Overcoming the Sussman Anomaly with Interleaving

The Sussman Anomaly refers to a near-trivial planning problem that cannot be overcome by *Linear Planning*. It was presented by Gerald Sussman in his PhD thesis [1] and consists of

- three cubes A, B & C
- the initial state of A and B sitting on a table, and C sitting on top of A
- the goal state of A sitting on B sitting on C, which can be formulated as the combination of the goals *G1: A on top of B* and *G2: B on top of C*
- and the rules that every cube can be moved from its current location to another location, but it may only be moved if no other cube rests on top of it, and only on top of another cube or onto the table.

Sussman's planning algorithm HACKER failed to solve this problem, whose solution requires only a breadth-first search of depth d=3, with the breadth being limited to b=6, i.e., less than 216 possibilities. The reason for this lies in HACKERs linear planning approach. In this approach, there are plans created for the creation of G1 and G2, which are then executed back to back. However, using the simplest possible plans for achieving either G1 or G2 further removes the system from the combined solution. As such, the solver ends in an infinite loop of states where only half of the objectives is fulfilled[1].

Different approaches have been taken to resolve this problem, which we will discuss below.

Critics Approach

Earl Sacerdoti [2] uses the original Sussman Anomaly, and resolves the planning challenge using a *Critics* approach. He creates three categories of critics, namely

- *Resolution of conflicts*: No action may remove a precondition of any following action, e.g., *Put(B, C)* may not be carried out as long as *On(C, A)* since *Not On (*, C)* is a precondition to *Put(C, Table)*
- *Use of existing objects*: Planning may not require specification of steps *beyond* the essential.
- Eliminate redundant preconditions: Actions that fulfil a precondition need not to be carried out if the current state already fulfils the preconditions, e.g., Put(C, Table) need not be carried out if the state already fulfils On(C, Table)

Sacerdoti's approach (named NOAH - Nets of Action Hierarchies) demonstrates that after resolving these critics, a planning algorithm that solves the Sussman Problem can be established.

Regression Approach

Richard Waldinger [3] introduces an approach dubbed *regression*, which involves *passing a goal state back over a relation*, i.e., determining the least specified relation *P'* such that after applying an action *F* the relation *P* holds true. This allows to re-order actions such that an action *G* that fulfils a goal *Q* can act completely within a relation *P'.* Fulfill-

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[1] In Sussman's own HACKER algorithm, the planner would actually notice that achieving the second goal destroys the achieved first goal, would then try to reverse the goal sequence, notice the same failure, and give up.

ing multiple goals is then achieved by in each step achieving individual subgoals while protecting fulfilled goals and preconditions.

Protected Sub-Goals

Austin Tate [4] extends the original HACKER algorithm by explicitly including the preconditions for each goal as additional sub-goals, creating his own INTERPLAN algorithm. INTERPLAN uses HACKER's protection approach, i.e., if an action that achieves a goal destroys an already achieved goal, it will reorder the sequence in which solving the goals is attempted, and try again. Due to inclusion of the the individual preconditions as subgoals, the Susan anomaly problem now becomes solvable.

Bibliography

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[3] Richard Waldinger: Achieving Several Goals Simultaneously, Technical Note 107, SRI Project 2245, 1975

[4] Austin Tate: Interacting Goals in Problem Solving, AISB Newsletter, 18, pp. 31-38, 1974