Symbolic Search for Total-Order HTN Planning

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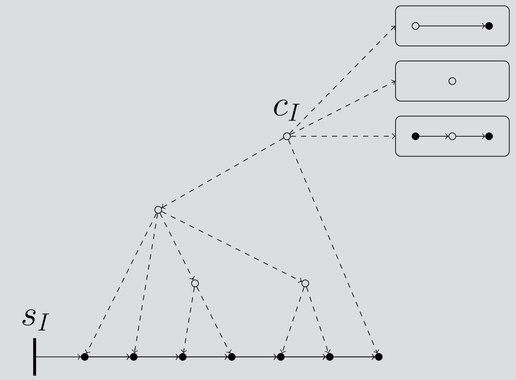
Motivation

HTN Planning has strong similarities with Formal Grammars. Can we exploit this?

HTN Planning



- Abstract tasks A ($\approx$ non-terminals)
- Primitive actions P ($\approx$ terminals)
- Decomposition methods M ($\approx$ refinement rules)
- Preconditions / Effects for actions
- Initial state s_I and initial task c_I

Objective: Find a refinement $\pi = \langle p_1, \ldots, p_n \rangle$ of c_I containing **only** primitive actions that is **executable** in s_I.

Progression

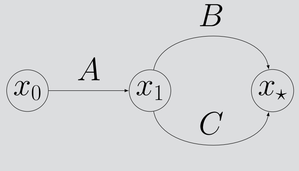
Search for a plan by applying methods to the **first** task or by applying the **first** action.

if $t_1 \in P$

if $t_1 \in A$ and $t_1 \mapsto t'_1 t'_2 \in M$

Symbolic Planning

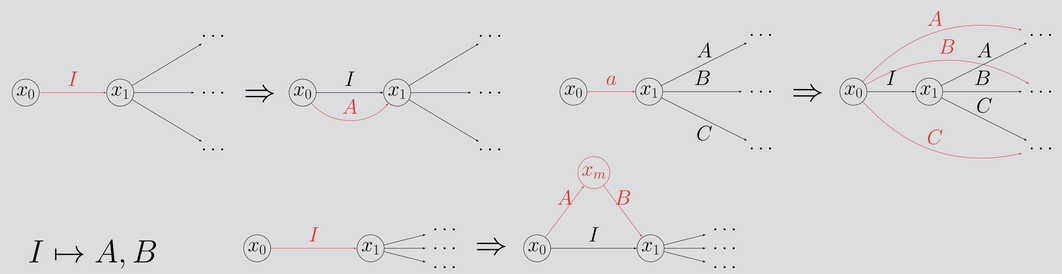
Idea: Use an automaton to represent Progression Search Nodes. Label the edges with BDDs to represent the state.



$\sigma(x_0, A, x_1) = \{(s_1, s_3), (s_2, s_4)\}$
$\sigma(x_1, B, x_\star) = \{(s_3, s_3)\}$
$\sigma(x_1, C, x_\star) = \{(s_4, s_4)\}$

Represents:
$\langle s_1, A, s_3, B, s_3 \rangle$
$\langle s_2, A, s_4, C, s_4 \rangle$

Performing Progression



Optimal Planning

Given $c : P \mapsto \mathbb{N}_0$, find a plan $\pi = \langle p_1, \ldots, p_n \rangle$ with minimal $\sum_{i=1}^{n} c(p_i)$.
Idea: Construct not one automaton, but one per cost c – the total cost of actions that have already been progressed.

Experiments

Domain (# Inst.)	BDD	SAT(bin)	SAT(dec)	LM-cut A*	TDG-c A*
Barman (20)	0	**12**	7	0	0
Blocksworld-GTOHP (20)	12	1	1	**18**	4
Blocksworld-HPDDL (20)	**3**	**3**	**3**	1	0
Childsnack (20)	2	**6**	**6**	0	0
Depots (20)	**20**	10	10	15	3
Entertainment (12)	**12**	10	**12**	5	5
Gripper (20)	**20**	**20**	**20**	17	4
Hiking (20)	**7**	0	0	0	0
Minecraft-Area (30)	**15**	0	0	0	0
Minecraft-Normal (30)	**19**	1	0	0	0
Multiarm-Blocksworld (74)	**10**	0	0	4	0
Robot (10)	**1**	**1**	**1**	0	0
Rover-GTOHP (20)	**7**	4	4	5	4
Rover-PANDA (20)	13	**18**	15	10	4
Satellite-GTOHP (20)	3	3	3	**5**	3
Satellite-PANDA (25)	**25**	**25**	**25**	**25**	22
SmartPhone (7)	6	**7**	**7**	5	4
Towers (14)	**10**	6	6	9	2
Transport (30)	**24**	14	12	5	2
UM-Translog (22)	**22**	**22**	**22**	**22**	**22**
Woodworking (11)	**11**	**11**	**11**	**11**	8
Overall (465)	**242**	174	165	157	87