Planning by Local Search (position paper)

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Solving planning problems by local search provides a promising alternative to both classical (i.e., purely deductive) AI planning and the use of special purpose planning algorithms. The success of this approach has been manifested by the recent award-winning paper [Kautz and Selman, 1996], which proves that a specific local search method can substantially outperform the best existing planning procedures. This particular approach is of course only one out of many possible ways to do planning locally. Ongoing research in both reasoning about actions and local search paradigms gives rise to a whole variety of roads worthwhile to explore. In this note, we name the most important principles underlying the approach of [Kautz and Selman, 1996]. For each we propose alternatives and argue why there is hope that following these suggestions leads to even more impressive results.

The underlying action calculus. The method described in [Kautz and Selman, 1996] is based on axiomatizing planning problems using the representation technique of Situation Calculus. As a consequence, the approach has to cope with the Frame Problem, in particular with the inferential aspect thereof. That is to say, one-by-one all properties must be carried to the next situation which are unchanged when an action is performed. Accordingly, the resulting axiomatization includes extra clauses which serve precisely this purpose. This favors the employment of alternative action calculi that provide better solutions to the inferential aspect of the Frame Problem. We pursue the use of the Fluent Calculus paradigm (see, e.g., [Thielscher, 1997]) as a promising candidate. The basic concept there is to encode states as terms so that the effects of actions can be modeled by removal and addition of sub-terms. Consequently, no effort is needed to conclude that unaffected properties continue to hold—the corresponding sub-terms being untouched induces this automatically.

The underlying ontology. The ontology on which [Kautz and Selman, 1996] is based is STRIPS-like but additionally supports the notion of state constraints. The latter, however, is not exploited for the automatic proliferation of indirect effects of actions. Rather these effects are all compiled into the action descriptions. As a consequence, a single cause-effect relation may be multiply encoded, which gives rise to possibly noticeable redundancy. The problem of how to derive the correct indirect effects from underlying state constraints is known under the name Ramification Problem. Recently it has been shown that the incorporation of a suitable notion of causality provides a broadly applicable solution to this problem [Thielscher, 1997]. The basic idea there is to start with the state resulting from executing the direct effects of an action and to repeatedly modify this state further, on the basis of formal so-called causal relationships between effects and their causes, until all indirect effects have been accounted for. The aforementioned Fluent Calculus principle is most suited for this approach since the latter, too, can be realized as modifying state terms.

Problem transformation. Prior to employing local search, [Kautz and Selman, 1996] transform a planning problem into some propositional clause set. In general, this transformation is neither trivial nor problem size preserving. (Although the size turned out never to explode exponentially, the resulting formula may be substantially larger than the original one.) The alternative would be to apply local search methods directly, i.e., without making the detour via propositional logic. In our setting, this amounts to using a Fluent Calculus axiomatization of a planning problem as starting point for local search.

Multi-agent search. Local search typically starts with some initial ad hoc solution that may be generated using some greedy heuristics. To improve the quality of initial solutions, we pursue the approach of constructing a number of competing solutions, obtained by collaboration of simple agents, e.g., a colony such as has been proposed for Ant System [Dorigo et.al., 1997]. By a communication mechanism, promising partial solutions are communicated among the agents so that better solutions should adaptively evolve, which can then be used as initial solutions in the subsequent local search phase. It has recently been shown that by such an approach near optimal solutions to large combinatorial optimization problems can be found [Stützle and Hoos, 1997]. This gives rise to hope for the success of a similar approach when addressing planning problems. Following the initial construction of partial solutions, local search operators perform small changes to the current solution, thus obtaining possibly improved neighboring solution. What needs to be defined for the application of local search is some measure of solution quality and the notion of neighborhood among solutions. One straightforward quality measure is to take the number of unsatisfied sub-goals, but alternatives and combinations should be explored as well. Neighborhood may be defined implicitly by the available operations that modify a current solution. Example operators are inserting or deleting an action, reversing the order of a pair of actions, etc.

Our conviction is that the recently proved success of local search on SAT-encoded planning problems indicates that local search in general is a viable alternative to both classical and global special purpose planning.

References

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