Divide-and-Evolve: the Marriage of Descartes and Darwin

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Abstract

DAE$_{\text{X}}$, the concrete implementation of the *Divide-and-Evolve* paradigm, is a domain-independent satisficing planning system based on Evolutionary Computation. The basic principle is to carry out a *Divide-and-Conquer* strategy driven by an evolutionary algorithm. The key components of DAE$_{\text{X}}$ are a state-based decomposition principle, an evolutionary algorithm to drive the optimization process, and an embedded planner X to solve the sub-problems. The release that has been submitted to the competition is DAE$_{\text{YAHSP}}$, the instantiation of DAE$_{\text{X}}$ with the heuristic forward search YAHSP planner. The marriage of DAE and YAHSP matches a clean role separation: YAHSP gets a few tries to find a solution quickly whereas DAE controls the optimization process.

Introduction

DAE$_{\text{X}}$, the concrete implementation of the *Divide-and-Evolve* paradigm, is a domain-independent satisficing planning system based on Evolutionary Computation (Schoenauer, Savéant, and Vidal 2006). The basic principle is to carry out a *Divide-and-Conquer* strategy driven by an evolutionary algorithm. The algorithm is detailed in (Bibaï et al. 2010a) and compared with state-of-the-art planners. In order to solve a planning task $\mathcal{P}_D(I, G)$, the basic idea of DAE$_{\text{X}}$ is to find a sequence of goals $S_1, \ldots, S_n$, and to rely on an embedded planner X to solve the series of planning tasks $\mathcal{P}_D(S_k, S_{k+1})$, for $k \in [0, n]$ (with $S_0 = I$ and $S_{n+1} = G$). A DAE$_{\text{X}}$ individual is thus a sequence of goals which define a sequence of subproblems to be solved (a *decomposition*). These subproblems are submitted successively to an embedded planner X and the global solution is obtained after the compression of these intermediate solutions. The overall optimization process is controlled by an evolutionary algorithm.

The decomposition principle of DAE$_{\text{X}}$ is very general and could be applied to any type of planning tasks. The scope of the planner is of course the one of the embedded planner X. The release that has been submitted to the competition is DAE$_{\text{YAHSP}}$, the instantiation of DAE$_{\text{X}}$ with the heuristic forward search YAHSP planner (Vidal 2004; 2011). The target is thus temporal satificing planning with conservative semantics, cost planning and classical STRIPS planning. The marriage of DAE and YAHSP matches a clean role separation: YAHSP gets a few tries to find a solution quickly whereas DAE controls the optimization process. In the current release we have introduced an initial estimation processing of the maximum number of tries allowed to YAHSP for all individual evaluations. This parameter is crucial for the time consumption of the algorithm.

The Evolutionary Engine

Figure 1 depicts the standard evolutionary loop which mimics a biological evolution. The fitness implements a gradient towards feasibility for unfeasible individuals and a gradient towards optimality for feasible individuals. Feasible individuals are always preferred to unfeasible ones. Population initialization as well as variation operators are driven by the critical path h^1 heuristic (Haslum and Geffner 2000) in order to discard inconsistent state orderings, and atom mutual exclusivity inference in order to discard inconsistent states. These two computations are done by YAHSP in an initial phase.

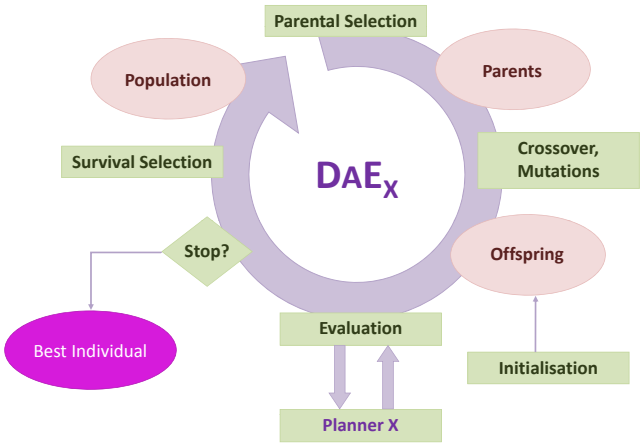

Figure 1: The standard evolutionary loop

Beside a standard one-point crossover for variable length representations, four mutations have been defined: addition

(resp. removal) of a goal in a sequence, addition (resp. removal) of an atom in a goal. Variation operators relax the strictly h^1 ordering of atoms within individuals, since it is only a heuristic estimate.

The selection is a comparison-based deterministic tournament of size 5.

For the sequential release, Darwinian-related parameters of DAE$_X$ have been fixed after some early experiments (Schoenauer, Savéant, and Vidal 2006) whereas parameters related to the variation operators have been tuned using the Racing method (Bibaï et al. 2010b). It should be noted that, due to the conditions of the competition, the parameter setting is global to all domains. In (Bibaï et al. 2010b) we showed that a specific tuning for an instance provides better results as expected and that what we would do for a real-life planning task.

We added two novelties to the version described in (Bibaï et al. 2010a). One important parameter is the maximum number of expanded nodes allowed to the YAHSP subsolver which defines empirically what is considered as an easy problem for YAHSP. As a matter of fact, the minimum number of required nodes varies from few nodes to thousands depending of the planning task. In the current release this number is estimated during the population initialization stage. An incremental loop is performed until the ratio of feasible individuals is over a given threshold or a maximum boundary has been reached. By default this number is doubled at each iteration until at least one feasible individual is produced or 100000 has been reached.

Furthermore we add the capability to perform restarts within a time contract in order to increase solution quality.

The fitness used for the competition differs from the one described in (Bibaï et al. 2010a). The fitness for bad individuals has been simplified by withdrawing the Hamming distance to the goal. The new fitness depends only on the "decomposition distance": the number of intermediate goals reached and more specifically the one that are "useful". A useful intermediate goal is a goal that require a non-empty plan to be reached.

Implementation

The implementation of DAE$_X$ has been made with the STL-based Evolving Objects framework[1] which provides an abstract control structure to develop any kind of evolutionary algorithm in C++. YAHSP is written in the C language.

In order to speed up search, a memozation mechanism has been introduced in YAHSP and carefully controlled to leave memory space for DAE. Indeed, most of the time during a run of YAHSP, and as a consequence during a run of DAE$_{YAHSP}$, is spent in computing the h^{add} heuristic for each encountered state (see (Vidal 2011) for more details about the algorithms of the new version of the YAHSP planner). During a single run of YAHSP, duplicate states are discarded; but during a run of DAE$_{YAHSP}$, the same state can be encoutered multiple times. We therefore keep track of the h^{add} costs of all atoms in the problem for each state, in order to avoid recomputing these values each time a duplicate state is reached. This generally leads to a speedup comprised between 2 and 4. When DAE$_{YAHSP}$ runs out of memory, which obviously happens much faster with the memoization strategy, all stored states and associated costs are flushed. More sophisticated strategies may be implemented, e.g. flushing the oldest or less often encountered states; but we found that the simplest solution of completely freeing the memoized information was efficient enough.

Several biases have been introduced in YAHSP, in order to help DAE$_{YAHSP}$ finding better solutions. The main one is that actions of lower duration are preferred to break ties between several actions of same h^{add} cost, when computing relaxed plans and performing the relaxed plan repair strategy. Another bias is that the cost incrementation made during h^{add}, which is usually equal to 1 for each applied action, is made equal to either the duration or the cost of the action. Although these biases do not change a lot the quality of the plans produced by YAHSP alone, we found that they are of better help to DAE$_{YAHSP}$. However, introducing such biases is not very satisfactorily; it would be better to exactly use the version described in (Vidal 2011). We still have to better investigate the relationships between the evolutionnary engine and the embedded planner, in order to determine how to manage such kind of biases and other tie-breaking strategies.

[1] http://eodev.sf.net

Acknowledgments

This work is being partially funded by the French National Research Agency (ANR) through the COSINUS programme, under the research contract DESCARWIN (ANR-09-COSI-002).

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