On the Generality of Parameter Tuning in Evolutionary Planning

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ABSTRACT

Divide-and-Evolve (DAE) is an original “memeticization” of Evolutionary Computation and Artificial Intelligence Planning. However, like any Evolutionary Algorithm, DAE has several parameters that need to be tuned, and the already excellent experimental results demonstrated by DAE on benchmarks from the International Planning Competition, at the level of those of standard AI planners, have been obtained with parameters that had been tuned once and for-all using the Racing method. This paper demonstrates that more specific parameter tuning (e.g. at the domain level or even at the instance level) can further improve DAE results, and discusses the trade-off between the gain in quality of the resulting plans and the overhead in terms of computational cost.

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I.2.8 [Computing Methodologies]: Artificial Intelligence - Problem Solving, Control Methods, and Search

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1. INTRODUCTION

Parameter tuning is known as one of the main Achilles’ heel of Evolutionary Algorithms (together with their computational cost). Whereas the efficiency of EAs has been demonstrated on several application domains (see for instance [33]), their successes were in general obtained through a tedious and time consuming parameter tuning phase. Furthermore, the newcomer to the field cannot benefit from theoretical guidance or recognized guidelines, and is then tempted to use off-the-shelf parameters, i.e. either default parameters of the framework he is using, or parameter values given in the literature for problems that resemble his.

Parameter setting, however, has today become an important field of research [19]. Following [9], one distinguishes between parameter tuning, that is done off-line, before running the algorithm, and parameter control, that is performed during the run, either based on the behavior of the algorithm (referred to as parameter adaptation), or relying on random modifications of the parameters together with the idea that fitness-based selection will also select adapted parameters (referred to as parameter self-adaptation). This paper is concerned with parameter tuning, i.e. off-line setting of the parameters of an Evolutionary Algorithm, in the domain of AI planning.

Several methods have been proposed for parameter tuning since Grefenstette’s pioneering work [14]. However, they all face the same generalization issue: can a parameter set that has been optimized for a given problem be successfully used to some other problem? The answer of course depends on the similarity between both problems – and the issue then is to estimate the similarities between different optimization problems. However, even restricted to some precise optimization domain (like AI Planning), there are very few examples today of meaningful similarity measures between optimization problems, or, alternatively, of sufficiently precise and accurate features that would allow the user to describe the problem at hand with sufficient accuracy so that the optimal parameter set could be learned from this description, and carried on to other problems with similar description. The one exception we are aware of is the work of Hoos and co-authors in the SAT domain [17]: based on half a century of SAT work, and hundreds of papers, many relevant features have been gathered. Extensive parameter tuning on several thousands of instances have allowed the authors to learn a meaningful mapping between several parameterization of a given algorithm and the resulting performance of the algorithm (in terms of time to solution for satisfiable
SAT problems). Such mapping allows the user to come up with a good, if not optimal, set of parameters by applying this mapping to the features that can be easily computed for each unknown instance she/he has to solve.

This paper is concerned with such issues in the domain of the Artificial Intelligence (AI) Planning problems. An AI planning task written in PDDL (more details in Section 2.1) is specified by a domain, that defines the predicates and the actions, and an instance, that instantiates the objects, and specifies the initial state and a list of goals to reach. A solution is a plan, or a sequence of actions, such that when applied to the initial state it leads the system into a state where all goal atoms are true. Hence, for a given domain, there can exist several instances sharing the same predicates and actions, but differing either by the number of objects, or the initial and goal states.

Unfortunately, there does not exist any set of features for the AI Planning problem that are sufficient to describe the characteristics of a planning task, like mentioned above for the SAT domain [17]. The goal of this paper is hence less ambitious, though it can be seen as a first step in the direction of automatic parameter setting for the Evolutionary AI planner considered here. We will investigate the generality of behavioral parameters, i.e. parameters of the algorithm that directly impact on its behavior during the run (mainly the parameters related to the different variation operators, from their application rates to their internal parameters). We will also consider some structural parameters, namely here the set of predicates that are used to build the candidate solutions in the Evolutionary planner at hand, and analyze whether this set can be reduced, based on the analysis of previous runs, in order to reduce the size of the search space, and, hopefully, the computational cost of the optimization, without degrading the quality of the resulting solutions.

More practically, the experimental investigation proposed here will use 3 different domains of the AI Planning problem that have been proposed in the past International Planning Competitions (of 3 different types, see Section 4.1). Each domain contains a series of instances. Racing [7] will be conducted at a global level (aggregating quality from one instance from each domain), at the domain level (aggregating quality of the biggest instance of the domain), and at the instance level (an optimal parameter set will be determined for each instance). The way the performance of the algorithm decreases when going from instance to domain to global levels will give indications about both the homogeneity of the different domains and instances inside a domain, and the robustness of the parameter setting for the Evolutionary Planner at hand. Furthermore, the very good results that have already been obtained by DAE on those instances compared with the state-of-the-art have used a single parameter set (i.e. the result of global racing) [4]. The results presented here will assess that there is still room for improvement for the Evolutionary Planner DAE.

The paper is organized as follows: domain independent AI Planning is briefly introduced in Section 2.1. Section 2 presents DAE, the specific Evolutionary Planner. Section 3 rapidly recalls the basics of the Racing procedure that has been used here, as well as the experimental protocol. Experimental results are presented and analyzed in Section 4, comparing the performances of the parameter sets obtained with different levels of racing, and comparing the variation among the sets. As usual, Section 5 concludes the paper by sketching directions for further research.

2. DIVIDE AND EVOLVE

2.1 AI Planning

An Artificial Intelligence (AI) planning task is specified by the description of an initial state, a goal state, and a set of possible actions. An action can be applied only if certain conditions in the current state are met, and modifies the current state when applied. A solution to a planning task is an ordered set of actions, whose execution from the initial state transforms it into a state that includes the goal state. The quality criterion of a plan depends on the type of available actions: number of actions in the simplest case (aka STRIPS domain); total cost for actions with cost; total makespan for durative actions which, in addition, may temporally overlap.

Domain-independent planners rely on the Planning Domain Definition Language (PDDL) [22], inherited from the STRIPS model [10], to standardize and represent a planning task. The language has been extended for representing temporality and action concurrency in PDDL2.1 [11]. The history of PDDL is closely related to the different editions of the International Planning Competitions (IPCs http://ipc.icaps-conference.org/), and the problems submitted to the participants are still the main benchmarks in AI Planning (see Section 4.1).

The description of a planning task splits into two separate parts: the generic domain on the one hand and a specific instance scenario on the other hand. The domain definition specifies object types, predicates and actions which capture the possible state changes, whereas the instance scenario declares the objects of interest, gives the initial state and provides a description of the goal. A state is described by a set of atomic formulae, or atoms. An atom is defined by a predicate symbol from the domain definition, followed by a list of object identifiers: (PREDICATE_NAME OBJ1 ... OBJN).

The initial state is complete, i.e. it gives a unique status of the world, whereas the goal might be a partial state, i.e., it can be true in many different (complete) states. An action is composed of a set of preconditions and a set of effects, and applies to a list of variables given as arguments, and possibly a duration or a cost. Preconditions are logical constraints which apply domain predicates to the arguments and trigger the effects when they are satisfied. Effects enable state transitions by adding or removing atoms.

A solution to a planning task is a consistent schedule of grounded actions whose execution in the initial state leads to a state that contains one goal state, i.e., where all atoms of the problem goal are true. A planning task defined on domain D with initial state I and goal G will be denoted \( P_D(I, G) \) in the following.

2.2 Evolutionary AI Planning

Early approaches to AI Planning using Evolutionary Algorithms directly handled possible solutions, i.e. possible plans: an individual is an ordered sequence of actions [28, 23, 31, 32, 8]. However, as it is often the case in Evolutionary Combinatorial optimization, those direct encoding approaches have limited performance in comparison to the traditional AI planning approaches, and hybridization with
classical methods had been the way to success in many combinatorial domains, as witnessed by the fruitful emerging domain of memetic algorithms [15]. Along those lines, though relying on an original “memeticization” principle, a novel hybridization of Evolutionary Algorithms (EAs) with AI Planning, termed Divide-and-Evolve (DaE) has been proposed [26, 27]. For a complete formal description, see [4].

In order to solve a planning task \( P_D(I,G) \), the basic idea of DaE is to find a sequence of states \( S_1, \ldots , S_n \), and to use some embedded planner to solve the series of planning tasks \( P_D(S_k, S_{k+1}) \), for \( k \in [0,n] \) (with the convention that \( S_0 = I \) and \( S_{n+1} = G \)). The generation and optimization of the sequence of states \( (S_1) \) is driven by an evolutionary algorithm, and we will now describe its main components: the problem-specific representation of individuals, fitness, and variation operators.

2.3 DaE Representation

A state is a list of atoms built over the set of predicates and the set of object instances. However, searching the space of complete states would result in a rapid explosion of the size of the search space. Moreover, goals of planning problem need only to be defined as partial states. It thus seems more practical to search only sequences of partial states, and to limit the choice of possible atoms used within such partial states. However, this raises the issue of the choice of the atoms to be used to represent individuals, among all possible atoms. The result of the previous experiments on different domains of temporal planning tasks from the IPC benchmark series [6] demonstrates the need for a very careful choice of the atoms that are used to build the partial states. The method used to build the partial states is based on an estimation of the earliest time from which an atom can become true. Such estimation can be obtained based on an estimation of the earliest time from which an all possible atoms. The result of the previous experiments to be used to represent individuals, among of the atoms \( \{1 \leq k \leq n \} \). The generation and optimization \( I, G \)

\[ H \] represents a heuristic function \( (e.g. h^1, h^2, \ldots) \) \[ 16 \]. The possible start times are then used in order to restrict the candidate atoms for each partial state. A partial state is built at a given time by randomly choosing among several atoms that are possibly true at this time. The sequence of states is then built by preserving the estimated chronology between atoms \( \text{(time consistency)} \). Heuristic function \( h^k \) has been used for all experiments presented here. However, these restrictions may still contain a large number of atoms, and it might be possible to further restrict this list only allowing atoms that are built with a restricted set of predicates. Manual choice had been used in the early versions of DaE [3]. However, it can be expected that such structural parameters can be learned by post-mortem analyzes of different runs of DaE on several problems of the same domain. This will be investigated in Section 4.

Nevertheless, even when restricted to specific choices of atoms, the random sampling can lead to inconsistent partial states, because some sets of atoms can be mutually exclusive \( \text{(mutex in short)} \). Whereas it could be possible to allow \text{mutex} atoms in the partial states generated by DaE, and to let evolution discard them, it seemed more efficient to try to a priori forbid them. In practice, it is not possible to decide if several atoms are \text{mutex} unless solving the complete problem. Nevertheless, binary \text{mutexes} can be approximated with a variation of the \( h^k \) heuristic function \[ 16 \] in order to build quasi pairwise-\text{mutex}-free states \( \text{(i.e., states where no pair of atoms are \text{mutex})} \).

An individual in DaE is hence represented as a variable-length ordered time-consistent list of partial states, and each state is a variable-length list of atoms that are not pairwise \text{mutex}. Furthermore, all operators that manipulate the representation \( \text{(see below)} \) maintain the chronology between atoms and the local consistency of a state, i.e. avoid pairwise mutexes.

2.4 Initialization and Variation Operators

The initialization of an individual is the following: first, the number of states is uniformly drawn between 1 and the number of estimated start times (see Section 2.3); For every chosen time, the number of atoms per state is uniformly chosen between 1 and the number of atoms of the corresponding restriction. Atoms are then chosen one by one, uniformly in the allowed set of atoms, and added to the individual if \text{not \text{mutex}} with other atoms that are already there.

A 1-point crossover is used, adapted to variable-length representation in that both crossover points are independently chosen, uniformly in both parents. It is applied with probability \( p_{cross} \) to the individuals after selection.

After a possible crossover, an individual has a probability \( p_{mut} \) of being mutated. Four different mutation operators have been designed, and once an individual has been chosen for mutation \( \text{(according to a population-level mutation rate)} \), the choice of which mutation to apply is made according to user-defined relative weights (see Section 4.1). Because an individual is a variable length list of states, and a state is a variable length list of atoms, the mutation operator can act here at two levels: at the individual level by adding \( \text{(addAtom)} \) or removing \( \text{(delAtom)} \) a state; or at the state level by adding \( \text{(addAtom)} \) or removing \( \text{(delAtom)} \) some atoms in the given state. The choice between those operators is governed by user-defined relative weights \( w_{addAtom}, w_{delAtom} \).

Furthermore, mutation addAtom also modifies every other atom of the state it is applied to with probability \( p_e \), and, when adding a state, the possible new atoms are those that are possibly true in a time interval of radius \( r \) around the estimated time of the partial state at hand. \( r \) takes integer values, being an index in the array of possible times given by heuristic \( h^1 \) (see Section 2.3).

2.5 Fitness and Embedded Planners

In DaE, the fitness of a list of partial states \( S_1, \ldots , S_n \) is computed by repeatedly calling an external ‘embedded’ planner to solve the sequence of problems \( P_D(S_k, S_{k+1}), \{ k = 0, \ldots , n \} \). Any existing planner can be used, and the early versions of DaE used the optimal planner CPT \[ 30 \]. However, recent results \[ 5 \] have demonstrated that much better results can be obtained in a more robust way by using a suboptimal planner, namely YAHSP \[ 29 \], a lookahead strategy planning system for STRIPS planning which uses the actions in the relaxed plan to compute reachable states in order to speed up the search process.

For every given \( k \), if the chosen embedded planner succeeds in solving \( P_D(S_k, S_{k+1}) \), the final complete state is computed by executing the solution plan from \( S_k \), and becomes the initial state of the next problem. If all problems, \( P_D(S_k, S_{k+1}) \) are solved by the chosen embedded planner, the individual is called \text{feasible}, and the concatenation of all
solution plans for all \( P_D(S_k, S_{k+1}) \) is a global solution plan for \( P_D(S_0 = I, S_{k+1} = G) \). However, in the case of temporal planning, this plan can in general be optimized by rescheduling some of its actions, in a step called compression in order to get a better makespan (see [27] for detailed discussion). The quality of the compressed plan defines the fitness of a feasible individual.

On the other hand, as soon as the chosen embedded planner fails to solve one \( P_D(S_k, S_{k+1}) \) problem, the following problem \( P_D(S_{k+1}, S_{k+2}) \) cannot be even tackled by the chosen embedded planner, as its initial state is in fact partially unknown. All such plans receive a penalty inversely proportional to the number of solved subproblems, and such that the fitness of any infeasible individual is higher than that of any feasible individual.

Finally, in order to avoid the embedded planner to be stuck with subproblems that are in fact more difficult than the original one, YAHSP was constrained not to use more than a given number of nodes when solving any of the subproblems: first, a very large bound (e.g. 100000) is set when evaluating the initial population. The bound for the remaining of the run is then chosen as the median of the actual number of nodes that have been used to find the solutions during these evaluations.

### 3. PARAMETER TUNING FOR DAE

Two types of parameters are distinguished here: structural parameters act at the representation level, and include here the choice of the predicates that are used to build the intermediate states (see Section 2.3); Behavioral parameters directly impact on the way the optimization proceeds, and include the population size, the selection procedure and its parameters, plus all parameters related to the variation operators. However, the Darwinian-related parameters of DAE had been fixed after some early experiments [26, 27] (see Section 4.1), and only the 8 parameters related to the variation operators that have been described in Section 2.4 have been tuned using Racing.

Whereas tuning behavioral parameters pertains to standard Parameter Tuning procedure (Racing has been used here), problem-specific methods are required for the structural parameters. This Section details both tuning procedures in turn.

#### 3.1 Learning Predicates Across Runs

The set of predicates that are used to describe the partial states of intermediate goals (see Section 2.3) is an important component of the representation, and has a large impact on the size of the search space. Hence pruning it as much as possible can become a crucial issue in very large domains. In order to assess the usefulness of a possible Learning across runs technique, where, within a given domain, some runs could help identifying the useful predicates, the following statistics were gathered during the experiments. 50 runs were run on the first 11 instances of each domain, using the parameters learned at the domain level. All atoms of the 11 \( \times \) 50 best plans were gathered, and two figures were computed for each predicate: First, the frequency of appearance, i.e. the proportion of those optimal plans that did contain this predicate (number in [0, 1] for each predicate, 1 would mean that this predicate was present in every solution plan); Second, the proportion of atoms that did contain this predicate – all those proportions sum up to 1.

Based on those statistics, some clustering method was applied to this dataset. Relational analysis [2] with a threshold of similarity equal to 0.5 was chosen: initiated and developed at IBM in the 70s [20], relational analysis does not require to arbitrarily choose the number of clusters to be discovered. After this analysis, the predicates that belong to classes with more than 2 elements are retained, with the expectation that restraining the choice of predicates for the resolution of the other instances (not the first 11 ones, that were used to identify those predicates) would speed up the search (because the search space is smaller) while maintaining the same quality of the solution.

This approach was tried on several domains, and Figure 1 displays both statistics described above for the gold-miner domain, using the experimental settings described in next Section. Both statistics obviously capture different criteria of importance for the predicates. Unfortunately, the results obtained by DAE when using the restricted set of predicates chosen according to either of those statistics were not better, and sometimes even worse, than the results of DAE using the complete set of predicates. Furthermore, even when the results were similar in quality, they were not obtained significantly faster. Based on those experiments, it is not clear that a restricted set of predicates can be learned, and at least it cannot be learned as proposed here: the automatic choice of a restricted set of predicates is still an open issue, subject of further work.

#### 3.2 Racing Behavioral Parameters

Since the early days of Evolutionary Algorithms [14], researchers have tried to optimize the control parameters of their favorite algorithms. Classical statistical methods like ANOVA (Analysis of Variance), based on some extensive DOE (Design Of Experiment) can be used out-of-the-box: a finite number of parameter sets is chosen (e.g. a factorial design that includes all possible combinations of a finite number of values for each parameter), and a given number of runs is run for each set. Standard ANOVA test indicates whether some statistically significant difference exists among all the sets, and pairwise tests then designate the best set.

Originally proposed for solving the model selection issue in Machine Learning [21], Racing techniques were introduced in Evolutionary context [7] in order to decrease the computational cost of such naive approach by rapidly focusing the search on the most performing parameter configurations. The basic idea of Racing techniques is to identify, with a given statistical confidence level, the poorly-performing parameter configurations after only a few runs, and to go on running only the promising configurations: after each
run, all configurations are tested against the best one, and
the ones that are significantly worse are simply discarded.
Such cycle execution-comparison-elimination is repeated un-
til only one parameter configuration remains, or the total
number of experiments has been run.

The efficiency of such technique highly depends on the sta-
tistical test used for the comparison. Because no assumption
 can be made about the distribution of the results (e.g. nor-
mality), the most popular races [7, 34, 35] are based on the
non-parametric Friedman’s two-way analysis of variances by
ranks. Furthermore, given the statistical test, the user must
set two parameters for Racing: the number of initial runs
before starting the comparisons, and the confidence level of
the test.

The performance used for the comparison is generally the
best fitness reached for a given stopping criterion. Here, in
order to slightly favor the algorithms that run faster, a sec-
ondary component was added to the performance measure:
the fitness takes only integer values (however much the type
of problem, see Section 4.1), and some penalty in [0,1] was
hence added to the fitness. This penalty is proportional to
the computational time of the algorithm (normalized by the
maximum allowed time).

4. EXPERIMENTAL RESULTS

4.1 Experimental Setting

Previous experiments demonstrate that DAE can greatly
increase the performance of an encapsulated suboptimal plan-
ner, both in terms of coverage and solution quality, making
it competitive with state-of-the art planners [4] even when
it have used a single parameter set for all problems.

In order to show that there is still room for improvement
for the Evolutionary Planner DAE, experiments have been
run on 3 domains, and represent 3 different types of prob-
lems: gold-miner is a STRIPS problem (the quality of a
plan is the number of actions) from the IPC6 learning track,
openstacks uses actions with costs (the quality of a plan is
the total cost) of the IPC6 sequential satisficing track, and
zeno is a temporal problem (the quality of a plan is the total
makespan) from IPC3. All are available from IPC web site
at http://ipc.icas-conferece.org/.

Furthermore, in addition to comparing the results of the
different parameter sets obtained by the different param-
ter tuning procedures described in Section 3, DAE results
have been compared to those of the best learner in their
category: the optimal CPT [30] for STRIPS domain, LPG
[12, 13] for temporal domain, and LAMA [25] (updated ver-
sion kindly given by the authors) for actions with costs. As
is the case for CPT, however, those learners were given a
strict 30min time limit. In particular, this explains why the
best learner is not always CPT, which is an optimal learner,
and could find the optimal value for most instances if given
enough time (though it cannot solve the largest zeno in-
stances whatever the time it is given).

DAE has been implemented within the Evolving Objects
framework (http://eodev.sourceforge.net/), an Open Source,
STL-based, C++ Evolutionary Computation library. The
fixed evolution engine is a (100-700)-ES: 100 individuals
generate 700 offsprings without selection. The survival se-
lection is performed among those 800 individuals using a de-
termistic tournament of size 5. For all runs, the stopping
criterion is the following: After at least 10 generations, evo-
lution is stopped if no improvement of the best fitness in the
population is made during 50 generations, with a maximum
of 1000 generations. Furthermore, all runs were allowed a
maximum CPU time of 30mn (running on 3.4 GHz cores).

For the Racing procedure (see Section 3.2), the initial
number of runs was set to 11 (the lowest number for sig-
nificance of the statistical test), and the confidence level to
0.025 (strong constraint for the rejection of equality hypo-
sis between two parameter configurations). The racing pro-
cess was stopped after at most 50 runs.

For the 8 behavioral parameters (Section 2.4), 2 values
were tried, giving a total of 256 different parameter config-
urations (more configurations would have resulted in too
additional experiments). The following values were used: \(p_{cross} = 0.2\)
or 0.6, \(p_{mut} = 0.6\) or 0.8, \(w_c = 1\) or 3, the relative weights of
the 4 mutation operators, \(r = 1\) or 2, the tolerance radius for
time consistency, and \(p_s = 0.2\) or 0.8, probability to modify
an atom in a state undergoing mutation.

The global racing was performed by aggregating the per-
formances over one instance per domain, namely goldminer30,
openstacks21, and zeno14. For the racing per domain, the
instance with highest index (supposedly the most difficult
one) was chosen, namely goldminer30, openstacks30, and
zeno20.

4.2 Best Behavioral Parameters

Whereas 336 \(\times 50 = 12080\) runs would have been run
by a full factorial DOE, the global racing needed only 4351
runs, and racing per domain 4013, 4021 and 3966 runs for re-
spectively gold-miner, zeno simple time, and openstacks
domains. The full per instance racing required on average
5259, 5817 and 5473 runs for respectively gold-miner, zeno
simple time, and openstacks domains. However, those av-
erages hide large variations: paradoxically, all easy instances
required the maximum number of runs (12080), as several
parameter configurations could solve the instance to opti-
mum. This was the case for instances 1-20 for gold-miner,
1-12 for zeno and 1-18 for openstacks. Racing did save
around 65% CPU time for the global or per-domain ver-
sions, and little less for the racing per instance - though we
could have saved doing racing on the easy instances, as the
comparative results below will confirm.

Regarding the best parameter configurations, Figure 2 dis-
plays them all, on 8 lines: the horizontal line represents the
value obtained by the global racing, and only the values that
differ from this one are marked for each instance (column)
or the racing per domain (last column of each plot). There
seems to be a large consensus on the highest value for \(p_c\),
(0.8, second line from bottom), that matches the results of
the global racing and all 3 domain racings. There is, too,
a reasonable consensus for choosing \(r = 2\) (bottom line) for
gold-miner and zeno domains, matching the result of the
global racing, too, but openstacks racings preferred the other
value. On the other extreme, the values retained by the
instance-racings for \(p_{cross}, p_{mut}, \text{WdelState}, \text{WdelAtom},\) and
\(\text{WaddState}\) (lines 3-7 from bottom) seem to contradict those of
the global racing, while matching those of the domain-racing
only very partially. It seems that even when restricting the
number of possible values of the behavioral parameters to 2,
different instances even belonging to the same domain are
globally quite heterogenous for DAE.

4.3 Comparing Racing Procedures

Figure 3 displays the box-plots of the 50 runs for each domain (top to bottom), each racing level (left to right), and each instance (the x-axis). Additionally, the results of YAHSP alone (the embedded planner), as well as the results of the best opponent in its category. The numerical values of the means and minimal values reached are also given, for the sake of completeness, in the large unlabeled table (for space reasons) at the end of the paper.

An immediate conclusion is the confirmation that DaE outperforms by far YAHSP alone (as already demonstrated in [4]). A second obvious conclusion is that the performances of DaE when doing one racing per instance are better than the other racing options. However, this is particularly true for the most difficult instances (the instances with the highest index, at least), and for domains zeno and openstacks, whereas gold-miner seems easier to solve to optimality, or near-optimality, with either global or per-domain racing; only slight differences for few instances can be reported for the best achieved values. However, the variation among runs, as witnessed by the height of the box-plots of Figure 3, are clearly smaller with racing per instance. . . some difference that is not so large on both other domains. Surprisingly, on several instances (e.g. zeno 14, 15, 18 and openstacks 24, 25, 28), the global racing found better results (lower minimum, similar median) than the per-domain racing. This seems to indicate that those domains are rather heterogeneous in difficulty for the large instances.

Finally, one good news, on the other hand, is that DaE is able to find equal or better results than its best opponent in the experimental conditions chosen here, as witnessed by the last column of the final table: for some large instances, both LAMA and LPG, at least when limited to the same harsh 30min constraint that was imposed here, are frequently outperformed by DaE – at the cost of an instance-based racing to tune DA E parameters.

5. CONCLUSION

DAE is an original “memeticization” of Evolutionary and planning algorithms in the area of AI Planning. A lot of progress has been made since its original inception [26, 27], and it has now reached a level of performance that is able to compete with the best state-of-the-art planners even when it uses one single parameter configuration for all problems [4]. In this paper, however, the results on three different types of IPC problems showed that the quality of the results obtained with DAE can be further improved with more specific parameter tuning, although these results were not uniform over all tested domains. The practicality of such approach remains however questionable, as racing per instance requires to solve around 5000 times the instance with different parameter configurations. Racing per domain is an alternative whenever the user has to repeatedly solve new instances from the same domain. However, referring to the values retained by the different procedures (as discussed in Section 4.2), the different instances even of the same domain require different parameter settings, and the costly instance-based racing seems to be mandatory to get the best results on the large and difficult instances.

Nevertheless, there is still room for improvement in tuning DAE’s parameters. The choice of the set of parameter configurations for the racing is still an open issue. Furthermore, it was limited here by the CPU cost, and only 256 different parameter configurations could be tried. There are other alternatives to racing, that have the advantage that they actually optimize the parameters, i.e., are not restricted to a pre-defined set of configurations.

For instance, the Sequential Parameter Optimization method (SPO) [1] alternatively tries to build a model of the performance of the algorithm as a function of the parameters using Gaussian Kernels. Some improvements to SPO have already been proposed [18], that reduce its computational overhead and increase its accuracy. However, it remains to be compared to Racing for the Evolutionary Planning with DAE. Also, recently, the REVAC method has been proposed [24], that uses as a meta-EDA (Estimation of Distribution Algorithm) to optimize the parameters of an EA, but also estimates the relevance of each parameter at hand. This could confirm some results obtained here, where some parameters seem irrelevant because most racing results proposed the same value.

But the ultimate step in the direction proposed in this paper would be to design a completely automated procedure for parameter tuning, that would not require extensive runs that are unaffordable in real world situations for instance. The way toward this grac probably lies in Adaptive or Self-Adaptive techniques, yet to be proposed outside the continuous domain where such techniques have now reached maturity [9].

6. REFERENCES

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Figure 2: Best parameter configurations after racing per instance, for gold-miner, zeno and openstacks domains. From top to bottom, \( \text{WaddAtoms, WaddStates, WdelAtoms, WdelStates, Pmut, Pcross, Pc, r} \), and each parameter could take 2 values (see text). For each of those parameters, the horizontal line represents the value retained by the global racing, the last column shows that retained by the racing per domain, and each other column is the value obtained from racing on a single instance.

Figure 3: Results for DaE on gold-miner, zeno and openstacks, together with the value found by YAHSP alone (Δ), and the value from the best competitor, CPT (*), LPG (♦), or LAMA (†). Note that YAHSP did solve all instances, though the poor quality of its solution prevents from displaying it for the sake of readibility.


