HTN IPC-2020 Domains: Towers

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Abstract

The Towers domain from the 2020 HTN International Planning Competition was adapted from the HTN translation papers by Alford et al.. The domain encodes a solution to the Towers of Hanoi problem, admitting a unique, optimal solution and having no branches in the search space.

Towers of Hanoi is a puzzle consisting of a set of rings of decreasing size and three pegs. The rings are initially stacked in size-order on one ring, with the smallest at the top. The goal of the puzzle is to move the rings one at a time between the pegs such that the entire tower ends up on the goal peg without ever placing a larger ring on top of a smaller.

Optimal solutions for Towers of Hanoi problems have $2^{|\text{rings}|} - 1$ moves. The Towers domain, introduced in works translating HTNs to PDDL (Alford, Kuter, and Nau 2009; Alford et al. 2016), encodes a tail-recursive, optimal solution without any branching in the forward search space. The solution moves the smallest disk in a rotating pattern between the ring. After each move of the smallest ring, it moves the smallest of the other two exposed rings to the larger. There is an initial phase of the methods which determines whether there are an odd or even number of rings, which determines which tower the smallest ring goes to first.

The Towers domain has one operator, five compound tasks, and eight methods implementing those tasks. Any HTN progression of the initial task network of a Towers problem has at most two tasks, giving it a progression bound of 2 (Alford, Bercher, and Aha 2015). The outline of the tasks and methods are as follows:

- The top level task is `(shiftTower t1 t2 t3)`, which shifts the tower from `t1` to `t2` using `t3`. The `m-shiftTower` method has a single subtask, `selectDirection`.
- The `selectDirection` task has two methods, `m-selectDirection` which flips its planned order for shifting the tower, and `selectedDirection`, which initiates the `rotateTower` task.
- The `(rotateTower ?t1 ?t2 ?t3` task has a single method with two subtasks: moving the smallest ring from `?t1` to `?t2`, then starting the `(exchange ?t1 ?t2 ?t3)` task.
- The `(exchange ?t1 ?t2 ?t3)` has three methods:
  - An empty one if `?t1` and `?t3` are clear.
  - `exchangeLR` which moves `?t1` to `?t3` if `?t1` is the smaller.
  - `exchangeRL` which moves `?t3` to `?t1` if `?t1` is the larger.

  The later two methods then recurse to `(rotateTower ?t2 ?t3 ?t1)` to continue the solution.

The problem generator[1] for the Towers domain takes the number of rings as a parameter, and generates problem files with a single tower of rings. The problem generator outputs in PDDL format, which had to be hand adapted for the HDDL format of the HTN IPC (Höller et al. 2020). The IPC contained 20 problems with 1 to 20 rings.

References

[Alford, Bercher, and Aha 2015] Alford, R.; Bercher, P.; and Aha, D. 2015. Tight bounds for HTN planning. In *ICAPS*, volume 25, 7–15. AAAI Press.

[Alford et al. 2016] Alford, R.; Behnke, G.; Höller, D.; Bercher, P.; Biundo, S.; and Aha, D. 2016. Bound to plan: Exploiting classical heuristics via automatic translations of tail-recursive HTN problems. In *ICAPS*, volume 26, 20–28. AAAI Press.

[Alford, Kuter, and Nau 2009] Alford, R.; Kuter, U.; and Nau, D. S. 2009. Translating HTNs to PDDL: A small amount of domain knowledge can go a long way. In *IJCAI*, 1629–1634. AAAI Press.

[Höller et al. 2020] Höller, D.; Behnke, G.; Bercher, P.; Biundo, S.; Fiorino, H.; Pellier, D.; and Alford, R. 2020. HDDL: An extension to PDDL for expressing hierarchical planning problems. In *AAAI*, volume 34, 9883–9891.

[1] https://github.com/ronwalf/HTN-Translation/blob/master/examples/towers/genTowers.hs