IWLS 2022 Programming Contest

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Overview

- The fundamental problem of logic synthesis
  - Given a Boolean function as a truth table, find a minimal circuit
- After decades of research, logic synthesis remains hard
  - As we can see by analyzing the results of this competition
- Our plan for today
  - Introduce the participants
  - Review the problems
  - Show the results
  - Congratulate the winners!

Participants

- Team EPFL (École Polytechnique Fédérale de Lausanne):
  - Andrea Costamagna, Siang-Yun Lee, Alessandro Tempia Calvino, Hanyu Wang, Mingfei Yu, Professor Giovanni De Micheli
- Team Fudan (Fudan University, Shanghai):
  - Yishan Zhang, Professor Chang Wu
- Team NTU (National Taiwan University):
  - Hao-Ren Wang, Guo-Wei He, Professor Jie-Hong Roland Jiang
- Team TUW (Technische Universität Wien):
  - Franz-Xaver Reichl, Friedrich Slivovsky, Stefan Szeider
- Team UCAS (University of Chinese Academy of Sciences):
  - Liwei Ni
- Team UCB (University of California, Berkeley):
  - Yukio Miyasaka
- Team UFRGS/UFPEL (Federal University of Rio Grande do Sul / Federal University of Pelotas):
  - João Machado (UFPEL), Gabriel Ammes (UFRGS), Renato Peralta (UFRGS), Professor André Reis (UFRGS), Paulo Butzen (UFRGS), Leomar da Rosa (UFPEL), Professor Renato Ribas (UFRGS)

Problems

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

Participants vs Organizers (Round 1)

Example	Comment	Participants' best result	Organizers' best result
ex02	RAND8	88	110
ex03	RAND5 ⊕ RAND4	24	27
ex04	RAND10	304	508
ex05	RAND6 ⊕ RAND5	39	42
ex06	RAND12	1056	2236
ex07	RAND8 ⊕ RAND7	166	168
Geomean		**1.000**	**1.325**

Consider these 6 examples. Participants win in all cases!

Participants vs Organizers (Round 2)

Example	Comment	Participants' best result	Organizers' best result
ex50	add4	18	18
ex51	mul4	29	28
ex52	div4	19	19
ex53	mod4	40	43
ex54	sqrt8	12	13
ex55	square6	156	258
ex56	add6	29	29
ex57	mul6	180	91
ex58	div6	92	81
ex59	mod6	277	130
ex60	sqrt12	67	75
ex61	square12	1766	836
ex62	add8	40	40
ex63	mul8	801	184
ex64	div8	442	182
ex65	mod8	1580	272
ex66	sqrt16	329	179
ex67	pow5	4911	7165
Geomean		**1.000**	**0.719**

In the case of arithmetic circuits, knowledge of the function matters.

AIG Node Counts

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex00	26	25	26	**23**	26	26	28	**23**
ex01	32	28	33	**27**	35	32	36	**27**
ex02	97	100	107	**88**	127	94	103	**88**
ex03	**24**	28	29	28	38	32	26	**24**
ex04	312	368	405	382	518	**304**	345	**304**
ex05	44	43	44	**39**	110	62	46	**39**
…								
ex92	30	32	**29**	**29**	35	30	32	**29**
ex93	43	50	50	**41**	52	47	48	**41**
ex94	39	42	47	**36**	70	39	58	**36**
ex95	66	69	70	**65**	123	66	70	**65**
ex96	77	85	84	**76**	184	77	139	**76**
ex97	72	70	77	**69**	126	70	92	**69**
ex98	**142**	222	168	153	471	144	179	**142**
ex99	87	94	97	**84**	162	91	102	**84**
Total	32541	36274	49006	49550	74487	28918	35628	**27727**
Problem wins	36	10	9	48	6	35	7	
Unique wins	20	0	0	28	0	28	4	

Competition Scores

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex00	88.46	92.00	88.46	100.00	88.46	88.46	82.14	100.00
ex01	84.38	96.43	81.82	100.00	77.14	84.38	75.00	100.00
ex02	90.72	88.00	82.24	100.00	69.29	93.62	85.44	100.00
ex03	100.00	85.71	82.76	85.71	63.16	75.00	92.31	100.00
ex04	97.44	82.61	75.06	79.58	58.69	100.00	88.12	100.00
ex05	88.64	90.70	88.64	100.00	35.45	62.90	84.78	100.00
…								
ex92	96.67	90.63	100.00	100.00	82.86	96.67	90.63	100.00
ex93	95.35	82.00	82.00	100.00	78.85	87.23	85.42	100.00
ex94	92.31	85.71	76.60	100.00	51.43	92.31	62.07	100.00
ex95	98.48	94.20	92.86	100.00	52.85	98.48	92.86	100.00
ex96	98.70	89.41	90.48	100.00	41.30	98.70	54.68	100.00
ex97	95.83	98.57	89.61	100.00	54.76	98.57	75.00	100.00
ex98	100.00	63.96	84.52	92.81	30.15	98.61	79.33	100.00
ex99	96.55	89.36	86.60	100.00	51.85	92.31	82.35	100.00
Total	**9387.74**	8043.15	7598.37	**8320.02**	5489.04	**9117.16**	7898.14	10000.00

*Score = 100 * <cost_of_best_solution> / <cost_of_this_solution>*

This score favors good solutions among those that were not solved well by other teams.

Winners

- 1st place
  - Team EPFL (École Polytechnique Fédérale de Lausanne):
    - Andrea Costamagna, Siang-Yun Lee, Alessandro Tempia Calvino, Hanyu Wang, Mingfei Yu, Professor Giovanni de Micheli
- 2nd place
  - Team UCB (University of California, Berkeley):
    - Yukio Miyasaka
- 3rd place
  - Team TUW (Technische Universität Wien):
    - Franz Reichl, Friedrich Slivovsky, Stefan Szeider

- An honorable mention goes to Team UFRGS/UFPEL for synthesizing circuits with the smallest number of logic levels. The logic level count was not the official competition metric, but this is nevertheless a great result.

Additional Slides

Numeric Results

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex00	26	25	26	23	26	26	28	**23**
ex01	32	28	33	27	35	32	36	**27**
ex02	97	100	107	88	127	94	103	**88**
ex03	24	28	29	28	38	32	26	**24**
ex04	312	368	405	382	518	304	345	**304**
ex05	44	43	44	39	110	62	46	**39**
ex06	1056	1097	1517	1476	1892	1058	1141	**1056**
ex07	183	193	869	191	1073	195	166	**166**
ex08	564	590	736	678	929	544	617	**544**
ex09	561	607	737	678	933	555	606	**555**
ex10	10	10	10	10	10	12	10	**10**
ex11	20	20	24	20	24	24	24	**20**
ex12	32	33	40	30	40	40	38	**30**
ex13	48	50	60	46	60	60	60	**46**
ex14	68	79	84	63	84	84	82	**63**
ex15	92	104	112	82	112	110	110	**82**
ex16	18	18	20	18	18	20	18	**18**
ex17	24	28	28	28	30	30	27	**24**
ex18	32	38	40	36	42	42	36	**32**
ex19	38	52	54	48	56	56	56	**38**
ex20	60	68	70	56	73	72	63	**56**
ex21	70	86	88	82	90	90	90	**70**
ex22	86	108	108	88	113	110	110	**86**
ex23	104	130	128	114	135	132	132	**104**
ex24	116	154	156	118	168	156	156	**116**

Numeric Results (cont.)

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex25	146	182	180	160	199	182	182	**146**
ex26	163	208	210	177	228	210	210	**163**
ex27	183	241	238	201	247	240	239	**183**
ex28	39	45	49	39	80	47	50	**39**
ex29	39	39	47	39	53	49	49	**39**
ex30	68	412	465	68	888	69	468	**68**
ex31	1372	1542	1720	1769	2319	1351	1688	**1351**
ex32	46	47	46	44	51	47	48	**44**
ex33	79	101	100	77	114	88	115	**77**
ex34	48	69	54	46	127	58	71	**46**
ex35	16	16	15	15	17	15	16	**15**
ex36	1345	1733	2069	1969	2319	1525	1597	**1345**
ex37	152	165	167	147	241	151	188	**147**
ex38	29	34	35	28	39	33	37	**28**
ex39	220	516	361	202	924	208	540	**202**
ex40	197	288	277	195	484	196	335	**195**
ex41	17	21	17	17	23	17	21	**17**
ex42	28	38	39	28	72	35	40	**28**
ex43	37	62	51	37	106	47	60	**37**
ex44	59	89	95	58	118	64	102	**58**
ex45	196	309	298	191	522	214	360	**191**
ex46	32	32	38	32	42	34	37	**32**
ex47	25	25	25	25	25	25	25	**25**
ex48	598	801	905	793	1481	470	744	**470**
ex49	39	47	51	39	86	51	51	**39**

Numeric Results (cont.)

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex50	18	18	18	18	18	19	19	**18**
ex51	32	36	50	37	79	40	29	**29**
ex52	19	19	19	19	19	20	20	**19**
ex53	42	44	49	40	65	47	49	**40**
ex54	13	13	13	12	13	12	13	**12**
ex55	170	186	202	156	251	164	185	**156**
ex56	29	29	29	29	31	29	31	**29**
ex57	242	233	510	255	554	229	180	**180**
ex58	92	120	113	93	170	93	119	**92**
ex59	287	407	496	363	644	277	440	**277**
ex60	73	73	83	67	107	75	81	**67**
ex61	2129	1867	2881	3036	4055	1875	1766	**1766**
ex62	40	40	40	40	40	40	43	**40**
ex63	2316	1101	7924	4188	5888	801	1415	**801**
ex64	452	848	536	717	1157	442	574	**442**
ex65	3054	1823	3575	4778	6272	1580	2430	**1580**
ex66	361	368	382	420	747	329	370	**329**
ex67	4911	5474	7348	7039	8479	5028	5248	**4911**
ex68	266	304	317	311	746	270	298	**266**
ex69	245	405	321	428	677	255	386	**245**
ex70	263	354	359	584	1160	225	380	**225**
ex71	369	421	418	665	1039	324	431	**324**
ex72	456	683	630	1172	1880	369	690	**369**
ex73	208	461	402	390	782	281	436	**208**
ex74	468	1080	703	1459	2086	437	798	**437**

Numeric Results (cont.)

	EPFL	Fudan	NTU	TUW	UCAS	UCB	UFRGS/ UFPEL	Best
ex75	489	724	631	1211	1957	477	715	**477**
ex76	246	284	280	340	654	240	263	**240**
ex77	319	535	449	463	773	277	355	**277**
ex78	369	586	472	519	838	339	399	**339**
ex79	365	420	431	662	994	332	424	**332**
ex80	627	549	809	1480	2151	497	583	**497**
ex81	355	388	412	599	1059	326	452	**326**
ex82	666	999	702	1697	2419	572	715	**572**
ex83	856	645	915	1635	2273	588	720	**588**
ex84	138	151	151	134	242	134	152	**134**
ex85	206	278	246	253	420	202	217	**202**
ex86	181	214	202	165	323	172	234	**165**
ex87	395	405	443	527	821	372	394	**372**
ex88	331	373	538	437	742	295	340	**295**
ex89	212	214	260	354	781	215	292	**212**
ex90	510	1023	629	1078	1641	449	553	**449**
ex91	275	296	319	282	676	240	270	**240**
ex92	30	32	29	29	35	30	32	**29**
ex93	43	50	50	41	52	47	48	**41**
ex94	39	42	47	36	70	39	58	**36**
ex95	66	69	70	65	123	66	70	**65**
ex96	77	85	84	76	184	77	139	**76**
ex97	72	70	77	69	126	70	92	**69**
ex98	142	222	168	153	471	144	179	**142**
ex99	87	94	97	84	162	91	102	**84**