

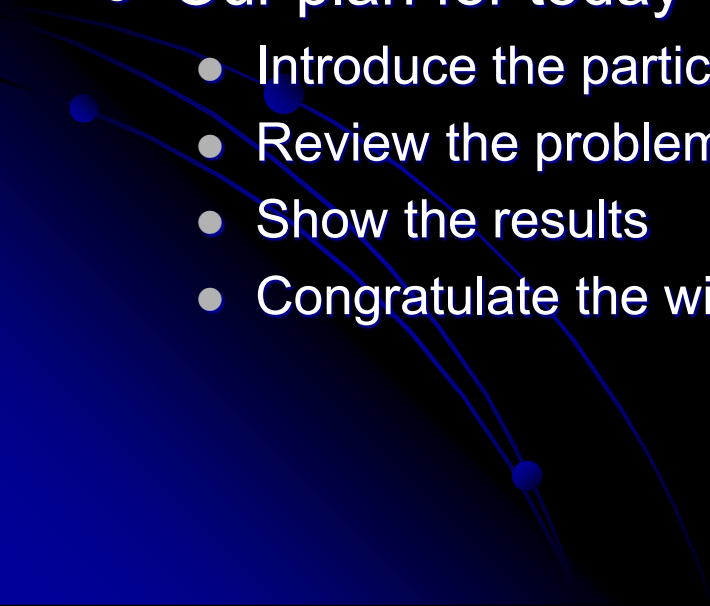
IWLS 2024

Programming Contest



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Overview

- Node minimization, continued from 2022 and 2023
 - Given a Boolean function as a truth table, find a minimal circuit
 - Two tracks: AIG and XAIG
 - Our plan for today
 - Introduce the participants
 - Review the problems
 - Show the results
 - Congratulate the winners!
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Participants

- **ALCom Lab (National Taiwan University and MediaTek)**
 - Yu-Hao Ko, Shao-Jui Wu, Jie-Hong Roland Jiang, Wei-Chen Chien
- **Gaiger (Uni Bremen)**
 - Liam Hurwitz, Heye Siad Hamadmad, Marcel Walter
- **Kapenga (Independent researcher)**
 - Wybren Kapenga
- **NBU (Ningbo University)**
 - Chengyu Ma, Zhang Hu, Jun Zhu, Zhufei Chu
- **NUP (Neapolis University Pafos)**
 - Daniil Averkov, Gregory Emdin, Mikhail Goncharov, Alexander S. Kulikov, Daniil Levtsov, Georgie Levtsov, Vsevolod Vaskin, Aleksey Vorobiev
- **Team EPFL (ETH Zurich and EPFL)**
 - Hanyu Wang, Chang Meng
- **Team TUM (Technical University of Munich)**
 - Marcel Walter, Benjamin Hien, Jan Drewniok, Simon Hofmann, Robert Wille
- **TU Wien (TU Wien and University of Liverpool)**
 - Franz-Xaver Reichl, Friedrich Slivovsky, Stefan Szeider
- **USTC & Huawei (University of Science and Technology of China and Huawei)**
 - Qingyue Yang, Zhihai Wang, Lei Chen, Xing Li, Yiwen Wang, Mingxuan Yuan, Jianye Hao, Jie Wang, Bin Li, Yongdong Zhang, Feng Wu

Problems

- We converted/renumbered the same benchmarks in such a way that the minimum number of nodes stays the same
- The following table shows the function of each benchmark in 2022 numbering

Examples	Description
ex00 - ex01	Known random-looking functions
ex02 - ex07	Random and modified random functions
ex08 - ex09	s-box and inverse s-box from AES [1]
ex10 - ex15	5-input through 15-input majority functions
ex16 - ex27	N-input N-output binary sorters
ex28 - ex49	Selected Espresso benchmarks with permuted inputs
ex50 - ex67	Arithmetic functions with permuted inputs / dropped outputs
ex68 - ex99	Three-output neurons from the LogicNets project [2]

[1] https://en.wikipedia.org/wiki/Rijndael_S-box

[2] Y. Umuroglu et al., “LogicNets: Co-designed neural networks and circuits for extreme-throughput applications,” Proceedings of FPL 2020, pp. 291–297. <https://github.com/Xilinx/logicnets>

Mapping from 2022 to 2024

2022	2024
ex00	ex60
ex01	ex59
ex02	ex64
ex03	ex14
ex04	ex38
ex05	ex82
ex06	ex93
ex07	ex41
ex08	ex06
ex09	ex48
ex10	ex19
ex11	ex75
ex12	ex10
ex13	ex42
ex14	ex46
ex15	ex36
ex16	ex72
ex17	ex35
ex18	ex67
ex19	ex02

2022	2024
ex20	ex76
ex21	ex92
ex22	ex08
ex23	ex11
ex24	ex37
ex25	ex07
ex26	ex39
ex27	ex87
ex28	ex90
ex29	ex83
ex30	ex52
ex31	ex40
ex32	ex00
ex33	ex71
ex34	ex61
ex35	ex03
ex36	ex25
ex37	ex69
ex38	ex23
ex39	ex43

2022	2024
ex40	ex95
ex41	ex16
ex42	ex99
ex43	ex70
ex44	ex53
ex45	ex22
ex46	ex94
ex47	ex55
ex48	ex31
ex49	ex13
ex50	ex66
ex51	ex63
ex52	ex49
ex53	ex29
ex54	ex80
ex55	ex05
ex56	ex26
ex57	ex12
ex58	ex78
ex59	ex27

2022	2024
ex60	ex89
ex61	ex96
ex62	ex47
ex63	ex21
ex64	ex88
ex65	ex33
ex66	ex65
ex67	ex79
ex68	ex44
ex69	ex24
ex70	ex74
ex71	ex28
ex72	ex73
ex73	ex98
ex74	ex57
ex75	ex68
ex76	ex84
ex77	ex85
ex78	ex09
ex79	ex17

2022	2024
ex80	ex77
ex81	ex56
ex82	ex30
ex83	ex20
ex84	ex62
ex85	ex58
ex86	ex04
ex87	ex81
ex88	ex91
ex89	ex54
ex90	ex51
ex91	ex97
ex92	ex86
ex93	ex32
ex94	ex45
ex95	ex18
ex96	ex50
ex97	ex34
ex98	ex15
ex99	ex01

AIG Track

	team1	team2	team3	team4	team5	team6	team7	team8	team9	virtual best
total nodes	20736	23470	25831	29815	28801	26710	39161	70384	53092	19653
wins	51	54	47	37	32	19	23	33	13	100
uniq. wins	19	20	14	3	2	0	0	2	0	60
score	9671.63	9440.92	8993.86	8674.37	8561.29	8181.69	7635.69	7031.72	6855.18	10000.00

$$\text{score} = \sum_{i=0}^{99} 100 \times \frac{\text{Minimum circuit size of all teams for example } i}{\text{Circuit size of the team for example } i}$$

XAIG Track

	team1	team2	team3	team4	team5	team6	team7	team8	team9	virtual best
total nodes	19081	22971	25562	28108	27510	26240	38305	70001	51816	18264
wins	57	19	13	17	15	2	5	41	4	100
uniq. wins	34	10	4	4	3	0	0	17	0	72
score	9666.61	8841.54	8261.68	8226.52	8080.74	7425.74	6976.81	6897.66	6135.46	10000.00

The same ranking as AIG track

Comparison with Past Results

AIG Track	2022 virtual best	2023 virtual best	2024 virtual best
total nodes	27727	23439	19653
geomean of ratios	1.2228	1.0000	0.9218

XAIG Track	2022 virtual best	2023 virtual best	2024 virtual best
total nodes	no contest	22119	18264
geomean of ratios	no contest	1.0000	0.8863

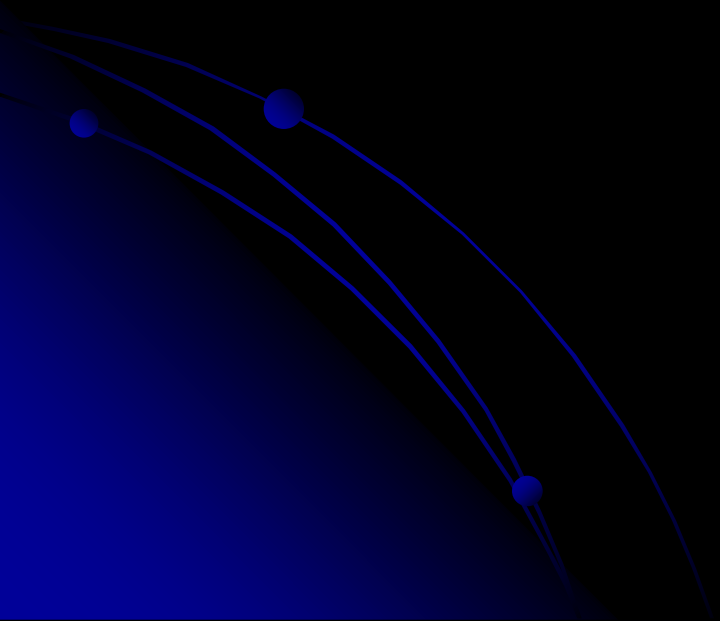
Breakdown of AIG Improvement

examples	description	2023 virtual best total nodes	2024 virtual best total nodes	ratio	diff
ex00 – ex01	random-looking functions	46	44	0.96	-2
ex02 – ex07	random functions	1605	1404	0.87	-201
ex08 – ex09	s-box functions	1066	1005	0.94	-61
ex10 – ex15	majority functions	220	218	0.99	-2
ex16 – ex27	binary sorters	781	720	0.92	-61
ex28 – ex49	ESPRESSO benchmarks	4315	4069	0.94	-246
ex50 – ex67	custom arithmetic functions	9288	6530	0.70	-2758
ex68 – ex99	quantized neuron functions	6118	5663	0.93	-455

Custom Arithmetic Functions

example	origin	2023 virtual best	2024 virtual best	ratio	optimized original AIGs
ex50	add4	18	18	1.00	18
ex51	mul4	26	26	1.00	28
ex52	div4	19	18	0.95	19
ex53	mod4	35	33	0.94	43
ex54	sqr8	12	12	1.00	13
ex55	square6	115	105	0.91	258
ex56	add6	29	29	1.00	29
ex57	mul6	81	80	0.99	91
ex58	div6	77	71	0.92	81
ex59	mod6	182	130	0.71	130
ex60	sqr12	56	51	0.91	75
ex61	square12	1319	476	0.36	836
ex62	add8	40	40	1.00	40
ex63	mul8	168	168	1.00	184
ex64	div8	317	176	0.56	182
ex65	mod8	1182	250	0.21	272
ex66	sqr16	239	176	0.74	179
ex67	pow5	5373	4671	0.87	7165

Winner Announcement



Winners

- 1st place: **NUP (Neapolis University Pafos)**
 - Daniil Averkov, Gregory Emdin, Mikhail Goncharov, Alexander S. Kulikov, Daniil Levtsov, Georgie Levtsov, Vsevolod Vaskin, Aleksey Vorobiev
- 2nd place: **ALCom Lab (National Taiwan University and MediaTek)**
 - Yu-Hao Ko, Shao-Jui Wu, Jie-Hong Roland Jiang, Wei-Chen Chien
- 3rd place: **USTC & Huawei (University of Science and Technology of China and Huawei)**
 - Qingyue Yang, Zhihai Wang, Lei Chen, Xing Li, Yiwen Wang, Mingxuan Yuan, Jianye Hao, Jie Wang, Bin Li, Yongdong Zhang, Feng Wu
- Honorable mention: **Kapenga (Independent researcher)**
 - Wybren Kapenga