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The VLSAT-1 Benchmark Suite

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Abstract: This report presents VLSAT-1 (an acronym for “Very Large Boolean SATisfiability problems”), the first part of a benchmark suite to be used in scientific experiments and software competitions addressing SAT-solving issues. VLSAT-1 contains 100 benchmarks of increasing complexity, proposed in DIMACS CNF format under a permissive Creative Commons license. These benchmarks have been used by the 2020 International Competition on Model Counting.

Key-words: benchmark suite, Boolean satisfiability problem, data set, DIMACS CNF, Nested-Unit Petri Net, NUPN, Petri Net, SAT formula, SAT solving

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Le jeu de tests VLSAT-1

Résumé : VLSAT-1 (acronyme anglais de “très grands problèmes de satisfaisabilité booléenne”) est le premier volet d’une suite de tests destinée aux expérimentations scientifiques et aux compétitions de logiciels pour la résolution de problèmes SAT. VLSAT-1 contient 100 tests de complexité croissante, fournis en format DIMACS CNF sous une licence Creative Commons permissive. Ces tests ont été utilisés lors de l’édition 2020 de la compétition internationale sur le comptage de modèles.

Mots-clés : DIMACS CNF, ensemble de données, formule SAT, Nested-Unit Petri Net, NUPN, problème SAT, réseau de Petri, satisfaisabilité booléenne, suite de tests

1 Benchmark Description

VLSAT-1¹ is a collection of 100 SAT formulas, which are listed in Table 1. All these formulas are satisfiable and have been designed to accept a large number of models. Each formula is provided as a separate file, expressed in Conjunctive Normal Form and encoded in the DIMACS-CNF format². Each file is then compressed using bzip2 to save disk space and allow faster downloads. The 100 formulas require 2.1 gigabytes of disk space and 419 megabytes when compressed using bzip2.

2 Scientific Context

These formulas have been generated as a by-product of our recent work [1] on the decomposition of Petri nets into networks of automata, a problem that has been around since the early 70s. Concretely, we developed a tool chain that takes as input a Petri net (which must be ordinary, safe, and hopefully not too large) and produces as output a network of automata that execute concurrently and synchronize using shared transitions. Precisely, this network is expressed as a *Nested-Unit Petri Net* (NUPN) [4], i.e., an extension of a Petri net, in which places are grouped into sets (called *units*) that denote sequential components. A NUPN provides a proper structuration of its underlying Petri net, and enables formal verification tools to be more efficient in terms of memory and CPU time. Hence, the NUPN concept has been implemented in many tools and adopted by software competitions, such as the Model Checking Contest³ [7, 6] and the Rigorous Examination of Reactive Systems challenge⁴ [5, 8]. Each NUPN generated by our tool chain is *flat*, meaning that its units are not recursively nested in each other, and *unit-safe*, meaning that each unit has at most one execution token at a time.

Our tool chain works by reformulating concurrency constraints on Petri nets as logical problems, which can be later solved using third-party software, such as SAT solvers, SMT solvers, and tools for graph colouring and finding maximal cliques [1]. We applied our approach to a large collection of more than 12,000 Petri nets from multiple sources, many of which related to industrial problems, such as communication protocols, distributed systems, and hardware circuits. We thus generated a huge collection of SAT formulas, from which we carefully selected a subset of 100 formulas for VLSAT. Figure 1 shows the scalability of our benchmark suite, which properly represents the diversity of our experiments.

3 Structure of VLSAT Formulas

Each of our formulas was produced for a particular Petri net. A formula depends on three factors:

- the set P of the places of the Petri net;
- a *concurrency relation* \parallel defined over P such that $p \parallel p'$ is the two places p and p' may simultaneously have an execution token; and
- a chosen number n of units.

¹<https://cadp.inria.fr/resources/vlsat>

²<http://www.satcompetition.org/2009/format-benchmarks2009.html>

³<https://mcc.lip6.fr>

⁴<http://rers-challenge.org>

| <i>no.</i> | <i>variables</i> | <i>clauses</i> |
|------------|------------------|----------------|
| 1 | 10 | 17 |
| 2 | 12 | 16 |
| 3 | 14 | 19 |
| 4 | 15 | 23 |
| 5 | 16 | 24 |
| 6 | 18 | 21 |
| 7 | 18 | 49 |
| 8 | 21 | 40 |
| 9 | 24 | 34 |
| 10 | 24 | 56 |
| 11 | 27 | 54 |
| 12 | 28 | 56 |
| 13 | 30 | 58 |
| 14 | 32 | 84 |
| 15 | 33 | 116 |
| 16 | 35 | 82 |
| 17 | 38 | 53 |
| 18 | 40 | 108 |
| 19 | 44 | 91 |
| 20 | 44 | 167 |
| 21 | 48 | 128 |
| 22 | 51 | 194 |
| 23 | 54 | 99 |
| 24 | 54 | 270 |
| 25 | 56 | 270 |
| 26 | 60 | 178 |
| 27 | 64 | 152 |
| 28 | 68 | 161 |
| 29 | 72 | 186 |
| 30 | 75 | 367 |
| 31 | 80 | 178 |
| 32 | 81 | 333 |
| 33 | 85 | 377 |
| 34 | 90 | 316 |

| <i>no.</i> | <i>variables</i> | <i>clauses</i> |
|------------|------------------|----------------|
| 35 | 93 | 409 |
| 36 | 96 | 611 |
| 37 | 102 | 481 |
| 38 | 108 | 345 |
| 39 | 112 | 238 |
| 40 | 117 | 328 |
| 41 | 120 | 724 |
| 42 | 120 | 1016 |
| 43 | 130 | 393 |
| 44 | 135 | 510 |
| 45 | 140 | 1371 |
| 46 | 144 | 648 |
| 47 | 153 | 714 |
| 48 | 160 | 1028 |
| 49 | 168 | 722 |
| 50 | 170 | 1247 |
| 51 | 185 | 1132 |
| 52 | 195 | 899 |
| 53 | 196 | 1092 |
| 54 | 210 | 1275 |
| 55 | 222 | 1477 |
| 56 | 228 | 3437 |
| 57 | 240 | 1624 |
| 58 | 252 | 3132 |
| 59 | 264 | 1474 |
| 60 | 272 | 1898 |
| 61 | 288 | 2066 |
| 62 | 304 | 2782 |
| 63 | 315 | 3608 |
| 64 | 336 | 2394 |
| 65 | 354 | 3239 |
| 66 | 378 | 1893 |
| 67 | 400 | 1580 |

| <i>no.</i> | <i>variables</i> | <i>clauses</i> |
|------------|------------------|----------------|
| 68 | 402 | 10,189 |
| 69 | 418 | 3119 |
| 70 | 448 | 7592 |
| 71 | 476 | 1523 |
| 72 | 496 | 18,680 |
| 73 | 510 | 9201 |
| 74 | 584 | 28,218 |
| 75 | 588 | 8050 |
| 76 | 652 | 29,387 |
| 77 | 702 | 5565 |
| 78 | 735 | 23,842 |
| 79 | 810 | 22,731 |
| 80 | 900 | 15,616 |
| 81 | 992 | 13,641 |
| 82 | 1104 | 75,598 |
| 83 | 1200 | 31,325 |
| 84 | 1365 | 26,963 |
| 85 | 1600 | 31,240 |
| 86 | 1984 | 60,716 |
| 87 | 2289 | 274,818 |
| 88 | 2450 | 58,066 |
| 89 | 3480 | 149,734 |
| 90 | 3920 | 93,576 |
| 91 | 4114 | 186,615 |
| 92 | 5184 | 184,104 |
| 93 | 6954 | 399,521 |
| 94 | 9588 | 392,364 |
| 95 | 14,847 | 1,769,105 |
| 96 | 15,498 | 838,393 |
| 97 | 22,110 | 2,753,207 |
| 98 | 49,200 | 7,490,695 |
| 99 | 227,046 | 49,947,755 |
| 100 | 4,114,810 | 3,879,649,625 |

Table 1: List of VLSAT-1 formulas

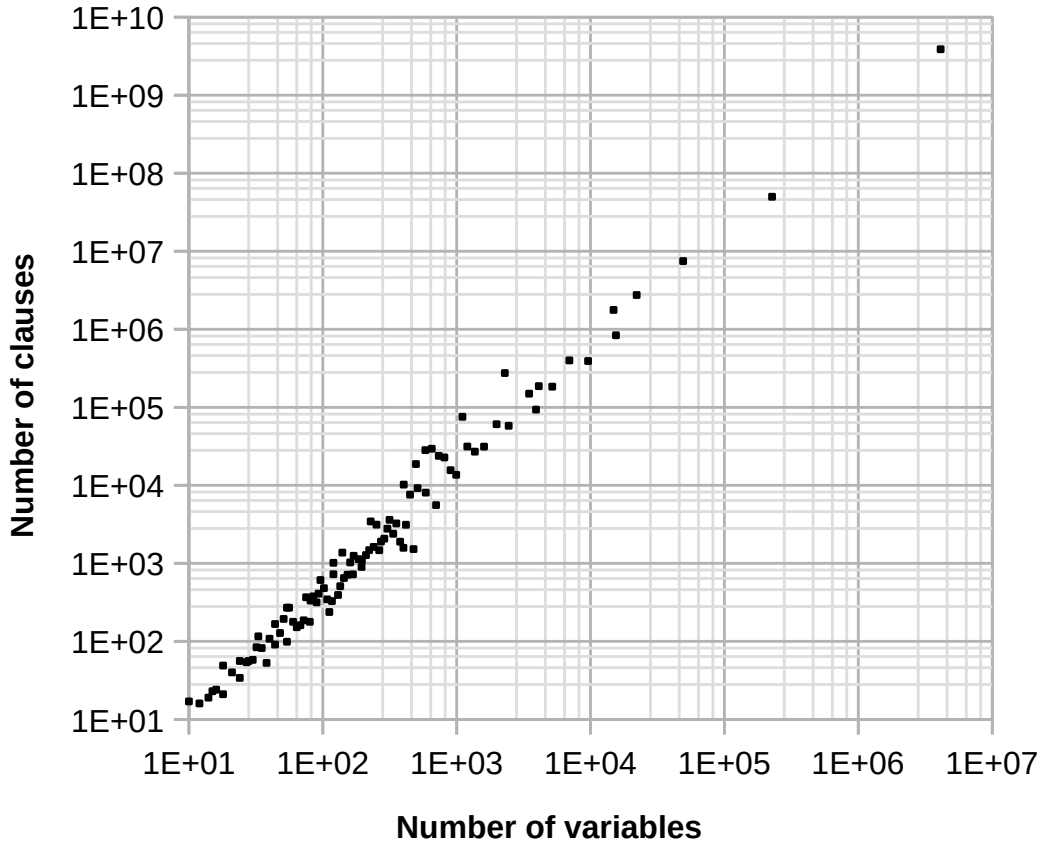


Figure 1: Dispersion of the VLSAT formulas

A formula expresses whether there exists a partition of P into n subsets P_i ($1 \leq i \leq n$) such that, for each i , and for any two places p and p' of P_i , $p \neq p' \implies \neg(p \parallel p')$. A model of this formula is thus an allocation of places into n units, i.e., a valid decomposition of the Petri net. The value of n is chosen large enough so that the formula is satisfiable, i.e., at least one decomposition exists. This can also be seen as an instance of the graph coloring problem, in which n colors are to be used for the graph with vertices defined by the places of P and edges defined by the concurrency relation.

More precisely, each formula was generated as follows. For each place p and each unit u , we created a propositional variable x_{pu} that is true iff place p belongs to unit u . We then added constraints over these variables:

- For each unit u and each two places p and p' such that $p \parallel p'$ and $\#p < \#p'$, where $\#p$ is a bijection from places names to the interval $[1, \text{card}(P)]$, we added the constraint $\neg x_{pu} \vee \neg x_{p'u}$ to express that two concurrent places cannot be in the same unit.
- For each place p , we could have added the constraint $\bigvee_u x_{pu}$ to express that p belongs to at least one unit, but this constraint was too loose and allowed $n!$ similar solutions, just by permuting unit names. We thus replaced this constraint by a stricter one that

breaks the symmetry between units: for each place p , we added the refined constraint $\bigvee_{1 \leq \#u \leq \min(\#p, n)} x_{pu}$, where $\#u$ is a bijection from unit names to the interval $[1, n]$.

Application

The VLSAT-1 benchmarks are licensed under the CC-BY Creative Commons Attribution 4.0 International License⁵.

Some of the VLSAT-1 formulas have been reused (after some scrambling) in the Instances Track 1 of the Model Counting 2020 Competition [2, 3].

Acknowledgements

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⁶<https://www.grid5000.fr>



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