

## Still Benchmarking After All These Years

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## Twenty years ago at ISPD 2001....

### **Reporting of Standard Cell Placement Results**

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It seemed like a good time to revisit this paper, and to look at what had happened with benchmarking over the years.

# Thirty years ago at DAC 1991....

## **Benchmarks for Layout Synthesis – Evolution and Current Status**

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# MCNC Benchmarks, 1991

Name	#cells	#nets	#I/O	pins/net	pins/cell
<i>fract</i>	125	147	24	2.79	3.63
<i>primary1</i>	752	985	81	3.35	3.97
<i>struct</i>	1888	1920	64	2.82	2.86
<i>industry1</i>	2271	2593	814	3.09	3.53
<i>primary2</i>	2907	3136	107	3.83	3.99
<i>biomed</i>	6417	5742	97	3.88	3.47
<i>industry2</i>	12142	13419	495	3.57	3.95
<i>industry3</i>	15059	21940	375	3.1	4.52

(From Benchmarks for Layout Synthesis..., K. Kozminski, DAC1991)

# MCNC Benchmarks, 1991

## **CONCLUSIONS AND FUTURE WORK**

It seems apparent that more benchmarks for layout synthesis are needed; they should be more fully described, as discussed earlier in the paper. In the opinion of the author, distributing pure geometrical data is no longer sufficient for meaningful benchmarking of algorithms used in real-life applications to produce working chip layouts. The circuit's function as well as its speed and timing requirements should be supplied together with technological data required to verify the performance of the completed design. As an unavoidable consequence, future benchmarks will have to come from sources willing to put the information about logical functions of the benchmark circuits in the public domain.

(From Benchmarks for Layout Synthesis..., K. Kozminski, DAC1991)

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– *K. Kozminski, DAC 1991*

# In the ten years from 1991 to 2001.... Not much had changed.

Benchmark	Rows	Cells	Nets	TW Result
fract	6	149	163	0.032
struct	21	1952	1920	0.383
primary1	17	833	904	0.974
primary2	22	3014	3029	3.594
biomed	44	6514	7052	1.690
industry1	24	3085	2594	1.540
industry2	69	12637	13419	14.064
industry3	52	15433	21967	42.264
avqsmall	79	21918	30038	6.152
avqlarge	83	25178	33298	6.580
golem3	117	100312	217362	25.113

**Table 1: MCNC placement benchmarks. The number of rows suggested was determined by the TimberWolf placement and routing tools, using row spacing equal to cell height.**

(from Reporting of Standard Cell Results..., ISPD2001)

Circuit sizes had grown rapidly since the start of the semiconductor revolution, but the benchmarks available to the academic community had lagged far behind industry.

The net result? Academic research often focused on old problems and outdated metrics. Reported results in papers were difficult to interpret due to wide variations. It was something of an "open secret" that things were not good....

	[13] Gordian	[9] PRC	[22] HALO	[14] POPINS	[19] TW7.0	[10] QUAD	[18] NRG
Fract				45225		337	25602
Struct	558+362					3780	287631
Primary1	841+553	999.5	1.439	1128245	0.83	8972	894545
Primary2	4761+3153	3665.6	6.73	4128324	3.53	36824	3412195
Biomed	5232+3123			4128324	3.22	23765	
Industry1							
Industry2					13.30	332318	
Industry3					41.53	938682	
Avqsmall				23848188	5.08	62890	
Avqlarge				28323022	5.65	65906	
Golem3					88.98		
Units	X1000	X1000	Meter	Micron	Meter	X100	Micron
Spacing	Routed				Routed	None	
	[5] FD98	[7] ARP	[21] Dragon	[24] SPADE	[11] Mongrel	[23] Feng Shui	[12] iTools
Fract		0.034		0.024		0.032	
Struct	0.338	0.34		0.291	0.266	0.380	0.272
Primary1	0.87	0.79		0.74	0.83	1.018	0.799
Primary2	3.72	3.61		3.13	2.94	3.684	3.37
Biomed	1.78	1.83		1.43		1.689	2.90
Industry1		1.50				1.606	
Industry2	14.6		12.88	11.90	11.89	15.408	11.4
Industry3	45.1	48.12	42.33	35.37	34.53	44.729	39.6
Avqsmall	4.91	6.06	5.17	5.08	4.4	5.960	4.48
Avqlarge	5.38	6.54	5.25	6.16	4.87	6.301	4.78
Golem3			77.56	19.84		21.882	79.9
Units	Meter	Meter	Meter	Meter	Meter	Meter	Meter
Spacing	Row		Row	None	None	Row	Routed

(from Reporting of Standard Cell Results..., ISPD2001)

# Benchmarks Needed!

- For academics to craft new algorithms, tools, methods
  - If we can't make comparisons, what hope is there for progress?
- **To train the next generation of EDA professionals!**

The solution? Reveal just enough to make placement and routing benchmarking possible, without revealing too much.

# Some big steps forward

- ISPD98 Partitioning Benchmarks
- GSRC and the GSRC Bookshelf Formats
- Dragon-IBM benchmarks
- IBM-MixedSize benchmarks
- **The ISPD Contests**
- RDF/OpenRoad Open Source Tools

# ISPD98 Partitioning Benchmarks

Chuck Alpert released the "ISPD98" set of partitioning benchmarks. Based on circuits developed at IBM, these net-lists had cell functions, sizes, and signal directions stripped off, and all names were anonymized. The net-lists were also modified somewhat.

Initially intended just for partitioning, they provide a path forward for place and route research.

# Partitioning to Placement

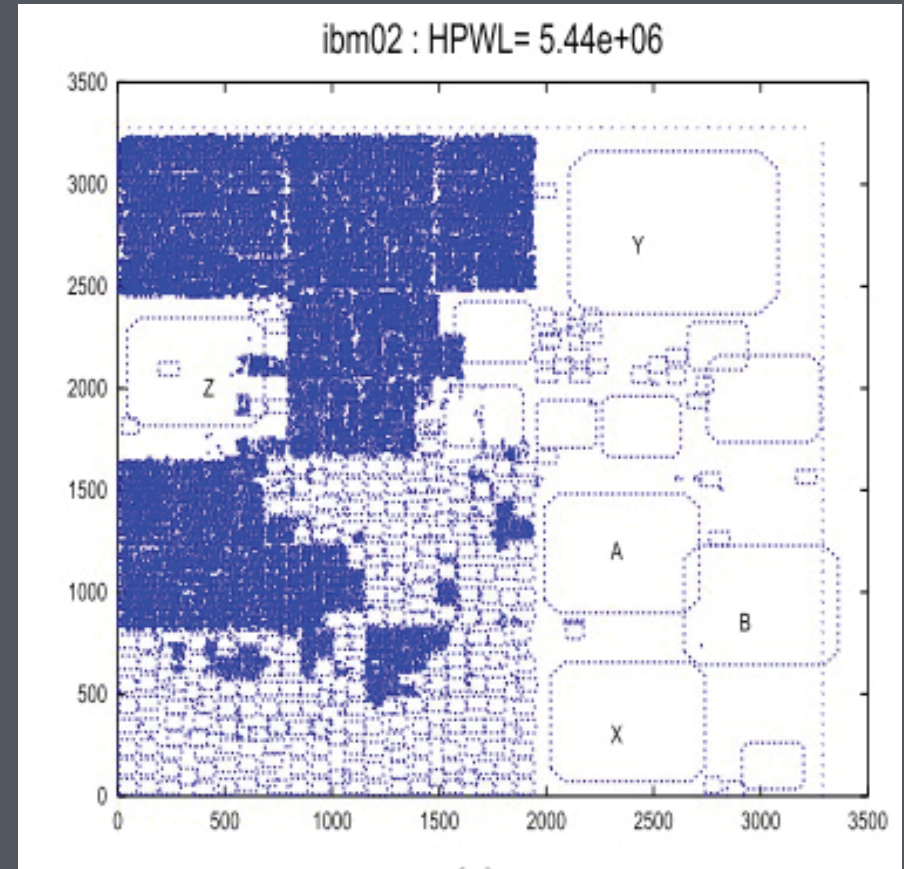
Ckts	#cells	#nets	#pins	#rows
in2	12142	13419	125555	72
in3	15059	21940	176584	54
avqs	21854	22124	82601	80
avql	25114	25384	82751	86
golem3	99932	143379	336299	128
ibm11	68119	78843	248889	128
ibm12	69026	75157	301604	128
ibm13	81018	97574	311403	128
ibm14	147088	147605	547333	128
ibm15	157861	183684	653684	128
ibm16	181633	188324	762218	128
ibm17	182359	186764	834953	128
ibm18	210323	201560	817331	128

**Table 4. Properties of the testing circuits.**

(Conversion of partitioning benchmarks to placement, figure from Dragon2000: Standard-Cell Placement Tool..., Wang/Yang/Sarrafzadeh ICCAD2000)

# Partitioning to Mixed Size Placement

Circuit	# Nodes	# Nets	# Macros	Area of biggest macro
ibm01	12752	14111	246	6.37%
ibm02	19601	19584	280	<b>11.36%</b>
ibm03	23136	27401	290	<b>10.75%</b>
ibm04	27507	31970	608	9.15%
ibm05	29347	28446	0	-
ibm06	32498	34826	178	3.95%
ibm07	45926	48117	507	4.75%
ibm08	51309	50513	309	<b>12.10%</b>
ibm09	53395	60902	253	5.42%
ibm10	69429	75196	786	4.79%
ibm11	70558	81454	373	4.47%
ibm12	71076	77240	651	6.42%
ibm13	84199	99666	424	4.22%
ibm14	147605	152772	614	1.98%
ibm15	161570	186608	393	<b>10.99%</b>
ibm16	183484	190048	458	1.89%
ibm17	185495	189581	760	0.94%
ibm18	210613	201920	285	0.96%



(Conversion of partitioning benchmarks to mixed size, figures from Consistent Placement of Macro Blocks...., Adya/Markov ISPD2003)

# GSRC Bookshelf

Underlying much of this work was the GSRC project led by Prof. Andrew Kahng. In particular, **GSRC Bookshelf file formats** made an impact.

Rather than the complex LEF/DEF of industry designs, bookshelf files were easy to parse. This enabled quick tool development, and opened the door for graduate students to enter the field.

# The ISPD Contests

To keep benchmarks fresh and relevant, the ISPD organizers began a series of contests in 2005.

Soliciting the help of industry researchers, new design problems, metrics, and more, have been made available each year.

# The ISPD2005 Placement Contest and Benchmark Suite

Gi-Joon Nam, Charles J. Alpert, Paul Villarrubia, Bruce Winter and Mehmet Yildiz

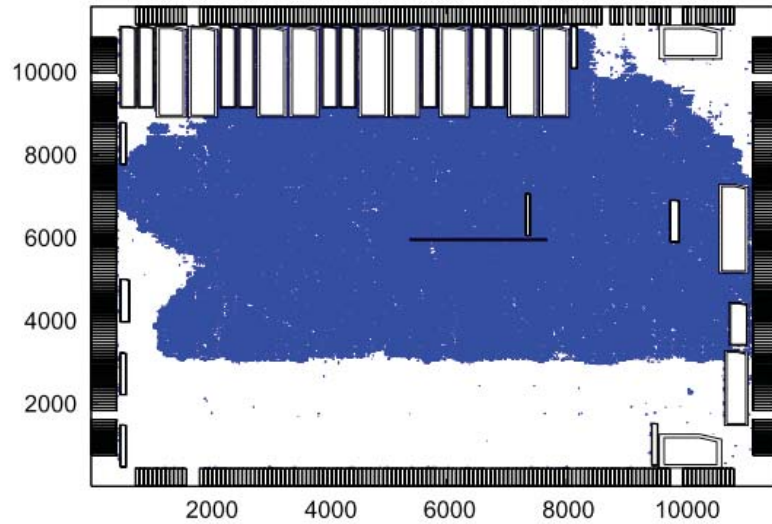
IBM Corp.  
11400 Burnet Road  
Austin TX 78758

{gnam, alpert, pgvillar, bbw, mcan}@us.ibm.com

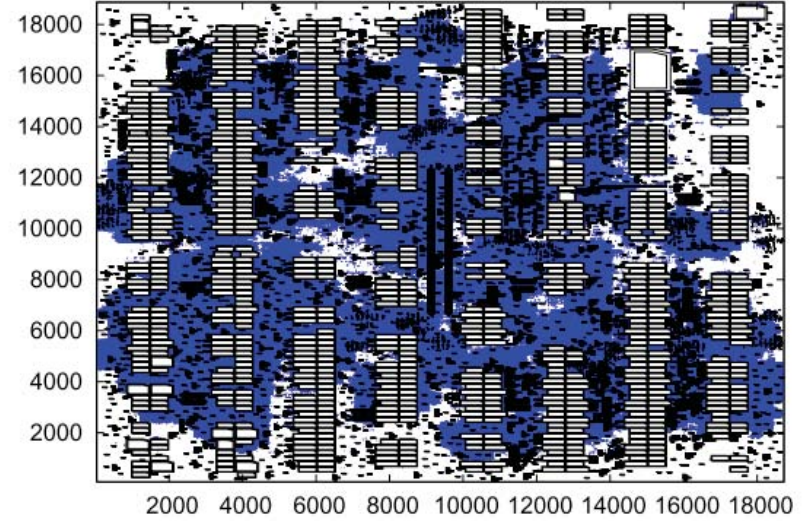
Circuit	#Total Objects	#Mov. Objects	#Fixed Objects	#Nets	#Total Pins	#Pins.Mov. Objs	#Pins.Fixed. Objs	Design Density	Design Util.	Peri. I/Os
adaptec1	211447	210904	543	221142	944053	923513	20540	75.71%	57.34%	480
adaptec2	255023	254457	566	266009	1069482	1045699	23783	78.56%	44.32%	407
adaptec3	451650	450927	723	466758	1875039	1843852	31187	74.53%	33.66%	0
adaptec4	496045	494716	1329	515951	1912420	1876563	35857	62.67%	27.23%	0
bigblue1	278164	277604	560	284479	1144691	1131856	12835	54.19%	44.67%	528
bigblue2	557866	534782	23084	577235	2122282	1979597	142685	61.80%	37.94%	0
bigblue3	1096812	1095519	1293	1123170	3833218	3790107	43111	85.65%	56.68%	0
bigblue4	2177353	2169183	8170	2229886	8900078	8710667	189411	65.30%	44.35%	0

Table 1. ISPD2005 circuit benchmark characteristics.

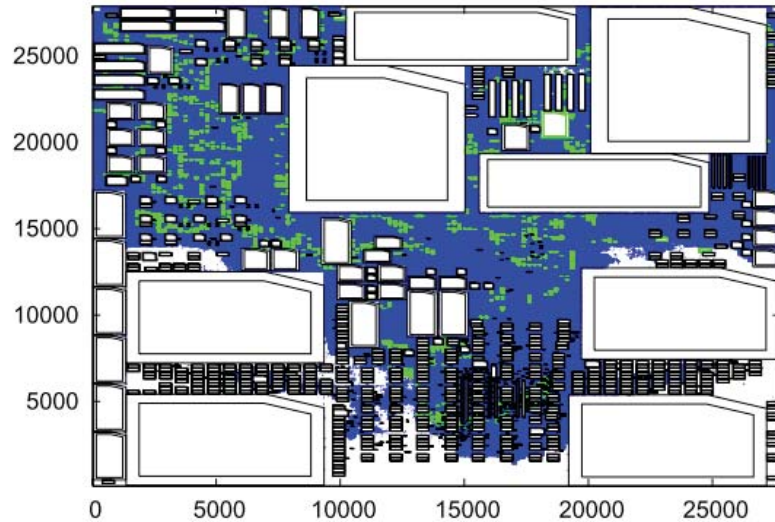
bigblue1 #Cells= 278164, #Nets= 284479



bigblue2 #Cells= 557866, #Nets= 577235



bigblue3 #Cells= 1096812, #Nets= 1123170



bigblue4 #Cells= 2177353, #Nets= 2229886

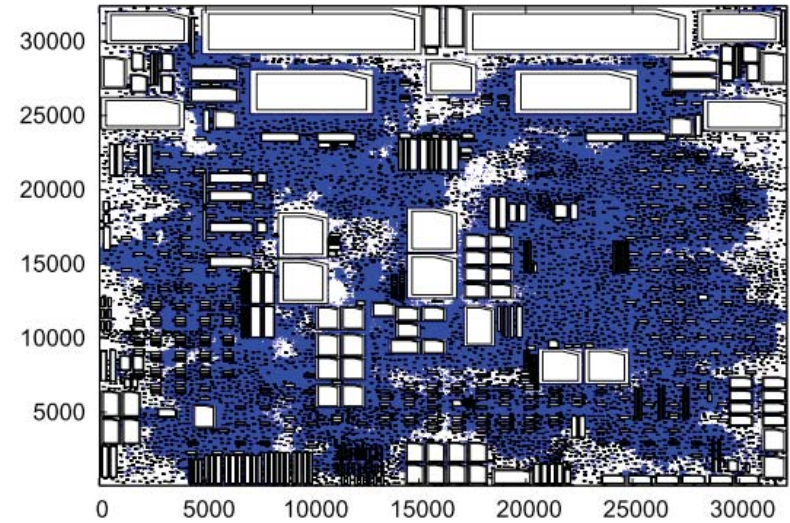


Figure 1. Layout figures of ISPD 2005 benchmark suite.

# Still benchmarking, after all these years...

- A somewhat rocky start for physical design
- Thanks to the help of **many, many** people, we now have regularly updated benchmarks and metrics
- The growth of open source tools is great news
- Much more detail in the paper!
  - My coauthors will continue with their video segments