Abstract

Planning involves finding a sequence of actions – i.e., a plan – that allows agents, operating within an environment, to reach a goal from a specified initial condition. Different flavours of planning exist depending on how the environment is represented: *classical* if it is represented only by propositional variables, *numeric* if variables can also assume numeric values, *temporal* if there is a concept of time, with actions having durations, and *hybrid* if the environment can act on its own. A technique for planning is *Planning as Satisfiability*, where one bounds the length of the plan by an integer n, translates a planning problem into a propositional formula encoding all possible plans up to length n, and checks for the satisfiability of the formula, increasing n upon failure.

This thesis introduces a novel approach called *Symbolic Pattern Planning* (SPP), based on Planning as Satisfiability. Given a planning problem, we propose to construct a plan for it by first fixing a pattern –defined as an arbitrary finite sequence of actions, roughly sketching an intuitive idea on how the actions in the final plan should be ordered– and then encoding as a formula the state resulting from the sequential execution of a subsequence of the actions in the pattern, starting from an arbitrary initial state. By imposing the conditions on the initial and goal states, we can check whether the pattern allows determining a valid plan – i.e., the formula is satisfiable – or whether the pattern needs to be extended and the procedure iterated until we find a valid plan as a subsequence of the pattern. We ground our proposal in the classical, numeric and temporal flavours of planning and prove the correctness (any returned plan is valid) and completeness (if there exists a valid plan, one will be returned) of the procedure. Moreover, for the three flavours, we show that our encoding allows to determine a valid plan in a number of iterations n which is never higher than the one needed by the state-of-the-art

planners for that flavour exploiting the planning as satisfiability approach. On the experimental side, we ran an extensive analysis for the numerical and temporal flavours, showing that the results validate the theoretical findings and that our planner PATTY has excellent comparative performances.

Regarding the classical planning flavour, we consider it as a special case of numeric planning – where there are no numeric variables – and we concentrate our attention to the special case of *classical planning with conditional effects*, where effects, i.e., the way the environment changes after an action in applied, can be *conditional*, meaning that their application depends on the agent's state before applying the action. This seemingly harmless modification makes the problem much more difficult than classical planning, and requires some non-trivial adjustments to the approach.

After presenting the SPP approach for all the aforementioned flavours, we push the envelope further and overcome some of its limitation, i.e., how the selection of a static pattern computed on the initial state can be detrimental when searching for plans where the order between actions changes during the plan. We show how to symbolically search for a valid plan by iteratively extending (adding actions to) and simplifying (removing actions from) the initially computed pattern, symbolically mimicking standard search-based procedures for planning. Again, the proposed procedure is proven correct and complete and, on the experimental side, it outperforms the previous SPP approach.

Finally, we conclude the thesis with a discussion on how to apply SPP techniques on the hybrid planning flavour and on an application domain, the *In-Station Train Dispatching Problem*, i.e., the problem of planning the movements of trains inside a railway station.