## Hardware Model Checking Competition 2010

Armin Biere, Koen Claessen

presented at

1<sup>st</sup> Hardware Verification Workshop HWVW'10

affiliated to

Computer-Aided Verification CAV'10 part of

Federated Logic Conference FLOC'10

Edinburgh, UK 15th July 2010

- revive interest in improving symbolic model checking technology
  - symbolic model checking does not scale enough
  - academic research kind of stalled
  - benchmarks were lacking
- repeat success story of the SAT competition
  - simple standardized input format
  - motivation for young researchers
  - competition benchmarks used in publications
- relies on active support by submitters of benchmarks and model checkers

AIGER format AVM'06 Ascona	1st HWMCC	2nd HWMCC CAV'08 Princeton		3rd HWMCC
Founding Lunch CAV'06 FLOC'06 Seattle	CAV'07 Berlin	HWMCC Lunch FMCAD'08 Portland		CAV'10 FLOC'10 Edinburgh
2006	2007	2008	2009	2010

- founding lunch CAV'06 (last FLOC!): Biere, Cimatti, Claessen, McMillan, Somenzi
- HWMCC lunch at FMCAD'08: should have benchmarks with multiple properties !!!
- 2010 reduced committee: Biere, Claessen acted as competition chairs
- ullet still no *multiple properties*  $\Rightarrow$  same competition mode as before

- 14 new benchmarks obtained from the PicoJava 2 case study
- Bob Brayton submitted new 47 instances
  - some of them had multiple properties
  - translated into 96 single property benchmarks
- Politecnico di Torino submitted new 48 benchmarks
  - 3 equivalence checking benchmarks, 45 from software verification (?!)
- Mentor Graphics submitted one new benchmark with 13 properties + env. constraint
  - translated into 15 AIGER benchmarks
- 173 new benchmarks + 645 HWMCC'08 benchmarks = **818 benchmarks**

- ABC by Bob Brayton's group (Berkeley): 4 variants incl. 2 BMCs
   new version
- BIP submitted by Niklas Eén (Berkeley): with / without ABC preprocessing new
- CIP + MBMC submitted by Stefan Kupferschmid (Freiburg)
- IC3 submitted by Aaron Bradley (Boulder) based on inductive clauses
- MCSTI by Anders Franzén (Sweden)
- TIP by Niklas Sörensson (Sweden): 3 variants incl. 1 BMC new version
- PDTRAV from Torino (Cabodi, Nocco, Quer)

- old model checkers: AigTrav + McAiger from JKU, NuSMV from Trento
- last winners: ABC08, TIPBMC08

altogether 21 model checkers

• single safety property benchmarks

as before in HWMCC'07 + HWMCC'08

- one output serves as "bad state detector"
- bad state reachable ⇒ instance satisfiable
- bad state unreachable ⇒ instance unsatisfiable
- all benchmarks in AIGER format

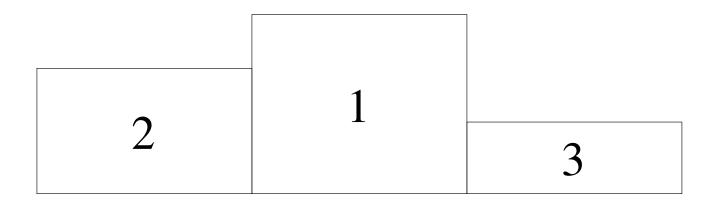
http://fmv.jku.at/aiger

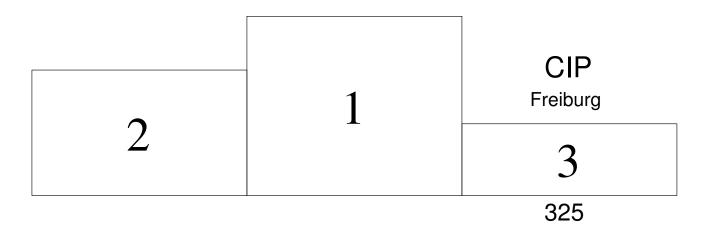
- AIGER = And-Inverter-Graphs (AIGs) with latches
- all submitted solvers can read AIGER now

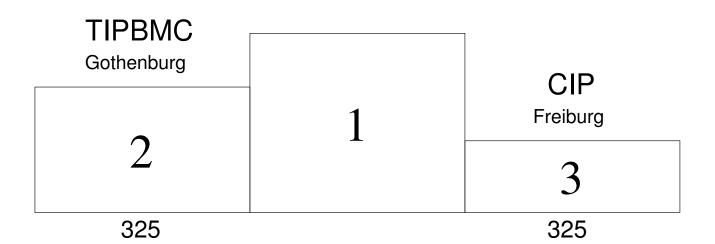
except NuSMV

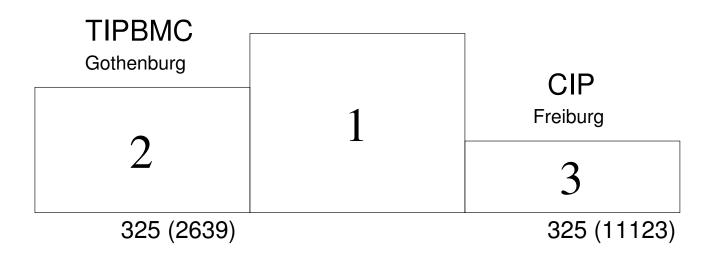
- 900 seconds time limit, 7 GB memory limit
  - 32 node cluster, Intel Quad Core 2.6 GHz processors, 8 GB, Ubuntu

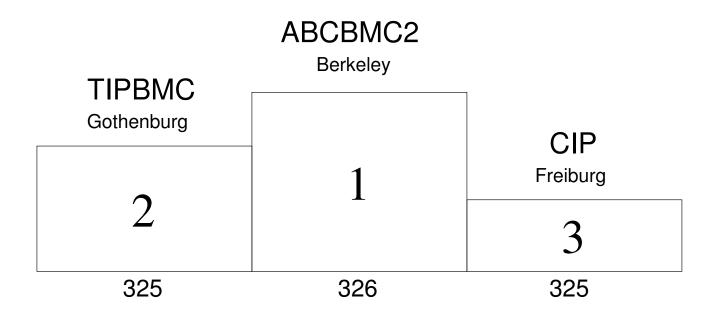
- while collecting solvers / instances did some 10 and 100 seconds mini-competitions
  - BIP fixed once, ABC fixed a couple of times due to discrepancies
  - PDTRAV fixed due to discrepancies and a "file race"
- one almost final 900 seconds test still had one discrepancy
  - ABC proved UNSAT and PDTRAV claimed SAT but can not produce witnesses
  - delta debugging the discrepancy hinted towards PDTRAV being wrong
  - PDTRAV was fixed for final run
- while running the final run Gianpiero sent another fix for PDTRAV
  - 2 benchmarks produced wrong result in his own tests, entered fixed version
- final run without discrepancies

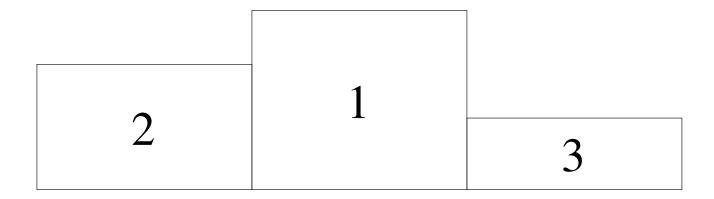


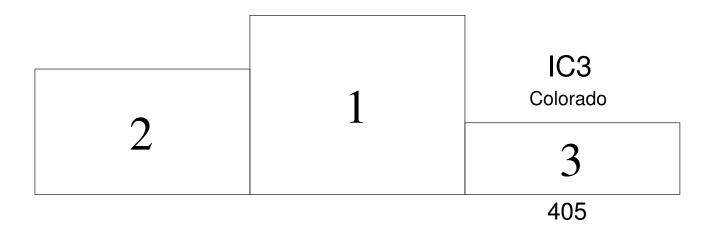




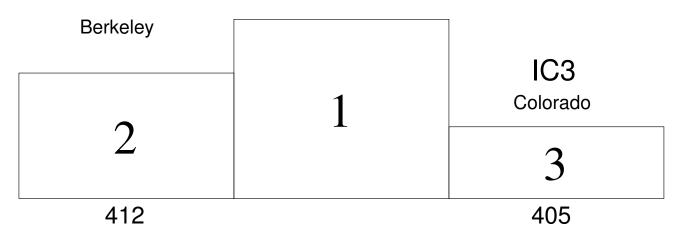








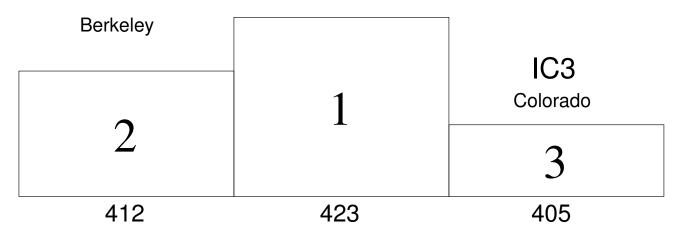
## **ABCSUPERPROVE**

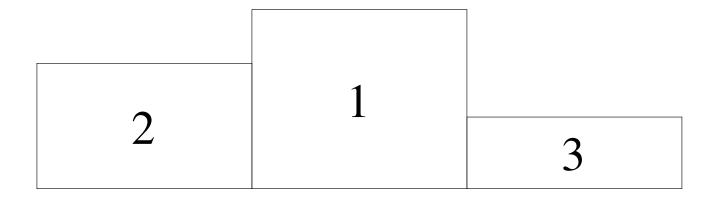


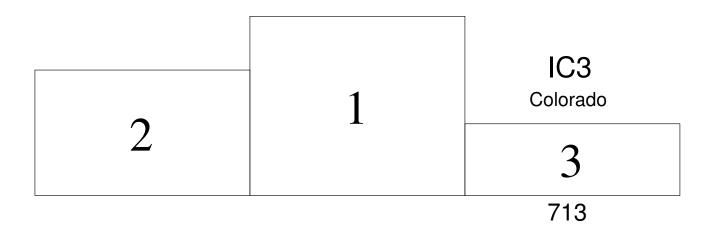
## PDTRAV

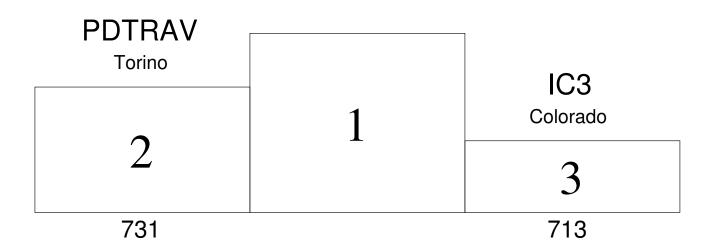
Torino

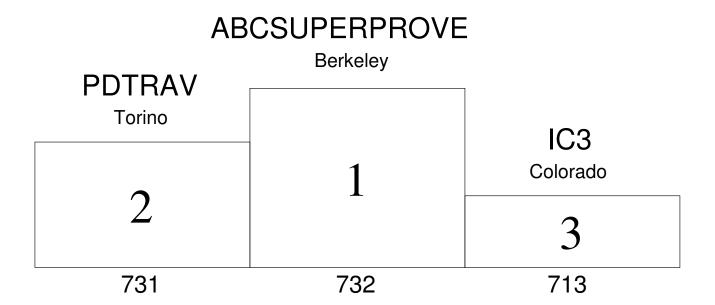
## **ABCSUPERPROVE**

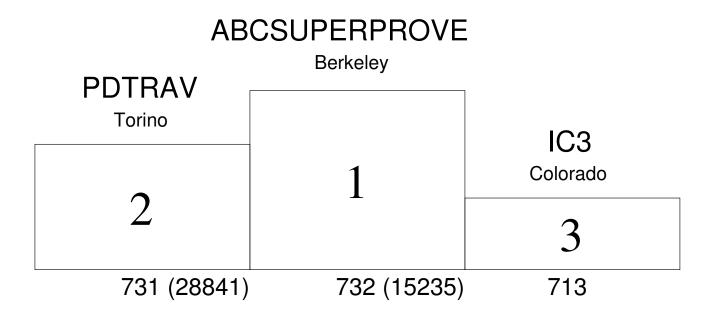




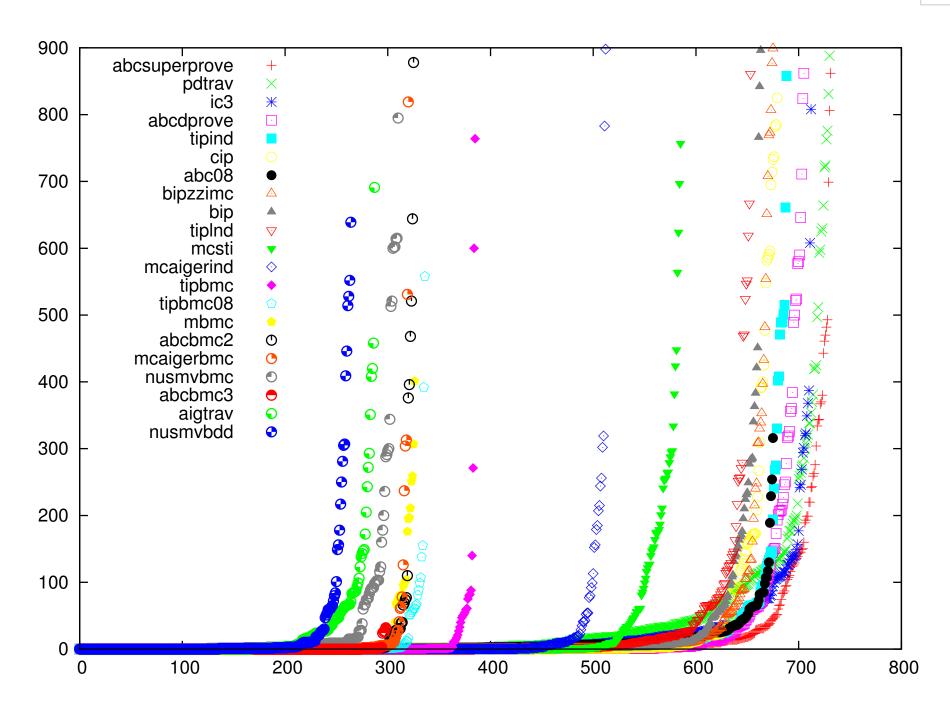


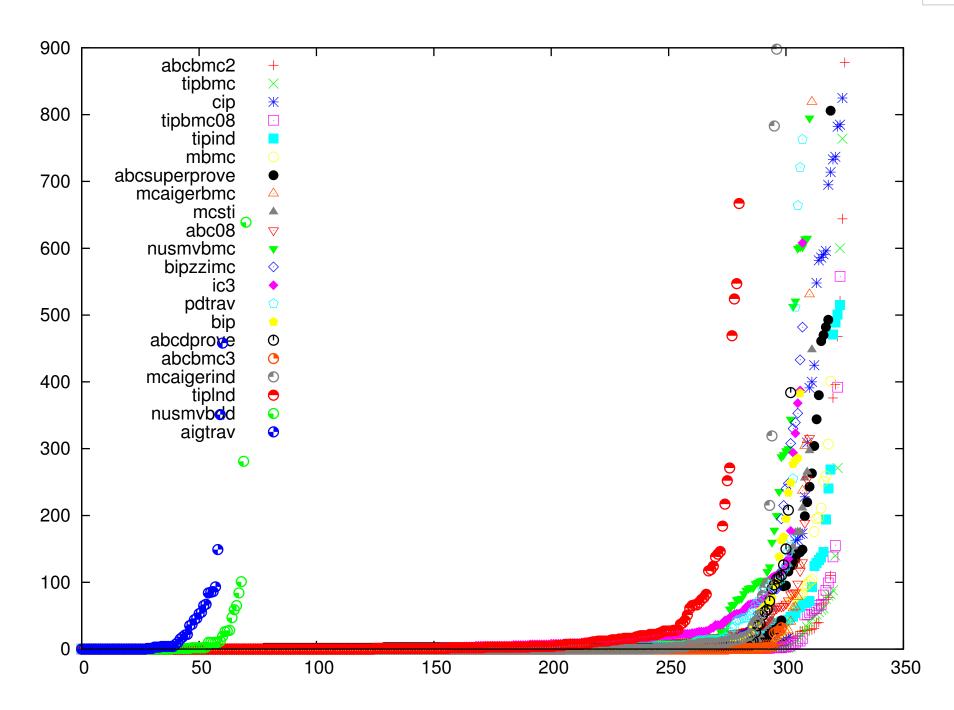


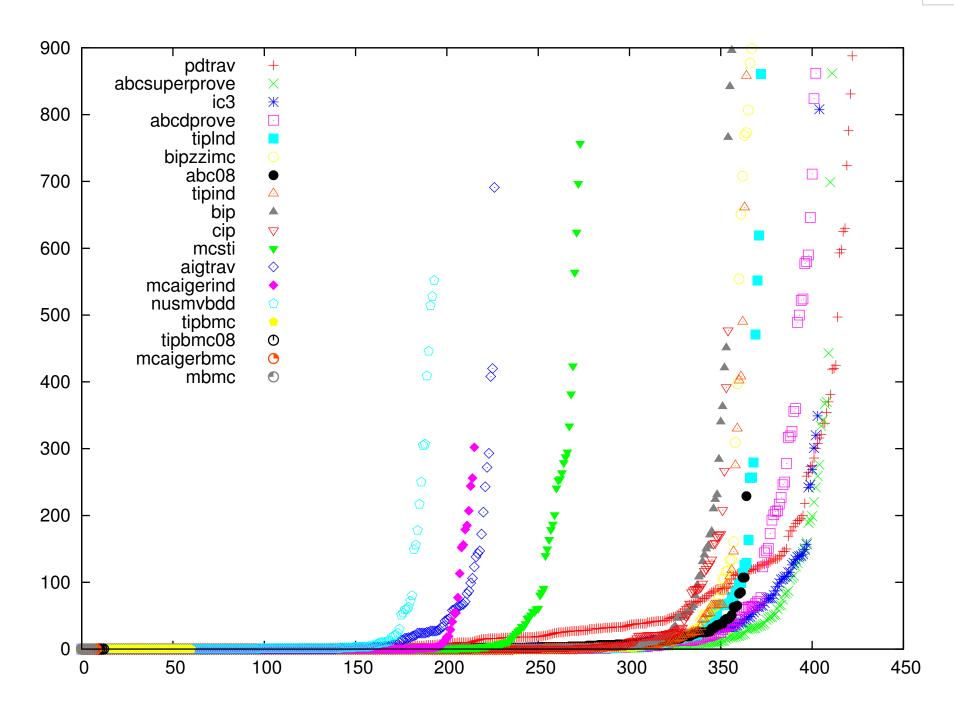




	solver	solved	sat	uns	faile	d to	mo	s11	s6	uk	time	sum-mb	max-mb
1	abcsuperprove	732	320	412	86	67	0	0	0	19	15235	39973	2509
2	pdtrav	731	308	423	87	84	0	0	2	1	28841	57557	1078
3	ic3	713	308	405	105	105	0	0	0	0	13476	22481	511
4	abcdprove	706	303	403	112	59	0	0	0	53	14985	25359	719
5	tipind	689	324	365	129	121	0	0	0	8	10576	7823	266
6	cip	680	325	355	138	138	0	0	0	0	15568	32163	1831
7	abc08	676	311	365	142	88	0	0	4	50	5788	33635	211
8	bipzzimc	676	308	368	142	129	0	0	4	9	13415	26652	1547
9	bip	664	307	357	154	138	0	0	6	10	10638	19469	2455
10	tiplnd	654	281	373	164	164	0	0	0	0	11360	9822	701
11	mcsti	586	312	274	232	229	0	3	0	0	11101	15492	672
12	mcaigerind	513	297	216	305	302	0	0	0	3	5162	4894	159
13	tipbmc	386	325	61	432	220	0	0	0	212	2639	5362	573
14	tipbmc08	337	324	13	481	235	0	16	0	230	2199	4570	504
15	mbmc	327	320	7	491	447	0	5	0	39	3236	20367	1828
16	abcbmc2	326	326	0	492	457	35	0	0	0	4126	17679	4254
17	mcaigerbmc	321	312	9	497	308	9	0	0	180	2831	11714	2128
18	nusmvbmc	311	311	0	507	486	0	0	0	21	9579	38472	959
19	abcbmc3	299	299	0	519	22	5	0	0	492	171	5509	497
20	aigtrav	288	61	227	530	358	172	0	0	0	6820	102731	6034
21	nusmvbdd	265	71	194	553	225	328	0	0	0	6230	37464	6710







• 0 / 1 / X initialized latches

(X = non deterministic, i.e. not 3-valued logic)

- multiple properties
  - 'b' section of bad state properties

(negation of safety)

- 'n' section of non progress properties

(negation of liveness)

- environment / fairness constraints
  - 'c' section of invariant environment constraints
  - 'f' section of fairness constraints
- binary encoding of literals in header sections

(and no ASCII format anymore)

• new witness / trace definition for multiple properties

- 173 new benchmarks: will be published in the AIGER 2.0 format
- 21 model checkers from 9 groups, 4 new entries, 3 new versions
- progress
  - mostly in unsatisfiable category

(no bad state found)

one promising new technology

(by Aaron Bradley)

• next time: AIGER 2.0 with multiple properties, qualification round

Thank you, to all the submitters!

solver	failed	to	mo	s11	s6	uk	
abcsuperprove	86	67	0	0	0	19	19 times 2
pdtrav	87	84	0	0	2	1	1 out of memory
ic3	105	105	0	0	0	0	
abcdprove	112	59	0	0	0	53	53 times 2
tipind	129	121	0	0	0	8	8 times UNKNOWN (> 1000 steps)
cip	138	138	0	0	0	0	
abc08	142	88	0	0	4	50	50 times 2
bipzzimc	142	129	0	0	4	9	7 mo, 4 assert, 2 s11
bip	154	138	0	0	6	10	10 mo, 6 assert
tiplnd	164	164	0	0	0	0	
mcsti	232	229	0	3	0	0	3 s11
mcaigerind	305	302	0	0	0	3	? (3 > 1000  steps)
tipbmc	432	220	0	0	0	212	212 UNKNOWN (> 1000 steps)
tipbmc08	481	235	0	16	0	230	230 UNKNOWN (> 1000 steps)
mbmc	491	447	0	5	0	39	35 UNKNOWN (?), 4 mo
abcbmc2	492	457	35	0	0	0	
mcaigerbmc	497	308	9	0	0	180	? (180 > 1000 steps)
nusmvbmc	507	486	0	0	0	21	21 times > 1000 steps
abcbmc3	519	22	5	0	0	492	492 times 2
aigtrav	530	358	172	0	0	0	
nusmvbdd	553	225	328	0	0	0	

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