Detailed Experimental Results on the QBF Preprocessor bloqqer

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Abstract

This document contains the detailed results of the experiments described in the paper *Quantified Blocked Clause Elimination*, where bloqqer, a preprocessor for quantified Boolean formulas (QBF), is introduced. In the following, the impact of applying bloqqer on the QBF used in the QBF Competition 2010 with respect to formula size as well as the impact with respect to the solving time spent by four different state-of-the-art QBF solvers. Furthermore, we compare bloqqer to sQueezeBF, another preprocessor for QBF and show the effects when both are sequentially applied.

1 Testing Environment

- *Testset*: QBF Competition 2010[1]
- *Testing environment*: 2.83 GHz Intel Core 2 Quad, 8 GB, Ubuntu 4.3.3
- *Solvers*:
  - **DepQBF** (internal version): available on request
    `http://fmv.jku.at/depqbf/`
  - **QuBE** (Version 7.1):
    `http://www.star.dist.unige.it/%7Eqube/Download/Data/Solver/QuBE7.1.gz`
  - **Nenofex** (internal version): available on request
    `http://fmv.jku.at/papers/LonsingBiere-SAT08.pdf`
  - **Quantor** (Version 3.0):
    `http://fmv.jku.at/quantor`
- *Preprocessors*:
  - **bloqqer**: Version 031
    `http://fmv.jku.at/bloqqer/`
  - **sQueezeBF** (Version 7.1 integrated in QuBE):
    `http://www.star.dist.unige.it/%7Eqube/Download/Data/Solver/QuBE7.1.gz`

[1] see `http://www.qbflib.org`

2 Formulas Solved by Preprocessors

Columns in Table 1:

- bloqqer: only bloqqer is applied
- sQueezeBF: only sQueezeBF is applied
- bloqqer/sQueezeBF: first bloqqer and then sQueezeBF is applied
- sQueezeBF/bloqqer: first sQueezeBF and then bloqqer is applied

- total: number of solved formulas
- sat: number of solved formulas which are true
- unsat: number of solved formulas which are false

Table 1: Formulas solved by preprocessors

Family	bloqqer			sQueezeBF			bloqqer/ sQueezeBF			sQueezeBF/ bloqqer		
	total	sat	unsat	total	sat	unsat	total	sat	unsat	total	sat	unsat
Abduction	23	10	13	2	2	0	23	10	13	27	12	15
Adder	2	2	0	0	0	0	2	2	0	2	2	0
blackbox-01X-QBF	11	0	11	4	0	4	11	0	11	11	0	11
Blocks	2	1	1	0	0	0	2	1	1	1	1	0
BMC	6	0	6	5	0	5	6	0	6	5	0	5
Chain	1	1	0	1	1	0	1	1	0	1	1	0
circuits	0	0	0	0	0	0	0	0	0	0	0	0
conformant	1	0	1	1	0	1	1	0	1	1	0	1
Connect4	7	0	7	7	0	7	7	0	7	7	0	7
Counter	1	1	0	0	0	0	1	1	0	2	2	0
Debug	0	0	0	0	0	0	0	0	0	0	0	0
evader	0	0	0	0	0	0	0	0	0	1	0	1
FPGA*	0	0	0	0	0	0	0	0	0	0	0	0
Impl	1	1	0	1	1	0	1	1	0	1	1	0
jmc	0	0	0	0	0	0	0	0	0	0	0	0
mqm	0	0	0	0	0	0	0	0	0	0	0	0
pan	65	34	31	6	4	2	65	34	31	64	33	31
Rintanen	0	0	0	0	0	0	0	0	0	0	0	0
Sakallah	2	1	1	0	0	0	2	1	1	4	3	1
Scholl-Becker	0	0	0	0	0	0	1	0	1	0	0	0
SortingNet	0	0	0	0	0	0	0	0	0	0	0	0
SzymanskiP	2	0	2	0	0	0	2	0	2	2	0	2
tipdiam	3	3	0	2	2	0	3	3	0	7	7	0
tipfixpoint	9	1	8	1	0	1	10	2	8	5	0	5
Toilet	10	7	3	7	5	2	10	7	3	16	7	9
VonNeumann	2	0	2	2	0	2	2	0	2	2	0	2
sum	148	62	86	39	15	24	150	63	87	159	69	90

3 Impact of Preprocessors on Formula Size

Columns in Table 2:

- V (%V): number of variables (increase/decrease of variable number in percent)
- C (%C): number of clauses (increase/decrease of clause number in percent)
- A (+/−A): number of quantifier alternations (increase/decrease of quantifier alternation number)

Family	none			bloqqer			sQueezeBF			bloqqer/ sQueezeBF			sQueezeBF/ bloqqer		
	V	C	A	%V	%C	+/−A	%V	%C	$+/-A$	%V	%C	+/−A	%V	%C	+/−A
Abduction	1474	3435	2	-38	-22	-2	-7	-20	-1	11	53	-1	-43	-28	-2
Adder	3527	4405	3	-67	266	-1	-26	-37	0	-62	316	0	-68	263	-1
blackbox*	11437	27819	153	-95	-77	-145	4	-81	-145	-94	-73	-144	-90	-70	-145
Blocks	518	6756	2	-44	-47	-1	7	-48	0	14	-10	0	-47	-54	5
BMC	265932	680732	2	-98	-92	-1	-78	-95	0	-98	-96	0	-98	-95	-1
Chain	3290	19663	2	-100	-100	-2	-100	-100	-2	-100	-100	-2	-100	-100	0
circuits	1400	1920	2	-61	137	0	0	-40	0	-61	137	0	-53	54	-2
confplan	1285	47890	2	-56	-6	-1	49	-70	0	-50	-52	0	-45	-71	0
Connect4	218810	93504	46	-99	-82	-32	-89	-45	-5	-96	-50	-6	-96	-53	-44
Counter	1951	5169	28	-80	-61	-22	1	-1	0	-71	-47	-20	-87	-74	12
Debug	159502	1036810	2	-3	-15	0	-63	-52	0	-100	-100	-2	-100	-100	1
evadepursue	7666	74014	9	-40	-54	0	-2	-51	0	-41	-54	0	-58	-63	-9
FPGA*	65	433	2	332	828	0	1	-5	0	362	828	0	322	845	7
Impl	74	146	36	-100	-100	-36	-100	-100	-36	-100	-100	-36	-100	-100	-34
jmc_quant	508	995	4	25	321	0	0	-68	0	25	321	0	71	325	-2
mqm	1724	5060	18	-50	10	-2	0	-14	0	-49	-1	-2	-50	12	-18
pan	1847	10999	32	-91	-87	-31	38	-40	-11	-48	80	-8	-88	-83	-28
Rintanen	1871	178750	2	-8	-1	0	7	0	0	-1	-1	0	-21	-2	14
Sakallah	44526	29282	2	-81	-50	-1	-79	-76	-1	-85	-61	0	-94	-81	-1
Scholl-Becker	2758	7712	5	-83	-30	1	34	-43	-1	-80	-29	1	-77	-14	-3
SortNet	1491	4972	2	-70	-10	0	21	-30	0	-70	-10	0	-70	-9	-1
SzymanskiP	148973	168917	2	-100	-100	-2	-7	-70	0	-100	-100	-2	-100	-100	3
tipdiam	5397	15428	2	-91	-79	-1	4	-78	0	-86	-73	0	-91	-80	0
tipfixpoint	9103	26407	2	-95	-88	-1	7	-71	0	-91	-80	0	-90	-81	-2
Toilet	365	3129	2	-52	-100	-2	30	-44	-2	-33	-100	-2	-46	-100	-1
VonNeumann	1040116	1523169	2	-100	-100	-2	-100	-100	-2	-100	-100	-2	-100	-100	-1

Table 2: Impact of preprocessors

4 bloqqer: Impact of Different Options

Columns in Table 3 (applied solver is DepQBF):

- sQueezeBF: sQueezeBF with all options enabled
- bloqqer: bloqqer with all options enabled
- bloqqer without BCE ext.: BCE extensions (i.e., covered literal detection, hidden blocked clause/tautology elimination) disabled
- bloqqer without BCE: BCE (and BCE extensions) disabled
- bloqqer BCE only: preprocessing techniques equivalent literal reasoning, variable elimination, and variable expansion are disabled

Table 3: Expermiments with different options enabled for bloqqer

		# formulas				runtime (sec)		
	preprocessor	SOLVED	SAT	UNSAT	UNKN	$\sum$ (10^3)	AVG	MEDIAN
DepQBF	sQueezeBF/bloqqer	482	234	248	86	102	180	5
	bloqqer	467	224	243	101	112	198	4
	bloqqer without BCE ext.	454	217	237	114	126	222	5
	bloqqer/sQueezeBF	452	213	239	116	147	258	18
	bloqqer without BCE	438	203	235	130	140	246	5
	sQueezeBF	435	201	234	133	131	231	5
	bloqqer BCE only	403	195	208	165	166	294	12
	DepQBF	373	167	206	195	189	332	25

5 Overview on Runtime Behavior

Table 4: Expermiments with various solvers

		# formulas				runtime (sec)		
	preprocessor	SOLVED	SAT	UNSAT	UNKN	$\sum$ (10^3)	AVG	MEDIAN
DepQBF	sQueezeBF/bloqqer	482	234	248	86	102	180	5
	bloqqer	467	224	243	101	112	198	5
	bloqqer/ sQueezeBF	452	213	239	116	147	258	19
	sQueezeBF	435	201	234	133	131	231	6
	no preprocessing	373	167	206	195	189	332	26
QuBE	sQueezeBF/bloqqer	454	207	247	114	129	227	7
	bloqqer	444	200	244	124	139	246	5
	bloqqer/sQueezeBF	421	183	238	147	174	307	27
	sQueezeBF	406	181	225	162	177	313	31
	no preprocessing	332	135	197	236	242	426	258
Nenofex	bloqqer/sQueezeBF	271	134	137	297	273	482	76
	sQueezeBF/bloqqer	270	136	134	298	277	488	31
	bloqqer	268	132	136	300	276	487	23
	sQueezeBF	246	122	124	322	297	524	88
	no preprocessing	221	107	114	347	319	561	113
Quantor	bloqqer	288	145	143	280	266	468	34
	sQueezeBF/bloqqer	285	147	138	283	268	472	39
	bloqqer/sQueezeBF	270	131	139	298	276	486	34
	sQueezeBF	222	106	116	346	318	561	49
	no preprocessing	206	100	106	362	333	587	38

6 Detailed Result for the Various Solvers

The following tables show the number of solved formulas (true solved formulas).

Table 5: Detailed results of DepQBF on benchmark set of the QBF Competition 2010

Family	sQueezeBF/ bloqqer	bloqqer/ sQueezeBF	bloqqer	sQueezeBF	no preproc.
Abduction (52)	48 (29)	49 (30)	49 (30)	48 (29)	50 (31)
Adder (15)	3 (3)	4 (3)	4 (3)	1 (1)	0 (0)
blackbox∗ (61)	52 (2)	45 (2)	46 (2)	55 (2)	43 (0)
Blocks (5)	4 (2)	5 (2)	5 (2)	5 (2)	4 (1)
BMC (18)	14 (5)	16 (6)	15 (5)	13 (5)	12 (5)
Chain (1)	1 (1)	1 (1)	1 (1)	1 (1)	0 (0)
circuits (3)	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)
conf_planning (15)	5 (4)	5 (4)	5 (4)	5 (4)	4 (3)
Connect4 (11)	8 (0)	8 (0)	8 (0)	8 (0)	8 (0)
Counter (4)	3 (3)	3 (3)	4 (4)	2 (2)	2 (2)
Debug (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
evader-pursuer (22)	17 (7)	11 (2)	11 (3)	10 (3)	10 (3)
FPGA∗ (3)	3 (1)	3 (1)	3 (1)	3 (1)	3 (1)
Impl (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
jmc_quant (3)	3 (2)	3 (2)	3 (2)	3 (2)	0 (0)
mqm (136)	136 (66)	123 (58)	136 (66)	136 (66)	136 (66)
pan (80)	75 (41)	76 (41)	76 (41)	44 (22)	26 (15)
Rintanen (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Sakallah (19)	11 (10)	13 (11)	15 (13)	10 (9)	0 (0)
Scholl-Becker (24)	15 (5)	14 (4)	14 (4)	13 (5)	11 (4)
Sorting_networks (6)	3 (1)	3 (1)	2 (1)	3 (1)	6 (4)
SzymanskiP (2)	2 (0)	2 (0)	2 (0)	2 (0)	0 (0)
tipdiam (14)	13 (12)	8 (8)	8 (8)	11 (10)	3 (3)
tipfixpoint (24)	19 (10)	13 (4)	13 (4)	16 (7)	9 (0)
Toilet (41)	41 (27)	41 (27)	41 (27)	40 (26)	40 (26)
VonNeumann (2)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)

Table 6: Detailed results of QuBE on benchmark set of the QBF Competition 2010

Family	sQueezeBF/ bloqqer	bloqqer/ sQueezeBF	bloqqer	sQueezeBF	no preproc.
Abduction (52)	51 (32)	50 (31)	50 (31)	51 (32)	51 (32)
Adder (15)	3 (3)	3 (3)	3 (3)	0 (0)	0 (0)
blackbox-01X-QBF (59)	55 (0)	50 (0)	50 (0)	55 (0)	46 (0)
blackbox_design (2)	2 (2)	2 (2)	2 (2)	2 (2)	0 (0)
Blocks (5)	3 (1)	3 (1)	4 (1)	3 (1)	3 (1)
BMC (18)	6 (1)	7 (1)	7 (1)	6 (1)	4 (1)
Chain (1)	1 (1)	1 (1)	1 (1)	1 (1)	0 (0)
circuits (3)	2 (2)	1 (1)	1 (1)	1 (1)	1 (1)
conformantPlan (15)	3 (2)	4 (2)	4 (2)	3 (2)	3 (2)
Connect4 (11)	9 (0)	9 (0)	9 (0)	9 (0)	9 (0)
Counter (4)	2 (2)	3 (3)	3 (3)	1 (1)	1 (1)
Debug (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
evader-pursuer (22)	17 (9)	12 (5)	16 (9)	16 (9)	9 (2)
FPGAFAST (2)	2 (1)	2 (1)	2 (1)	1 (0)	2 (1)
FPGASLOW (1)	1 (0)	1 (0)	1 (0)	0 (0)	0 (0)
Impl (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
jmc (3)	3 (2)	3 (2)	3 (2)	3 (2)	0 (0)
mqm (136)	115 (45)	98 (33)	117 (47)	114 (45)	115 (48)
pan (80)	75 (41)	77 (41)	77 (41)	37 (20)	19 (10)
Rintanen (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Sakallah (19)	13 (11)	15 (13)	15 (13)	11 (9)	0 (0)
Scholl-Becker (24)	13 (5)	12 (4)	12 (4)	12 (5)	10 (4)
SortingNets (6)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)
SzymanskiP (2)	2 (0)	2 (0)	2 (0)	2 (0)	0 (0)
tipdiam (14)	14 (12)	8 (8)	8 (8)	13 (12)	3 (3)
tipfixpoint (24)	17 (8)	13 (4)	12 (3)	20 (11)	9 (0)
Toilet (41)	39 (25)	39 (25)	39 (25)	39 (25)	41 (27)
VonNeumann (2)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)

Table 7: Detailed results of Quantor on benchmark set of the QBF Competition 2010

Family	sQueezeBF/ bloqqer	bloqqer/ sQueezeBF	bloqqer	sQueezeBF	no preproc.
bduction (52)	35 (18)	34 (17)	34 (17)	22 (8)	19 (7)
Adder (15)	4 (4)	4 (4)	4 (4)	4 (4)	4 (4)
blackbox-01X-QBF (59)	12 (0)	12 (0)	12 (0)	12 (0)	11 (0)
blackbox_design (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Blocks (5)	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)
BMC (18)	16 (7)	17 (7)	18 (8)	16 (7)	18 (8)
Chain (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
circuits (3)	2 (2)	3 (3)	3 (3)	2 (2)	3 (3)
conformantPlan (15)	8 (4)	9 (4)	9 (4)	9 (4)	10 (4)
Connect4 (11)	7 (0)	7 (0)	7 (0)	7 (0)	7 (0)
Counter (4)	4 (4)	4 (4)	4 (4)	3 (3)	3 (3)
Debug (5)	0 (0)	0 (0)	4 (4)	1 (1)	4 (4)
evader-pursuer (22)	5 (2)	3 (1)	4 (2)	1 (1)	1 (1)
FPGAFAST (2)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)
FPGASLOW (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Impl (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
jmc (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
mqm (136)	18 (10)	6 (2)	18 (9)	2 (2)	2 (2)
pan (80)	74 (41)	76 (41)	75 (41)	55 (25)	40 (19)
Rintanen (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Sakallah (19)	5 (4)	2 (1)	4 (3)	4 (3)	4 (3)
Scholl-Becker (24)	16 (4)	16 (4)	16 (4)	16 (4)	16 (4)
SortingNets (6)	6 (4)	6 (4)	6 (4)	6 (4)	6 (4)
SzymanskiP (2)	2 (0)	2 (0)	2 (0)	0 (0)	0 (0)
tipdiam (14)	8 (8)	4 (4)	4 (4)	4 (4)	2 (2)
tipfixpoint (24)	9 (3)	11 (3)	10 (2)	4 (2)	2 (0)
Toilet (41)	41 (27)	41 (27)	41 (27)	41 (27)	41 (27)
VonNeumann (2)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)

Table 8: Detailed results of Nenofex on benchmark set of the QBF Competition 2010

Family	sQueezeBF/ bloqqer	bloqqer/ sQueezeBF	bloqqer	sQueezeBF	no preproc.
bduction (52)	35 (18)	34 (18)	33 (17)	41 (22)	41 (23)
Adder (15)	8 (4)	8 (4)	8 (4)	13 (8)	12 (7)
blackbox-01X-QBF (59)	12 (0)	12 (0)	12 (0)	11 (0)	11 (0)
blackbox_design (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Blocks (5)	5 (2)	5 (2)	5 (2)	5 (2)	5 (2)
BMC (18)	16 (7)	17 (7)	17 (7)	16 (7)	15 (6)
Chain (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
circuits (3)	2 (2)	3 (3)	3 (3)	3 (3)	3 (3)
conformantPlan (15)	8 (4)	9 (4)	8 (4)	10 (5)	9 (4)
Connect4 (11)	7 (0)	7 (0)	7 (0)	7 (0)	5 (0)
Counter (4)	3 (3)	4 (4)	1 (1)	3 (3)	3 (3)
Debug (5)	0 (0)	0 (0)	3 (3)	0 (0)	2 (2)
evader-pursuer (22)	5 (2)	3 (1)	3 (1)	1 (1)	0 (0)
FPGAFAST (2)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)
FPGASLOW (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Impl (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
jmc (3)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
mqm (136)	2 (2)	1 (1)	2 (2)	0 (0)	0 (0)
pan (80)	74 (41)	74 (41)	73 (40)	55 (26)	41 (19)
Rintanen (1)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Sakallah (19)	6 (5)	7 (6)	7 (6)	5 (4)	2 (1)
Scholl-Becker (24)	14 (2)	15 (3)	14 (2)	14 (3)	11 (2)
SortingNets (6)	6 (4)	6 (4)	6 (4)	6 (4)	6 (4)
SzymanskiP (2)	2 (0)	2 (0)	2 (0)	0 (0)	0 (0)
tipdiam (14)	8 (8)	4 (4)	4 (4)	3 (3)	1 (1)
tipfixpoint (24)	7 (2)	10 (2)	10 (2)	3 (1)	4 (0)
Toilet (41)	41 (27)	41 (27)	41 (27)	41 (27)	41 (27)
VonNeumann (2)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)