Laying the Foundations for Solving FOND HTN Problems: Grounding, Search, Heuristics (and Benchmark Problems)

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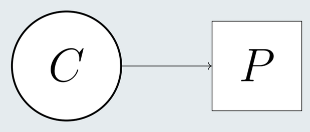
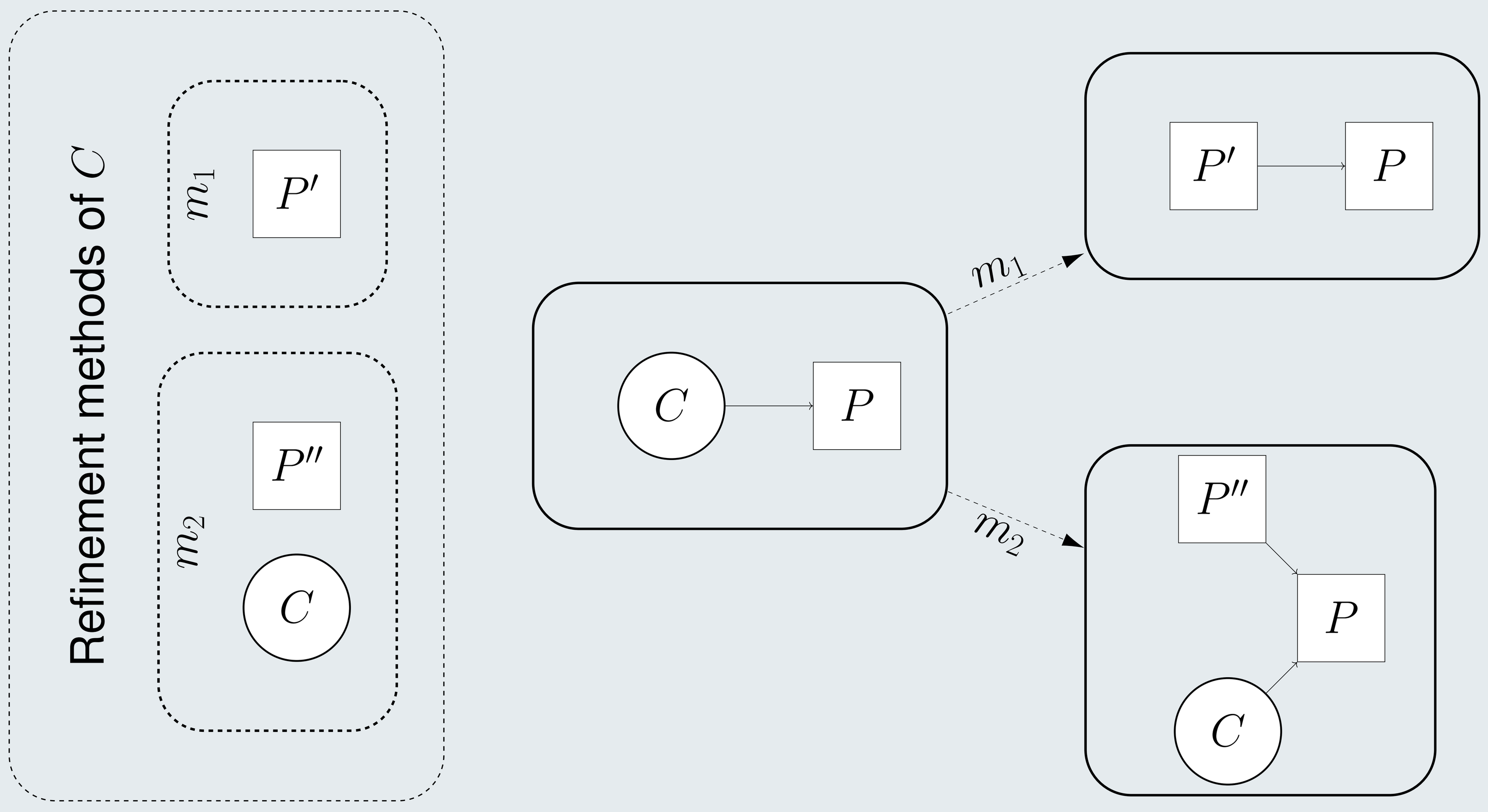
Formalization

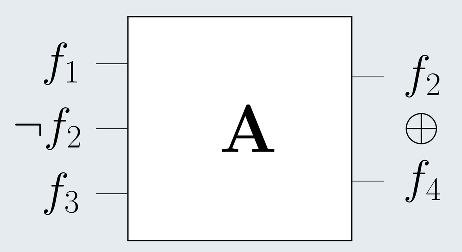
A **task network** $tn = \langle T, \prec, \alpha \rangle$ is a partially ordered multiset of primitive and abstract tasks.



A *compound task* can be decomposed using a **method** $m = \langle c, tn \rangle$.

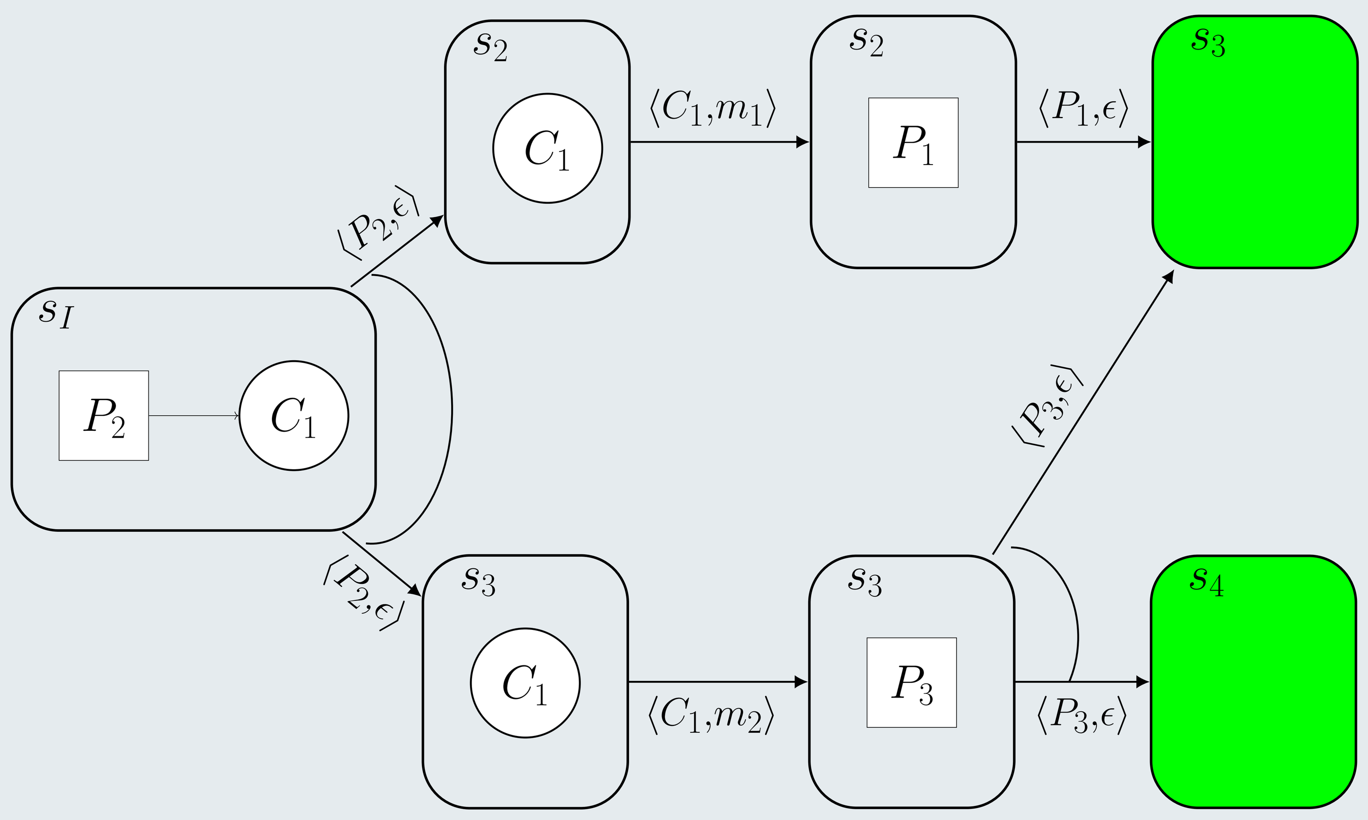


If the *precondition* of a **primitive action** is satisfied in the current *state*, it can be executed, resulting in a non-deterministic *effect* on the state.



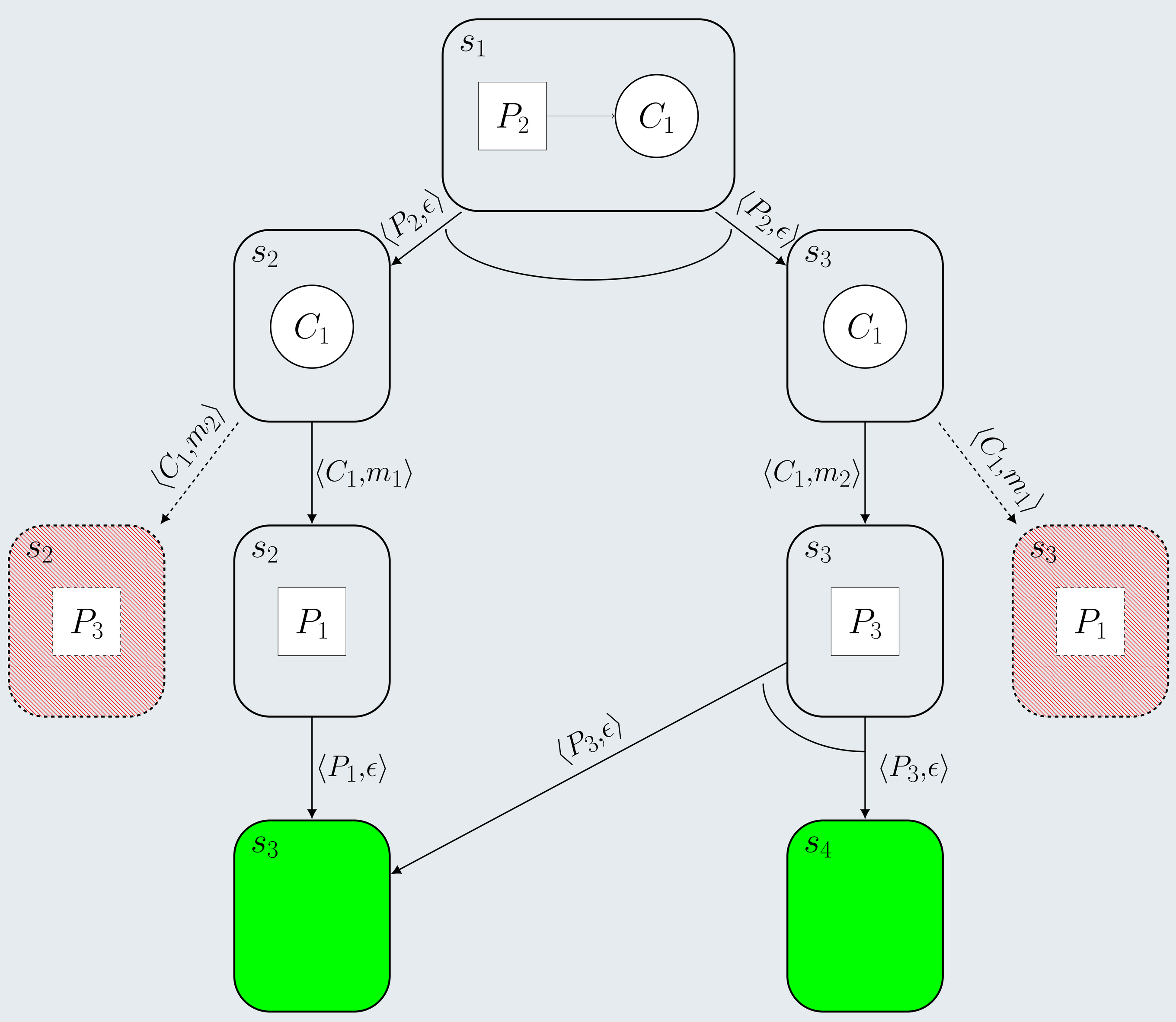
⟵ The new "`oneof`" keyword in HDDL!

A **strong solution** executes all tasks (even in the face of unfavorable outcomes) in a finite number of steps. Formally, policies are partial functions $\pi : TN \times S \to T \times M \cup \{\varepsilon\}$ (exploiting task network isomorphism)



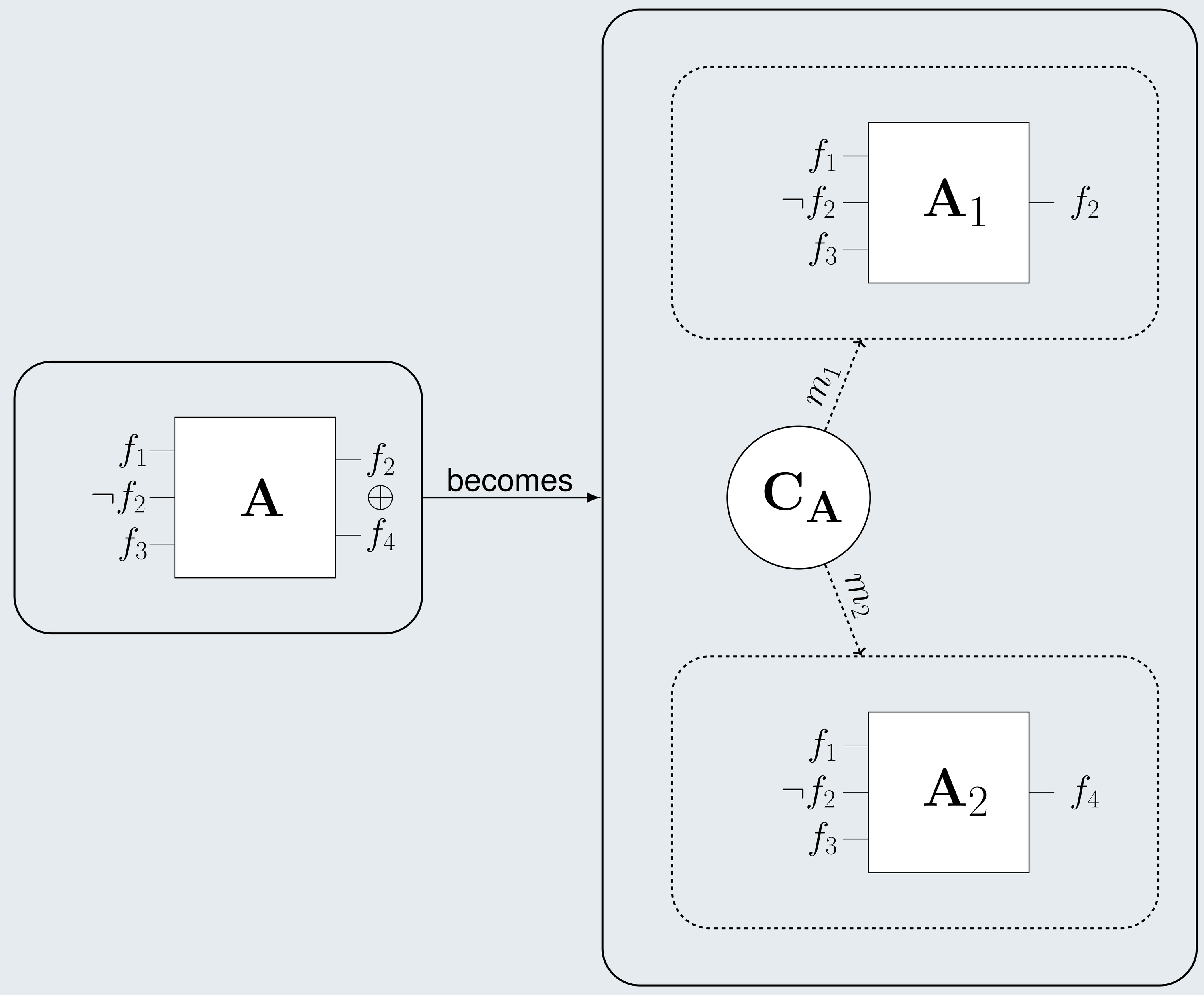
Search & Heuristics

We utilize **AO*** to gradually search the hypergraph of progression space, and use the AOD relaxation as a heuristic to guide the search.



All-Outcome-Determinization (AOD)

Replace all non-determinsitic actions with synthetic abstract tasks.



Grounding

1. Determinize the lifted domain,
2. Use any classical HTN grounder,
3. Re-infer a grounding for the FOND domain based on the number of groundings of the synthetic abstract tasks (e.g., if a synthetic task had 4 effects, but only 3 ground methods, it cannot contribute to a strong solution).

For example, consider a non-deterministic action `(A ?x ?y)` with two effects e_1 and e_2 where the groundings after AOD relaxation are as follows. We can infer that only `(A x2 y1)` is a valid grounding of `A`.

$e_1 \leftarrow$ `(A ?x ?y)`	$\rightarrow e_2$
$\langle x_1, y_1 \rangle$	$\cancel{\langle x_1, y_1 \rangle}$
$\cancel{\langle x_1, y_2 \rangle}$	$\cancel{\langle x_1, y_2 \rangle}$
$\langle x_2, y_1 \rangle$	$\langle x_2, y_1 \rangle$
$\cancel{\langle x_2, y_2 \rangle}$	$\langle x_2, y_2 \rangle$

Evaluation

We have evaluated our planner on **5 novel benchmark domains** (75 problem instances) with 3 heuristics on one CPU core, 8 GB of RAM, and a 30-minute threshold.

Domain	Heuristic	IPC Score	Coverage	Avg. Execution Structure	
				# of Nodes	CP Length
Depots	RC^{Add}	6.92	10 of 15	150.80	127.20
	RC^{FF}	6.99	10 of 15	150.80	127.90
	RC^{Max}	7.26	10 of 15	149.70	126.20
Rover	RC^{Add}	5.16	6 of 15	28.00	21.83
	RC^{FF}	5.00	5 of 15	23.80	17.80
	RC^{Max}	5.00	5 of 15	23.00	17.00
ChildSnack	RC^{Add}	1.66	3 of 15	64.00	45.00
	RC^{FF}	1.59	3 of 15	64.00	45.00
	RC^{Max}	1.66	3 of 15	64.00	45.00
Satellite	RC^{Add}	5.92	7 of 15	33.86	16.86
	RC^{FF}	4.16	7 of 15	33.71	16.86
	RC^{Max}	5.92	7 of 15	32.57	15.86
Transport	RC^{Add}	3.48	5 of 15	400.60	45.40
	RC^{FF}	4.04	5 of 15	99.20	33.80
	RC^{Max}	3.32	4 of 15	94.50	31.75