	43202.16	2920.63	40224.32
superblue16	293.42	894.76	558.78	394.11	423.91	1111.81	1345.16	43162.43	1440.52	24323.32
superblue18	194.21	613.07	484.2	355.11	315.65	955.84	951.87	40550.36	726.42	10198.86
Average	**155.41**	**434.39**	**248.16**	**258.62**	**210.09**	**1720.78**	**1738.00**	**42852.83**	**1756.10**	**27565.58**

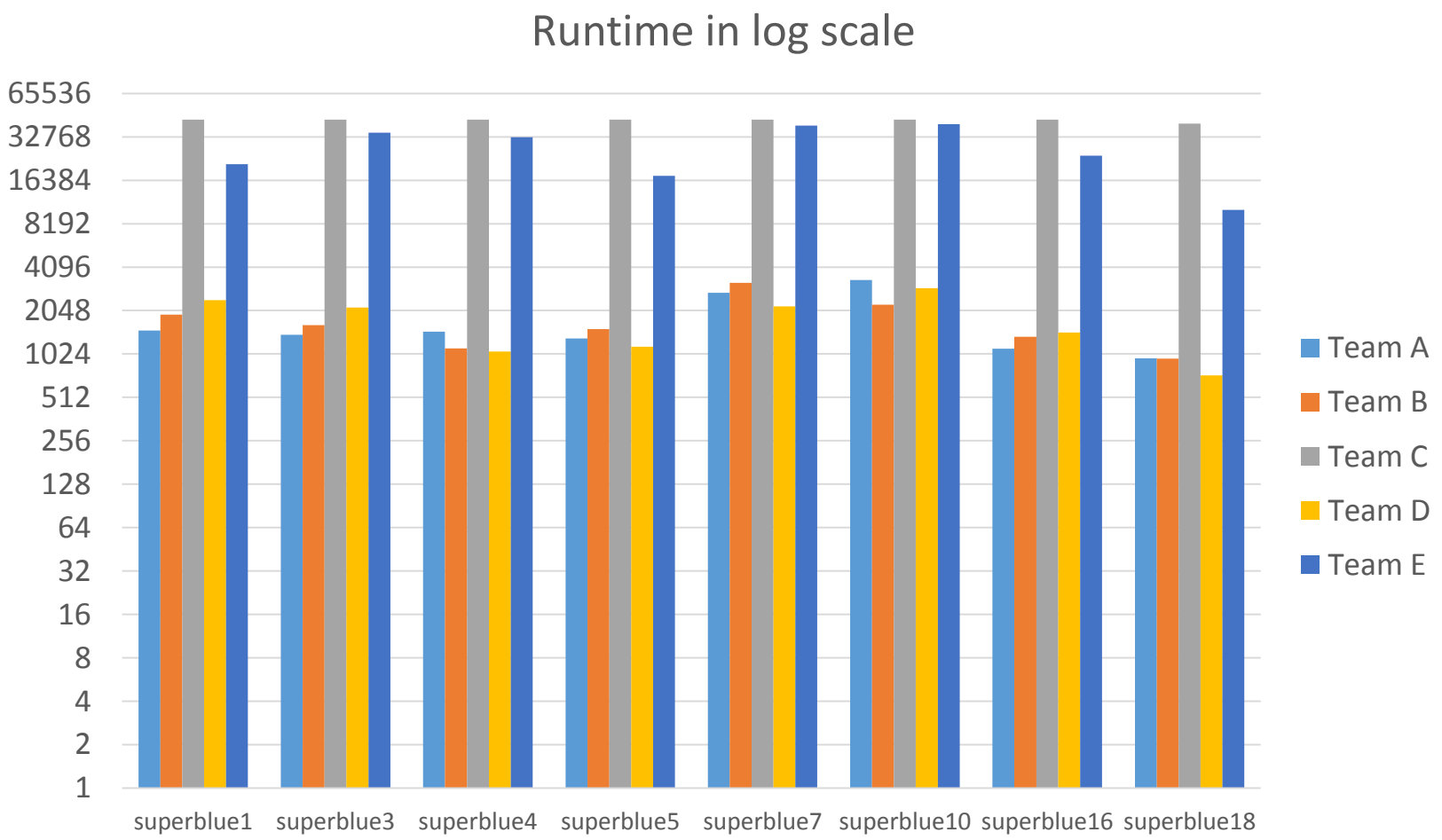
Results: Quality Improvements (long displ. limits)

	Team A	Team B	Team C	Team D	Team E
Avg. quality score (%)	155.41	434.39	248.16	258.62	210.09



Results: Runtimes (long displ. limits)

	Team A	Team B	Team C	Team D	Team E
Avg. runtime (sec)	1720.78	1738.00	42852.83	1756.10	27565.58

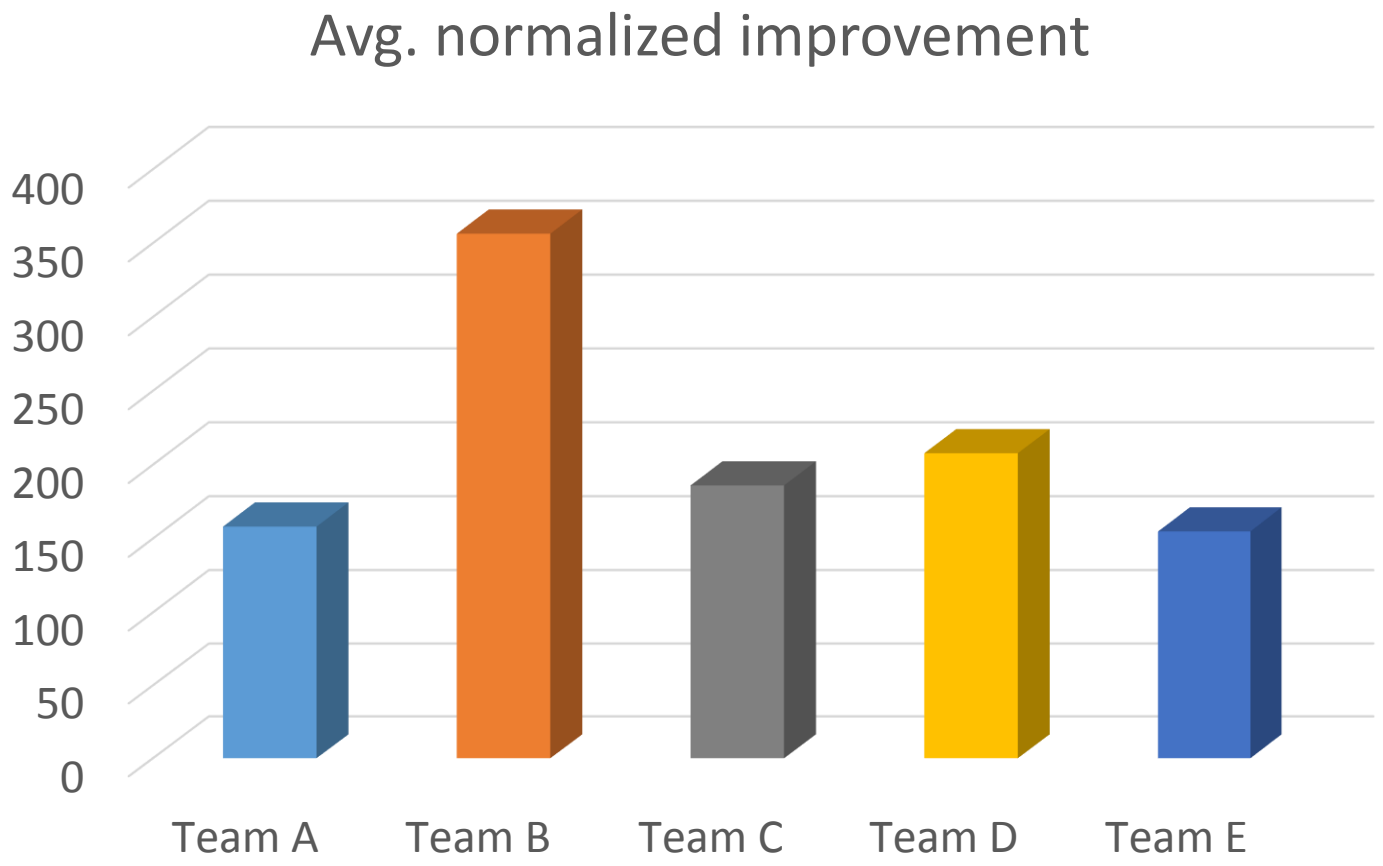


Normalized Improvements (short & long)

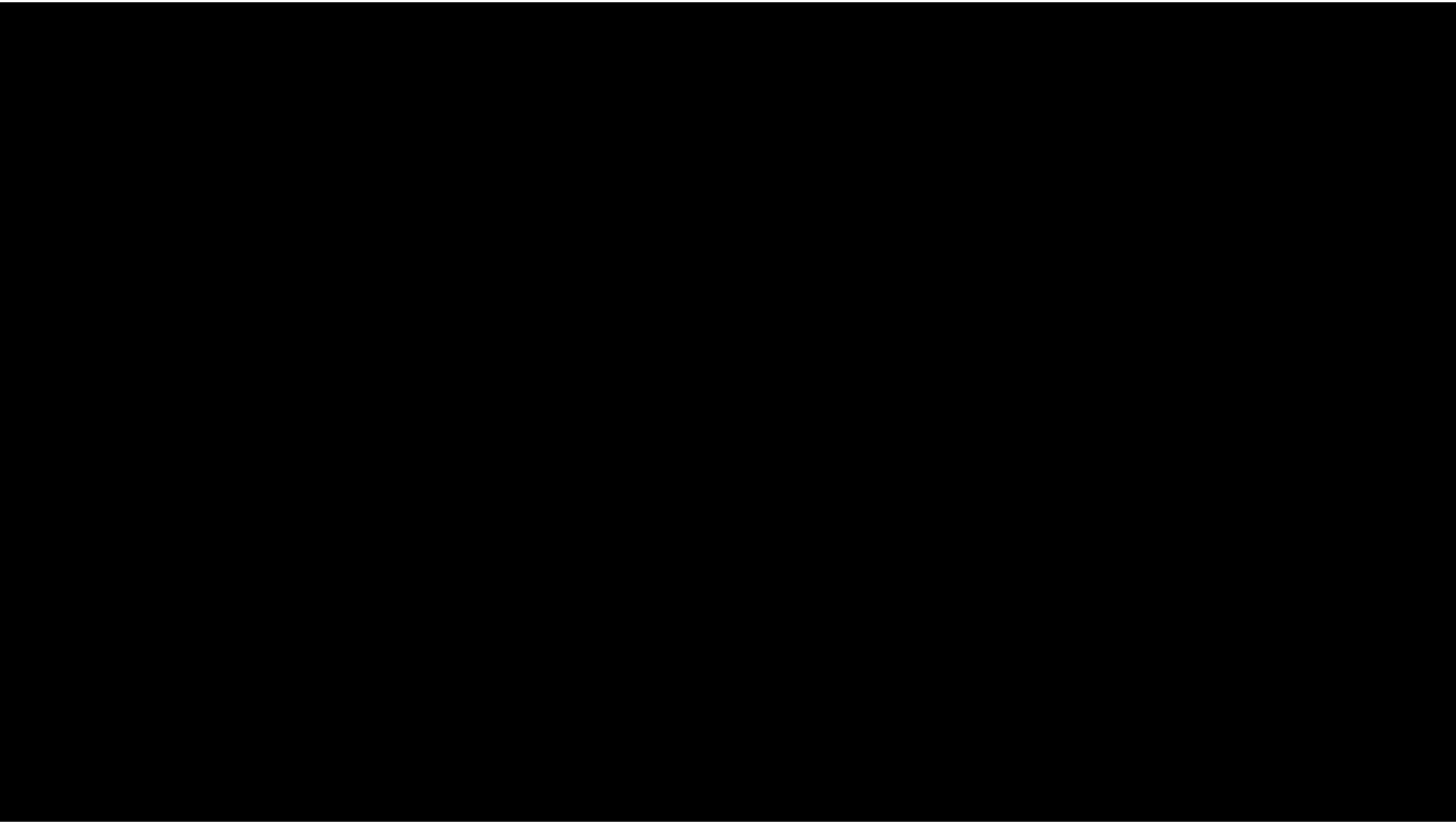
Design	Normalized Improvement - short(%)					Normalized Improvement - long(%)				
	Team A	Team B	Team C	Team D	Team E	Team A	Team B	Team C	Team D	Team E
superblue1	84.67	488.23	345.82	233.61	165.92	80.24	352.46	0.00	163.68	156.71
superblue3	130.30	248.75	165.82	160.07	132.59	132.33	562.91	316.18	427.69	134.00
superblue4	197.33	299.90	138.09	79.60	185.54	193.39	517.18	0.00	213.30	153.27
superblue5	100.85	40.67	111.23	100.91	82.87	101.62	179.53	187.66	254.45	74.46
superblue7	20.18	98.48	57.09	43.47	12.95	20.20	200.72	105.25	39.66	18.60
superblue10	239.65	115.98	120.98	60.55	113.65	235.95	186.48	131.85	234.02	227.13
superblue16	293.84	525.91	298.32	376.28	276.96	298.90	899.18	421.74	394.11	337.48
superblue18	200.21	367.21	211.12	179.95	137.45	194.21	613.26	353.30	362.14	261.74
Average	158.38	**273.14**	181.06	**154.31**	138.49	157.11	**439.97**	189.50	**261.13**	170.42

Normalized Improvements (avg. over all testcases)

	Team A	Team B	Team C	Team D	Team E
Avg. norm. Improv. (%)	157.74	356.05	185.28	207.72	154.46



THE TOP THREE TEAMS ARE …



THIRD PLACE

cada070: CUHK-ITP

Ka-Chun Lam, Wing-Kai Chow,
Peishan Tu, Jian Kuang,
Prof. Evangeline F.Y. Young

The Chinese University of Hong Kong

SECOND PLACE

cada085: UFRGS-Brazil

Jucemar Monteiro, Mateus Fogaca,
Tiago Reimann, Guilherme Flach,
Prof. Marcelo Johann, Prof. Ricardo Reis

Federal University of Rio Grande do Sul

FIRST PLACE

cada014: First Place

Vinicius Livramento, Chrystian Guth, Renan Netto,
Prof. José Luís Güntzel, Prof. Luiz C. V. dos Santos

Federal University of Santa Catarina

Special Thanks To..

- **Jiajia Li and UCSD VLSI CAD group (benchmark generation)**
- **Tsung-Wei Huang (OpenTimer & APIs for placers)**
- **Prof. Shih-Hsu Huang**
- **Contestants**

Top 5 Teams

Team		Affiliation
TEAM A	**NCTU-EDA**	National Chiao Tung University
TEAM B	***First Place***	Federal University of Santa Catarina
TEAM C	**CUHK-ITP**	Chinese University of Hong Kong
TEAM D	**UFRGS-Brazil**	Universidade Federal do Rio Grande do Sul
TEAM E	**NTUTDP**	National Taiwan University