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PeneLoPe, a parallel clause-freezer solver

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Abstract—This paper provides a short system description of our new portfolio-based solver called PeneLoPe, based on ManySat. Particularly, this solver focuses on collaboration between threads, providing different policies for exporting and importing learnt clauses between CDCL searches. Moreover, different restart strategies are also available, together with a deterministic mode.

I. OVERVIEW

PeneLoPe is a portfolio parallel SAT solver that uses the most effective techniques proposed in the sequential framework: unit propagation, lazy data structures, activity-based heuristics, progress saving for polarities, clause learning, etc. As for most of existing solvers, a first preprocessing step is achieved. For this step -which is typically sequential- we have chosen to make use of SatElite [3].

In addition, PeneLoPe includes a recent technique for its learnt clause database management. Roughly, this new approach follows this schema: each learnt clause is periodically evaluated with a so-called psm measure [1], which is equal to the size of the set-theoretical intersection of the current interpretation and c. Clauses that exhibit a low psm are considered relevant. Indeed, the lower is a psm value, the more likely the related clause is about to unit-propagate some literal, or to be falsified. On the opposite, a clause with a large psm value has a lot of chance to be satisfied by many literals, making it irrelevant for the search in progress.

Thus, only clauses that exhibit a low psm are selected and currently used by the solver, the other clauses being frozen. When a clause is frozen, it is removed from the list of the watched literals of the solver, in order to avoid the computational over-cost of maintaining the data structure of the solver for this useless clause. Nevertheless, a frozen clause is not erased but it is kept in memory, since this clause may be useful in the next future of the search. As the current interpretation evolves, the set of learnt clauses actually used by the solver evolves, too. In this respect, the psm value is computed periodically, and sets of clauses are frozen or unfrozen with respect to their freshly computed new value.

Let $P_k$ be a sequence where $P_0 = 500$ and $P_{i+1} = P_i + 500 + 100 \times i$. A function "updateDB" is called each time the number of conflict reaches $P_i$ conflicts (where $i \in [0..\infty]$).

This function computes new psm values for every learnt clauses (frozen or activated). A clause that has a psm value less than a given limit $l$ is activated in the next part of the search. If its psm does not hold this condition, then it is frozen. Moreover, a clause that is not activated after $k$ (equal to 7 by default) time steps is deleted. Similarly, a clause remaining active more than $k$ steps without participating to the search is also permanently deleted (see [1] for more details).

Besides the psm technique, PeneLoPe also makes use of the lbd value defined in [2]. lbd is used to estimate the quality of a learnt clause. This new measure is based on the number of different decision levels appearing in a learnt clause and is computed when the clause is generated. Extensive experiments demonstrates that clauses with small lbd values are used more often than those with higher lbd ones. Note also that lbd of clauses can be recomputed when they are used for unit propagations, and updated if it becomes smaller. This update process is important to get many good clauses.

Given these recently defined heuristic values, we present in the next Section several strategies implemented in PeneLoPe.

II. DETAILED FEATURES

PeneLoPe proposes a certain number of strategies regarding importation and exportation of learnt clauses, restarts, and the possibility of activating a deterministic mode.

Importing clause policy: When a clause is imported, we can consider different cases, depending on the moment the clause is attached for participating to the search.

- no-freeze: each imported clause is actually stored with the current learnt database of the thread, and will be evaluated (and possibly frozen) during the next call to updateDB.
- freeze-all: each imported clause is frozen by default, and is only used later by the solver if it is evaluated relevant w.r.t. unfreezing conditions.
- freeze: each imported clause is evaluated as it would have been if locally generated. If the clause is considered relevant, it is added to the learnt clauses, otherwise it is frozen.

Exporting clause policy: Since PeneLoPe can freeze clauses, each thread can import more clauses than it would with a classical management of clauses, where all of them are attached. Then, we propose different strategies, more or less restrictive, to select which clauses have to be shared:

- unlimited: any generated clause is exported towards the different threads.
- size limit: only clauses whose size is less than a given value are exported [5].
- lbd limit: a given clause $c$ is exported to other threads if its lbd value $lbd(c)$ is less than a given limit value $d$ (8
by default). Let us also note that the lbd value can vary over time, since it is computed with respect to the current interpretation. Therefore, as soon as lbd(c) is less than d, the clause is exported.

Restarts policy: Beside exchange policies, we define two restart strategies.

- **Luby**: Let li be the ith term of the Luby serie. The ith restart is achieved after li × α conflicts (α is set to 100 by default).
- **LBD** [2]: Let LBDg be the average value of the LBD of each learnt clause since the beginning. Let LBD100 be the same value computed only for the last 100 generated learnt clause. With this policy, a restart is achieved as soon as LBD100×α > LBDg (α is set to 0.7 by default).

In addition, the VSIDS score of variables that are unit-propagated thank for a learnt clause whose lbd is equal to 2 are increased, as detailed in [2].

Furthermore, we have implemented in PeneLoPe a deterministic mode which ensures full reproducibility of the results for both runtime and reported solutions (model or refutation proof). Large experiments show that such mechanism does not affect significantly the solving process of portfolio solvers [4]. Quite obviously, this mode can also be unactivated in PeneLoPe.

III. Fine Tuning Parameters of PeneLoPe

PeneLoPe is designed to be fine-tuned in an easy way, namely without having to modify its source code. To this end, a configuration file (called configuration.ini, an example is provided in Figure 1) is proposed to describe the default behavior of each thread. This file actually contains numerous parameters that can be modified by the user before running the solver. For instance, besides export, import and restart strategies, one can choose the number of threads that the solver uses, the α factor if the Luby techniques is activated for the restart strategy, etc. Each policy and/or value can obviously differ from one thread to the other, in order to ensure diversification.

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