The Automatic Validation Tool for PDDL2.1

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Overview

The 3rd International Planning Competition [1] was a great success and a cornerstone to this success was the initial definition of a semantics for the language used in the competition, PDDL2.1. This created a general understanding of the semantics of the domains defined using this language and therefore a general understanding of what constitutes a valid plan. With this consensus on what a valid plan is it was possible to implement an automatic plan validator, VAL. This tool conveys what is a valid plan in PDDL2.1 to anyone developing a planner using this language, as well as providing extra information in a LaTeX report featuring graphs of changing numerical values and a Gantt chart (see figure 2).

Actions With Continuous Effects

A numerical quantity that can be changed, a function in PDDL, is called a *primitive numerical expression* (PNE). These PNEs can have continuous change initiated with changes made to the values of their (time) derivatives by durative actions. The effect starts at the beginning of the durative action and ends at the end of the durative action.

The introduction of continuous change creates two further complications to the discrete temporal model: 1) Continuous changes can interact with one another, and 2) Invariant conditions may depend on values that are continuously changing. The key extension to the discrete temporal model is that interacting processes are described by systems of differential equations, whose effects can be resolved at the conclusion of each interval over which they act uninterrupted. Invariants can be checked by considering the functions describing the change in variables over the same intervals. This is illustrated in figure 1. In (1) we show how the interval of a durative action effecting continuous change can be handled by updating the continuously changing variables discretely at the end of the interval and checking any invariants at this point (respecting the continuous change). In (2) we show that if another action punctuates the interval then the evaluation of continuous effects and invariant checks are managed at each point of change. Part (3) illustrates how discrete affects can arise, due to parallel activity during the intervals, breaking the continuous change into piece-wise continuous components.

Interacting Continuous Effects

There may be a number of continuous effects active at one time each of which modifies the derivative of a PNE. The complexity of the differential equations that can be expressed far exceeds the practical possibility of solving them analytically and even numerically. It is therefore necessary to impose certain restrictions on the differential equations to guarantee that they can be solved. If the dependencies of the PNEs are such that there are no loops then it can be shown that the PNEs will be described by polynomials in t, the time over which the action is executing.

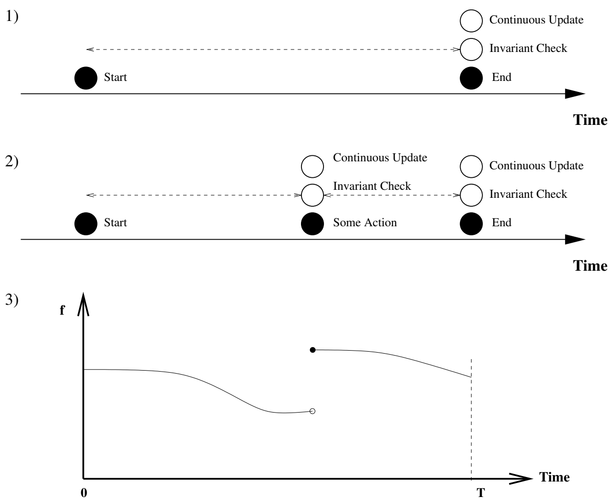

Figure 1: Durative action with continuous effects. Graph shows the values of a PNE, f.

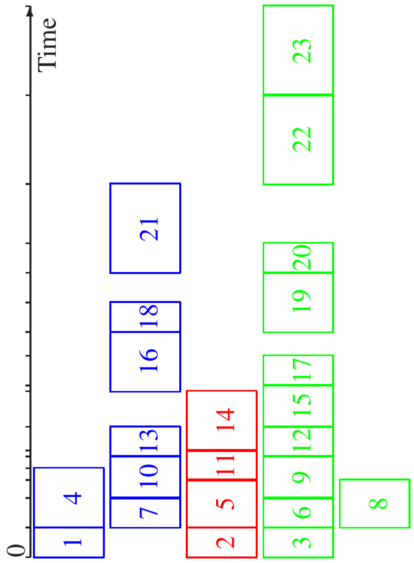

Figure 2: Gannt Chart

Invariants

An invariant condition must be evaluated on an interval by checking that the continuously changing PNEs that appear within it do not assume values that lead to a violation of the invariant. The key to the problem of checking invariants that are comparison expressions in t is one of finding the roots of any function that can arise. In our case we are currently considering polynomials so the problem is to find the real roots of a polynomial on a given interval. We are only interested in methods that guarantee that all the roots are found, so it is not acceptable to trade in accuracy for speed of validation.

For one-clause invariants we are only interested in the existence of real roots on a given interval. This can be reliably checked by applying Sturm's Theorem or Descartes' Rule of Signs Theorem which show the existence of real roots of a polynomial on a given interval.

In general an invariant condition can be considered as a proposition in DNF that must hold over an interval, say $(0, T)$. To confirm the invariant, we must then find a set of intervals, C, covering $(0, T)$, such that a disjunct is satisfied in each interval in C. In order to find the values that a disjunct is satisfied on it is necessary to find the roots of a continuous function. In our case we can reliably find the real roots of a polynomial (within a degree of accuracy) using an algorithm based on Descartes' Rule of Signs Theorem.

Conclusion

Currently, to guarantee the validation of a plan containing durative actions with continuous effects certain restrictions have to be met, either all continuous effects must be linear, or all continuous effects must be polynomial and no invariants contain comparisons using a polynomial of degree greater than two. We intend to progress to validate plans subject initially to the restriction that all continuous effects must be polynomial.

References

[1] M. Fox, D. Long, and Committee. International planning competition. Web-site at `www.dur.ac.uk/d.p.long/competition.html`, 2002.