

Improving a Planner’s Performance through Online Heuristic Configuration of Domain Models

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Abstract

The separation of planner logic from domain knowledge supports the use of reformulation and configuration techniques, such as macro-actions and entanglements, which transform the model representation in order to improve a planner’s performance. One drawback of such an approach is that it may require a potentially expensive training phase.

In this paper, we introduce heuristic approaches for the online configuration of planning domain models. The proposed heuristics consider different aspects of PDDL-encoded operators for reordering such operators in the domain model, relying on the assumption that the way in which operators are encoded carries useful information about their expected use.

Heuristics for Domain Model Configurations

Operator ordering in domain models has shown to have considerable impact on the planning process (Howe and Dahlman 2002). Recently, Vallati et al. (2015b) developed an approach that automatically configures domain models by re-ordering their elements (e.g. operators, predicates). This approach relies on an expensive training phase, that requires the availability of a large number of training instances which are representative of the testing ones, in order to effectively configure a domain model for improving the performance of a given domain-independent planner.

Here we propose heuristics for ordering operators in PDDL models. The underlying idea is that the way in which operators are encoded in PDDL carries some knowledge about the expected use of the corresponding actions. Such knowledge can thus be exploited for providing a more suitable ordering of operators, for improving the performance of the planner that will be used for solving the given problem. As we consider the typical domain-independent scenario, where configuration should be performed online, the focus on operators provides a good trade-off between the additional overhead and the potential impact on performance.

Formally, given a planning domain model \mathcal{M} , and the corresponding set of operators $O = (o_1, \dots, o_m)$, we propose heuristics that, by considering some aspects of the operators in O , provide as output an ordered list of operators O_h . Operators are then listed in the domain model accordingly. We introduce five heuristics for ordering operators,

that consider the following aspects: **EFF**, The number of effects; **PRE**, The number of preconditions; **RAT**, The ratio between effects and preconditions; **NEG**, The number of negative effects; and **PAR**, The number of parameters. Considered aspects are quick to compute, and can provide intuition about the expected use of operators. For instance, the presence of a large number of negative effects imply that the corresponding actions are strongly affecting the world, and could therefore be an indication that they are rarely used. On the contrary, the presence of very few preconditions can be an indication of actions that are often used, as the required condition can be easily satisfied. The ratio between effects and preconditions can give some further insights by considering both aspects at the same time: a high ratio value points to actions that have many effects and few preconditions, so that can be used often; a low ratio value may denote some more problematic actions, that require many conditions to be satisfied and have a limited impact on the world –but such limited impact may be of critical importance for achieving goals. Finally, the number of parameters is an indicator of the expected number of grounded actions.

Each heuristic has two possible instantiations: ordering operators according to decreasing or increasing values of the considered metric. Hereinafter, we will use numbers to refer to the ordering, and letters for identifying the heuristic. For instance, **EFF2** indicates that operators are ordered increasingly according to the number of effects, i.e., the first listed operator is the one with the least number of effects. In our implementation, ties are broken following the relative order of operators in the original PDDL model.

Experimental Analysis

We selected 8 planners, based on their performance in the Agile track of IPC 2014 (Vallati et al. 2015a) and/or the use of different planning approaches. Experiments were performed on a quad-core 3.0 Ghz CPU, with 4GB of available RAM and 300 seconds cutoff time. We considered all the domain models used in the Agile track of IPC 2014, but Maintenance, Visitall and Openstack. Maintenance and Visitall have a model composed by only one operator, and proposed heuristics aim at ordering operators within domain models. Openstack has a different model per each problem, where elements of problem and domain models are mixed. This can add noise to the empirical evaluation of the effec-

tiveness of proposed heuristics on domain models that are shared among different problems. Performance is measured in terms of runtime IPC score, PAR10 and coverage.

Firstly, we compared the performance of planners run on the original domain model and on the best heuristically-configured domain model. The best domain model configuration has been selected on a domain-by-domain basis. Remarkably, for all considered planners but Freelunch and Mercury, the IPC score is increased by more than 10%. All the planners but Freelunch show an increased percentage of solved instances when running on the best heuristically-configured models. Mpc, Yahsp3, and Mercury show statistically significant PAR10 performance improvements, according to the Wilcoxon signed rank test. Noteworthy, Mercury shows a very limited PAR10 and IPC score improvement, but the use of the best configured domain models allows the planner to be consistently –even though by few tenths of seconds– faster on most of the benchmarks, when compared to the performance achieved on the original domain model. Freelunch performance is unaffected by the configuration of the domain model. Even the exploitation of specifically configured models, obtained through the approach proposed by Vallati et al. (2015b), does not lead to any noticeable performance improvement. This is possibly due to the peculiar SAT encoding used by Freelunch.

Domain-wise, for most of the planners the IPC score obtained on the original domain model is close to the IPC score achieved on the best configured model only in the Hiking domain. In some domains, i.e. Barman, Cave-diving, Parking, and Tetris, the performance gap between the best and the worst configurations is very large: up to 5 IPC score points out of a maximum of 20. In these domains, the proposed heuristics have an exceptional –either positive or negative– impact on performance, and are therefore able to extract useful information from the PDDL encoding of operators. In the other domain models, we observe that a limited –thus still noticeable– improvement is due to a number of circumstances, such as the fact that all the operators have a very similar structure, or that there are no actions that are used significantly more (less) often than others.

In the typical domain-independent scenario, the configuration that allows a planner to achieve the best performance is unknown. A promising heuristic should be picked beforehand and used on every domain. Interestingly, we observed that it is possible to identify a single domain model configuration heuristic for each planner that generally improves its performance. As a general trend, if a certain heuristic provides the best or nearly the best results on several domain models for a given planner, then we can assume that the heuristics will provide the best or nearly the best results on other domain models for the given planner too. It should be noted that for some of the considered planners, the use of the original models leads to the worst possible performance. This seems to indicate that benchmark models are not usually encoded in a “planner-friendly” strategy.

Interestingly, for BFS, Mpc, Yahsp3, and Jasper, it is possible to identify a domain configuration heuristic that achieves the best runtime performance on most of the domains. Instead, Probe and ArvandHerd are very sensitive to

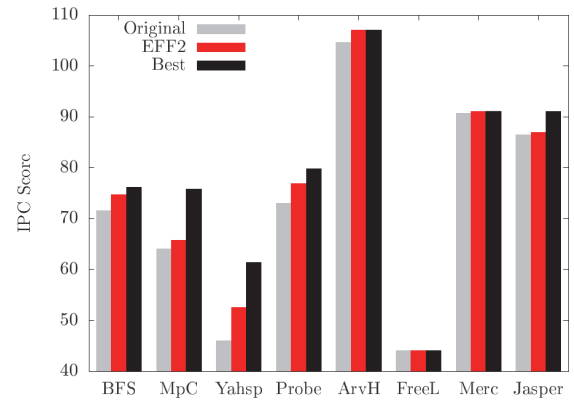


Figure 1: IPC score achieved by planners running on models configured using: the single Best heuristic of a planner, the EFF2 heuristic, and on the original models. IPC score cannot be compared across planners.

the configuration of the domain models, and thus the best configuration heuristics varies between particular domains.

It comes as no surprise that each planner reacts differently for different domain model configurations, and thus there is no “rule them all” configuration heuristics. Nevertheless, our experimental analysis indicates that the EFF2 heuristic outperforms the original models for all the considered planners: the EFF2 heuristic was never the worst, but was the best for ArvandHerd and Freelunch. The differences in the total IPC score for the original models, the EFF2 heuristic and the best planner-specific heuristic are shown in Figure 1. These results indicate that the EFF2 heuristic provides a reasonable alternative that still leads to a better performance than the original models.

Conclusion

In this paper, we proposed a set of heuristics for ordering planning operators in domain models; the approach is based on the idea that the encoding of operators carries knowledge about their expected use in solution plans.

Our extensive experimental analysis demonstrates that proposed heuristics are able to configure domain models for having strong positive impact on performance of state-of-the-art planners, and provides guidelines for identifying an appropriate domain configuration heuristics for a given planner. Specifically, the EFF2 heuristics achieves overall performance improvement with respect to the original models.

References

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